Brianna Bergen - Comments and documents for Nursery Products WDRs 1

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Ms Bergen

Please consider these documents for the Nursery Products WDRs and any other permits for Nursery Products LLC or sewage sludge related issues:

1. "The Dirty Work Of Promoting "Recycling" of America's Sewage Sludge" Article by Caroline Snyder, PHD

2 "Organic Contaminants in Sewage Sludge For Agricultural Use"

3. "Biocycle What's New In Vessel Composting"

4. "Compost Air Emissions Health Studies" Cornell Waste Management Institute 2007

5. "The Dispersion Of Flies by Flight" , Bishop

6. "Fly Dispersion From A Rural Mexican Slaughterhouse", Greenberg, 1964

7. "Firm Ordered to Stop Spreading Sewage Sludge", Berstein 1998

8. "Compost Operation Red-Lighted Once Again", Maeshiro 1998

9. "Accumulation of Heavy Metals In Plants and Potential phytoremediation of lead by potato, …". Antonious, 2007

10. "Effect of Temperature on Composting of Sewage Sludge", Nakasaki
11. "Biosolids Tech Fact Sheet" EPA
12. Center for Biological Diversity comments on project 2006
13. Center for Food Safety comments SEIR 2009
14. "Organic chemicals in sewage sludges", Harrison 2006
15. "Compost Fact Sheet #6", Cornell Waste Management Institute 2004/2005
16. Conner comments on DEIR, 2006
17. Conner comments on impact report

thanks
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The Dirty Work of Promoting "Recycling" of America's Sewage Sludge

CAROLINE SNYDER, PHD

Serious illnesses, including deaths, and adverse environmental impacts have been linked to land application of sewage sludge. EPA and the wastewater treatment industry have worked with Congress to fund wastewater trade associations to promote land application, supporting industry-friendly scientists and discouraging independent research, to prevent local governments from restricting land application and to thwart litigation against municipalities and the industry. *Key words*: sewage sludge; biosolids; EPA; conflicts of interest; industry influence; corporate control; suppression of research.

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The United States Federal Clean Water Act defines municipal sewage sludge as a pollutant. Typical sludges from industrialized urban centers contain tens of thousands of contaminants, from industry, institutions, businesses, landfills, and households, that discharge into sewers. Wastewater treatment plants are designed to remove these pathogens, metals, and chemical compounds—many of which are toxic and persistent—from wastewater. Almost all the removed material, by necessity, concentrates in the resulting sludge. Every month, every industry in the country is permitted to discharge up to 33 pounds of hazardous waste into sewers without reporting.[1]

Despite the fact that sewage sludge is a contaminated waste product, it is being commonly treated and used as a fertilizer, without informing the recipients about the complete contents of the sludge. In 2002, a National Academy of Sciences (NAS) panel warned that treated sewage sludge is such a complex and unpredictable mix of biological and chemical wastes that its risks, when used for farming, can not be reliably assessed. Therefore, the panel concluded, standard strategies to manage the risks of land application do not protect public health.[2, pp 104,252–53]

Even though the effects of treated sludge are unpredictable, complex, and potentially harmful, the United States Environmental Protection Agency (EPA) has failed to appropriately manage its disposal. Instead, upper-level managers in the agency's Office of Water (OW) and Office of Research and Development (ORD) abandoned their agency's mission by yielding to industry pressure to promote and defend the risky practice of using a contaminated waste product as a fertilizer.

Reports of adverse health effects linked to the use of sludge as fertilizer have mounted, especially in the last ten years. Over the same time, EPA forged a powerful alliance with municipalities that needed an inexpensive method of sludge disposal and sludge-management companies that profit from this practice. The alliance's primary purpose was to control the flow of scientific information, manipulate public opinion, and cover up problems, in order to convince an increasingly skeptical public that sludge farming is safe and beneficial. The alliance ignored or concealed reported health problems, threatened opponents with litigation, distributed misleading information to the media, legislators, and the public, and above all, attempted to silence critics.

Since 1996, EPA's efforts to silence opponents have been the subject of Labor Department investigations[3] congressional hearings,[4,5] Inspector General audits,[6,7] and lawsuits filed by farmers and residents.[8–10] This article draws on these proceedings and other information by explaining how EPA uses industry-friendly scientists and corporate influence to defend an unprotective policy. It's a carrot-and-stick approach. Supportive scientists receive federal grants,[11,12] while economic threats are used to silence unsupportive scientists, private citizens, and local governments.[3,4,12,13]

IN THE BEGINNING

Since its inception, EPA has been promoting sludge use for farming. In the late 1970s, the first land application regulations were formulated by managers and scientists in EPA's Office of Water (OW): Henry Longest II, John Walker, and Alan Hais. As Deputy Assistant Administrator of OW, Longest was one of the people responsible for administering the funds for EPA's multi-billion-dollar Construction Grants Program, the United States' largest public works project ever. The purpose of the project was to build wastewater treatment plants, as mandated by the Clean Water Act.

The rapid proliferation of new wastewater treatment plants produced vast quantities of sludge. And because industrial wastes that used to be dumped into rivers were now discharged into sewage systems, the sludge became much more hazardous, often qualifying as haz-

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ardous waste. At the time, the Resource Conservation and Recovery Act (RCRA) was being developed to regulate hazardous waste. During this inflationary period, municipalities demanded an inexpensive way of disposing of their sludge. President Carter's appointee to OW, Thomas Jorling, insisted that sludge not be regulated under RCRA, and the Act was weakened. The watered-down Act allowed not only sludge but also industrial wastes to be legally used as fertilizer.[14] A 1978 memorandum from Walker to Longest outlined the purpose of EPA's land application program[15]:

> The goal of 405/4004 sludge regulations should be to promote low cost sludge management . . . [the proposed RCRA provisions] would essentially preclude [land application] as an option. The application of some low levels of toxic substances to land for food crop production should not be prohibited. . . .

A significant amount of the country's hazardous waste from industries and other institutions is in the form of wastewater. Under the domestic sewage exclusion, industries are permitted to discharge hazardous wastewater into sewer lines to mix with domestic sewage entering publicly owned treatment plants. The assumption that this wastewater has been adequately pretreated by the sources, so that sewage sludge contains only "low levels of toxic substances," has been widely questioned.[2 p 69,16]

There were early warning voices within the agency that sludge and industrial waste used as fertilizer would lead to serious problems down the road. William Sanjour, chief of EPA's Office of Solid Waste Management Programs Technology Branch, warned repeatedly that Mr. Jorling's order to reduce the scope of RCRA so that sewage sludge and other industrial waste could be land applied "was illegal and inconsistent with the agency's congressional mandate to protect human health and the environment." Sanjour's warnings, however, went unheeded, and EPA removed him from his position.[17]

The campaign to promote "beneficial use" of sewage sludge continued in the 1980s. It was becoming "a murky tangle of corporate and government bureaucracies, conflicts of interest, and cover up of massive hazards to the environment and public health."[18] In 1981, EPA published a document describing the various persuasion techniques that could be used to induce the public to accept land application.[19] Preferred application sites were rural low-income neighborhoods where cash-strapped farmers were told municipal sewage sludge was superior to manure and commercial fertilizer, would dramatically increase yields, and, best of all, was free. EPA and wastewater treatment plants did not inform rural residents about the potential hazards that might occur from using this material.

The only thing missing at EPA was a body of scientific evidence that explained why chemical pollutants, considered toxic and regulated elsewhere, are somehow beneficial when present at the same or higher levels in processed sewage sludge. In 1987 Congress reaffirmed its 1977 directive that EPA develop "a comprehensive framework to regulate the disposal and utilization of sludge."[20] The fact that EPA developed these regulations post hoc to justify an existing policy was problematic. Would the regulations be truly science-based and protective, or would they merely rationalize an existing policy?

The sludge-disposal problem became more urgent in 1988, especially in the Northeast. Sludge generated in coastal cities was being dumped into the ocean. This impacted marine organisms and damaged beaches. Outraged environmentalists succeeded in having Congress pass legislation prohibiting ocean dumping. Environmental groups unwisely agreed to sign a consent decree supporting land application if, in return, ocean dumping would stop.[21]

From 1989 to 1992, land application was governed by a stringent interim rule, the 1989 proposal In the absence of good science, this first version of the 503 rule included strict precautionary metal standards as well as standards for 12 toxic organic chemicals.[20] The interim rule met with strong opposition from municipalities and sludge-management companies. Sludge generated in many large urban centers could not meet these strict standards. In addition, the extra testing requirements for toxic organics would be time-consuming and expensive. Cities that had depended on cheap ocean dumping insisted that disposal of sewage sludge should remain convenient and inexpensive. Also, hauling sludge from cities to nearby farms was becoming a growing and lucrative business. Robert O'Dette, representing the sewerage industry, warned in 1990 that if the interim rules were adopted, beneficial reuse of sludge would end.[22]

Thus, pressure from municipalities and the sewerage industry ensured that the final rule, the 503 rule, would be so lenient that virtually all municipal sewage sludge could legally be land applied. Alan Rubin, an EPA scientist working in OW, led the effort to craft the final rule and have it peer-reviewed by research scientists in EPA's Office of Research & Development (ORD). Based on risk analyses and a national survey of priority pollutants found at approximately 180 wastewater treatment plants throughout the country, the final part 503 sludge rule exempted all organic priority pollutants and regulated only ten heavy metals: arsenic, cadmium, chromium, copper, lead, mercury, molybdenum, nickel, selenium, and zinc. Chromium was later de-listed and molybdenum was largely deregulated.[2 p 30]

Potentially toxic organic and inorganic chemicals regulated under the Clean Water Act and RCRA were exempt from regulation based on a variety of scientifically unsupportable rationales.[2 p 129; 23 p 21]For example, the national survey relied on insensitive analytical methods for many chemicals, and all chemicals detected at less than 5% or 10% frequency were automatically exempted. The EPA exempted other chemicals based on risk analyses incorporating questionable assumptions about land application practices and exposure levels, which were made despite a paucity of data.[2, p 136; 23 p 20]

Under the 503 rule pathogens were regulated based on numbers of indicator microorganisms (fecal coliforms or Salmonella, and enteric viruses) and parasites (helminth ova). Two classes of sewage sludge were established: Class A (no detectible indicator pathogens) and Class B (low levels of indicator pathogens, e.g., < 2 million CFU of fecal coliforms/g). Non–spore-forming bacteria, including fecal coliforms and Salmonella, are among the most easily disinfected pathogens found in sewage sludge. More resistant microorganisms likely to be present in sewage sludge (e.g., hepatitis A virus, rotovirus, norovirus) may survive even when the processed sewage sludge meets all federal and state requirements for pathogen testing.[2 p 60; 24]

ORD's internal scientific peer review severely criticized the 503 rule.[3] OW claimed that numerous studies demonstrated that heavy metals, organic chemicals, and pathogens in processed sewage sludge posed no significant risk to human health or the environment. Rubin, however, could provide only a few laboratory studies and no relevant field studies.[3] ORD was unconvinced that any credible scientific evidence existed to support key parts of the proposed rule. On Sept 6, 2000, Robert Swank Jr., former research director at the ORD laboratory at Athens, Georgia, stated under oath "We did not think the rule passed scientific muster. If the sludge rule were put to the test today, it would miserably fail EPA's own scientific peer review process."[25] As the process concluded in 1992, the peer-review coordinator sent the following message to reviewers prior to a meeting with the Administrator[26]:

> The sludge rule discussions with OW are on hold waiting for Ryan and Chaney's rewrite . Committing to success raises the horizon of our discussion. Options facing the Agency . . . include boldly publishing admittedly weak science, using a factor of safety to compensate for any weakness, or scrapping the whole exercise, and promulgating the Feb 89 proposal as interim. Your advice is solicited. Are human health and the environment "pretty safe" with the application rates drafted, or does the Administrator need to hear that major work is necessary just to be pretty safe? Can we feel ok as long as the uncertainty is fully discussed, both in the preamble and guidance documents?

Despite these major concerns, 40 CFR Part 503 became the final and remains the current rule governing the land application of municipal sewage sludge. To deal with the unresolved safety questions, EPA committed to spend $10 million for a five-year research program to address six major areas of concern. The overall objective of the research was to reduce uncertainties and provide a basis for revising the rule. As soon as the rule was promulgated, however, EPA designated it low priority, and almost none of the work has ever been done. The 503 rule is, in fact, the least protective rule governing land application of all such rules in industrialized countries that regulate this material.[2 pp 45-55;23 pp 7–10;27 p 11]

THE UNHOLY ALLIANCE

The Office of Water makes policy, which is then reviewed independently by ORD to see whether it is scientifically sound. Longest eventually left OW and became Deputy Assistant Administrator for Management at ORD, making him the highest-ranking career manager over EPA's research scientists at ORD.[28] Longest, therefore, was now in charge of policies that he had initiated and supported while at OW. This obvious conflict of interest virtually guaranteed that agency research scientists would not be able to publish findings critical of the 503 rule or argue for more protective land-application policies. Instead of working independently, OW and ORD managers became close allies, supporting the newly crafted land-application policies.

Problems with the 503 rule developed almost immediately after its promulgation. In 1994 and 1995 three deaths occurred that were linked to land-applied sludge. In response to mounting public concerns, those at EPA responsible for land-application policies allied themselves more closely with sludge management companies, which knew how to deal with public opposition. An April 1994 article in the industry trade journal *Biocycle* explained the strategies that "project managers" should use to silence opponents[29 p 34]:

> Controlling the flow of information from the start is the most important aspect for managing the first impression the public receives about a project. To minimize vulnerability in the press, a preemptive strike is usually launched to catch the opposition off guard and get positive messages out about the project before the counter messages start.

When planning an acceptance campaign, "countering the opposition without letting them determine the approval process is the most important goal of a good campaign manager. In the political world, this is called "'controlling the debate.'"[29 p 33] Eventually this alliance forged a smoothly running and well-funded infrastructure that controlled the debate and manipulated public opinion. The alliance formed by EPA and USDA managers who crafted the 503 rule primarily included trade and lobbying groups—e.g., the Water Environment Federation (WEF) and the Association of Metropolitan Sewerage Agencies (AMSA)—state environmental protection departments, university scientists funded to support "beneficial reuse" of sewage sludge, municipal sewerage agencies, and industries marketing sewage sludge.

For land application to continue, it was essential to change the public image of sewage sludge. Accordingly, the alliance changed the name of this material to "biosolids" and defined the transfer of thousands of pollutants from industrialized urban centers to relatively pristine rural farmland as "recycling." Most states appointed "biosolids" coordinators, who worked closely with state agencies and received direction, information, and advice from OW and sludge-management lobbying groups on how to promote land application and deal with public safety concerns.[3 pp 604, 1205–1224;30] The alliance EPA formed with the sludge industry focused its main efforts on assuring the public that the federal rule was protective and scientifically sound in order to discourage states and counties from promulgating stricter rules or bans.[30–32]

In March 1997, the prestigious Cornell Waste Management Institute (CWMI) released a working paper "The Case for Caution," which was revised in 1999 and published in a peer-reviewed journal under a different title.[23] This was the first comprehensive science-based critique of the 503 rule. In their opening sentence the authors boldly state: "Current US federal regulations governing the land application of sewage sludges do not appear adequately protective of human health, agricultural productivity, or ecological health." Between April and December 1997, New York State regulators worked closely with Alan Rubin, John Walker, EPA's Assistant Administrator, and Rufus Chaney, of USDA, on a response to the Cornell paper.[33,34] Copies of their correspondence were sent to the President of Cornell University. On July 24, 1997, EPA's Assistant Administrator wrote to the Deputy Secretary of USDA: " I am quite concerned about the Cornell paper. We believe the publication being proposed by Cornell . . . will have a negative impact on the use of biosolids."[35] Subsequently the nation's leading sludge-management company paid a group of sludge-friendly scientists to attack the paper.[36] Cornell scientists, however, have not wavered in their critique of the 503 sludge rule.[37]

At the same time, David Lewis, one of EPA's internationally known senior research scientists, began investigating reported cases of illnesses and deaths among sludge-exposed individuals and started to form a theory of why some of them were suffering serious health problems.[38] Lewis presented his findings at various scientific meetings[39] and began submitting the work to EPA managers for clearance as a series of research articles and commentaries in peer-reviewed scientific and technical journals. EPA managers in Washington, DC, and at Research Triangle Park, NC, responded by ending all of his research funding in 1998 and instructing his local supervisors in Georgia not to let him collaborate with other EPA scientists or let him have access to agency resources.[40,41 pp 5,9,40] He raised enough, including $80,000 of his own personal funds, to continue his sludge research until 2004.[40]

Simultaneously members of the alliance put incredible roadblocks in Lewis' way to prevent the dissemination and publication of his groundbreaking research and to discredit his expertise. They attacked him at scientific conferences, at public hearings, on their Web sites, and in their promotional literature, claiming that his theories "are far outside the realm of accepted science and have been rebutted by leading researchers around the country."[3 p 602–11;,41 pp 6,27; 42,43] Often his credibility and credentials were questioned by alliance scientists at public meetings he did not attend, eliminating any opportunity for Lewis to respond.[31,44] In October 2001 at a public meeting in Franklin County, GA, an attorney for a sewage sludge management company held up a "white paper" written by another sewage-sludge-management company that attacked Lewis' credentials and credibility and claimed that EPA had forbidden him to do sludge research. The attorney had received this document from EPA's Biosolids Manager, John Walker. Audience members were not informed that this defamatory "white paper" had not been fully endorsed by the EPA.[41 p 29;45]

In 2002, because of repeated attacks on his scientific credibility and his inability to do research in a hostile work environment, Lewis filed suit against the EPA.[3] In 2004, Labor Department Administrative Law Judge Jeffrey Tureck defended EPA's conflict of interest with the regulated industry, ruling that EPA could not be held liable for Walker's misconduct and that whistleblowers should not expect EPA to jump to their defense when industry goes after them. The Labor Department's Administrative Review Board has undertaken a de novo review of the case.[46]

By 2001, Helane Shields had compiled a 382-page victims' package composed of published newspaper articles and investigative reports that, for the most part, described the plight of rural residents who had experienced serious health problems after having been exposed to land-applied sewage sludge.[47] Apparently EPA was aware of "thousands of allegations of problems."[48] But instead of investigating these reports and strengthening the sludge regulations accordingly, EPA strengthened its alliance with the industry it regulates In 1997 EPA, WEF, and AMSA formed the National Biosolids Partnership (NBP). One of NBP's primary goals was to control negative media reports and the public perception that "risks are high, biosolids qualities are poor, inspections and enforcement are small or nonexistent, and EPA does not know what is going on."[49] For example, the agenda for the January 14, 1998, NBP Management Committee Meeting listed as its top priority projects "Communications Plan Update, Code of Good Practice, Public Information Survey, and Technical/Public Acceptance Support."[50]

THE CARROT-AND-STICK APPROACH

Tens of millions of dollars in research funding to NBP members have been earmarked by Congress for land-application research. According to cooperative agreements between EPA and WEF, a considerable portion of congressional funding is used to overcome "misinformation spread by project opponents" who "politicize the decision-making process."[11] Project opponents, as it turns out, are mainly residents living near land-application sites who complain of adverse health effects and scientists who document problems.[11] Other opponents include major environmental groups, such as the Sierra Club, which had protested selective funding of supporters and retaliations against scientists who question the practice.[13] EPA/WEF gave generous grants to regional lobbying groups, such as the New England Biosolids and Residuals Association (NEBRA), to develop an EPA-funded Web site.[3 pp 601–602,1106] The Web site touted the benefits of "biosolids recycling" and attacked researchers that questioned the 503 rule.[43]

The alliance between EPA, sludge management industries, municipalities, and industry-friendly scientists was mutually beneficial: the scientists received grants; the sludge industries and municipalities could continue to profit from the least costly and most convenient method of sludge disposal. EPA, on the other hand, used the public relations expertise of sludge-trade organizations and the findings of EPA/WEF-funded scientists to defend its inadequate rule. This partnership spoke with one voice and was united by one purpose: to vigorously promote sludge farming by ignoring or denying health concerns.

ILLNESSES, DEATHS, AND DENIALS

Meanwhile, hundreds of rural neighbors living or working adjacent to sludged fields reported unbearable quality-of-life conditions as the stench from this chemical and biologically active waste material forced them to retreat inside their homes.[47,51] Many reported serious adverse health effects after being exposed to sludge. These included nausea, vomiting, burning eyes, burning throats, congestion, various infections, and serious respiratory problems.[24,38,47,51–53] Others, including infants, had to be rushed to hospitals because they had trouble breathing.[51] The three deaths linked to land application were those of Shayne Connor, from Greenland, NH, Daniel Pennock, from Robesonia, PA, and Tony Behun, from Osceola Mills, PA.[8,24,38,47,52] While the parents of Shayne, Daniel, and Tony were mourning their sons' deaths, WEF distributed EPA-funded "fact sheets" with EPA assurances that there were "no documented cases of illnesses" and "no public health concerns from the use of biosolids whatsoever."[54]

Tony Behun's death intensified the public concern over sludge application in Pennsylvania. For land application to continue under the current policies, it was essential for the Pennsylvania Department of Environmental Protection (PA DEP) to deny that sludge might have caused the death of a Pennsylvania child. Len Martin compiled a chronological and detailed account of how, for almost two years, the PA DEP went to extraordinary lengths to hide the circumstances of the child's death.[55] In October 1994, 11-year old Tony had ridden his dirt bike through sludge that had been applied to a reclaimed mining site. The child developed headache, sore throat, furuncles on one leg and arm, difficulty breathing, and a high fever. On October 21, a week after he had been exposed to sludge, Tony died of staphylococcal septicemia.[38]

In 1999, Tony's mother, who had heard that sludge was causing health problems in other parts of the country, sought answers from the state about her son's mysterious death. The PA DEP repeatedly and publicly denied that there was any connection between sludge exposure and her son's death.[55 pp 8,9,15,16] According to public statements made by the agency and the company that had spread the sludge, Tony's death resulted from a bacterial infection caused by a bee sting, and sewage sludge had not been applied on the mining site.[55 p 3] In May 2000, PA DEP secretary, James Seif, drafted a report claiming that both the National Institute of Occupational Safety and Health (NIOSH) and the state health department had investigated the case thoroughly and ruled out sludge as the cause or contributing factor of Tony's death.[56] Every one of the above-cited claims proved to be false. The DEP was forced to retract the fabricated bee-sting story; truck weigh slips indicated that about 5,600 wet tons of sludge had been spread on the site next to the child's home; and on August 7, 2000, the PA Department of Health sent a letter to State Representative Camille George confirming that the department "in fact, did not conduct an investigation into Tony Behun's death."[57] NIOSH also stated that it "had no involvement [in the case] because "our agency only investigates workers' health complaints."[55 pp 21–22]

Subsequent public testimony by EPA's Robert Bastian illustrates how EPA and the state agencies responsible for land-application policies work together to misrepresent facts to cover up incidents. On March 13, 2001, Bastian presented Seif's report to the NAS panel that was investigating information about alleged health incidents linked to sludge and assured the panel that "the findings of [PA] state and local health officials have indicated that the Pennsylvania death was not attributable to biosolids."[58]

REACTION AT ORD

EPA's handling of the biosolids issue disturbed many ORD scientists, who were concerned that EPA was developing other regulations based on weak or biased science. Also, managers working under Longest at OW had developed a reputation for retaliating against employees who questioned government policies.[17] By 1996, the consensus was that ORD was truly in a state of crisis and had reached a turning point. David Lewis and others believed that an attempt to work within ORD, bolstered by outside efforts to get congressional and public attention, stood the best chance of correcting the situation. After meeting with two members of Congress and explaining what they had in mind, Lewis was introduced to leading members of Congress who had EPA oversight responsibilities. Combining insights into the political process and examples of weak science identified by some of EPA's best scientists, Lewis wrote a commentary published in *Nature* in 1996, titled "EPA Science: Casualty of Election Politics."[59]

The commentary was followed by a research article, published in *Nature* in 1999.[60] In this article Lewis specifically criticized the 503 sludge rule. Later, Lewis worked with researchers at the University of Georgia and physicians treating sludge-exposed patients to document illnesses in a series of research articles and commentaries.[24,38,52] Over all, the research indicated that residents exposed to dusts blowing from treated fields experienced hypersensitivity reactions consistent with many occupational diseases involving endotoxin-contaminated organic dusts. Most patients were susceptible to recurring respiratory and skin infections, especially involving *Staphylococcus aureus*. Residents experiencing problems generally lived within 1 km of land-application sites, where lime-stabilized (Class A or B) sewage sludge was applied at a rate of several metric tons per hectare annually.[38]

Up to this time, the debate about the safety of land application had primarily been among soil scientists, who focused on the fate and mobility of toxic metals and PCBs degrading soils and contaminating the food chain, as well as on children ingesting sludge. Rufus Chaney, of USDA, key author and defender of the 503 rule, views the inorganic fraction of sludge as a virtually permanent repository for strongly-bound heavy metals. Murray McBride, an independent soil scientist at Cornell University, believes the 503 rule is simplistic, grounded on a weak hypothesis, and that the organic matter in sludge is more important in binding several of the toxic metals; since the organic matter in the soil decomposes, there is always the potential for metal release into soluble and bioavailable forms over time.

The interactions of irritant chemicals and pathogens, which most likely are causing the immediate health problems of rural sludge-exposed residents and which Lewis was investigating, had not been addressed in the risk assessment for the 503 rule. Documentation and explanation of these incidents in the scientific literature would disprove the long-held and frequently quoted industry–EPA position that "there is no documented scientific evidence that the Part 503 rule has failed to protect public health."

Consequently, Longest and others began to retaliate in response to Lewis' *Nature* articles, prompting two hearings by the full Science Committee in the U.S. House of Representatives: *EPA's Sludge Rule: Closed Minds or Open Debate?*,[4] and *Intolerance at EPA: Harming People, Harming Science*.[5] The first hearing focused on retaliations or threats by Alan Rubin against scientists and private citizens who questioned EPA policy.[3] The second hearing dealt with the director of the Athens EPA laboratory, Lewis' second-line supervisor, who, on advice from Henry Longest, was notified that she would be transferred after she approved his second *Nature* article. Earlier the Labor Department had found that EPA's actions against her were retaliatory, and she kept her position at the Athens laboratory. Subsequently the Science Committee drafted the *No Fear Act* (H.R.169) to better protect federal employees against retaliation.[61] The Act required agencies to inform employees of whistleblower protections and pay for judgments in favor of whistleblowers out of their own budgets. It passed with unanimous support in the House and little change in the Senate, and was signed into law by President George W. Bush. Before it passed the Senate, however, the Act was revised to protect managers like Henry Longest. "After months of work with Senate and House Staff, and members of the Government Affairs Committee in the Senate, much of the bad language has been deleted or substantially altered, and specific language has been inserted stating that managers would not be adversely affected by the bill."[62]

Lewis was terminated by EPA in 2003 but continued his sludge research at the University of Georgia (UGA) until attacks on his work, which EPA directly coordinated with industry, forced him to finally abandon his research on adverse effects of sewage sludge and develop other areas of research.[40,45,46,63,64] In his final (unpublished) sludge research, he and other UGA scientists, working with pulmonary and heart specialists in Tennessee, isolated and were in the process of identifying bacterial DNA from the lower lung of a teenaged boy who was hospitalized after inhaling sewage sludge dusts.[65] The patient's physicians concluded that the dusts, which he had inhaled while spreading sludge, had caused bacterial infections and severely damaged his heart and lungs.

Lewis' report states that the patient's medical records between 1996 and 1998 show that he "had normal heart and pulmonary function prior to spreading sewage sludge" and that after spreading sludge beginning in 1999 he had frequently been treated for "recurring sinus infections, allergies, and bronchitis.[65 p 5] By 2001, the patient was being treated for "respiratory infections and the resulting reduction in lung capacity, which physicians found had also affected his heart." According to Lewis' report, pathologists identified the infectious organisms as Nocardia, *Enterococcus faecalis*, and *Moraxella catarrahalis*. After the UGA researchers identified bacterial DNA in a lower lung biopsy sample, Lewis pointed out that the microorganisms involved in the infections "have individual cell sizes within the range of respirable particles (0.5–7 μm). Therefore, they would penetrate the lower lungs when inhaled. . . ." This was to be the first DNA tracking study ever proving that sludge dusts cause pulmonary hypersensitivity complicated with bacterial infections.[65 p 4; 66]

POISONED CATTLE: EPA DEFENDS ADMITTEDLY INACCURATE DATA

In Georgia two large dairy farms receiving Augusta's "Class B" sewage sludge experienced a precipitous drop in milk production and a high cattle mortality rate when dairy herds were fed forage crops grown on treated land. Experts, including bovine nutritionists and a veterinarian, found the cause to be silage grown on sludged fields after observing that affected cattle recovered when fed forage crops grown on fields that were not treated with the sludge. Also, liver and kidney samples of the cattle had toxic levels of copper and zinc, as well as high levels of cadmium, lead, and other pollutants found in the sewage sludge, which could account for the observed impacts.[67,68]

In 1998, the dairy farmers filed lawsuits[9,10] after experts hired by the farmers discovered that the sewage sludge that was put on these fields contained hazardous wastes, damaged the lands, and caused excess mortality in the dairy herds.[69–72] Repeatedly, during the period when sludge was applied, the City of Augusta assured the farmers that " the sludge was safe, non-toxic, and being applied in compliance with appropriate regulations."[68] One of the affected dairy farmers stated[74]:

> Every time I asked a question about problems occurring on the fields, the answer always came back, that there was nothing in the sludge that could cause problems. They never informed us that they were land applying sludge in violation of 40 CFR 257. Never did they tell us that large quantities of toxic hazardous industrial wastes that had little or no industrial pretreatment were being dumped into the sewers.

Chemical analyses of Augusta's sewage sludge reported to the Georgia Environmental Protection Division (EPD) had indicated that the contaminants were within regulatory limits. However, a 1998 EPD audit of the wastewater-treatment facility, prompted by the lawsuits, found that these data were unreliable and perhaps manipulated.[74] The plant manager at the treatment facility later testified that reported data were approximately four orders of magnitude lower than actual concentrations.[71] Indeed, handwritten laboratory records oftentimes did not match the contaminant concentrations reported[75] (see Table 1). The EPD audit also noted many compliance violations in procedure records and concluded that the plant was in total disarray. The lab "was very dirty and this . . . may possibly compromise data." Much of the equipment "was not working properly or was out of service." The overall condition of the plant was described as "horrible." Also, there was only "marginal implementation and administration of the pretreatment program." As a result, the EPD recommended that the land-application program be shut down immediately and that the city should landfill its sludge.[74]

TABLE 1 Discrepancies in Cadmium Concentrations on Worksheets and in Official Reports at the Augusta Wastewater Treatment Plant*

Date	Worksheets†	Reported‡
Jan 90	926	181.21
Feb 90	1,200	378.05
Mar 90	516	458.38
May 90	219	521.5
Oct 90	54	54.3
Nov 90	32	32
Nov 93	29	29
Dec 93	19	19

*Concentrations (mg/kg) in processed sewage sludge (biosolids).[69,75]

†Wastewater treatment plant laboratory notebook (handwritten entries).

‡Corresponding data reported to Georgia Environmental Protection Division.

Source: Dr. Lewis Goodroad. Reproduced by permission.

The head of EPA's Biosolids Incident Response Team (BIRT), Robert Brobst, had participated in the EPD audit and was fully aware of these facts, including the reported data that were unreliable. To help defend EPA policy, Brobst worked closely with attorneys representing the City of Augusta in the lawsuits filed by the dairy farmers.[76] In 1999, EPA assigned Brobst the task of working with UGA's Julia Gaskin on an EPA-funded project to conduct a field study of Augusta's land-application program.

Brobst co-authored the UGA study, "Long-term biosolids application effects on metal concentrations in soil and Bermudagrass forage."[77] To disprove any connection between toxic chemicals in sewage sludge and cattle deaths, Brobst and his UGA co-authors incorporated the unreliable analytical data that the Augusta wastewater-treatment plant had reported to the State of Georgia indicating that the city had complied with state and federal regulations. Authors of the EPA–UGA study intentionally ignored the fact that the historical data indicating the quality of Augusta's sewage sludge and the rates at which it was applied to farmland had been falsified to appear in compliance with applicable laws.[77,78]

Using the unreliable data, Gaskin et al. concluded that metal levels in Augusta sludge were mostly within regulatory limits and that forage samples they took indicated that "the quality of forage grown on these sludged fields should not pose a risk to animal health."[77 p 151] The authors knew the implications of testing samples during a severe drought, and thus these data would not accurately reflect metal levels in forage during normal growing conditions. In a handwritten

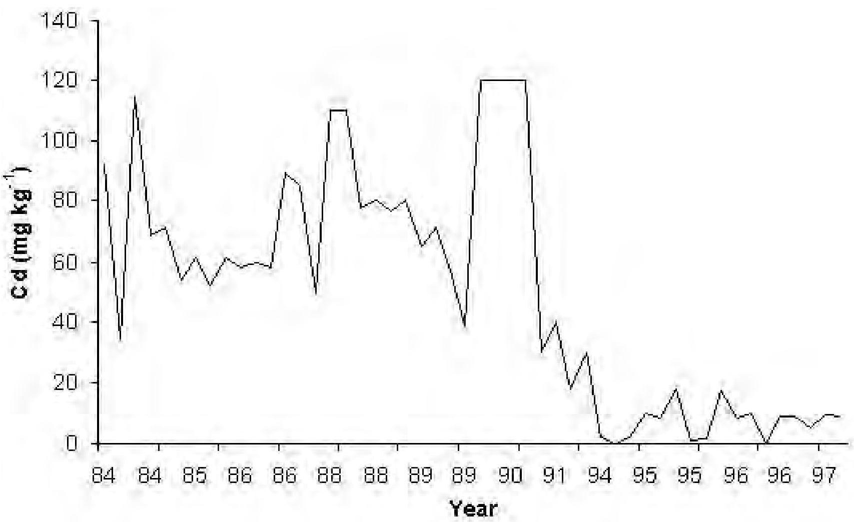

Figure 1, Cadmium levels in treated sewage sludge applied to two dairy farms, reported by Augusta, Georgia's waste treatment plant. Sludge was applied to either or both farms from February 1979 to March 1997. Dairy herds experienced a high mortality rate when fed forage grown on the treated fields.[69,75] The ceiling concentration for Cd in the 503 Sludge Rule is 85 mg/kg. Data truncated at 120 mg/kg for display purposes were: 181.26, 378.05, 458.38, and 521.5 mg/kg (Table 1). Source: *Dr. Lewis Goodroad. Reproduced by permission.*

comment addressed to Gaskin on page 8 of her final draft, one of her co-authors wrote " we should fess up here that we DON'T know exact rates of application, or specific characteristics of sludges applied. . . .??" And on the cover page of the draft the co-author also recommended that Gaskin should "discuss overall sludge quality—pretty BAD in this case."[79]

Brobst's co-authorship ensured that the Gaskin et al. paper would easily pass through EPA's clearance process for policy-related scientific products. In 2003, the UGA–EPA paper was published in a peer-reviewed scientific journal. EPA and its alliance partners cite the Gaskin paper as conclusive scientific evidence that forage fertilized with Augusta sewage sludge did not cause the cattle deaths. Yet the paper was based entirely on forage samples taken during a severe drought and falsified analytical data regarding sludge quality and land-application rates.

EPA's grant to UGA was never meant to be used for a thorough and honest investigation of the poisoned-cattle cases. Instead, the agency funded and "commissioned" this paper expressly to protect EPA's position that its land-application polices are safe and to help the City of Augusta with the pending lawsuits. For example, during the Boyceland Dairy trial against the City of Augusta, Augusta attorneys cited the conclusion of the Gaskin paper in their opening and closing arguments. The jury was not persuaded and ruled in favor of the farmers that hazardous material in sludge had indeed caused the severe damage and deaths of their herds.

To begin with, EPA's misuse of university resources to promote the agency's land-application policies and defend municipalities against lawsuits raises serious questions about the agency's integrity. Beyond that, EPA also gave a pre-publication copy of the Gaskin study to members of the NAS panel, who stated in their 2002 report: "EPA investigated [allegations of animal deaths caused by land application of biosolids] but . . . found no substantiation for the allegations."[2 p 39] In 2003, after the Boyce family won a jury verdict,[80] 73 farm, health, and environmental organizations petitioned EPA for an emergency moratorium on land application. On December 24, 2003, EPA denied the petition, again citing the Gaskin et al. study as primary scientific evidence that land appliction is safe.[81]

Attorneys representing the dairy farmers have asked Gaskin and her co-authors to withdraw her paper.[82] The authors, however, have steadfastly refused to do so. In an apparent move to defend the work of Gaskin and her co-authors in its College of Agricultural and Environmental Sciences, the University of Georgia recently announced the appointment of Jay Scott Angle as the new Dean of the School of Agriculture. Angle is a prominent sludge researcher from the University of Maryland who has worked closely with Rufus Chaney, USDA's main author and defender of the 503 sludge rule.[83]

Figure 1 illustrates examples of high levels of regulated pollutants that the city of Augusta frequently reported to agencies and property owners prior to 1989, when the interim rule [which preceded the less restrictive 503 rule] went into effect. After 1990, the data leveled off below regulatory limits, even though procedures for treating, sampling, and analyzing sewage sludge had remained unchanged.

The metal levels reported by the Augusta treatment plant raise a serious issue. The implications of the Augusta data profiles represented in Table 1 and Figure 1 are enormous because they are similar to others that have been reported throughout the United States.[2 p 125] Trends in data reported by waste-treatment plants are used to argue that large reductions in heavy metals and other contaminants in sewage sludge have resulted from federal and state regulations,[23 p 13] and the National Academy of Science (NAS) recommended that EPA undertake a new national survey based on these databases.[2 p 129–130] Most municipalities, however, have experienced severe budgetary shortfalls and could incur very large costs to upgrade their facilities if they report that they are noncompliant with the 503 rule. "The virtual absence of any independent monitoring of sewage sludge quality by EPA and the states only encourages municipalities to manipulate data. The fact that most pollutant data profiles in the national data banks follow the trend reported by Augusta therefore may simply reflect massive fraud."[84]

EPA DELAYS PUBLICATION OF LEWIS' GROUNDBREAKING RESEARCH WHICH IS NOT CITED IN THE 2002 NAS REPORT

Whereas EPA funded, expedited, and co-authored a fraudulant study that was meant to prove that land application was safe, the agency tried to prevent or, at least, delay the publication of the Lewis et al. research that criticized the 503 rule and documented adverse health effects from land application. To do so, EPA's John Walker solicited help from a vice president of the nation's leading sludge-management company, to prepare and distribute his internal EPA peer review of the Lewis et al. paper.[3 pp 766–811] Walker, who has a PhD in soil science and used to work for the Department of Agriculture (USDA), admitted under oath that he was not competent in microbiology.[41 p 20] He first sent Lewis' paper to an outside colleague in USDA for technical comments, submitted the comments verbatim as his own official EPA peer review, added negative comments, and then recommended against publication of the paper.[41 pp 19–22]

The sludge-management company then shared the negative peer-review comments with the EPA Administrator and requested that the agency stop supporting Lewis' research.[85] WEF made the same request of the Administrator[86]; and AMSA contacted Longest to discuss the matter.[87] To assist in their efforts, the sludge-management company provided Walker with an anonymous "white paper" outlining scientific arguments to be used against the Lewis et al. manuscript and its authors. It included allegations that conducting research on sewage sludge was outside the scope of Lewis' EPA appointment to UGA, a misuse of federal and state resources, and therefore potentially a violation of criminal law. Walker widely distributed this document both inside and outside EPA.[41 p 27] The EPA, however, ultimately rejected the company's allegations and Walker's recommendations, and finally approved the Lewis et al. paper for publication.[88]

Lewis provided the NAS panel investigating the scientific basis of the 503 rule with final and in-press versions of all of his sludge articles, and the 2002 NAS report incorporated many of his ideas and recommendations. One panel member testified under oath to the Department of Labor: "[Lewis'] ideas . . . were important to sort of framing the NAS panel's report. He gave legitimacy to the allegations that has made it impossible to ignore alleged health issues. [Without Lewis' research] EPA's position would still be that nobody has gotten sick and biosolids are safe. He has been the most important player in all this."[41 p 3] Yet, whereas earlier drafts of the NAS report had referenced some of Lewis' papers, the final report mentions neither his name nor his research. The decision to omit all references to Lewis' work apparently was prompted by members of the alliance. On the day the report was scheduled to be released, panel member Greg Kester, biosolids coordinator for Wisconsin and spokesperson for all of the states' biosolids coordinators, sent an e-mail to the panel chair objecting to "elevating David Lewis" and "criticizing the EPA."[89] Subsequently the panel chair removed the last remaining reference to Lewis' papers from the final version of the NAS report. By deleting all references to Lewis' peer-reviewed research, although once vaguely alluding to it as unsubstantiated "speculation,"[2 p 209] EPA and its partners could assure the public that now the prestigious National Academy of Sciences agreed with the agency and its partners that "there is no documented scientific evidence that the Part 503 Rule has failed to protect public health."[2 p 3]

Two months after the NAS report was released, the nation's leading residuals management company distributed a publication titled "Biosolids Recycling" that said that the NAS panel had dismissed Lewis' views.[42 p 9] On four occasions the industry document cites the 2002 NAS conclusion that "there is no documented scientific evidence that the 503 rule fails to protect public health." The publication also cites EPA Deputy Administrator of OW, Benjamin Grumbles: "The NAS report confirms EPA's view that the existing sewage sludge regulations protect human health."[42 p 10] The message to farmers, property owners, land appliers, legislators, the public, and the media couldn't be clearer: NAS agrees with EPA, the industry, and with those scientists who are funded to promote the current policies. Not only EPA, but also NAS "has divorced itself from Lewis' theories."[42 p 12]

Alluding in 2002 to the combined efforts of EPA, industry, and their various trade associations to stop Lewis' sludge research at UGA, and to discredit his research that had already been published in the peer-reviewed literature, the vice president of the company commented[90]:

> What we don't need are more so-called scientists whose research findings are predetermined by scientific or personal bias. These people will find their work rightly discredited and their funding will disappear while credible researchers continue to have funding.

EPA THREATENS HONOLULU WITH FINES

In the third example of how EPA interfered with scientific research on sewage sludge, the agency provided the state of Hawaii with a letter supporting approval of a sludge-management company's contract to build a sewage-sludge-processing plant on Sand Island.[91] EPA claimed that this product is pathogen-free and environmentally safe. When Lewis' input was sought by local businesses and residents, Lewis presented the Council with a plan to test the efficacy of EPA's claims before approving the contract. EPA learned of the plan and threatened Honolulu with $5.5 million in fines if the Council delayed the contract.[92]

The Council, however, rebuffed the threat. Tests carried out at the University of Hawaii found the product met all EPA requirements for indicator pathogens; however, it contained "high levels" of unidentified heterotrophic bacteria.[93] Heterotrophic bacteria include all human, animal, and plant bacterial pathogens. EPA again informed Honolulu of the agency's concerns about delaying the contract, but the Council has extended the delay while considering additional pathogen testing.[94]

BIOSOLIDS SCIENCE

Thirty years ago, Henry Longest committed the nation to the concept of land-applying sewage sludge and then set out to create the science necessary to support it. By funding a network of industry-friendly scientists and discouraging independent research, EPA succeeded in building a body of science around the notion that hazardous biological and chemical wastes in sewage sludge are rendered innocuous, even beneficial, simply by adding lime or passing the material through a digester. This accomplishment necessitated the creation of "biosolids science."

Biosolids scientists believe that heavy metals are immobilized in sludge forever, don't migrate into groundwater, never become bioavailable, and will not accumulate over time at sites where this material is applied.[42 p 6,95,96] They also claim that the organic nature of sludge ensures that land-applied sewage sludge releases nitrogen only as plants need it, and only in the amounts needed.[42 p 7] Even pathogens, they contend, are perfectly harmonized with nature: "The organic nature of biosolids means pathogens, if present, adhere to soil, effectively preventing them from entering groundwater; [then] naturally occurring enemy microbes destroy the remaining pathogens."[42 p 15] According to Walker and others, heavy metals are permanently bound to organic matter such that even children ingesting biosolids are protected from lead poisoning.[3 pp 1305–1311] Walker also considered illnesses reported by residents to be psychosomatic responses to odor and organized an EPA-funded workshop with Duke University psychologists and odor specialists to explore this theory.[97]

Some EPA partners continue to disseminate absurd claims about the safety and benefits of sludge: that crops grown on sludged fields "are healthier" and that sludge used on agricultural land "builds healthy soils"[98]; that mixing sewage sludge with another industrial waste product and placing this mixture at 500 tons an acre on highly permeable soil a few feet above the water table will prevent contaminants from impacting ground water.[99] They also assure the public that regulations prohibit pollutants generated by industry from entering the municipal wastewater-collection system."[31,54,98 p 21] A spokesperson for the New Hampshire Department of Environmental Services, defending unrestricted use of Class A sewage sludge, recently told a legislative subcommittee that this material [which can legally contain up to 32 mg/kg of arsenic, 14 mg/kg of cadmium, 10 mg/kg of mercury, 300 mg/kg of lead, as well as potentially harmful organic chemical compounds and viable disease-causing pathogens] is so safe "that you can eat it."[100] Such statements are liable to reduce these agencies' credibility in the eyes of the scientific community and the public. It is not surprising that surveys indicate that EPA's credibility among citizens concerned about the sludge issue is extremely low.[24]

CONCLUSION

EPA promoted land application largely on the basis that processed sewage sludge possesses certain unusual properties, which prevent the material from polluting the environment. By taking this approach, rather than promulgating more restrictive regulations, EPA has shifted much of the burden of the nation's water-pollution problems, and their associated risks, to cash-strapped farmers and poor, minority neighborhoods.[45,47,51] To deal with the backlash, EPA is attempting to manage negative press,[101–105] while working with the alliance to purge or frighten its critics into silence. Unfortunately, the problems poorly managed biosolids programs are creating will be far more challenging to solve than simply preventing surface-water contamination, which is the goal of our municipal waste-treatment system.

Despite EPA's well-coordinated public-acceptance campaign, many organizations involved with agriculture and the food industry do not support sludge use. H. J. Heinz Company, Del Monte, Western Growers, and other major food suppliers refuse to accept produce grown on land treated with sewage sludge. J. M. Dryer, General Manager of Heinz' Food & Technology Systems, wrote: "[The] risk of utilizing municipal sludge, which is known to be high in heavy metals, such as cadmium and lead, is not a health risk which we need to take. This is not a publicity statement since it is rigorously enforced and we have at times dropped suppliers who have used sludge on their crop land."[106] Del Monte recently confirmed its earlier position not to accept produce grown on sludged land, awaiting more convincing scientific evidence while holding to the "more conservative and prudent" position of the National Food Processors Association and the American Frozen Food Institute.[107] In 2004, the National Farmers Union enacted a policy stating: "The current practice of . . . spreading hazardous wastes and Class B biosolids on land surfaces . . . should be discontinued [to] protect the soil and water of agricultural lands, from which the nation's food is produced."[108]

EPA's handling of the biosolids issue is an important lesson in political science. It illustrates what appears to be the complete corporate control of EPA's land-application policy. Top managers at OW and ORD have failed to honestly address the flaws of a policy that protected neither human health nor the environment. Instead, they leverage corporate influence to their own advantage, expend vast amounts of taxpayer' resources to protect their careers, and wield the awesome power of a federal agency against those who stand in their way. Lewis stood in their way for seven years in his battle to improve EPA's regulatory science. The battle cost him two career jobs, and he is currently unemployed. In November 2004, he finally gave up the fight: "I have taken this effort as far as humanly possible," he wrote to friends and colleagues.[64] In retrospect, Lewis' critical comments in the 1996 *Nature* article about the role of science at EPA were vastly understated. Progress in science and environmental protection depends on open and honest debate. Silencing scientists who question an unwise government policy does not further such progress.

Meanwhile, the dirty work goes on. Health impacts reported by sludge-exposed rural families are countered with EPA's 12-year-old refrain "there is no documented scientific evidence" that land application of sewage sludge is causing adverse health effects,[2 p 3;3 p 610;42,44,54] and reported symptoms are blamed on "mass hysteria" and lack of education.[109] To "educate" the public, WERF earlier this year released another EPA-supported public-relations document, co-authored by NEBRA, entitled "Public Perception of Biosolids Recycling: Public Participation and Earning Trust."[110]

EPA claims it no longer promotes land application of treated sewage sludge. Yet there is no indication that the agency has divorced itself from the industry it is supposed to regulate. Grants to deal with "public perception issues" and promote "better communication approaches"[11] continue to go to alliance researchers, with WERF controlling who gets the money.[11,12 pp 17385–87,17392] Epidemiologic studies are not among the projects that EPA plans to fund.[12 p 17390] To assure legislators, the media, and the concerned public that the current rules, when followed, are protective, the National Biosolids Partnership is touting a voluntary alliance-funded and alliance-run Environmental Management System (EMS). It will never be possible to identify, monitor, and regulate the thousands of industrial and commercial chemical compounds contained in land-applied sewage sludge and their fate and interactions.[2 pp 252-53] Yet at public meetings, EPA and its alliance partners continue to assure increasingly skeptical audiences that land-applied sludge is "an extremely safe material,"[44] while they pressure employers to withdraw support from independent scientists who investigate complaints.

Dr. David Lewis collaborated with the author in writing this paper until giving up his research on sewage sludge in November 2004. He is currently doing humanitarian work in AIDS-stricken areas of sub-Saharan Africa (<www.RoyalLaw.org>).

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ORGANIC CONTAMINANTS IN SEWAGE SLUDGE FOR AGRICULTURAL USE

PROJECT COORDINATION

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FOREWORD OF THE EDITORS

European dimension of organic contaminants

Sewage sludge has been used in agriculture over a long time. Since 1986 the utilization of sewage sludge has been subject to provisions stipulated in the EU Directive (86/278/EEC). The Directive sets out requirements with respect to the quality of sludge, the soil on which it is to be used, the loading rate, and the crops that may be grown on treated land. The European Commission considers that 86/278/EEC has been a success because there have been no reports of adverse effects wherever it has been applied. Consideration has been given to revising the directive in order to further improve the situation

In the majority of cases the most direct risk would currently be considered adverse effects to consumers of crops (humans and animals) by virtue of uptake by crops or contamination of crops. An important risk at heavily amended sites is that of groundwater pollution. Many countries in Europe rely heavily on groundwater for drinking water and irrigation water. Persistent contaminants in groundwater can eventually reach and potentially pollute surface waters.

According to the European Commission, the quantity of water available per human being has dropped by 40% since 1970 and two out of five people living on the planet have water supply problems (RTD info 21). One of the reasons for that is the contamination of land and the groundwater resources especially in highly industrialised regions, which are typical for Central and Eastern Europe. Furthermore, 60% of Europe's cultivated land contains fertilisers and pesticide levels, which are a threat to the quality of groundwater. Contaminated soils loose their functions as a buffer for pollutants and eventually the subsoil environment and groundwater will be contaminated.

The European commission aims to control substances which in a general European view (decision) are undesired in it present concentrations. Organic micro pollutants have got greater attention with the increased knowledge about their toxicity. Halogenated organics (PCB and their prohibition by legal regulations, the Seveso accident with PCDD/F, halo forms in drinking water) have received special attention. For sewage sludge Germany in 1992 was the first European country to introduce national regulations. With growing experience and results from scientific sludge and soil examination programmes other countries have gone the same way. This approach has proven to be successful in reducing the load of pollutants to tolerable levels .This study is a review of the present situation with respect to organic contaminants in sewage sludge and existing limits in the EU Member States

JRC Recommendations

Organic contaminants in sludge are not expected to pose major health problems to the human population when sludge is re-used for agricultural purposes. In comparison, metal contamination of sludges is much more important with respect to human health.

The chemical properties of organics of health concern – hydrophobic and not water soluble - results in a low bioavailability to plants. Plant growth is dependent on the water solubility of nutrients and minerals and water is the transporting vector. Organics with a low water solubility will therefore not be taken up by plants. The presence of organic environmental pollutants, like dioxins and PCBs in agricultural crops is more the result of atmospheric deposition than direct absorption from contaminated soil. The analytical procedures for many organics are complicated and expensive – dioxins are a good example – which is an additional factor to be kept in mind when discussing monitoring of organics in sludges. Monitoring must also pay attention to the origin of sludge because the level of organic contamination may be very different when for example comparing municipal sewage sludge (mostly households) with sludges of industrial origin or sludges from storm- and run-off waters.

The conclusion when analysing table 4.2-1 is that it does not make much sense to include dioxins (PCDD/F), PCBs and PAHs in routine monitoring programmes but occasionally it may be motivated with respect to the origin of the sludge. The same applies to TBT, which is indeed very toxic, but at the same time is almost non-existing in sludges because of a use (antifouling) in other contexts.

There are environmental reasons for monitoring sludges for detergents like LAS and nonylphenoles because they are high volume chemicals with an extensive household and industrial use. They are also more water soluble than the organics previously discussed and therefore more mobile and bioavailable in soils. Again the impact on human health is low because of a low transfer from soil to human consumers. The environmental impact, however, could be significant through leaks to surface waters. Many detergents are clearly toxic and harmful to aquatic organisms and detergents have been indicated as responsible for changes in aquatic populations.

AUTHORS' PRELIMINARY REMARKS AND ACKNOWLEDGEMENT

This study gives an overview of the most recent literature on the subject. There seem to be more than a thousand publications. However there are only few field data, especially from studies on soil-water and soil-plant transfer and on the long-term behaviour of contaminants in soils.

Unfortunately there are very little publications in English from some EU-countries. The study gives an overview of the conclusions of various national working groups and makes suggestions on how to direct future research activities.

So far limit values for pollutants in sewage sludge or soils were based on background concentrations and set with the explicit political intention to avoid adverse effects. It will never be possible to derive limit values solely from scientific research. Limiting pollution so far always resulted in improvements of the environmental situation. Accordingly the continuing development of regulations is a very important matter, especially when regarded from an integrative point of view. The study tries to contribute to this attempt.

We thank all the experts who helped us by sending literature, especially Prof. Dr. Leschber and the Joint Research Centre for financing the study.

The Chapter "Basic toxicological data" was prepared by the FoBiG Institute as a subcontrator.

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TABLE OF ABREVIATIONS

50.P	50. percentile (median)
90.P	90. percentile
AOX	sum of adsorbable organic halogen compounds
BaP	Benzo[a]pyrene
CAS	Chemical Abstracts Service
CB	Chlorobenzene
CMR	Carcinogenicity, Mutagenicity and Reproductive Effects
DBP	Dibutylphthalate
DEHP	Di-2-(ethylhexyl)phthalate
DEP	Diethylphthalate
DNBP	Di-n-butylphthalate
DOC	Disolved organic carbon
EDs	Endocrine disruptors
EDTA	Ethylene diaminetetraacetic acid
EPA	Environmental Protection Agency
GLP	Good Laboratory Practice
HCH	Hexachlorocyclohexane
LD	Lethal Dose
LOES	lowest observed effect concentration
NOEC	no observed effect concentration
NOEL	no observed effect level
NP	Nonylphenole
NPE	Nonylphenole(+ethoxylate)
PAH	Polynuclear aromatic hydrocarbons
PBB	Polybrominated biphenyls
PBDE	Polybrominated diphenyl ether (flame retardants)
PCA	Chlorinated paraffins
PCB	Chlorinated biphenyle
PCDD/F	Polychlorinated dibenzo-p-dioxins and -furans
PCP	Pentachlorphenole
PEC	Predicted environmental concentration
PNEC	Predicted no-effect concentration
POP	Persistent organic pollutants
TBT	Tributyltin
TBTO	Bis-tributyltin oxide
TEF	Toxicity Equivalency Factor
TOC	Total organic carbon
TRGS	Technische Regel für Gefahrstoffe (Technical Rule for Hazardous Substances)
VOC	volatile organic chem.

0 ABSTRACT

The European Union has developed the draft of a "Working document on sludge" (EU 2000), to promote the use of sewage sludge in agriculture while improving the safety and harmonize quality standards. It proposes limit values for concentrations of heavy metals and organic compounds that should restrict the use of sewage sludge in agriculture if the limits are exceeded and provides suggestions for good practice in treatment and agricultural use. The compounds or respectively groups of compounds that are suggested for regulation are LAS, DEHP, NP(E), PAH, PCB and PCDD/F.

This desk study was financed by the EUROPEAN COMMISSION, Joint Research Centre, Ispra. It gives an overview of the occurrence of these organic compounds in sewage sludge, basic toxicological data, a review on persistence of organic contaminants in soils and risk assessments for the various pathways. The attempt was made to identifiy additional substances or substance groups which might cause hazards and should be regulated. Thus it is recommendended that the benzo(a)pyrene concentration in soil is regulated.

To do the review a literature search was run in January 2001 and experts were asked for literature or references, members of ISO TC 190 and CEN TC 308 were contacted and the Internet was searched.

As a result of inquiries and research about 800 references were found. About 150 papers were selected for use in this study. Main criteria for the selection of the papers were, that they were published fairly recently (mostly after 1995) in English or German.

The study gives a priority list of organic contaminants which is meant to be completed with contributions representing the views of the different member states. Chapter 4 gives a summary of conclusions of the pertinent publications and points out where further information is needed.

1 INTRODUCTION

The objective of waste water treatment is to prevent large quantities of substances to reach and impact the environment in high doses and concentrations.

Areas of high population densitiy naturally are areas were production of sewage sludge is high (see Figure 1-1). Presently about 8 million t of sewage sludges (MAGOAROU 2000) are produced each year in the EU member states (Table 1-1). Its high content of organic materials, of nitrogen and phosphorous suggest their use as soil conditioner and fertilizer in agriculture. Consequently it is one of the EU policies to enhance sludge use in agriculture (MARMO 2000).

However a wide variety of undesired chemicals may be found in sludge which could have adverse effects on the environment. They also may affect soils, plant, animals and human health, and have impacts on the environment (LANGENKAMP & MARMO 2000). Because of

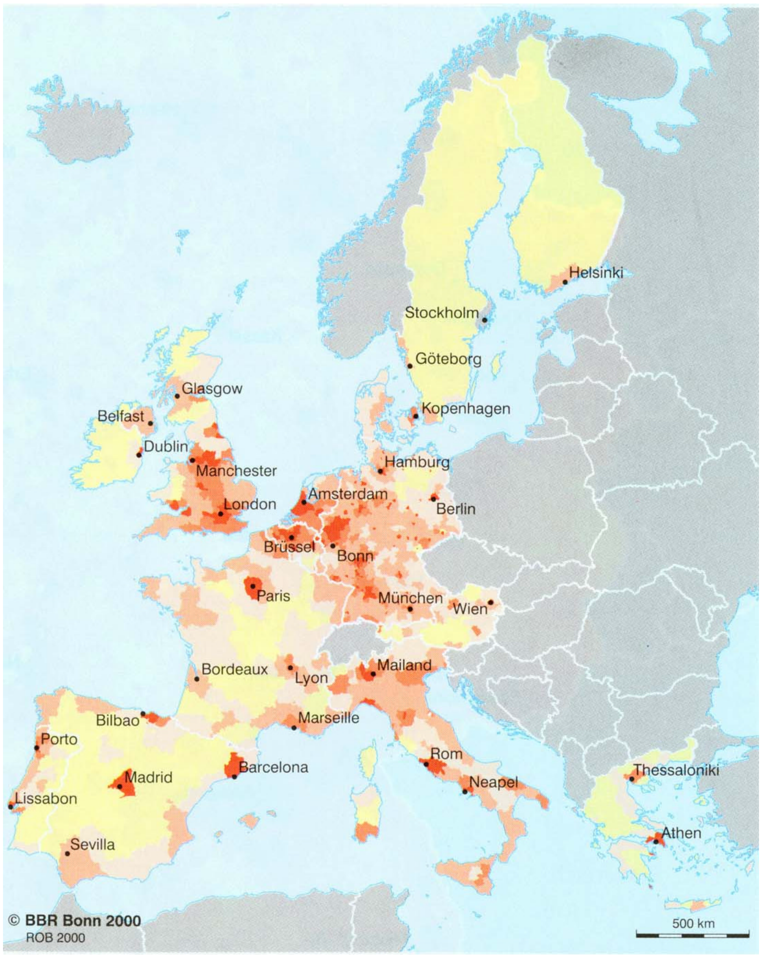

Figure 1-1: *Population densitiy in the EU in 1995 (yellow: <50, red: >500 inhabitants per km²) (BBR 2000)*

Table 1-1: *Area, population and sewage sludge production of EU member states in the year 2005 (MAGOAROU 2000)*

	Area	Population		Sludge destination [1000 t dm/a] in 2005			Relative sludge production
	[km^2]	**[Million]**	**Density**	**total**	**reuse**	**percentage**	**[kg/person/a]**
FIN	338.000	5,1	15	160	115	72%	31
S	450.000	8,9	20	-	-	-	-
IRL	70.000	3,7	53	113	84	74%	31
E	504.782	39,4	78	1088	589	54%	28
GR	131.957	10,5	80	99	7	7%	9
A	88.945	8,1	91	196	68	35%	24
F	550.000	60,4	110	1172	765	65%	19
P	92.072	10,8	117	359	108	30%	33
DK	43.094	5,3	123	200	125	63%	38
L	2.586	0,4	166	14	9	64%	35
I	301.263	57,6	191	-	-	-	-
D	356.854	82,0	230	2786	1.391	50%	34
UK	242.500	58,6	242	1583	1.118	71%	27
B	30.158	10,2	338	160	47	29%	16
NL	41.864	15,8	377	401	110	27%	25

these potential toxicological properties the public expect and demand more legislative control of environmental contamination problems.

Table 1-1 gives an overview of the expected sewage sludge production in the EU member states for the year 2005. Denmark, Luxembourg and Germany are expected to have the highest sewage sludge production per population equivalent. Germany, United Kingdom, France and Spain will probably still be the countries which use the highest amounts of sewage sludges in agriculture (> 500.000 t/a), with Ireland, Finland and United Kingdom reusing the highest percentage of their sludges in agriculture (> 70%).

1.1 Definitions

The terminology used in this review follows the definitions given in the Working Document on Sludge, 3rd draft, (EU 2000):

sludge**:** "mixture of water and solids separated from various types of water as a result of natural or artificial processes"

sewage sludge: sludge from urban waste water treatment plants, whereby 'urban waste water' is understood as: "domestic waste water or the mixture of domestic waste water with industrial waste water and/or run-off rain water" (Directive 91/271/EEC). The definition of 'domestic waste water' in Directive 91/271/EEC reads: "waste water from residential settlements and services which originates predominantly from the human metabolism and from household activities"

treated sludge: sludge which has undergone one of the treatment processes envisaged in Annex I or a combination of these processes, so as to significantly reduce its biodegradability and its potential to cause nuisance as well as the health and environmental hazards when it is used on land.

1.2 Objective of the study

The European Union has developed the draft of a "Working document on sludge" (EU 2000), to promote the use of sewage sludge in agriculture while improving the safety and harmonize quality standards. It proposes limit values for concentrations of heavy metals and organic compounds that should restrict the use of sewage sludge in agriculture if the limits are exceeded and provides suggestions for good practice in treatment and agricultural use.

The Joint Research Center's objective with this desk study was to give an overview on the occurrence of organic compounds in sewage sludge, basic toxicological data (e.g. teratogenic, mutagenic, cancerogenic effects), a review on persistence of organic contaminants in soils, a review on risk assessment for the various pathways and possibly a priority list of organic contaminants. The study also attempts to summarize conclusions of the pertinent publications and to point out where further information is needed.

The 3rd draft of the "Working document on sludge" proposes limit values for concentrations of the following organic compounds or compound groups if sludge is to be used in agriculture:

- 'AOX', the so-called 'sum of halogenated organic compounds'
- linear alkylbenzene sulphonates (LAS)
- di(2-ethylhexyl)phthalate (DEHP)
- 'NPE' (nonylphenole and nonylphenole ethoxylates with 1 or 2 ethoxy groups)
- polynuclear aromatic hydrocarbons (PAHs)
- polychlorinated biphenyls (PCBs)
- polychlorinated dibenzo-p-dioxins and -furans (PCDD/Fs)

One of the purposes of this study was to review the literature for substances or substance groups which might cause hazards and should be included in the priority list.

2 MATERIAL AND METHODS

The desk study is based on the following steps:

1 A literature search run was done in January 2001 by means of the System STN International The Scientific & Technical Information Network. The following data bases turned up references in the field in question: BIOSIS, ENERGY, MEDLINE, UFORDAT, CABA, ENTEC, NLDB, ULIDAT, CEABA-VTB, GEOREF, POLLUAB, COMPENDEX, HSDB, SCISEARCH, EMBASE, LIFESCI, TOXLINE (background information on the respective databases see <http://www.fiz-karlsruhe.de>). Excluding redundant nominations 280 references were pertinent.

2 More than 30 experts were written to or asked for literature or references in other ways, (e. g. Alice Saabye; Antonio De Angelis; Armin Melsa; Claus Bannick, Claus Bergs; Rufus Chaney, Daniel Villessot; Dieter Fuhrmann; Emanuel Adler; Esch, Franz Mochty; Hans Leser; Hartmut Witte; Helmut Kroiss; Ian Evans; Jeremy Hall; Leschber; Joaquim Pocas Martins; Juan Azcarta; Mach Rudolf; Michal Dohanyos; Nico Hoffmann; Paul Woodcock; Peter Balmer; Roland Wolf; Roman Llagostera; Siguard van Riesen; Steinar Nybruket, R. S. Smith,

3 with the support of DIN members of ISO TC 190 and CEN TC 308 were contacted (AFNOR; BSI; CSNI; DIN; DS; ELOT; IBN; ICONTEC; IPQ; JISC; NEN; NSAI; NSF; ÖNORM; PKN; SEE)

4 the Internet was searched, especially the following websites:
www.ademe.fr
www.ains.at/etc&egc/gov/denmark.html
www.iacr.bbsrc.ac.uk/iacr/tiacrhome.html
www.internat.environ.se/index.php3
www.dino.wiz.uni-kassel.de/dain/
www.vdlufa.de/vdl_idx.htm

5 Further references were taken directly from the literature .

As a result of inquiries and research about 800 references were found. About 150 papers were selected for use in this study. Main criteria for the selection were that the papers were published recently (mostly after 1995) and that they provided an overview of the aspects in question.

3 Results and Discussion

3.1 General aspects

Sewage sludge as an uncalled for product of wastewater treatment poses the challenge to society of disposing of it, but at the same time gives us the opportunity of beneficial use by closing the cycle of nutrients: sludge derived from agricultural activity must return to soil if a sustainable and ecologically sound management of these materials is desirable (SEQUI et al. 2000). At present the major ways of disposing of sewage sludges are deposition, landfill and incineration, only part of the sludges are used in agriculture.

Application of sewage sludge to agricultural land may be beneficial because it can improve the physical, chemical and biological properties of soils which may enhance crop growth (BECK et al. 1996). To achieve this, sludge application cannot just be a way of disposing of the sludges but a deliberate application in order to recycle nutrients and to restitute organic matter to soils in order to prevent over-exploitation of agricultural soils in the Community (MARMO 2000). In addition the use of sludge as a fertilizer would decrease the amounts of chemical fertilizers needed in agriculture (TIDESTRÖM 1997) and supply micro-nutrients which are not commonly restored in routine agricultural practice. Thus sludge use in agriculture could help save non-renewable materials or energy, a prerequiste to achieve sustainable production (OCDE 1992 cit in SEQUI et al. 2000).

The major organic loading originates from human excreta, and is a complex mixture of fats, proteins, carbohydrates, lignin amino acids, sugars, celluloses, humic material and fatty acids. A large proportion of this organic material is in the form of both live and dead microorganisms which provide a large surface area (0.8-1.7 m^2 g^{-1}) for sorption of hydrophobic organic residues and it is within this fraction that most synthetic organic compounds are located (ROGERS 1996).

Waste waters and hence sewage sludges contain a wide variety of pathogens, which can be infectious for different species of animals and plants as well as for humans (BÖHM 2000). Therefore hygienic principles must be followed in collection, transport, processing, storage and distribution of such materials. Pathogens may survive for a remarkable period of time in sludges and the environment (BÖHM 2000).

3.1.1 Legislative measures

While it encourages the use of sewage sludge, the EU Directive 86/278/**EEC** regulates its use to prevent harm to the environment, in particular to soil. In order to improve the long-term protection of Community soils the Commission is currently working on some aspects of the Directive in the light of new scientific evidence and technological progress (MARMO 2000). Table 3.1-1 shows limit values for concentrations of organic compounds in sludge of different countries and as suggested in the 3rd draft of the “Working paper on sludge”.

Tabel 3.1-1: *Standards for concentrations of organic contaminants in sewage sludge in different countries of the EU*

	AOX mg/kg dm	DEHP mg/kg dm	LAS mg/kg dm	NP/NPE mg/kg dm	PAH mg/kg dm	PCB mg/kg dm	PCDD/F ng TEq/kg dm
EU 2000 (3rd draft)	500	100	2600	50	6[1]	0,8[2]	100
Denmark (Danish Ministerial Order No. 823, 16 Sept. 1996, cit in MADSEN et al. 1997)	-	50	1.300	10	3[1]	-	-
Sweden (LRF & SEPA & VAV; 1996)	-	-	-	50	3[3]	0.4[4]	-
Lower Austria (NÖ, 1994 cit. FÜRHACKER &LENCE 1997)	500	-	-	-	-	0,2[5]	100
Germany (Sauerbeck & Leschber 1992)	500	-	-	-	-	0,2[5]	100

[1] Sum of acenapthene, phenanthrene, fluorene, fluoranthene, pyrene, benzo(b+j+k)fluoranthene, benzo(a)pyrene, benzo(ghi)perylene, indeno(1, 2, 3-c,d)pyrene.

[2] sum of 6 congeners PCB 28, 52, 101, 138,153, 180.

[3] sum of 6 compounds

[4] sum of 7 congeners

[5] each of the six congeners PCB 28, 52, 101, 138, 153, 180.

Tabel 3.1-2: *French guide values for PAH concentrations in sewage sludges and maximum amounts in soils of pastures (CSHPF, 1998)*

compound	**concentrations in sludge to be used in agriculture at a rate of no more than 30 tons/ha/10a (mg/kg dw)**	**maximum permissible cumulated input on pasture soils per hectare in 10 years (g/ha dw)**
fluoranthene	4	60
benzo(b)fluoranthene	4	60
benzo(k)fluoranthene	4	60
benzo(ghi)perylene	4	60
benzo(a)pyrene	1,5	20
indeno(1, 2, 3-c,d)pyrene	4	60

Table 3.1-2 gives the French guide values for concentrations of PAH and for the maximum cumulated input over a period of 10 years.

In 1995, a working group of the **Danish** Ministry of Environment and Energy identified organic chemical residues, for which limit values should be elaborated (DK-EPA 1996a, DK-EPA 1996b cit in MADSEN et al. 1997). Until 1997, the use of sludge in Denmark was regulated with respect to the maximum content of selected heavy metals, maximum of phosphorus, nitrogen and dry matter of waste to be applied per hectare and year and regulations regarding the use of waste-treated farmland (no root crops, cattle grazing or other direct non-processed use for consumption until one year after application) (MADSEN et al. 1997). The primary targets are consumers of products grown on sludge-amended fields, consumers of ground water from areas where sludge is applied as fertilizers and the biological structure and function of the soil ecosystem exposed to contaminants from sludge. The quality criteria elaborated by the above procedure is used as “Predicted no-effect concentration” (PNEC) for protection of farmland quality (PNECsoil , PNECplant , PNECgroundwater) (MADSEN et al. 1997).

In **Germany** the fertilizer effects of sludges have to be taken into account according to the rules of the German Fertilizer Act and its respective ordinances when sewage sludge is to be used in agriculture (LESCHBER 1997). It is prohibited to use sludge in fruit and vegetable cultivation, on grassland, in nature conservation areas, in forests and near water catchments/wells respectively in water protection areas. The German regulation comprises limits for AOX, PCB und PCDD/F. SAUERBECK & LESCHBER (1992) report, that the German Ministry of the Environment set these limit values as a purely precautionary measure, they were not based on scientific evidence of immanent toxicological implications. Instead the limit values were based on the current concentrations of the respective compounds in German sewage sludges. Concentrations of AOX in sludges do not really give information about the absence or presence of hazardous substances, this could mean a measure of careful soil protection to prevent the input of high amounts of anthropogenic compounds into soil, some of which may be persistent pollutants (LESCHBER 1992).

Surface application of undigested or digested sludges on grazing land were banned in the **UK** in January 1999, although the injection of digested sludge into grazed pasture soils is currently allowed (SMITH 2000).

There are, actually, no formal **Swedish** regulations for organic contaminants in sludge. There is an informal agreement between the Swedish EPA, the Farmers Union and the Water and Wastewater Association which includes the recommendations in table 3.1-1. These agreements are based more on practical experience than on scientific data. Sweden also used to have a recommended limit value for toluene, but this has been omitted (WALLGREN 2001).

The **US** regulation on the use of sewage sludge in agriculture does not establish numerical pollutant limits of any organic pollutants, because at least one of the following criteria applied for the organics considered (USEPA 1995): the pollutant is banned for use, has restricted use or is not manufactured for use in the US; the pollutant is detected infrequently in sludge and is present in 5% of sludge samples; the limit for an organic pollutant derived from the 503 exposure assessment is greater than the 99th percentile concentration in sludge (SMITH 2000).

3.1.2 Background information about contaminants

3.1.2.1 AOX

The analytically determined parameter of adsorbable organic halogen compounds (AOX) does not represent a specified chemical substance. Rather, it is defined by the binding of a halogen-containing chemical to activated carbon. In given samples, e.g. different sewage sludges or waste waters, AOX can be composed of quite diverse compounds depending on the origin of the samples. The formation of AOX has been observed in the context of drinking-water desinfection. Both chlorination and ozone treatment may lead to the formation of trihalomethanes (THM) with bromine derivates being formed when small amounts of bromine are present in the water. The German drinking-water directive mentions chloroform, bromodichloromethane, dibromochloromethane and bromoform as analytical parameters for THM. While other organic halogens are formed in these processes as well, which are all detected as AOX, THM serve as an indicator class of compounds. As a rough estimate, the relation of AOX to THM in drinking-water is estimated to be 10 : 1 (GROHMANN 1991). One of the main sources of AOX has been the bleaching of paper pulp leading to the formation of organic halogens. In Finland, this industry was responsible for about 50 % of the total organic halogen emissions into the environment. Several other industries, such as the manufacture of polyvinyl chloride (PVC), and waste incineration are important sources of AOX formation as well. PVC itself, which is otherwise regarded as inert, may enhance the AOX measured significantly. In the context of soil contamination it is noteworthy that some organic halogens may be transformed in the soil to more toxic compounds such as vinyl chloride, which is a known human carcinogen (SALKINOJA-SALONEN et al., 1995; AURAS 2001).

3.1.2.2 NPE

4-Nonylphenole is a widespread degradation product of non-ionic alkylphenole polyethoxylate surfactants (HARMS 1997). Due to the problems caused by foaming on surface waters, there has been an increase in the adoption of more readily biodegradable detergents such as non-ionic 4-alkylphenole polyethoxylates, which are used in large quantities in detergents. 4-nonylphenole has been identified as a toxic degradation product of alkylphenole polyethoxylate (JONES & NORTHCOTT 2000). NPEs are used as surface active agents in cleaning products, cosmetics and hygienic products, and in emulsifications of paints and pesticides. Due to the hazardous properties, the NPEs are slowly being phased-out of the market.

3.1.2.3 LAS

Linear alkylbenzene sulphonates (LAS) are the most widely used anionic surfactants in cleaners and detergents. LAS was introduced as a substitute for the slowly biodegradable ABS in the mid-1960s (JONES & NORTHCOTT 2000). Production is 1.5 to 2 million t/yr worldwide and 300 000 t/yr within the EU. LAS is readily degraded under aerobic conditions, but not at all in anaerobic environments (MADSEN et al. 1997). Since a large part of the LAS is absorped onto sewage solids during primary settlement of sewage, it will bypass the aeration tank and hence not degrade in the regular treatment process. Degradation can only occur when aerobic conditions are restored during storage of sludge, and after application to land thus preventing LAS accumulation in the soil environment (DE WOLFE & FEIJTEL 1997).

3.1.2.4 DEHP

Phthalates are incorporated into plastics as plasticisers. Di-2-(ethyl-hexyl)-phthalate (DEHP) is the most common of the phthalate esters. Phthalates are used as softeners in plastic (PVCs). Other uses include additive functions in paints, laquers, glues, inks, etc. Many phthalates are degradable under both aerobic and anaerobic conditions but the sorption to particles reduces the actual degradation rate considerably. The substances have a potential for uptake in plants. They are toxic to soil organisms and some phthalates are suspected to have hormone mimic properties (MADSEN et al. 1997).

3.1.2.5 PAH

PAHs are a by-product of incomplete combustion, their main source is the burning of fossil fuels. PAHs are ubiquitous in the environment and may be formed naturally, e.g. by forest fires. Many PAHs are known or suspected carcinogens/mutagens.

3.1.2.6 PCB

Commercial production of polychlorinated biphenyls (PCBs) began in 1929. PCBs are produced by chlorination of biphenyl, which has 10 positions available for chlorine atoms, producing a theoretical mixture of up to 209 possible compounds distributed among 10 levels of chlorination. The chemical and physical stability of PCBs, their electrical resistance, low volatility and resistance to degradation at high temperatures added to the commercial utility of PCBs.

3.1.2.7 PCDD/F

Polychlorinated dibenzo-p-dioxins and -furans (PCDD/Fs) are two groups of tricyclic, planar aromatic compounds. They are not intentionally produced, but may form during the production of chlorinated compounds such as e.g. pentachlorophenole, or during combustion processes where chlorinated substances are present. There are potentially 75 PCDD and 135 PCDF congeners, which belong to 8 homologue groups according to the numbers of chlorine atoms present. PCDD/Fs are ubiquitous in the environment at extremely low levels.

3.1.2.8 Other Pollutants

Organotins

To date, organotins are the most widely used organometallic compounds. Recent estimates assumed that the annual world production of organotins may be reaching 50.000 tonnes

(FENT et al. 1995). They have high fungicidal, bactericidal, algicidal, and acaricidal properties. Of particular importance to the environment is the high toxicity of tributyl-, triphenyl-, and tricyclohexxyltin derivatives. Organotins are used as agrochemicals and as general biocides in a broad spectrum of applications. The use of TBT containing antifouling paints is now controlled or banned in many countries, but a change in applications from antifouling paints to wood preservation seems to occur at present (FENT et al. 1995).

Musk ketone and musk xyxlenes

Musk xylene and musk ketone are used as substitutes for natural musk in perfumes and other cosmetics, soaps and washing agents, fabric softeners, air fresheners etc. The production in Europe is estimated to be 124 tonnes/yr for musk ketone and 75 tonnes/year for musk xylene (ALCOCK et al., 1999), most of which is expected to be released into sewers because of there useage. TAS et al. (1997) give a review of environmental data and a risk assessment procedure for these compounds.

3.2 Occurrence of contaminants in sewage sludges

3.2.1 General aspects

In a literature review of DRESCHER-KADEN et al. (1992) including 900 papers published since 1977, residue data about the level of organic pollutants in German sewage sludges were collected. 332 organic compounds with known or suspected toxic effects have been detected in sewage sludges, 42 of them regularly, most of them within the range of g/kg to mg/kg dry matter. Except volatile and easily degradable chemicals, the residue level increases from raw to digested sludge. Samples from rural treatment works have a more balanced residue pattern than from urban origin where the highest and also the lowest values have been found. But generally, the residues in rural areas tend to be slightly lower, particularly for typical industrial chemicals (DRESCHER-KADEN et al. 1992).

3.2.2 Pollutant specific data

3.2.2.1 AOX

In a survey of contamination levels of Danish sewage sludges, MADSEN et al. 1997 found concentrations for AOX in the range from 75-890 mg Cl/kg dm in sludge samples of 19 municipal waste water treatment plants in the year 1995. UMK-AG 2000 report concentrations and percentiles for the years 1994 to 1996 (Table 3.2-1).

Tabelle 3.2-1: *AOX content in sewage sludges from Germany (UMK-AG 2000)*

year	**Mean** mg/kg dm	**highest 90-perzentile among German Bundeslaender** mg/kg dm
1994	206	370
1995	201	400
1996	196	363

3.2.2.2 NPE

In their survey of Norwegian sewage sludges PAULSRUD et al. (2000) found Nonylphenole (+ ethoxylates) in high concentrations in sludge samples from all the sewage treatments plants they investigated. All of these sludges would have exceeded the Swedish and Danish standards. There has been a minor decrease in nonylphenole concentration in Norwegian sludges since 1989s, which is mainly attributed to the industries phasing out these compounds from their products (i.e. detergents, paints). Similar experiences have been reported from Switzerland (GIGER 1997 cit. in PAULSRUD et al. 2000). In 1997, at the "Specialty Conference on Mangement and Fate of Toxic Organics in Sludge Applied to Land", the Swedish Environmental Protection Agency reported a mean value for

Nonylphenole of 46 mg/kg dm (TIDESTRÖM 1997). PAULSRUD et al. give an overview of concentrations found in various surveys in Scandinavia (Table 3.2-2)

Table 3.2-2: *Overview of concentrations of Nonylphenole (+ ethoxylates) in Scandinavian sewage sludges*

Investigations	Number of samples	Range	Median	References
	36	22-650 (mg/kg dw)	136	PAULSRUD et al., 2000
Norwegian (1989)	19	25-2298 (mg/kg dw)	189	VIGERUST, 1989
Swedish (1993)	23	23-171 (mg/kg dw)	82	National Swedish Environmental Protection Board, 1995 cit in PAULSRUD et al., 2000
Swedish (1989-91)	27	44-7214 (mg/kg dw)	825	National Swedish Environmental Protection Board, 1992 cit in PAULSRUD et al., 2000
Danish (1995)	20	0,3-67 (mg/kg dw)	8	TÖRSLÖV et. al., 1997
Danish (1993-94)	9	55-537 (mg/kg dw)	–	TÖRSLÖV et. al., 1997

3.2.2.3 LAS

JONES & NORTHCOTT 2000 compiled data on LAS concentrations in sewage sludges for a number of countries (table 3.2-3a). Ranges of concentrations in Danish and Norwegian sludges are found in table 3.2-3b. MADSEN et al. (1997) report LAS concentrations for Norway in the range of < 1 to 424 mg/kg dm which are far lower than in sludges from other countries. The relatively low concentrations in Norway may be accounted for by the predominant use of detergents that do not contain LAS (PAULSRUD et al. 2000). Since LAS biodegrade under aerobic conditions, the low concentrations in part of the German sludges may be due to aerobic digestion, whereas missing treatment (digestion of organic matter leads to relative concentration of contaminants), may have kept the concentrations down in the non-treated Spanish sludges.

Table 3.2-3a: *Concentrations (mg/kg) of LAS in sewage sludge from selected countries (JONES & NORTHCOTT 2000)*

Country	No of WWTP	Sludge description	Range
Denmark	19	Various	11-16100
Germany	8	Anaerobically digested	1600-11800
Germany	10	Aerobic	182-432
Italy	1	Anaerobically digested	11500-14000
Spain	3	Anaerobically digested	12100-17800
Spain	2	Non-treated	400-700
Switzerland	10	Anaerobically digested	2900-11900
UK	5	Anaerobically digested	9300-18800

Table 3.2-3b: *Concentrations (mg/kg) of LAS in sewage sludge from Norway and Denmark*

Country	Number of samples	Range of concentratio ns	Median	References
Norway (1996-97)	36	< 1-424	54	PAULSRUD et al. 2000
Danish (1995)	20	11-16100	530	TÖRSLÖV et. al., 1997
Danish (1993-94)	6	200-4640	455	TÖRSLÖV et. al., 1997

3.2.2.4 DEHP

DEHP was detected in almost all sewage sludge samples, and three of the plants revealed concentrations above the Danish 1997-standard (MADSEN et al. 1997). DBP was detected less frequently and also at lower concentrations than DEHP. There has been a significant reduction in DEHP content of Norwegian sludges since 1989, but the values are still higher than in the Danish investigations. Both DEHP and DBP were also found in compost and manure, but at lower levels than in sewage sludge (PAULSRUD et al. 2000)

Also DEHP appeared in relatively high concentrations in water extracts of sludge (mean concentration: 55 µg/l, highest measured value: 310 µg/l). Although DEHP is expected to sorb firmly to sludge particles, the concentration in sludge is sufficiently high to result in measurable concentrations in water extracts (MADSEN et al. 1997). MADSEN et al. 1997 found, that the most common phthalates in the sludges were DEHP with concentrations between 4 and 170 mg/kg (d.m.). Table 3.2-4 gives data on concentrations found in various investigations.

Table 3.2-4: *Concentrations of DEHP in Sewage Sludges of various countries (mg/kg dw)*

Investigations	Number of samples	Range	Median	References
Norway	36	<1-140	58	PAULSRUD et al. 2000
Norwegian (1989)	19	27-1115	83	VIGERUST, 1989
Swedish (1989-91)	27	25-661	170	National Swedish Environmental Protection Board, 1992 cit in PAULSRUD et al., 2000
Danish (1995)	20	3,9-170	24,5	TÖRSLÖV et. al., 1997
Danish (1993-94)	9	17-120	38	TÖRSLÖV et. al., 1997

3.2.2.5 PAH

In Danish sludges the concentrations of PAHs (sum of 9 PAHs) were typically below 3 mg/kg (d.m.) (MADSEN et al. 1997). WILD et al. (1992) reported concentrations of polynuclear aromatic hydrocarbons in UK sewage sludges in the range of 1-10mg PAH/kg, which is significantly higher than the normal range of concentrations found in agricultural soils. In their study of Norwegian sludges PAULSRUD et al. (2000) found PAH concentrations below the Swedish and Danish standards of 1997 in most samples. There were large monthly variations in most treatment plants and hence the authors suggest that one single sample is not sufficient to evaluate the level of toxic organics in sewage sludge. The PAH concentrations of this study were almost at the same level as in the previous Norwegian investigation, but above the more recent values reported in Sweden and Denmark (PAULSRUD et al. 2000). Data of different countries are shown in Table 3.2-5.

Table 3.2-5:*Concentrations of PAH in Sewage Sludges of various countries (mg/kg dw).*

Investigations	Number of samples	Range	Median	References
Danish (1995) (sum of 18 compounds)	20	<0,01-8,5	–	TÖRSLÖV et. al., 1997 (cit. in Paulsrud 2000)
Danish (1993-94) (sum of 18 compounds)	9	0,42-2,4	–	TÖRSLÖV et. al., 1997 (cit. in Paulsrud 2000)
Norway	36	0,7-30	3.9	PAULSRUD et al. 2000
Sweden (sum of 6 compounds)	-	-	1.6	TIDESTRÖM 1997
parts of Germany (sum of 6 compounds)	124	0,4-12,83	-	UMK-AG 2000
parts of Germany (sum of 16 compounds)	88	0,25-16,28	-	UMK-AG 2000

3.2.2.6 PCB

SCHAAF (1992) found PCBs in nearly every sample of a selection of sewage sludges from different parts of Germany, with the congeners 138 and 153 being the most important among 28, 52, 101, 138, 153 and 180. MCGRATH et al. (2000) found PCBs in almost all the sample that were examined, with a maximum concentration of 0.105 mg/kg. Results from the first US National Sewage Sludge Survey, confirmed that concentrations of PCBs in most US biosolids were much lower than found in previous US surveys (CHANEY et al. 1998). According to an estimation of the US-EPA the 98th percentile of biosolid PCB concentration was 0.21 mg/kg dw. PAULSRUD et al. (2000) found that PCB contents in Norwegian sludge samples were far below the German and Swedish standards for PCB and, in general, were lower than in previous studies in Scandinavia. They found variations between monthly samples from each plant to be larger than differences between plants. HEMBROCK-HEGER (1992) compared untreated soils and soils treated with sewage sludge. Most PCB concentrations were near the detection limit (1 µg/kg for each congener).

Table 3.2-6a gives an overview of concentrations of PCB sums found in various countries while table 3.2-6b shows mean concentrations of PCB congeners in Germany.

Table 3.2-6a: *Concentrations of PCB in Sewage Sludges of various countries (mg/kg dw)*

Investigations	Number of samples	Number of congeners	Range	Median (Mean)	References
Norway	36	7	0,017-0,10	0,0422	PAULSRUD et al. 2000
Swedish (1993)	23	7	0,0006-0,232	0,113	National Swedish Environmental Protection Board, 1995 cit in PAULSRUD et al., 2000
Swedish (1989-91)	27	7	0,080-7	-	National Swedish Environmental Protection Board, 1992 cit in PAULSRUD et al., 2000
Sweden (sum of 7 congeners)	-	7	-	(0.1)	TIDESTRÖM 1997
Germany	-	each of 6 congeners	< 0,2	-	UMK-AG 2000

Table 3.2-6b: *Mean PCB-concentrations in sewage sludge in Germany (mg/kg dm)(UMK-AG 2000)*

	PCB 28	PCB 52	PCB 101	PCB 138	PCB 153	PCB 180	Sum
1989	0,041	0,028	0,052	0,082	0,084	0,053	0,340
1994	0,015	0,015	0,024	0,039	0,039	0,026	0,158
1996	0,016	0,017	0,020	0,037	0,038	0,026	0,154

3.2.2.7 PCDD/F

Some PCDD/Fs have been shown to form during wastewater treatment processes, however, this is considered minimal and insignificant compared with inputs via the sludge itself (ALCOCK & JONES 1996).

In the **UK** PCDD/F is reported to be ubiquitous in sewage sludge. Estimates of the inputs of PCCD/Fs from sewage sludge applied to agricultural land in the U.K. (JONES & SEWART 1995 cit in DUARTE-DAVIDSON et al. 1997) are currently about 25 g TEQ/year respectively 21 kg/PCDD/F per year. Interestingly, the input of TEQ via sludge use is only about 1.8% of the estimated input from atmospheric deposition, while the PCDD/F input is a more significant portion, because sludge contains very high concentrations of non-2,3,7,8-substituted and/or low TEF-rated congeners (DUARTE-DAVIDSON et al. 1997). For Denmark too, the use of sewage sludge in agriculture is considered a minor source of dioxin emissions to soils than deposition from the atmosphere (HANSEN 2000).

PAULSRUD et al. (2000) found in a survey of **Norwegian** sludges, that concentrations of PCDD/PCDF were in general very low and showed only small monthly variations (PAULSRUD et al. 2000).

I-TEQ values in **Catalonian** sludges of 1987 and of 1993-1994, were higher than those measured in contemporary sludges (ELJARRAT et al. 1999). The lower levels detected in the contemporary samples seem to reflect a general decline in PCDD/F inputs to the environment, owing to tighter controls on PCP use and disposal (ELJARRAT et al. 1999).

Table 3.2-7: *Comparison of Investigations of PCDD/F in Sewage Sludge (ng/kg dm)*

Investigations	Number of samples	Range	50.P	mean	90.P	References
	36	3,0-68,8	6,26	-	-	PAULSRUD et al. 2000
Swedish (89/91)	14	5,7-115	20,5	-	-	National Swedish Environmental Protection Board, 1992 cit in PAULSRUD et al., 2000
Danish (93/94)	9	10,3-34,2	-	-	-	TÖRSLÖV et. al., 1997
Germany 1994			-	22	46	UMK-AG 2000
Germany 1995			-	19	51	UMK-AG 2000
Germany 1996			-	17	56	UMK-AG 2000

In their compilation of environmental levels of dioxins AEA TECHNOLOGY (1999) reported the data given in table 3.2-8 to the European Commissions respectivey to the UK Department of the Environement, Transport and the Regions.

Table 3.2-8: *Comparison of Investigations of PCDD/F in Sewage Sludge (ngTEQ/kg dm)*

Country	**Austria**	**Denmark**	**Germany**	**Spain**	**Sweden**	**UK**
Range	*8,-38*	*0,7-55*	*0,7-1207*	*64*	*0,02-115*	*9-192*
Average	*14,5*	*21*	*20-40*		*20*	

3.2.2.8 Others

3.2.2.8.1 Organotins

From the production figures and use pattern, it becomes evident that a significant portion of organotins may enter wastewaters. A study of FENT et al. (1995) on the occurrence of organotin compounds in municipal wastewater and sewage sludge identified several compounds in these media. These compounds have been found to become enriched in sewage sludge, where they are not substantially degraded during treatment (FENT et al. 1995). A survey conducted in four treatment plants in 1988-1990 showed that MBT, DBT and TBT were generally present in digested sludges. In addition to butyltins, in one sample mono-, di and triphenyltin residues in the range of 0.1-0.4 mg/kg were found. Mono-, di- and tributyltin concentrations in nine sludge samples of four different treatment plants were in the range of 0.10-0.97, 0.41-1.24 and 0.28-1.51 mg/kg (d.m.), respectively (FENT & MULLER 1991 cit in FENT et al. 1995). Other sewage sludge samples from Switzerland were found to be similarily contaminated, whereas sludges of three out of five Canadian cities had butyltin residues which were somewhat lower than those in Switzerland (FENT et al. 1995).

3.3 Basic toxicological data

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3.3.1 Notes on the basic toxicological data sets

Non-carcinogenic as well as carcinogenic effects are described briefly in chapter 3.3.2. Exact dose and effect levels are not mentioned but the most relevant endpoints, i.e. those for which effects at lower dose levels are known, are emphasized. The risk phrases (and their meaning) according to the classification and labelling legislation within the EU are given. The basis for these risk phrases is Annex I of Council Directive 67/548/EEC of June 27 1967 and the respective amendments. Table 3.3-1 lists classifications in relation to carcinogenicity, mutagenicity and reproductive (CMR) effects. The basis for these classifications are the Council Directive mentioned above, the assessment of the German „Technical Rule for Hazardous Substances“ (TRGS 905) and classifications by the International Agency for Research on Cancer (IARC) of the World Health Organization (WHO) in its Monograph series. In the section guidance and limit values some health-related guidance and limit values are given. In cases, where reliable risk estimates of carcinogenic potency exists, these are given after the table of guidance / limit values. In general, unit risk estimates are reported in this section which are based on animal experiments or epidemiological data. They describe the excess risk of cancer resulting from lifetime exposure to the respective chemical at a given dose or concentration. These values do not represent a threshold.

Table 3.3-1: *Definitions of terminology used in chapter 3.3.*

Ref.	***Category***	**Erläuterung**
EU, 1993	*Carcinogenicity*	(The assessment of the German TRGS 905 relies on similar criteria)
	Category 1:	Substances known to be carcinogenic to man.
	Category 2:	Substances which should be regarded as if they are carcinogenic to man.
	Category 3:	Substances which cause concern for man owing to possible carcinogenic effects but in respect of which the available information is not adequate for making a satisfactory assessment.
IARC, 1999	*Carcinogenicity*	
	Group 1:	The agent (mixture) is carcinogenic to humans.
	Group 2A:	The agent (mixture) is probably carcinogenic to humans.
	Group 2B:	The agent (mixture) is possibly carcinogenic to humans.
	Group 3:	The agent (mixture or exposure circumstance) is not classifiable as to its carcinogenicity to humans.
	Group 4:	The agent (mixture) is probably not carcinogenic to humans.
EU, 1993	*Genotoxicity*	(The assessment of the German TRGS 905 relies on similar criteria)

Ref.	*Category*	**Erläuterung**
	Category 1:	Substances known to be mutagenic to man.
	Category 2:	Substances which should be regarded as if they are mutagenic to man.
	Category 3:	Substances which cause concern for man owing to possible mutagenic effects.
EU, 1993	*Reproductive effects and fetotoxicity*	(The assessment of the German TRGS 905 relies on similar criteria)
	Category 1:	Substances known to impair fertility in humans.
	Category 2:	Substances which should be regarded as if they impair fertility in humans.
	Category 3:	Substances which cause concern for human fertility.
Guidance and limit values		
WHO - Acceptable daily intake		ADI values (or similar values such as Tolerable daily intake (TDI)) are usually derived for non-carcinogenic endpoints.
EPA - Reference dose		Derived with a similar concept and usually listed in the „Integrated Risk Information Systems" (IRIS) of the United States Environmental Protection Agency (EPA, 2000a).
EU - Drinking water directive		Drinking water parameters as set out in Commission Directive 98/83/EC (EU, 1998).
WHO - Air quality guidelines		Guideline values for a contaminant in the air derived for non-carcinogenic endpoints (risks for exposure to carcinogens are described below).
EPA - Reference concentration		Same as above („reference dose") but for inhalation exposure.
D - „water hazard class"		The „water hazard class" reflects acute toxicity in mammals, acute ecotoxicity, degradation and distribution in environmental media as well as hazardous reactions with water and is detailed in UBA (1996).

3.3.2 Pollutant specific data

3.3.2.1 AOX Adsorbable organic halogen compounds

The analytically determined parameter of adsorbable organic halogen compounds (AOX) does not represent a specified chemical substance. Rather, it is defined by the binding of a halogen-containing chemical to activated carbon. The formation of AOX has been observed in the context of drinking-water desinfection. Both chlorination and ozone treatment may lead to the formation of trihalomethanes (THM) with bromine derivates being formed when small amounts of bromine are present in the water. The German drinking-water directive mentions chloroform, bromodichloromethane, dibromochloromethane and bromoform as analytical parameters for THM. While other organic halogens are formed in these processes as well, which are all detected as AOX, THM serve as an indicator class of compounds. As a rough estimate, the relation of AOX to THM in drinking-water is estimated to be 10 : 1 (GROHMANN 1991).

Because AOX is an analytically determined parameter and represents a wide range of substances, differing not only in their chemical structure but also in their toxicological profile, a description of relevant **toxicological endpoints cannot be given**. There are no toxicologically relevant guidance or limit values for AOX as a parameter.

3.3.2.2 NP nonylphenoles and NPE nonylphenole ethoxylates

This chapter summarizes toxicological data for 4-nonylphenole (NP, CAS No.: 25154-52-3). Because this is the breakdown product of the respective ethoxylates, a discussion of its health effects covers the main effects of the ethoxylates as well. Branched NP (CAS No.: 84852-15-3) is not considered explicitely in this document but seems to exert in part similar toxic effects as the non-branched isomer.

NP is harmful after acute **oral exposure** in rats (LD50 approx. 1900 mg/kg, OECD guideline 401) and should be classified as corrosive (BUA, 1988; ECB, 2000). Reproductive effects represent the most important toxicological endpoint and NP has been recently tested for this endpoint in a number of studies. In vitro, NP showed affinity for binding to the estrogen and progesterone receptors (LAWS et al., 2000). In vivo, data on reproductive effects in the male rate are somewhat conflicting. Postive results obtained by LEE (1988) in neonatal male rats could not be confirmed in a repetition of the central experiment (ODUM & ASHBY 2000). CHAPIN et al. (1999) observed mild reproductive as well as nephrotoxic effects in a recent rat multi-generation study. Reproductive effects in these studies consisted e.g. of accelerated vaginal opening and increased uterine weights in females and effects on testes size and sperm parameters in males. In summary, NP seems to be a reproductive toxicant. Its estrogenic activity, which is believed to be mediating at least some of the reproductive effects, is weak compared to both estradiol and octylphenole (UBA, 1997).

Studies on the **carcinogenicity** of NP could not be located. In vitro and in vivo genotoxicity studies do not point to a mutagenic potential (ECB, 2000; BUA, 1988).

There is no EU risk phrase-or CMR classification. Guidance and limit values are reported in Table 3.3-2.

Table 3.3-2: *Toxicological classification of NP and NPE*

Guidance / limit value for NP and NPE	**Value**	**Remarks**	**Reference**
German “water hazard class”	3 (highly hazardous) 2 (hazardous)	NP NPE	UBA, 1996

3.3.2.3 LAS Linear alkyl benzene sulfonic acids and their sulfonates

There are several linear alkyl benzene sulfonic acids and respective sulfonates with varying chain lengths (C11, C12, C13 and - in the USA - also C14). Commercial mixtures consist of compounds of varying chain lengths and the carbon number given is only an average value, e.g. C11,8. The substances with a chain length of 12 carbon atoms (C12), i.e. dodecylbenzene sulfonic acid and its sodium sulfonate, are referred to as LAS and Na-LAS, respectively, in RIPPEN (2000). Their CAS No. are 27176-87-0 for the acid and 25155-30-0 for the sodium salt. According to SÖDERLUND (1993), the latter seems to be the most predominant analog in commercial mixtures. Therefore, dodecylbenzene sulfonic acid and its sodium salt are primarily considered in this document and are referred to as LAS and Na-LAS. Some information is given for the group as well.

LAS is harmful in the rat **after acute oral administration** (LD50 = 500-2000 mg/kg, test according to OECD guidelines, GLP) with similar values for Na-LAS and a couple of mixtures as well. LAS is irritating to the skin and the eyes of experimental animals in tests according to OECD guidelines. Similar results were observed for Na-LAS and other alkylbenzene sulfonic acids/sulfonates. Skin and mucous membrane irritation was also observed in humans. In general, alkylbenzene sulfonic acids/sulfonates may lead to increased skin penetration of other substances due to damage of the lipid layer. They do not, however, seem to be sensitizing to the skin (ECB, 2000; SÖDERLUND, 1993; WHO, 1996). After both oral and dermal repeated exposures to linear alkylbenzene sulfonic acids/sulfonates, hepato- and nephrotoxicity seem to be most relevant apart from local effects (e.g. irritation of the skin or the gastro-intestinal mucosa). One study reported lung damage (e.g. alveolar inflammation and hyperplasia) in monkeys after subchronic inhalation of a commercial detergent containing 13 % Na-LAS. In addition, there is limited evidence for reproductive and fetotoxic effects in some studies but probably only at doses causing maternal toxicity. A larger number of other studies showed no such effects (SÖDERLUND, 1993; WHO, 1996).

There is no evidence of **genotoxicity** (in vitro and in vivo) or **carcinogenicity** (oral and dermal application) of alkylbenzene sulfonic acids or their sulfonates (WHO, 1996; SÖDERLUND,1993). There is no EU risk phrases or CMR classification.

Table 3.3-3: *Toxicological classification of LAS*

Guidance / limit value for LAS	Value	Remarks	Reference
German “water hazard class”	2 (hazardous)	LAS	UBA, 1996

3.3.2.4 DEHP Di(2-ethylhexyl) phthalate

This chapter summarizes toxicological data for di(2-ethylhexyl) phthalate (DEHP; CAS No.: 117-81-7). The acute **oral toxicity** of DEHP is relatively low with LD50 values in rats generally above 25000 mg/kg. Long-term administration of DEHP to laboratory animals resulted in hepato- and nephrotoxic effects. Furthermore, DEHP reduces the fertility of both male and female rats and seems to have effects on the developing fetus. At higher dose levels (several thousand mg/kg diet) DEHP leads to testicular atrophy in a number of species (WHO, 1992; ATSDR, 1993; IARC, 2000). In a recent chronic toxicity study in mice DEHP caused, among other things, changes in kidney, liver and testis weights in male animals (DAVID et al., 2000). Because of pronounced species differences, e.g. in human metabolism compared to rodents, it is difficult to extrapolate these findings to humans (WHO, 1992; ATSDR, 1993).

While DEHP generally showed no genotoxic effects in vitro and in vivo, the substance proved to be carcinogenic in several studies in mice and rats (ATSDR, 1993; IARC, 2000; WHO, 1992). In a recent re-assessment, the IARC has withdrawn its former classification of DEHP as "possibly carcinogenic" because of the finding that the carcinogenic effects in rats and mice are probably mediated by peroxisome proliferation which has not been seen in human hepatocyte cultures after DEHP application. The current classification is group 3 (not classifiable) (IARC, 2000). A similar approach has been proposed for reconsidering the EPA (U.S. Environmental Protection Agency) carcinogenicity classification of DEHP (DOULL et al., 1999). There is no EU risk phrase. Due to marked species differences a reliable risk estimate for carcinogenicity in humans cannot be given. The CMR classification is: Carcinogenicity, WHO (IARC): 3 and for Reproductive effects and fetotoxicity, Assessment of German TRGS 905: RE2, RF2.

Table 3.3-4: *Guidance and limit values for, respectively toxicological classification of DEHP*

Guidance / limit value for DEHP	**Value**	**Reference**
Oral exposure, Tolerable daily intake (WHO)	25 µg/kg • d	WHO, 1996
Oral exposure, Reference dose (EPA)	20 µg/kg • d	EPA, 2000a
German "water hazard class"	1 (generally not hazardous)	UBA, 1996

3.3.2.5 PAH Polycyclic aromatic hydrocarbons

Polycyclic aromatic hydrocarbons (PAH) are formed by various combustion processes and are found in the environment in complex mixtures of differing composition. Benzo[a]pyrene (BaP; CAS No.: 50-32-8) has been chosen as an indicator substance for this group of compounds by numerous national and international bodies (SCHNEIDER et al., 2000). It is therefore treated in this document as representing PAH in general.

The acute **oral toxicity** of PAH appears to be low to moderate. Adverse haematological effects are observed after long-term administration in experimental animals. Other effects include dermal (irritation, sensitizing activity), immunosuppressive as well as reproductive and fetal effects but carcinogenicity (see below) is the most important endpoint as it is already triggered at dose levels necessary for non-carcinogenic effects (WHO, 1998; FRIJUS-PLESSEN & KALBERLAH, 1999).

PAH mixtures lead to tumors of the respiratory tract after inhalation and to **skin tumors** after dermal application. These effects were seen in both experimental animals and epidemiological studies. Carcinogenic activity varies between individual PAH. WHO (1998) found that 26 out of the 33 PAH covered in their monograph are, or are suspected of being, carcinogenic. The following classifications exist for benzo[a]pyrene (EU risk phrases): 45 (May cause cancer), 46 (May cause heritable genetic damage), 50/53 (Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment), 60 (May impair fertility) 61 (May cause harm to the unborn child).

The following risk estimates for BaP were judged to be reliable (SCHNEIDER et al., 2000): 2,15 • 10-6 per 1 ng/kg • d (SCHNEIDER et al., 2000) (oral exposure). For the evaluation of the carcinogenicity of PAH mixtures see SCHNEIDER et al. (2000).

The following CMR classifications exist for benzo[a]pyrene: Carcinogenicity, EU: 2; Carcinogenicity, Assessment of German TRGS 905: 2; Carcinogenicity, WHO (IARC): 2A; Genotoxicity, EU: 2; Genotoxicity, Assessment of German TRGS 905: 2; Reproductive effects and fetotoxicity, EU: RE 2, RF 2; Reproductive effects and fetotoxicity, Assessment of German TRGS 905: RE 2, RF 2. Various PAH containing mixtures as well as some occupations with contact to PAH are classified as carcinogenic to humans

Table 3.3-5: *Guidance and limit values for, respectively* **t***oxicological classification of benzo[a]pyrene*

Guidance/limit value [1,2]	Value	Remarks	Reference
Acceptable daily intake (WHO)	only risk-based values for carcinogenicity (see below [1])		
Drinking water directive (EU)	0,010 •g/l [2]		EU, 1998
Air quality guidelines (WHO)	only risk-based values for carcinogenicity (see below)		
German “water hazard class”	3 (highly hazardous)	carcinogens not otherwise listed	UBA, 1996

1 WHO (1996) derived a drinking-water guideline of 0,7 •g/l for BaP. This is based on carcinogenic effects and corresponds to an excess risk of 1 • 10-5 (for carcinogenic potency evaluation see below).

2 EU (1998) also lists a value of 0,10 •g/l for the sum of benzo[b]fluoranthene, benzo[k]fluoranthene, benzo[ghi]perylene and Indeno[1,2,3,-cd]pyrene.

3.3.2.6 PCB Polychlorinated biphenyls

This chapter summarizes toxicological data for polychlorinated biphenyls (PCB, CAS No.: 1336-36-3), a mixture of individual congeners with a chlorine content of 20 - 68 %. The most well-known of these are “Aroclor” mixtures with a defined chlorine content (e.g. Aroclor 1254, chlorine conten 54 %).

In both animals and humans PCB exposure irritates the skin and the eyes and leads to chloracne, neurotoxicity, hepatotoxicity as well as elevated blood pressure and reproductive effects. Some of the human studies have to be judged carefully due to the presence of contaminants (PCDF, DDE). Immunological changes represent one of the most sensitive endpoint of PCB toxicity in laboratory animals, specifically rhesus monkeys, and have also been observed in humans (HASSAUER & KALBERLAH, 1999).

There is some evidence of carcinogenic activity of PCB in humans although possible concurrent exposure to contaminants makes it difficult to to finally assess carcinogenicity in humans. In rats and mice, oral exposure to PCB lead to an increased incidence of tumors of the liver (HASSAUER & KALBERLAH, 1999). IARC (1987) judged the human data as "limited evidence" and the data from animal experiments as "sufficient evidence". Older unit risk estimates (see table 3.3-6) by the U. S. Environmental Protection Agency were judged to be not reliable (HASSAUER & KALBERLAH, 1999).

The EU risk phrases are: 33 (Danger of cumulative effects) and 50/53 (Very toxic to aquatic organisms, may cause long-term adverse effects in the aquatic environment). The CMR classification is as follows Carcinogenicity, Assessment of German TRGS 905: 3; Carcinogenicity, WHO (IARC): 2A; Reproductive effects, Assessment of German TRGS 905: RF2, RE2.

Table 3.3-6: *Guidance and limit values for, respectively toxicological classification of polychlorinated biphenyls*

Guidance / limit value	Value	Remarks	Reference
Acceptable daily intake (WHO)	TCDD-equivalents for dioxin-like compounds including dioxin-like PCB		WHO, 1999
Reference dose (EPA)	70 ng/kg • d 20 ng/kg • d	Aroclor 1016 Aroclor 1254	EPA, 2000a
Air quality guidelines (WHO)	see above		WHO, 1999
German "water hazard class"	3 (highly hazardous)		UBA, 1996

3.3.2.7 PCDD/F Polychlorinated dibenzodioxins und dibenzofurans

There are 75 congeners of PCDD and 135 congeners of PCDF which differ in their degree of chlorination and the position of the chlorine atoms. With regard to PCDD and PCDF, the approach of Toxicity Equivalency Factors (TEFs) is widely accepted although there are different concepts proposed by a number of both national and international organisations (see Safe, 1990). TEFs rank an individual dibenzodioxin or dibenzofuran according to its potency relative to 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD; CAS No.: 1746-01-6). As the most toxic and as the best studied compound TCDD is considered in this document as representing PCDD/PCDF.

TCDD exposure may result in a number of different effects only some of which are mentioned below. High doses of TCDD lead to chloracne, porphyria, hepatotoxic effects and neurological symptoms. In addition, diabetes, immunotoxicity, reproductive effects as well as effects on the developing fetus are described in the literature. Reproductive and fetotoxicity were observed at low dose levels and formed the basis for the derivation of a TDI (SCHNEIDER AND KALBERLAH, 1999; SCHRENK & FÜRST, 1999; EPA, 2000b).

TCDD was mostly negative when tested for genotoxicity and DNA-adducts but showed cell transforming activity. TCDD was carcinogenic in rats and mice after oral (e.g. hepatocarcinoma) and dermal application (fibrosarcoma). An increase in tumor incidence or mortality was found in several studies of occupationally exposed subjects with the respiratory tract as the most consistent localisation (Schneider and Kalberlah, 1999). There exists no EU risk phrase-classicifation. IARC (1997) classified TCDD as carcinogenic to humans (group 1). Other polychlorinated dibenzo-p-dioxins and polychlorinated dibenzofurans were judged to be not classifiable as to their carcinogenicity to humans (group 3). Based on epidemiological mortality studies in workers, BECHER et al. (1998) in a recent assessment estimated the following risks for TCDD: 0,5 - 5 • 10-3 per 1 pg TCDD/kg • d (oral, Becher et al., 1998). The U. S. Environmental Protection Agency (EPA), in a recent draft document, derived a similiar unit risk for TCDD intake with a slope factor of: 1 • 10-3 per 1 pg TCDD/kg • d (EPA, 2000b (draft)). The CMR-Classification is Carcinogenicity, Assessment of German TRGS 905: 2 (TCDD) and Carcinogenicity, WHO (IARC): 1 / 3.

Table 3.3-7: *Guidance and limit values for, respectively toxicological classification of polychlorinated dibenzodioxins and dibenzofurans*

Guidance / limit value[1]	**Value**	**Remarks**	**Reference**
Tolerable daily intake (WHO) 1	1-4 pg/kg • d	TCDD equivalents for dioxin-like compounds	WHO, 1999; SCHRENK & FÜRST, 1999
Air quality guidelines (WHO)	The publication lists the oral value above	-	WHO, 1999
German “water hazard class”	3 (highly hazardous)	TCDD, because of carcinogenicity	UBA, 1996

1 derived by an expert panel of the WHO but not an official WHO value.

3.4 Occurrence and persistence of organic contaminants in soils

3.4.1 General aspects

The total input rate of organic pollutants to soils should not exceed the rate of degradation. Once added to the soil, sludge-borne persistent organic pollutants are subject to a variety of processes, e.g. adsorption/desorption, degradation (biotic and abiotic), volatilization, erosion/runoff and leaching, that can act to reduce the concentration of persistent organic pollutants potentially available for plant uptake (O'CONNOR 1996). There is accumulation in soils, but the persistence varies between different groups and specific compounds within each group. Soil sorption is now widely recognized to affect microbial degradation of many compounds. Strongly adsorbed chemicals are apparently unavailable to microbes because only low concentrations are desorbed in solution and available for microbial uptake and intercellular metabolism (O'CONNOR 1996).

Surfactants can affect the fate and behaviour of hydrophobic organic compounds in soil, the potential for detergent ingredients to cause significant effects is limited due to the relatively low concentrations found compared with CMCs (critical micelle concentration). Typical soil concentrations of LAS, the most heavily used surfactant in domestic detergents, are significantly lower than those required to produce micelles in pore water. Therefore, it is unlikely that surfactants present in domestic detergents will contribute significantly to the mobilization of hydrophobic organic compounds in sludge-amended soil (HAIGH 1996).

Table 3.4-1: *Chemical properties of organic contaminants in soils (LITZ 1998)*

	soluability in water at 20°C [mg/l]	vapor pressure bei 20o C [hPa]	Henry-Constant [9,8*10^{-4} hPa*m3 /mol]	n-Okt./ H_2O coeff. log K_{ow}	adsorption to humus	adsorption to clay	aerobic degradation[1]	anaerobic degradation[1]
LAS	62,5	0,0001	-	1,96	3 to 4	1	4	3
DEHP	40	6 x 10^{-4}	1,1 x 10^{-5}	4,88	4 to 5	3 to 4	3 to 4	2
NP	3.000	0,1	-	3,28	2 to 3	2	4	2 to 3
PAH								
Fluorene	1,8	9,6 x 10^{-4}	0,00021	4,31	4to5	3	3	1
Pyrene	150	0,8 x 10^{-5}	0,00002	4,88	5	3	2	1
Benzo[a]pyrene	0,004	0,7 x 10^{-8}	2,4 x 10^{-6}	6,15	5	3	2	1
PCBs								
4toChlorobiphenyl	1,65	2,0 x 10^{-2}		4,5	4 to 5	1 to 2	3	2
2,4,4 TriCB	0,085	1,1 x 10^{-3}	2.4 x10^{-2}	5,8	5	3	2 to 3	2
2,2,4,4,5,5toHexa CB	0,001	1,1 x 10^{-5}	0.8	6,9	5	3 to 4	1	1
PCDD/Fs								
2,3,7,8 TCDD	4,7 x 10^{-5}	6,2 x 10^{-9}	5,4 x 10^{-23}	7,1	5	3	1	1
1,2,3,7,8toPCDF	0,118 x 10^{-3}	5,8 x 10^{-10}		6,79	5	3	1	1
OCDD	0,004 x10^{-3}	4,1 x10^{-10}	0.14	7,59	5	3	1	1

[1]: time to 90% degradation: 1: > 3 years, 2: >1 years, 3: >18 weeks, 4: > 6 weeks

Table 3.4-1 provides an overview of the chemical properties of the respective organic substances from LITZ (1998). Adsorption to humus and clay particles as well as biological degradation (anaerobic or aerobic) are decisive factors for the persistency of organic contaminants in soils. LAS, DEHP and NP are less likely to absorb to humus and more easily degraded than are PAH, PCB or PCDD/F.

3.4.2 Pollutant specific field data

3.4.2.1 AOX

Instead of AOX concentrations as in sewage sludges, in soils the EOX values are used as sum parameters to describe the burden. According to studies in Northrhine-Westfalia EOX values in rural areas range from 0,3 (median) to 0,6 mg/kg (90.P) and from 0,4 (median) to 0,9 mg/kg (90.P) in urban agglomerations (LITZ 1998). Both AOX and EOX values are influenced by the amount of PVC present (MERTENS 1996, MERTENS 1999).

3.4.2.2 NPE

Nonylphenole does not show significant movement towards groundwater, as least in a sandy loam soil (MCGRATH 2000). 4-nonylphenole is more persistent as LAS, but there has been no evidence of an accumulation after repeated applications of sewage sludge at the same site (GÜNTHER & PESTEMER 1994). Under aerobic and anaerobic conditions the nonylphenole poly-ethoxylates will be decomposed to short chain nonylphenole poly-ethoxylates and nonylphenole, which has a tendency to absorb to the sludge, but under anaerobic conditions nonylphenole will degrade very slowly, and hence this substance will increase in concentration during anaerobic digestion of the sludge (GRÜTTNER et al. 1997).

3.4.2.3 LAS

LAS is rapidly degraded in soils under aerobic conditions (half-life < 10 days) (LITZ et al. 1987, MADSEN et al. 1997). Aerobic biodegradation in soil is considered the most important removal mechanism of LAS loading to the terrestrial environment through sludge-amendment (DE WOLFE & FEIJTEL 1997). The rates of degradation are described by GIGER et al. (1997) in terms of three periods: The initial one (0 to 10 days) shows a very fast rate of disappearance, followed by a time of transition (approximately 90 days), and then finally a long term (>150 days) persistence in the soil. Immediately following the application of the sludge to the soil, LAS disappear quickly (initial period) because they are readily available to the soil microorganisms, e.g. LAS is in the aqueous phase or sorbed to the surface of the particles. The residues are slowly incorporated into the soil particles and/or more strongly bound to the soil organic fraction making them less available (transition period) or unavailable (final period) to biodegradation. Similar types of transformation kinetics are very common in pesticides in soil which also can lead to persistent residual levels.

MIEURE et al. (1990) found four groups of researchers that had studied the concentrations and fate of LAS in sludge amended soil in field situations. LAS half-lives were calculated to be between **7 and 22 days**. Investigations by MARCOMINI et al. (1989 cit in Amundsen et al.

1997) demonstrated a decrease in concentrations of alkylbenzene sulphonate (LAS) of as much as 80% within the first month after sludge application. All of them exhibited, however, a residual concentration in the soil after 320 days, indicating that the residual fraction may be incorporated into organic material in the soil and be **less available for biodegradation** (AMUNDSEN et al. 1997). According to LITZ (2000) the degradation of 90 % of LAS takes place within 22 to 122 days depending on the type of soil (Table 3.4-2).

Table 3.4-2: *Degradation (dt 90%), leaching of LAS in different soils (summarized by LITZ 2000 from different sources)*

Soil type	Rainfall (mm)***	Mean temperature (°C)	dt 90**	Leaching Max. (cm)
Luvisol	195	17,8	28	30
Cambisol	563*	13,9	>56	30
Gleysol	187	13,8	24	30
Eutric Gleysol	175	16,4	100	40
Humic Gleysol	228	17,0	93	30
Dystric Gleysol	214	13,0	122	40
Rendzina	125	17,5	78	35
Calcic Gleysol	100	16,0	68	30
Vertisol	furrow irrigation	>25 (arid)	60	≥50

* inclusive waste water irrigation, ** 5 g LAS/m2 *** first 2 months of the field investigations

3.4.2.4 DEHP

DEHP shows rapid degradation in soils (DUARTE-DAVIDSON et al. 1995, GRÜTTNER et al. 1997). According to RIPPEN (2001) 50% of the DEHP are degraded within a time span from one week to three months after application of sludges on agricultural soils. Frequently 90% of DEHP will have disappeared within half a year, but there is little field data on how long complete degradation will take.

Examples of typical phthalate concentrations in soils of the area around Stuttgart are given in table 3.4.2.4-1. It is interesting that grassland concentrations are higher than concentrations in tillage land, inspite of the fact that sludge application to grassland has been forbidden for many years. This suggests that deposition from air is an important source for DEHP in soils. DEHP concentrations in agricultural soils range from 0,3 to 0,7 mg/kg (median and 90.P, Table 3.4-3).

Table 3.4-3: *Phtalate concentrations in soils of the area of Stuttgart, Germany (UMEG 1999)*

	n	**50.P [µg/kg]**	**90.P [µg/kg]**
sum of phtalates according to EPA 606			
arable land	61	786	1262
grassland	99	893	1825
individual compounds			
Dimethylphtalate (DMP)	152	78	252
Diethylphtalate (DEP)	159	73	250
Di-n-butylphtalate (DNBP)	162	307	421
Butylbenzylphtalate (BBP)	160	18	59
Bis(2-ethylhexyl)phtalate (DEHP)	162	249	667
Di-n-octylphtalate (DNOP)	108	82	199

3.4.2.5 PAH

In 1968, the UK AGRICULTURAL DEVELOPMENT ADVISORY SERVICE and the MACAULAY INSTITUTE FOR SOIL RESEARCH set up identical experiments at the Luddington and Lee valley experimental field stations. Results from these sites show a clear decrease in PAH concentrations through time and chemical breakdown and biotic degradation seem to be responsible for it. At both sites the higher molecular weight PAHs, such as benzo[ghi]perylene and coronene appear to be more persistent (WILD et al. 1992). Volatilization was only significant for naphthalene. However strong retention to soil organic matter will reduce losses by volatilization (WILD et al. 1992).

Literature data on benzo[a]pyrene degradation in soils vary strongly (see RIPPEN 2001), but for highly contaminated soils (> 10 mg/kg BaP) degradation rates of up to 90% within one year are reported. There seem to behardly any reliable field data on BaP degradation for soils BaP concentrations of 0,1 to 1 mg/kg.

Table 3.4-4 gives examples of PAH concentrations in soils of the area of Mannheim/Heidelberg; Germany. Apart from medians and 90.Ps it shows the average PAH profile (percentages of compounds). The PAH profiles are basically the same in rural and urban soils and seem to be independent of sewage sludge application. This suggests that the persistence of compounds is more decisive for their presence in soils than the original characteristic of the contamination.

Table 3.4-4: *Medians and 90.Ps of PAH concentrations in soils of the area of Mannheim/Heidelberg, Germany (UMEG 1998)*

	Rural soils				**Urban soils**			
	n	**median [µg/kg]**	**%**	**90.P [µg/kg]**	**n**	**median [µg/kg]**	**%**	**90.P [µg/kg]**
Naphthalin	52	-	-	<0,10	80	-	-	<0,10
Acenaphtylen	52	-	-	<0,10	80	-	-	<0,10
Acenaphten	52	-	-	<0,10	80	-	-	<0,10
Fluoren	52	-	-	<0,10	80	<0,10	0,70%	0,08
Phenanthren	52	0,06	7,10%	0,28	80	0,14	6,00%	0,66
Anthracen	52	<0,10	2,20%	0,09	80	<0,10	1,90%	0,2
Fluoranthene	52	0,16	17,80%	0,71	80	0,45	18,20%	1,99
Pyren	52	0,15	15,00%	0,6	80	0,42	18,70%	2,04
Benzo[a]anthracen	52	0,08	8,70%	0,35	80	0,29	9,70%	1,06
Chrysen	52	0,08	8,70%	0,35	80	0,24	7,20%	0,79
Benzo[b]fluoranthene	52	<0,10	7,90%	0,32	80	0,14	6,10%	0,66
Benzo[k]fluoranthene	52	0,05	6,30%	0,25	80	0,17	5,70%	0,63
Benzo[a]pyren	52	0,09	9,60%	0,38	80	0,3	9,30%	1,01
Indeno[c,d]pyren	52	0,06	4,60%	0,18	80	0,19	6,40%	0,7
Dibenz[a,h]anthracen	52	<0,10	2,70%	0,11	80	0,06	2,30%	0,25
Benzo[ghi]perylen	52	0,08	8,00%	0,32	80	0,24	7,60%	0,83
PAH - Sum (16)	52	0,82	100%	3,99	80	2,67	100,00%	10,92

3.4.2.6 PCB

Fifteen years after sewage sludge was used as filler material, as much as 20 percent of the added PCB are still present in the surface soil (AMUNDSEN et al. 1997). The result of AMUNDSEN et al. (1997) further indicates a high stability of heavily chlorinated PCBs in the sludge, which suggests a more precautious use of sewage on surface soils in public areas.

The experimental data of COUSINS et al. (1997) suggest that for the surface and plough layer applications volatilisation is an important loss process for PCBs. Volatilisation losses of PCBs from the subsurface layer of sludge were very low during the 32-day experiment, although fluxes were steadily increasing with time (COUSINS et al. 1997).

In a study of GAN & BERTHOUEX (1994) seventy-nine PCB congeners were identified in the sludge and soil. Each of these was quantified and studied. About 85% of the total PCBs in the sludge were 2-, 3-, 4-, and 5-chlorinated PCB congeners, and most of these showed a significant decrease in their soil concentrations over time. More highly chlorinated PCBs were more persistent in the sludge-amended farmland, but some of them did disappear. Most of the 2-, 3-, and 4-chlorinated PCB congeners showed significant decreases in their soil concentrations with half-lives in the range of **4 to 58 months**. The PCBs were associated with the runoff sediments and there was no measurable PCB in the liquid portion of the runoff.

There are no persuasive reasons to believe that dislocation by leaching or volatilisation are significant mechanisms for PCB disappearance from the surface soil layer. Biodegradation is thought to be the predominant mechanism. The environment in the surface soil is predominantly aerobic and most of the disappearing PCB species are aerobically biodegradable. Anaerobic micro-environments also exist in soil and this could explain the degradation of the more highly chlorinated forms, which degrade anaerobically but not aerobically (GAN & BERTHOUEX 1994).

Table 3.4-5 contains PCB concentrations in soils of the Stuttgart area as examples. Contrary to PAH, PCB concentrations in soils are largely influenced through local sources. That grassland soils show higher PCB concentrations than field soils suggests that athmospheric depositions is very important. The PCB profiles of urban soils are not significantly different from the ones in rural areas. As was shown with PAH compounds, the physico-chemical properties of the individual PCB congeners seem to be more important for the occurrence in soils than the composition of the original contamination. In more than 1000 soil samples of Southwest Germany, only one profile could be attributed to a single source (UMEG 1995).

Table 3.4-5: *Medians and 90.Ps of PCB concentrations in soils of the area around Stuttgart (UMEG 1999)*

		[µg/kg]		
	n	**50.P**	**90.P**	**%**
Sum PCB 6				
rural vs. urban				
rural soils	290	14	98	-
urban soils	74	34	243	-
according to land use				-
arable land	85	10	40	-
grassland	171	16	101	-
special cultures	14	13	39	-
private gardens	40	30	284	-
forest and ecosyst.	20	18	85	-
parks	16	80	193	-
industrial and traffic	11	48	484	-
single congeners				
rural vs. urban				
rural soils				
PCB 28	283	1	3	3%
PCB 52	288	1	4	5%
PCB 101	290	2	12	13%
PCB 138	290	4	28	29%
PCB 153	290	4	23	24%
PCB 180	290	2	19	20%
urban soils				
PCB 28	74	<1	2	1%
PCB 52	74	<1	7	3%
PCB 101	74	4	35	14%
PCB 138	74	10	85	35%
PCB 153	74	10	73	30%
PCB 180	74	9	50	21%

3.4.2.7 PCDD/F

The literature shows that PCDD/Fs are ubiquitous contaminants in municipal sewage sludge and that they are virtually completely persistent in soil following application of sewage sludge to agricultural land (HEMBROCK-HEGER 1992). The concentrations of PCDD/F in soils generally increase with the applied rate of sewage sludges (MCLACHLAN & REISSINGER 1990; ELJARRAT et al. 1997). Assuming that all sources of PCDD/F can be capped, there will still be residual contamination of sewage sludge due to atmospheric deposition through surface runoff. Land application of sewage sludge will therefore continue to contribute to the contamination of soils (MCLACHLAN et al. 1996).

Table 3.4-6 shows average PCDD/F profiles in top soils of the area around Stuttgart. As with PAH and PCB, the profiles of PCDD/F homologues get to be similar over time, in only one case of the above mentioned series of samples the profile found could be connected to a particular source (UMEG 1995b).

Table 3.4-6: *Concentrations of the 17 PCDD/F-cogeneres and average profile of homologues in soils of tillage land, grass land and forest of the area around Stuttgart (UMEG 1999)*

			[ng/kg]		
	I-TEF	**n**	**50.P**	**90.P**	**%**
Rural soils					
2,3,7,8-TCDD	1,0	107	<0,5	<0,5	-
1,2,3,7,8-PCDD	0,5	107	<0,5	2,0	-
1,2,3,4,7,8-HCDD	0,1	107	<0,5	2,0	-
1,2,3,6,7,8-HCDD	0,1	107	2,0	10,0	-
1,2,3,7,8,9-HCDD	0,1	107	<0,5	6,0	-
1,2,3,4,6,7,8-HeptaCDD	0,01	107	18,0	185,6	-
Octa-CDD	0,001	107	105,0	928,8	-
2,3,7,8-TCDF	0,1	107	3,0	7,1	-
1,2,3,7,8-PCDF	0,05	107	2,0	6,7	-
2,3,4,7,8-PCDF	0,5	107	2,0	7,0	-
1,2,3,4,7,8-HCDF	0,1	107	3,0	13,8	-
1,2,3,6,7,8-HCDF	0,1	107	2,0	7,0	-
1,2,3,7,8,9-HCDF	0,1	106	-	<0,5	-
2,3,4,6,7,8-HCDF	0,1	107	1,4	6,8	-
1,2,3,4,6,7,8-HeptaCDF	0,01	107	13,0	101,2	-
1,2,3,4,7,8,9-HeptaCDF	0,01	107	1,0	9,0	-
Octa-CDF	0,001	107	20,8	367,8	-
I-TEq nach NATO	**-**	**132**	**2,4**	**13,3**	-
Summe TCDD	-	86	4,1	13,1	1%
Summe PCDD	-	86	7,0	32,8	2%
Summe HexaCDD	-	87	14,8	63,0	3%
Summe Hepta CDD	-	87	31,0	126,8	7%
Summe Octa-CDD	0,001	107	105,0	928,8	50%
Summe TCDF	-	87	23,0	92,6	5%
Summe PCDF	-	87	23,0	84,9	5%
Summe HexaCDF	-	87	18,0	72,9	4%
Summe Hepta CDF	-	87	18,7	81,6	4%
Summe Octa-CDF	0,001	107	20,8	367,8	20%

3.4.2.8 Others

Organotins

Photo- and biodegradation may diminish organotin residues transferred to agricultural fields. TBT residues found in sludge amended soils are low. Dumping of sludge and transfer to soil are of ecotoxicological relevance, since these transfer paths give rise to organotin pollution of both aquatic and terrestrial systems (FENT et al. 1995).

CB and pesticides

There is little information about the biodegradation of CBs in soils. A few studies have shown that the level of the biodegradation was generally very low (Baize 1994). Compounds (like 1,2-DCB) with a higher tendency to volatilise (higher vapor pressure and Henry's constant) had smaller residues than those (like HCB) with lower volatility. This implies that the CBs may have continually spread over other habitats since they were introduced into the soil (WANG et al. 1995).

Tabelle 3.4-7: *Concentrations of chlorinated pesticides in soils of the area of Stuttgart (UMEG 1999)*

		[µg/kg]	
	n	**50.P**	**90.P**
Hexachlorobenzene (HCB)	291	<1,0	5,0
Alpha-HCH	212	-	<1,0
Beta-HCH	147	-	<1,0
Gamma-HCH (Lindan)	269	<1,0	3,4
Delta-HCH	128	-	<1,0
HCH-Summe	269	<1,0	4,3
Aldrine	47	-	<1,0
Heptachlor	71	-	<1,0
Dieldrin	106	-	<1,0
Endrinee	99	-	<1,0
Alpha-Chlordan	42	-	<1,0
Gamma-Chlordan	65	-	<1,0
Chlordan-Summe	42	-	<1,0
DDE p,p'	246	1,3	20,9
DDE o,p'	96	<1,0	3,2
DDD o,p'	106	-	<1,0
DDD p,p'	200	<1,0	2,0
DDT o,p'	216	<1,0	2,6
DDT p,p'	229	1,2	15,2
DDT-Summe	260	3,6	45,5

Concentrations of CBs in sludge usually decrease with increase of chlorination level. Most CBs applied to field soils in sewage sludge are likely to evaporate into the atmosphere over relatively short periods, but a certain proportion of the chemicals would stay in the soil for much longer periods, especially HCB and PCB. About 10% of the CBs introduced into field soil by multiple application of sewage sludge became recalcitrant and remained in the soil for more than thirty years after the application (WANG et al. 1997).

Table 3.4-7 gives background values of chloro-organic pesticides. Besides DDT, HCB and Gamma-HCH are the most frequently found pesticides in soils.

3.5 Risk assessment

CHANEY et al. (1998) conclude, that beside direct ingestion of biosolids by children, the greatest risk from persistent lipophilic organic compounds arises when fluid biosolids are applied so that they adhere to to forage/pasture crops and are subsequently ingested by livestock used as human food.

SMITH (2000) too considers uptake of organic contaminants via direct ingestion of sludge adhering to grass and/or sludge-treated soil by grazing livestock and subsequent accumulation in animal as the main route of human exposure from agricultural use of sludge. However he summarizes, that the total human intake of identified organic pollutants from sludge application to land is minor and is unlikely to cause adverse health effects.

FRIES (1996) reports, that of the many organic contaminants in sludges, only lipophilic halogenated hydrocarbons accumulate in animal tissues and products. Compounds like phthalatee esters, PAHs, acid phenoleics, nitrosamines, volatile aromatics, and aromatic surfactants are metabolized and do not accumulate. Among halogenated hydrocarbons, compounds with low degrees of halogenation are metabolized and do not accumulate, but higher degrees of halogenation block metabolism, and concentrations in milk and tissue fat may be several-fold greater than in the diets. Polyhalogenated organics, including halogenated biphenyls, chlorinated pesticides and hydrocarbons, and chlorinated dibenzo-p-dioxins and dibenzofurans, are of greatest importance to animal farming because these compounds are persistent and tend to bioconcentrate in the lipids of tissues and products (FRIES 1996).

3.5.1 Transfer sludge-man by handling

All available epidemiological data indicate that probably the level of sanitary risks is low: workers on wastewater treatment plants or on composting units do not show more specific disease than others (LEGAS 2000). Workers and farmers may also be exposed during treatment, handling or application of sludge to land. This exposure is assumed to be small, but would need further documentation (ANDERSEN 2001).

3.5.2 Transfer soil-man (soil ingestion by humans)

The EU draft is the first regulation to allow the use of sewage sludge in parks, providing it is sufficiently treated to be hygienically benign. If sludge is to be used in parks, however, its burden with contaminants gains importance because of the contamination pathway sludge-soil-man. The German Soil Protection Directive (Bundesbodenschutzverordnung, BBodSchV 1999) gives an example of threshold values for organic pollutants in soil (table 3.5-1), which are meant to limit the uptake of contaminants via direct ingestion through young children to tolerable levels (cf. EIKMANN et al., 2000)

Table 3.5-1: *Threshold values for organic contaminants in soils of playgrounds, parks and residental areas in Germany*

compound	unit	playgrounds	parks	residential areas	industrial areas	Quelle
Aldrine	mg/kg soil	2	**10**	4	-	BMU (1999)
BaP	mg/kg soil	2	**10**	4	12	BMU (1999)
DDT	mg/kg soil	40	**200**	80	-	BMU (1999)
HCB	mg/kg soil	4	**20**	8	200	BMU (1999)
HCH-mix.	mg/kg soil	5	**25**	10	400	BMU (1999)
PCP	mg/kg soil	50	**250**	100	250	BMU (1999)
PCB_6	mg/kg soil	0,4	**2**	0,8	40	BMU (1999)
PCDD/F	ng I-Teq/kg	100	**1.000**	1.000	10.000	UM (1996)

3.5.3 Transfer soil-plant-animal

3.5.3.1 Transfer soil-plant

Four main pathways by which a chemical in the soil can enter a plant have been described by (TOPP et al. 1986 cit in DUARTE-DAVIDSON & JONES 1996) as follows:

- Root uptake from soil solution and subsequent translocation from roots to shoots (i.e. liquid phase transfer) in the transpiration stream;
- absorption by roots or shoots of volatilized organics from the surrounding air (i.e. vapour phase transfer);
- uptake by external contamination of shoots by soil and dust, followed by retention in the cuticle or penetration through it; and
- uptake and transport in oil channels which are found in some oil-containing plants such as carrots.

SMITH (2000) reports, that soluable organic compounds have the potential to enter the soil-root-plant system and to accumulate in crop tissues, but these chemicals are also usually subject to volatilization and/or degradation. The strongly bound compounds (e.g. PCBs, PAHs) are insoluble; they are not biologically active or available for crop uptake and soil-plant transfers are very low. Accordingly they are not considered to constitute a risk to the human foodchain from this environmental pathway (USEPA 1992a cit in MCLACHLAN et al. 1996). Except when vegetables have been sprinkled with raw wastewater, there is no proof of any epidemic induced by consumption of vegetables. Furthermore, analysis of food products coming from soils receiving sludge or coming from soils receiving others fertilizers do not indicate important differences (LEGAS 2000). Plant uptake is concentration dependent, hence a compound's persistence in soil has an obvious impact on potential uptake (O'CONNOR 1996).

Chemicals may come into contact with foliage following direct application (e.g. by spraying of pesticides or the surface application of sludge), deposition in association with dust, aerosols or atmospheric particulate matter and contacting the surrounding compound vapour volatilized from soil. Organic compounds may reach plant foliage directly from the air through the cuticle or the stomata. Retention by root surfaces and root crops has been shown for several compounds, mainly chlorobenezenes, PAHs, PCBs, PCDD/Fs and some organochlorine pesticides (pentachloronitrobenzenes, DDT, heptachlor epoxide and delta HCH) (DUARTE-DAVIDSON et al. 1996).

Plant uptake will be influenced by the soil type so that availability to plants will generally be highest in sandy soils and soils with low organic matter content. According to HEMBROCK-HEGER 1992 transfer factors of PAH, PCB and PCDD/PCDF from soil to plants seems to be lower than 0.1, probably lower than 0.01. Hence deposition from ambient air to plants predominates for these compounds.

Plant uptake of non-ionic organic chemicals from sludge-amended soils is usually dominated by vegetative uptake of contaminated vapour from the surrounding air. Heavily contaminated soils can influence the concentrations of organics in above-ground vegetation by the soil-air-plant route (BECK et al. 1996). Even if a compound can penetrate the plant, the polar nature of sap will avoid its transfer to the upper parts (DUARTE-DAVIDSON & JONES 1996). Carrots can concentrate lipophilic chemicals in their roots because of their lipid content (WILD & JONES 1992).

In pot experiments with carrots in sandy soil with a low sorption capacity several pesticides were more easily available to plants when LAS was added. In a high sorptive humic soil surfactants in average caused a decrease of availability (GÜNTHER & PESTEMER 1992).

ROMMEL et al. (1998) summarise the results of an extensive literature review about the transfer of organic contaminants as follows: Compared to other parts of plants, the surfaces of root and tubers are especially prone to absorb contaminants from soil, with the transfer from surface into the interior depending on the contents of lipophillic substances (cf carrots). For leaves, the volatiliziation of organic contaminants from soils (2-3 ring PAHs, lowchlorinated PCBs) and their condensation on the leave surfaces, is a more important pathway than systemic transport. This is especially true for plants grown under foil. Fruit and fruity vegetables as well as cereals hardly take up any organic contaminants.

The concentrations of **PAHs** in different crops/crop parts were measured in some archived crop materials from Luddington, Lee Valley and Woburn Market Garden experiments (WILD et al. 1992). Of the crops, carrots showed the highest concentrations, and adsorption of the PAHs to the root surface was considered to be responsible for this. In above ground parts, the plant materials were relatively enriched with low molecular weight PAHs.

MCGRATH 2000 concluded from a comparison between the PAH congeners in soil, sludge, air and plants that to the atmosphere was the main source of PAHs in the above-ground plant parts.

HEMBROCK-HEGER (1992) found an enrichment of **PCBs** from vegetable products over the food chain up to mother's milk. The author considers this enrichment to be predominantly caused by other paths of input than the transfer soil - plant. The results of an investigation into the uptake of polychlorinated biphenyls (PCBs) from soil by barley and tomato plants by QIUPING et al. (1991) suggest that there is no active transport of these compounds. However they concluded, that plants readily trap airborne PCBs escaping from soil and observed a close correlation between vapor pressure of PCBs and their concentration in plant tissue.

MCLACHLAN et al. (1994) found similar PCB concentrations in hay from different farms despite large differences in their soil levels of PCBs and concluded that under normal circumstances atmospheric deposition is responsible for most of the PCBs and **PCDD/Fs** in plant leaves. However they consider the presence of contaminated soil particles in the feed as an important pathway for PCDD/F or PCB uptake in farm animals (MCLACHLAN et al. 1994).

3.5.3.2 Transfer soil-(plant)-animal

The influence of the agricultural use of sewage sludge on the concentrations of PCBs and PCDD/Fs in soil, feed and milk was investigated on four **dairy farms** by MCLACHLAN et al. (1994). Evidence of contaminant accumulation in the soil was found on both farms that fertilized with sewage sludge. The concentrations in feed and milk from one of these farms were elevated. MCLACHLAN found out, that the agricultural use of sewage sludge does under some conditions lead to higher levels of PCBs and PCDD/Fs in food products.

Application of sludge to established forage crops provides the greatest potential for transport of persistent chemicals to human foods. The importance of this pathway relative to other pathways depends on the time between the application of sludge and harvest, including grazing (FRIES 1996)

A large number of studies have shown that livestock regularly ingest soils, and that soil ingestion is able to cause significant transfer of contaminants from soil to edible tissues of grazing livestock (CHANEY et al. 1996; JONES & ALCOCK 1997). CHANEY & LLOYD (1979; cit in CHANEY et al. 1996) evaluated adherence of spray applied fluid biosolids to forage crops and observed that biosolids adhered to forages for a prolonged period after application. Compared to the intake of roughage (stems and leaves of plants) as a source of contamination, the intake of feeds derived from seeds is not important (FRIES 1996).

Cattle can ingest soil either directly while grazing or indirectly through contamination of feed with soil. There are indications that the latter process may on average be more important. The amount of soil ingested and hence the risk of food chain contamination is largely dependent on farming practices employed. (MCLACHLAN et al. 1996).

Thus when sewage sludge containing organic compounds is spread on grassland, the effects are dependent upon the concentrations of contaminants in the sludge and upon the level of soil intake. Measures taken to minimize soil intake by livestock will have significant effects on the intake of organic contaminants (STARK & HALL 1992)

Soil ingestion will vary inevitably according to the individual situation and it may be prudent to recommend that sludge should only be applied to **grazing land where soil conditions and grazing management are such that soil intakes are likely to be low**. It is also important to ensure that sludge disposal techniques do not increase the risk of soil ingestion. Soil injection of sludges should avoid any increase of contaminants in the soil surface of pastures (STARK & HALL 1992).

3.5.3.3 Threshold values for the path soil-plant-animal

In 1996 for the first time in Germany threshold values were set for DDT, PCB, PAH and PCDD/F in respect to the pathway soil-plant (UM 1996, table 3.5.3-1). Extensive evaluation of literature had shown that benzo(a)pyrene concentrations in carrots and other root, tuberous or leavy vegetables in many cases surpassed the critical value of 1 µg/kg BaP fm when soil concentrations were above 1 mg/kg BaP (see DELSCHEN et al. 1996, ROMMEL et al. 1998). The threshold value for BaP concentrations in soil was therefore set for 1 mg/kg (BMU 1999), the thresholds for the other substances were set on a precautionary basis.

Table 3.5-2: *Threshold values for organic pollutants in respect to the contamination pathways soil-plant and soil-animal*

Substance	unit	threshold value	pathway	reference
HCB, HCH, heptachlor, Endrine	mg/kg soil	0,05	Soil-plant/-animal	UM 1996
DDT-Sum	mg/kg soil	0,10	Soil-plant/-animal	UM 1996
PCB (congere)	mg/kg soil	0,05	Soil-plant/-animal	UM 1996
PAH 16	mg/kg soil	10	Soil-plant/-animal	UM 1996
BaP	mg/kg soil	1	Soil-plant	BMU 1999
PCDD/F	ng I-TEq/kg soil	40	Soil-plant/-animal	UM 1996

3.5.4 Transfer soil-water

The transfer soil-water of organic contaminants has only been studied intensively for a few years. This is partly due to the high cost of such studies but also to the uncertainty of methods. Building lysimeters is very expensive and methodically questionable. The extraction of seepage water by use of vacuum lysimeters (suction cups) is less expensive, but necessitates assessing the water balance of the respective soil. Sampling soil water by centrifugation or extraction of soil samples is debatable and the results can only be evaluated by means of lysimeter or suction cup results. Most of the time the occurrence of substances in deeper layers of the soils is used as an indirect means for assessing soil-water transfer.

The transfer of organic substances from applied sewage sludges depends on the following factors:

- soil erosion (wash off of soil particles with precipitation)

- DOC-content (the proportion of soluable organic substance is the most important parameter for the transfer of hydrophobic contaminants. A prognosis of the mobility of contaminants therefore has to take the DOC into account)
- the soluability of contaminants in water

The following measures are important for avoiding the transfer of substances when sewage sludges are applied on land:

- sewage sludge is not applied close to surface water
- sewage sludge is not applied in areas where the ground water table is just below the surface
- sewage sludge is not applied when the soil is saturated with water.

MADSEN et al. (1997) describe that if LAS content in sludge samples was high, water extracts of the sludges were also high. Consequently, even though LAS is expected to degrade in the soil system, there may be a risk of groundwater contamination. The long-chained NPEs have a potential for leaching to ground water.

Table 3.5-3 contains the current German threshold values based on the soil-water pathway for seepage water in soil (BMU 1999) and for the soil matrix (UM 1996).

Table 3.5-3: *German threshold values for the soil water and soil matrix .*

compounds/compound groups	unit	threshold value	reference
Aldrine	µg/l soilwater	0,1	BMU 1999
DDT	µg/l soilwater	0,1	BMU 1999
Phenole	µg/l soilwater	20	BMU 1999
PCB 6	µg/l soilwater	0,01	BMU 1999
PAK 15 (without naphthalene)	µg/l soilwater	0,20	BMU 1999
HCB, HCH, heptachlor, Endrine, total-DDT, PCB (per congener)	µg/kg soil	20	UM 1996
PCB6	µg/kg soil	100	UM 1996
PAK16	µg/kg soil	5.000	UM 1996
BaP	µg/kg soil	200	UM 1996

3.5.5 Effects on microbial activity, soil living animals and plant growth

For effects on microbial activity, soil living animals and plant growth only POPs in dissolved state or gasous phase are of importance, because they have to actually enter cells in order to affect organisms. Effects of organic contaminants in sewage sludges on microbial activity, soil living animals and plant growth are difficult to study, because they are influenced by a multitude of interdependent factors (e.g. fertilization, water capacity, etc.).

SCHNAAK et al. (1997) found out, that all the sludges examined demonstrated a fungitoxic effect in the plate-inhibition test which was not explicable by the heavy-metal content.

FLIEßBACH et al. (1994; cit in KROGH et al. 1997) reported that sludge deposited over a period of ten years at rates of 5 or 15 t ha^{-1} yr^{-1} d.m. increased microbial biomass and decreased the bacterial activity relative to the fungal activity. BRENDECKE et al. (1993; cit in KROGH et al. 1997) found that applications of 2 or 6 t $ha^{-1}yr^{-1}$ over a period of years did not result in detectable long-term changes in microbial populations and activity.

Eartworms are known to accumulate many non-ionic, hydrophobic compounds such as chlorobenezenes, chlorophenoles and polychlorodibenzo-p-dioxins (BECK et al. 1996).

Xenobiotic organic compounds may inhibit nitrifiers. KROGH et al. (1997) reported, that field measurements of ammonium oxidation potential resulted in either no response or a positive response of sludge compared to manure. Accumulated effects after repeated sludge applications cannot be excluded on a long-term basis, although no toxic effects on ammonia oxidizing bacteria were found six months after sludge application in his study.

KROGH et al. (1997) used two types of sludge in a study, both having a relatively high content of heavy metals, nonylphenole, LAS and phthalates. At doses of up to 21 t ha^{-1}, which are 5 to 10 times higher than the average sludge application rate in Denmark, no negative effects on soil fauna or microbial ammonium oxidation rate were apparent.

3.5.5.1.1 NPE

The nonylphenoles may bioaccumulate and are highly toxic to living organisms, the long-chained NPEs having a potential for uptake in plants (MADSEN ET AL. 1997). Microbial activity is significantly reduced if concentrations of NP are higher than 50 mg/kg soil (BMU 1999a). In laboratory-tests by KROGH et al. (1997) acute and chronic effects on microorganisms and other soil fauna were observed, but only when LAS and NP were present in concentrations at least 50 times above the concentrations likely to be found in soils treated with sewage sludge. In fields where sewage sludge had been applied no adverse effects were found one year after application. HARMS & KOTTUTZ (1992) investigated phytotoxic effects of **4-nonylphenole**. Carrot growth did not seem to be influenced by 4-nonylphenole at any concentration, whereas in tomato, concentrations higher than 0.05 mM inhibited growth completely.

3.5.5.1.2 LAS

KLOEPPER-SAMS et al. (1996) list a number of studies with different plant species, study designs and test durations concerning phytotoxicity of LAS. The growth of plants appeared to be a more sensitive endpoint than their emergence.

FIGGE & SCHÖBERL (1989; cit in KLOEPPER-SAMS et al. 1996) applied LAS concentrations of 16 and 27 mg/kg dry soil to plants in metabolism boxes and found that no changes in growth or yield of bush beans, grass, radish and potatoes were to be observed in a complete growing season (76 and 106 days).

Comparing concentrations that caused harm to terrestrial animals and plants with concentrations found in soils after fertilization with sludge, MIEURE et al. (1990) point out, that the margins of safety appear more than adequate. The assessment was based on toxicity test results from 22 terrestrial plant species and two strains of terrestrial invertebrate and on more than 100 measurements of LAS concentrations in the environment.

In long-term assays covering the whole growth period LAS and 4-nonylphenole caused inhibition of growth and germination of test plants. The injury of the plants increased during the trial (GÜNTHER & PESTEMER 1992)

In laboratory experiments the EC10 values of LAS and NP in spiked sludge were higher than or equal to the EC50 values for the pure chemicals mixed directly in the soil. The effect levels observed in the laboratory (EC10, EC50) appeared at concentrations approximately 25-50 times higher than the estimated soil concentration of 7,5 mg LAS/kg and 1.0 mg NP/kg in a corresponding field experiment (KROGH & JENSEN cit in KROGH et al. 1997).

3.5.5.1.3 PAH

In a investigation of phytotoxic effects of environmental chemicals HARMS & KOTTUTZ (1992) incubated cell suspension cultures of barley, carrot and tomato plants with different concentrations of **phenanthrene**. Whereas carrot growth was hardly influenced at any of the tested concentrations, tomato cultures showed a drastic decrease in growth at concentrations higher than 0.01 mM. Barley growth was decreased by about 35% at concentrations higher than 0.5 mM.

3.5.5.1.4 Others

Ecotoxicological consequences of sludge derived **organotin** pollution to soils are not well understood. Apart from possible bioaccumulation within the terrestrial food webs, ecological effects of sludge derived organotin soil pollution are assumed not to be serious (FENT et al. 1995). A study with a terrestrial microcosm has shown that 5% of TBTO which was applied to wood blocks as a preservative was released into the upper soil layer and distributed through biota (FENT et al. 1995). Concentrations of up to 50 µg/g TBT were shown to enhance nitrate-nitrogen production in soil, and to inhibit ammonification (FENT et al. 1995). Inhibitory effects on nitrification were found at concentrations of 100-250 µg/g, whereas ammonification was stimulated. It should be noted, however, that photo- and biodegradation may diminish organotin residues transferred to agricultural fields, and that TBT residues found in sludge amended soils are lower. However, possible effects on mould counts, fungi and algae, which are also essential for soil biocoenoses, have to be considered (FENT et al. 1995).

3.6 Priority of organic pollutants

Table 3.6-1 shows a list of organic pollutants relevant in the field of soil protection. The priorities of organic contaminants for the sludge-soil pathway is set according to UMK-AG (2000). However, some pollutants (e.g. PAHs and PCDD/Fs) seem to have relatively high rates of deposition from air, so that there is considerable discussion about the significance of atmospheric deposition of pollutants onto soils versus introduction via sludge. For comparison table 3.6-1 shows priorities for the air-soil pathway of the various pollutants according to Jensen & Endres (1999) and some typical concentrations in rain water. The compounds' names and abbreviations in the table are used as done in literature, the grouping is done mostly according to the compound's chemical properties (e.g. PAH, PCB) in some cases according to its use (e.g. flame retardants, organochlorinated pestizides).

Table 3.6-1: *Typical concentrations of organic pollutants in rain water, their vapor pressure, priorities in respect to the air-soil pathway according to Jensen and Endres [1999] and priorities in respect to the sludge-soil pathway according to UMK-AG (2000, see also Litz 2000)*

Compounds/compound groups	**typ. conc. in rain [ng/l]**	**typ. conc. in sludge [mg/kg dm]**	**vapour pressure at 20-25 °C [Pa]**	**priority* air-soil pathway**	**priority** sludge-soil pathway**	**EU 2000**
AOX	-	< 400	-	-	1 (no)	x
Brominated Flame retardants	-	-	-	-	-	-
PBB Polybrominated Biphenyls	-	-	-	-	-	-
PBDE Polybrom. diphenyl ether	-	-	-	-	-	-
Decabromodiphenylether	-	-	-	-	3	-
Pentabromodiphenylether	-	-	-	-	3	-
Octabromodiphenylether	-	-	-	-	3	-
TBBPA Tetrabromoobisphenol	-	-	-	-	-	-
CB Chlorobenzenes	< 15	-	-	No	-	-
1,4-Dichlorobenzene	-	-	-	-	2	-
1,2,4 - Trichlorobenzene	-	-	-	-	2	-
HCB Hexachlorobenzene	0,1 - 2	-	1,40E-03	No	2	-
Chloroorganic Phosphate	-	-				-
Bromophosethyl	-	-	-	-	2	-
Tris-(chloroethyl)-phosphate	-	-	-	-	3	-
Chlorophenols	-	-	-	No	-	-
2,4-Dichlorophenol	-	-	-	-	2	-
2,4,6-Trichlorophenol	-	-	-	-	3	-
PCP Pentachlorophenol (1986)	-	-	5,00E-03	No	2	-
Chloro aceti acids	-	-	-	A	-	-
Monochloro acetic acid	-	-	-	A	-	-
TCA Trichloro acetic acid	50 - 5.000	-	-	A	-	-
Ethylenediaminetetraacetate	-	-	-	-	3	-
Lipid-lowering substances	-	-	-	-	-	-
Clofibrine acid	-	-	-	-	3	-
EDs Endocrine disruptors	-	-	-	-	-	-

Compounds/compound groups	typ. conc. in rain [ng/l]	typ. conc. in sludge [mg/kg dm]	vapour pressure at 20-25 °C [Pa]	priority* air-soil pathway	priority** sludge-soil pathway	EU 2000
Ethynyl estradiol	-	-	-	-	3	-
Ethanolamine	-	-	-	-	-	-
EDTA Ethylenediaminetetraacetic acid		-	-	-	3	-
Musk xylenes and ketones	-	-	-	-	-	-
Musk xylene	-	-	-	-	3	-
Musk ketone	-	-	-	-	-	-
Pestizides	-	-	-	-	-	-
Aldrine (1979)	-	-	3,10E-03	C	-	-
Chlordan (1971)	-	-	-	-	-	-
DDT+metabolites (1977)	-	-	2,50E-05	B	2	-
DDE	0,1 - 20	-	9,90E-04	C	2	-
DDD	0,1 - 2	-	-	-	2	-
Dieldrine	-	-	3,60E-04	B	-	-
Endosulfan (1991)	-	-	1,40E-03	-	-	-
Endrine (1982)	-	-	-	-	-	-
Hexachlorocyclohexane (HCH)	-	-	-	-	-	-
Alpha-HCH	0,1 - 5	-	5,30E-03	A	-	-
Beta-HCH	-	-	4,30E-05	A	-	-
Gamma-HCH (Lindane)	0,1 - 150	-	2,90E-03	A	2	-
Heptachlor (1981)	-	-	-	-	-	-
Nitrofen (1980)	-	-	-	-	-	-
Quintozen (1987)	-	-	-	-	-	-
Precipitation chemicals	-	-	-	-	-	-
Polyacrylamide (cationic)	-	-	-	-	3	-
Phenols	-	-	-	-	2	-
Alkylphenol	-	-	-	-	-	-
Methylphenol	-	-	-	-	-	-
NP Nonylphenol	-	-	1,00E+01	No	1	x
NPE Nonylphenol (+ethoxylate)	-	1 – 1.000	-	-	-	x
Nitrophenol	-	-	-	A	-	-
DNOC 2-Methyl-4,6-dinitrophenol	-	-	8,70E-03	A	3	-
2,4-Dimethylphenol	-	-	-	-	3	-
Phthalates	-	-	-	-	-	-
DEHP Di-2-(ethylhexyl) phthalate	-	200 - 3.000	1,00E-05	A	1	x
DBP Dibutylphthalate	-	50 - 1.000	9,70E-01	(A)	-	-
DEP Diethylphthalate	-	-	2,40E-01	(A)	-	-
DNBP Di-n-butylphthalate	-	-	-	-	3	-
PAHs	-	0,1 - 30	-	-	-	x
Naphthalene (2-Ring)	-	-	1,10E+01	-	-	-
Acenaphtene (3-Ring)	-	-	3,10E-01	B	-	-
Fluorene (3-Ring)	-	-	9,60E-02	B	-	-
Fluoanthene (4-Ring)	1 - 150	-	7,00E-04	B	-	-
Pyrene (4-Ring)	1 - 100	-	8,20E-04	A	-	-
Benz[a]anthracene (4-Ring)	1 - 25	-	2,50E-05	B	-	-

Compounds/compound groups	typ. conc. in rain [ng/l]	typ. conc. in sludge [mg/kg dm]	vapour pressure at 20-25 °C [Pa]	priority* air-soil pathway	priority** sludge-soil pathway	EU 2000
BaP Benzo(a)pyren (5-Ring)	1 - 15	-	7,00E-05	A	1	-
Dibenz[a,h]anthracen (5-Ring)	-	-	1,30E-08	A	-	-
PCA Chlorinated paraffins	-	-	-	B	3	-
C10-13	-	-	-	-	-	-
C14-17	-	-	2,30E-03	-	-	-
C20-30	-	-	2,70E-02	-	-	-
PCB Chlorinated biphenyle	0,1 - 5	0,001 – 0,1	-	-	3	x
Coplanar PCBs	-	-	-	-	no	-
Trichlorobiphenyls (PCB 28)	-	-	1,30E+01	-	-	-
Tetrachlorobiphenyls (PCB52)	-	-	4,40E+00	-	-	-
Pentachlorobiphenyls (PCB101)	-	-	8,80E-01	-	-	-
Hexachlorobiphenyls (PCB 138, 153)	-	-	2,00E-01	-	-	-
Heptachlorobiphenyls (PCB180)	-	-	4,80E-02	-	-	-
PCDD/F	-	-	-	-	1	x
2,3,7,8-TCDD	-	-	6,00E-07	-	-	-
1,2,3,7,8-PeCDD	-	-	5,80E-08	-	-	-
1,2,3,4,7,8-HxCDD	-	-	5,10E-09	-	-	-
1,2,3,4,6,7,8-HpCDD	-	-	7,50E-10	-	-	-
OCDD	-	-	1,10E-10	C	-	-
2,3,7,8-TCDF	-	-	2,00E-06	-	-	-
OCDF	-	-	5,00E-10	B	-	-
Polycarboxylates (anionic)	-	-	-	-	-	-
Polyacrylic acid-Na-salt	-	-	-	-	3	-
Silicones	-	-	-	-	-	-
Silicone oil	-	-	-	-	2	-
Surfactants		-	-	-	-	-
Fluortensides	-	-	-	-	No	-
LAS Linear alkylbenzol sulphonates	-	10 – 10.000	-	-	1	x
TBTO Tinorganic compounds	-	-	-	-	-	-
TBT Tributyltinoxide	-	-	-	-	1	-
Ugilec (60% Tetrach.benzyltol.)	-	-	-	-	2	-
VOC volatile organic chem.	-	-	-	-	-	-
BTX-Aromatics	<15 - 250	-	> 100	No	-	-
Toluene	-	-	-	-	2	-
Trichloroethylene	-	-	-	-	2	-
Tetrachloroethylene	-	-	-	-	2	-

* Volatility of substances found in the geosphere: A: very low to low volatility, B: medium volatility and C: compounds with high volatility from soils

** Prioritization of compounds according to their behavior in the environment or the amounts in which they are present in sewage sludges: highly relevant (1), relevant (2) and (3) there seems to be not enough information

4 CONCLUSIONS AND SUGGESTIONS FOR FURTHER ACTIVITIES

4.1 General conclusions

(1) Sewage sludge application in agriculture is only one source for organic contamination of soils, water or plants. Consequently environmentally sound decisions need to be based on an **integrative evaluation** of contaminant sources and transfer pathways.

(2) The centuries' old idea of nutrient recycling gains new importance as development is seen in the light of **sustainabilitiy**. There is general agreement however, that the recycling of nutrients by means of sludge application in agriculture must not lead to adverse effects on the quality of products nor on the environment and hence contamination of the sludges has to be prevented.

(3) Among fertilizers sewage sludge is generally the product **carrying the highest load of organic contaminants** (KJÖLHOLT 1997).

(4) The **monthly variations** in toxic organic content can be substantial for most of the parameters analyzed, and the **variation within each waste water treatment plant** can be greater than the variation between different plants (PAULSRUD et al. 2000, MCGRATH et al. 2000).

(5) In a risk assessment KROGH et al. (1996) expect from laboratory tests with earthworms and Collembola that the detergents LAS and nonylphenole, have no effect at presently allowed doses of sludge

(6) Persistent compounds such as PCBs, PCDD/Fs and PAHs are generally not **transferred** from soil to crops, meat and milk although the possible evaporation of PCBs and foliar uptake needs more attention. Little is known about the uptake of phtalates and nonylphenole which are present in relatively high levels in sludge (RUDLING et al. 1997).

(7) To prevent elevated levels in digested sewage sludge, organic substances must be **aerobically and anaerobically degradable**. Such properties must be postulated in particular for chemicals like the components of laundry- and dish-washing detergents and surface cleaners which are used in high amounts directly in water. If this condition is not fulfilled, problems of residual levels in sludge-treated soils will be encountered (GIGER et al. 1997).

(8) The objective of sewage sludge application to farmland must be for the purpose of fertilization and hence the need for fertilizer should decide on the amount applied. Except for soils with a deficit in phosphorous supply or where sludge is used on tillage land, MCGRATH et al. (2000) consider 1 t/a dm of sludge as a prudent maximum application rate.

(9) Ideally, the total input rate of organic pollutants to soil should not exceed the rate of degradation. Maximum application rates are thus determined by the local factors that control the physical, chemical, and biological properties. (AMUNDSEN ET AL. 1997).

(10) The Norwegian authorities have decided not to include limit values for toxic organics in the existing regulations for sewage sludge and compost (PAULSRUD et al. 2000). However, nonylphenole (+ ethoxylates) will be phased out in domestic and industrial products in Norway by the year 2000 and thus the presently high amounts of these chemicals in sewage sludge will be reduced. The new regulation aims at promoting sludge management practices that allow the beneficial use of sludge in agriculture while maintaining or improving environmental quality and protecting human health. One goal announced by the authorities is to recycle at least 75% of the total sewage sludge production by the year 2000.

(11) JONES and NORTHCOTT (2000) state that the existing limits have no scientific basis and are set rather arbitrarily and are inherently pre-cautionary. According to their findings, there is little uptake of organic chemicals by crop plants from soil and for many chemicals the transfer from the atmosphere onto leaves or grain is a more important route of contamination. The standards proposed in the Draft Document for PAHs, PCDD/Fs, phthalate, nonylphenole and LAS would have very serious implications for the use of sewage sludge in agriculture in the UK, if they were to be adopted. The authors expect that many/most sewage sludges in Europe are likely to exceed the proposed limits for PAHs and LAS, even those originating from rural/domestic waste water treatment plants. Also they point out that analyses of trace organic contaminants require sophisticated analytical instrumentation and specialized analysts and can be very expensive. There are often no 'recommended or certified methods' and no commercially available certified reference materials to ensure analytical compliance (JONES & NORTHCOTT 2000).

(12) According to the German Ministry of the Environment the limit values for AOX, PCB and PCDD/F are intended as precautional and are not justified solely by toxicological implications (SAUERBECK & LESCHBER 1992). In 1999 the Ministery reconsidered the regulation and did not see it necessary to introduce limits for organic contaminants of sewage sludge beyond PCDD/F, PCB and AOX (BMU 1999a). A working group set up by the Conference of the Ministers of Environment is currently reviewing the relevance of organic pollutants in sewage sludge (UMK-AG 2000, LITZ 2000). They found PCDD/F contents in sewage sludges have decreased in recent years and recommend that monitoring sewage sludges for PCDD/Fs should be reduced (UMK-AG 2000) accordingly. Since the use of PCP as a fungicide on textiles was identified as one major source of PCDD/F in waste water (MCLACHLAN et al. 1996), UMK-AG (2000) recommend to intensify monitoring such textiles for their content of PCP and PCCD/F. Also water used for cleaning buildings where PCBs were used in building materials, could be a source of PCBs in sewage sludge and should be monitored. DEHP and TBT should be replaced altogether. In the case of PAHs only general reductions of emissions will improve the situation.

(13) The following priorities are recommended for research projects on organic compounds in Germany (UMK-AG 2000):

Group 1:	AOX, NPE, LAS, DEHP, BaP, PCB, PCDD/F, TBT
Group 2:	Toluolene; 1,4-Dichlorobenzene; 1,2,4-Trichchlorobenzene; Hexachlorobenzene; 1,1,1-Trichloroethan; Tetrachloroethan; DDT and Metabolite; Lindan; 2,4-Dichlorophenol; Pentachlorophenol; Ugilec; Bromophosethyl; Siliconoil; Phenols
Group 3:	Clofibrine acid; Chloro paraffines; Ethylenediaminetetraacetate; Musk xylol; Tris-(choroethyl)-phosphate; Decabromodiphenylether; Pentabromodiphenylsäure, Octabromodiphenylether; 2,4,6-Trichlorophenole; 2,4-Dimethlyphenole; Ethinylöstradiol; Polyacrylic acid-Na-salt (anionic); Polyacrylamide (cationic) und Dibuthylphthalate

(14) CHANEY et al. (1998) conclude that biosolids can be beneficially used in sustainable agriculture with so low risk to agriculture or environment, that utilization on farmland should be the preferred method of "Ultimate Disposal". Pretreatment of industrial and non-industrial sources of some contaminants may be required to achieve the NOAEL biosolids quality. Technology is presently available to achieve the needed pretreatment. They conclude, that PCB concentrations will limit utilization of biosolids from only a few of the 14,000 POTWs in the US. (CHANEY et al. 1998).

4.2 Pollutant specific conclusions

Table 4.2-1 provides an overview on the behaviour of organic substances in soils.

Table 4.2-1: *Classification of organic substances (UMK-AG 2000, see also LITZ 2000)*

Substance	Mammalian/ human toxicity (acute)	Ecotoxicity	Water solubility	Persistence	Concentration levels
AOX (summative parameter)	-	-	-	-	high, indicator
LAS	Medium	aquatic: high; terrestrial: medium; bioaccu-mulation: high	high; enhances mobility of other pollutants	medium	high
DEHP	low; suspected estrogenic effect	aquatic: medium to high; terrestrial: low; bioaccu-mulation: high	low	medium	high
Nonylphenole	medium; suspected estrogenic effect	aquatic: high; terrestrial: medium; bioaccu-mulation: high	high	medium	high
B[a]P single substance (**PAH**)	carcinogenic, mutagenic, teratogenic	high; bioaccumulation: high	low	high	high
PCBs, single sub-stances/summative parameter	medium; tumour promoting, immunotoxic	aquatic: high; terrestrial: high; bioaccumulation: high	low	high	low and continuing to decline
PCDD/Fs,single substance/summative parameter	high; carcinogenic	aquatic: high; terrestrial: high; bioaccumulation: high	low	high	low
TBT Tributyltin oxide	high	aquatic: high; bioaccumulation: high; endocrine effect	medium	high	high

AOX

(15) AOX as a sum parameter does not represent a specific chemical substance and is not a direct measure for toxicity. PVC which is otherwise regarded as inert, may enhance the AOX measured significantly. In Finland, paper pulp industry was responsible for about 50 % of the total organic halogen emissions into the environment. Several other industries, such as the manufacture of polyvinyl chloride (PVC), and waste incineration are important sources of AOX formation as well. In the context of soil contamination it is noteworthy that some organic halogens may be transformed in the soil to more toxic compounds such as vinyl chloride, which is a known human carcinogen (SALKINOJA-SALONEN et al., 1995; AURAS 2001). Concentrations in 90% of German sludge samples were below the German limit values and concentrations have been decreasing in recent years (UMK-AG 2000).

DEHP

(16) PAULSRUD et al. 2000 report a significant reduction of phthalates (DEHP) in Norwegian sewage sludges, even though three plants in Norway exceeded Danish standards. In Germany too, the use of DEHP is decreasing slowly, with DEHP being replaced by more highly substituted phthalates (UMK-AG 2000) and other plasticizers.

LAS

(17) In sewage treatment, a proportion of the LAS is absorbed onto sewage solids during primary settlement of sewage and will not undergo normal aerobic treatment since this part of the sewage stream will bypass the aeration tank (BIRCH et al. 1993 cit in DE WOLFE & FEIJTEL 1997). Thus sludges can still contain considerable amounts of LAS when they are applied to soils. However, laboratory and environmental studies show that LAS is biodegradable at high rates under aerobic conditions. Thus, when judging potential risk, the rapid biodegradation of LAS after application of the sludges to soils has to be taken into account. However, when the Danish PEC values were calculated this was not considered which makes the Danish scenario unrealistic as compared to the EU-approach. (DE WOLFE & FEIJTEL 1997).
The LAS content of Norwegian sewage sludges is very variable, but in general far below the Danish standard and the concentrations reported in the Danish investigations (TÖRSLÖV et al. 1997 cit in PAULSRUD et al. 2000). This is mainly due to the fact that most Norwegian households use **eco-labeled detergents** which do not contain LAS (PAULSRUD et al. 2000). In Germany the amounts of LAS used are approximately constant and hence no significant change of concentrations in sewage sludges is to be expected (UMK-AG 2000). The majority of the UK samples exceed the LAS concentrations limits of the 3rd Draft of the EU-Initiative (JONES & NORTHCOTT 2000).

NPE

(18) There has been a significant reduction of nonylphenole (+ ethoxylates) in Norwegian sewage sludges between 1989 and 1997, still Nonylphenole (+ ethoxylates) were found in high concentrations in sludge samples from all the sewage treatments plants in the survey, and all the plants would have been classified as non-compliant with the Swedish and Danish standards (PAULSRUD et al. 2000) and hence the proposed EU standards. Of the UK samples three exceeded the EU proposal (JONES & NORTHCOTT 2000). In Germany NPE is also a relevant contaminant in waste water, but here too amounts have drecreased since the eighties, because industries volontarily reduced the amounts used in household and industrial cleaners (UMK-AG 2000).

PAH

(19) The most relevant sources for PAHs are coal burning for heating of buildings and tractor-trailer traffic. Shifting from coal to oil for heating and improvements in heating technology have reduced PAHs emissions in Germany significantly in recent years. This has resulted in a steady decrease of PAH concentrations in sewage sludges (UMK-AG 2000). The EU proposals include limit values for the sum of 9 PAHs (including benzo(b+j+k)fluoranthene), but it is not clear what criteria have been used to select these compounds (JONES & NORTHCOTT 2000). The PAH concentrations in sewage sludges in relation to the limits of the 3rd Draft of the EU-Initiative are as such:

Norway	The PAH content was low in most sewage sludge samples and well below the Swedish and Danish standards	PAULSRUD et al. 2000
UK	all samples above EU limit, even those WWTPs for which there was 0% trade effluent and purely rural, domestic wastewater	JONES & NORTHCOTT 2000

(20) On the grounds that a soil limit value for benzo[a]pyrene is set in BMU (1999) in respect to the pathway soil - plant, the introduction of a limit value for soil concentrations of BaP into the EU-Initiative is recommended. A regulation seems important, because there will be atmospheric deposition as well as introduction of benzo[a]pyrene to agricultural soils via sludge application for years to come.

PCB

(21) JONES & NORTHCOTT (2000) conclude from the small variation in PCB-values between WWTPs in UK, that there are very few fresh or ongoing primary sources of PCBs to the environment. In Germany concentrations have been nearly constant during the last decade (UMK-AG 2000). AMUNDSEN et al. (1997) warn that the high stability of heavily chlorinated PCBs in the sludge, calls for a more precautious use of sewage on surface soils in public areas. CHANEY et al. (1996) consider the low concentrations of PCBs in sludges and the setback distances and use of erosion control practices required in the US as providing high protection against the risks from sludges getting washed into surface waters. The PCB concentrations in sewage sludges in relation to the limits of the EU-Initiative (3rd draft) are as such:

Norway	all samples far below German and Swedish Standards	PAULSRUD et al. 2000
UK	all below EU-limit	JONES & NORTHCOTT 2000
Germany	all samples below German limit	BMU 1999a
Ireland	all samples below German limit	MCGRATH et al. 2000

PCDD/F

(22) HORSTMANN &MCLACHLAN (1994) estimates that ~20 to 40% of the TEQ entering German WWTPs nationally comes from imported **cotton textiles** that were treated with pentachlorophenole. The banning of PCP use in Germany and restrictions on the allowable concentrations in consumer products brought about a significant **reduction** in PCDD/F levels in sewage sludges (MCLACHLAN et al. 1996, UMK - AG 2000). The concentration of PCDD/PCDF show only **small monthly variations** (PAULSRUD et al. 2000). Addition of sewage sludges to agricultural land will increase the soil PCDD/F concentration. While **atmospheric deposition** provides a direct source of PCDD/Fs to foliage, the transfers of PCDD/Fs from soils into plant roots and their translocation into the aboveground portions of plants are **negligible,** except in Cucurbitacea (HÜLSTER 1994). Root crops may take up PCDD/Fs from soil, but mostly it stays restricted to the peel (JONES & SEWART 1995). PCDD/F transfer into livestock via soil ingestion or uptake of sludge adhering to feed are critical with respect to human dietary intake and are believed to be the major exposure

route (>99%), while intake from water and air are negligible (WILD et al. 1994). The PCDD/F concentrations in sewage sludges in relation to the limits of the EU-Initiative (3rd draft) are as such:

Norway	all samples below German Standard	PAULSRUD et al. 2000
Germany	average sewage sludges are below limit of "Klärschlammverordnung" (some exceed limit!)	BMU 1999a

Others

PBB/PBDE Brominated flame retardants

(23) The ubiquitous presence ofpolybrominated biphenyls (PBB) and polybrominated diphenyl ether (PBDE) flame retardants in the environment has begun to attract international attention. Researchers and environmental groups are concerned about emerging pollution problems and evidence suggesting that low-level exposures may produce detrimental health effects in humans and animals (RENNER 2000). Sweden has requested a freeze on the use of PBB and PBDE with EU authorities, because of an increase of concentrations found in breast milk and fish (HELLSTRÖM 2000)

EDs Endocrine disruptors

(24) More than a hundred chemicals are suspected to have hormone-like effects in organisms, that potentially result in reproductive impairment or disorders. Most are likely to be found in sewage sludge (SMITH 2000). Many persistent organic pollutants like PCBs, dioxins and pesticides (DDT) have endocrine properties, however, since persistent pollutants are already covered by a number of EC Directives and Regulations because of their toxic properties, their potential as EDs does not necessitate additional regulatory activity (PÄRT 2000). SMITH (2000) states that natural **estrogens** are readily biodegraded by the activated sludge process, PÄRT (2000) reports that little is known about the extent to which natural hormones (**estrogens**) and **pharmaceutical residues** are accumulated in sewage sludge and what happens with these compounds when the sludge is used on soils.

CB Chlorobenzenes and COP Chlororganic Pestizides

(25) Sludge application to soil can increase the CB content in crops which may limit the land use of sewage sludge in a certain extent. Sludges from industrial areas may contain significantly higher amounts of CBs than those from urban areas. CB concentrations in sludges from sewage treatment works can be relatively stable, with certain effluent sources. CB content of modern sludges is somewhat higher than those sampled during the 1940's and 1950's (WANG et al. 1997).

(26) Chlorobenzenes (CBs), a major group of substituted monocyclic aromatics, are ubiquitous in sewage sludges. Volatilisation is regarded as the main loss mechanism for CBs from the soils. The 1,4-dichlorobenzene (DCB) content in both the sludge-amended and the control

soils increased remarkably during the 1960s; trace level impurities in pesticides and /or atmospheric deposition are possible sources (WANG et al. 1995).

(27) The CB concentrations in U.K. sewage sludges have been reported to be between 0.795 and 193 mg kg^{-1} (Wang et al. 1995). Dichlorobenzenes (DCBs), 1,2,4-trichlorobenzenes (1,2,4-TCB), and hexachlorobenzene (HCB) have been classified as priority pollutants by the United States Environmental Protection Agency (U.S. EPA) and by the EC. Some CBs (e.g., HCB) are known human carcinogens (U.S. ENVIRONMENTAL PROTECTION AGENCY 1985 cit in WANG et al. 1995), (WORLD HEALTH ORGANIZATION 1991 cit in WANG et al. 1995).

Musk ketone and Musk xylene

TAS et al. (1997) consider the risk that musk ketone and musk xylene pose to organisms in the aquatic environment and to fish-eating birds and mammals as low. No monitoring data are available to evaluate the predicted soil concentrations, whereas presently PEC/PNEC ratios in soil around 1 indicate a need for refinement of the risk assessment for this compartment by obtaining experimental data under realistic environment conditions.

PCA Chlorinated paraffins

(28) Following their widespread and unrestricted use in predominantly open systems, PCAs are now present in a range of environmental compartments (TOMY et al. 1998 cit in JONES & NORTHCOTT 2000). PCAs are not known to occur naturally and are of concern owing to their toxic properties and to their capacity to bioaccumulate (BMU 1999a). They can be classified as persistent organic pollutants (POPs). Total concentrations in UK sewage sludges of the short-chained and medium-chained PCAs ranged between 7-200 mg/kg and 37-9700 mg/kg, respectively. Nonetheless, some of the sludge samples contain very high levels of these substances (JONES & NORTHCOTT 2000). At present a satisfactory evaluation of the environmental effects of chlorinated paraffins seems not possible (BMU 1999a).

TBTO Organotins

(29) Municipal wastewater and sewage sludge are contaminated with organotins, but knowledge in this field is till limited. It is necessary to quantify inputs from wastewater and sludge, and to understand the fate and behavior in aquatic and terrestrial environments in order to predict the impact of the growing use of organotins, in particular related to the use of TBT compounds in wood preservation. It should be borne in mind that tributyltin compounds are among the most hazardous organic pollutants known for aquatic systems. The availability to biota, uptake by plants, biodegradation and possible toxic effects should be investigated in order to evaluate and assess risks arising from sewage sludges as sources of organotins in sludge amended soils (FENT et al. 1995). According to UMK-AG (2000) knowledge about pathways of organotin compounds in the environment and its presence and fate in sewage sludges is not yet satisfying.

VOC Volatile organic chemicals

(30) The sludge application to agricultural land is unlikely to increase the VOC concentration of the soil to levels which may cause concern for human health and the environment (WILSON et al. 1994). Volatilization and loss of VOC occur rapidly from soils. VOC in sludge do not represent a hazard to agriculture except possibly where sludge is spread on soils with high content of organic carbon. It is recommended that sludges containing VOC not be spread on organic soils (WEBBER & GOODIN 1992).

4.3 Suggestions for further work

(31) The Priority list of contaminants should be elaborated and the member states should contribute their priorities so that the list gains pertinence EU-wide and regionally (Harmonized EU Priority List)

(32) The Priority list of contaminants should contain key substances instead of substance classes as long as there are no internationally recognized toxicity equivalence factors.

(33) Concerning organic contaminants in sewage sludge existing information should be reviewed or research be initiated on the relative importance of contamination sources **(air-water-soil integrated research**). This would clarify for which contaminants the contribution of sewage sludge to soil concentrations is important enough to necessitate regulation in the future and have influence on the priorities of contaminants in sewage sludge (see table 3.6-1).

(34) An EU website on "Organic Contaminants in Sewage Sludge for Agricultural Use" could be built up e.g. in connection with http://europa.eu.int. Such a website could offer the following informations

- original literature, e.g. reports initiated by national authorities,
- the priority lists of pollutants with background information,
- state of the art of national standardization,
- information on national research projects,
- knowhow on the prevention or reduction of the contamination of sewage sludges.

(35) Research soil-plant and soil-water transfer of organic contaminants should be initiated on a number of sites across the EU that were given extremely high amounts of sewage sludge in the past. These field studies could provide the scientific basis for limit values for soil concentrations. If soil-plant and soil-water transfer would not exceed the limits mentioned in chapter 3.5, it would not seem necessary to set limits for soil concentrations for regulating sludge use in agriculture.

(36) If quality standards for sewage sludges are to be set, there will be need for standardized methods of analysis. Therefore **prenormative research** in coordination with ISO- and CEN-groups should be supported.

(37) To facilitate the further development of the EU guideline on sewage sludge a „Survey of Organic Pollutants in EU Sewage Sludges" (**EU-databank/cadastre**) should be carried out. To standardize data the median/90-perzentile-method should be established.

(38) The input of organic pollutants to soil via sludge application cannot be considered separately from other inputs. If the **total input rate** is to be kept below the rate of degradation, tolerable total yearly input rates have to be determined that take all possible pathways into account. These tolerable total yearly input rates could later be used for a EU-soil-protection Directive.

(39) So far only incomplete information on the fate of contaminants and their metabolites in soils is available. **Permanent (>30 years) soil observation** with standardized methods should be established EU-wide as a prerequisite for final evaluation of persistence.

(40) **New technologies** such as wet oxidation, pyrolysis or gasification have come up. More information concerning their effectiveness with sludges and their environmental impact is needed (ANDERSEN 2001). Such technologies may have to be applied if sludge production goes up as predicted. According to BÖHM (2000) surveillance of pathogens could be developed further.

(41) The EU-draft contains a number of important measures for the „Safer practice of sewage sludge application“. Some of these methods can still be refined, e.g. application of sludge on **hydrogeologically sensitive areas** ("water-saturated soils"). A setback distance for sludge application near surface waters should be considered in order to prevent particles from being washed into water bodies with run-off or floods.

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BioCycle

ADVANCING COMPOSTING, ORGANICS RECYCLING & RENEWABLE ENERGY

WHAT'S NEW - IN-VESSEL COMPOSTING

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Based on a survey of in-vessel system manufacturers, there are both new systems as well as new component and design innovations to report. Combined, the 19 vendors responding account for 587 plants worldwide. Part I

Robert L. Spencer

IF YOU are considering some sort of enclosed vessel for composting food residuals, yard trimmings, biosolids, manure, animal mortalities or other waste streams, there is no shortage of options to consider. Domestic and international technology providers offer agitated and nonagitated enclosed systems, as well as rigid and nonrigid containment. Unlike some of the other equipment categories in BioCycle's What's New? series (e.g., grinders, screens), almost all the in-vessel systems, perhaps with the exception of the plastic tube technologies, were developed strictly for composting.

This fifth article in our What's New? series shines some light on the 19 vendors who responded to our 4-page survey of in-vessel composting technologies. It was sent to the 40 vendors listed in BioCycle's 2007 Equipment and Systems Directory (April, 2007) under the following subcategories of Composting Systems: Aerated Containers, Enclosed Aerated Static Piles, Horizontal Agitated Beds, Aerated Piles, Rotating Drums, and Vertical Reactors. For purposes of this What's New? article, however, we decided to group the respondents' technologies into three more general categories of enclosed (in-vessel) aerobic composting:

Enclosed Aerated Static Piles: Aerated Piles covered with fabric, and Aerated Containers/tunnel reactors. None of these systems use agitation other than periodic remixing of the material.

Agitated Beds and Vessels: Horizontal concrete bays with mechanical agitators, and horizontal or vertical metal or plastic vessels of various shapes with mechanical agitators.

Rotating Drums: Cylindrical vessels that are automatically turned on a continuous basis, usually at speeds of 1 rpm or less.

Given the volume of information received, we are running What's New? In-Vessel Composting in two parts. Part I covers the first two categories of systems - Enclosed Aerated Static Piles and Agitated Beds and Vessels. Part II will include information received on Rotating Drums.

While not all survey respondents had a “new” feature or application to report, a description of their process is included since some readers may not be familiar with the particular technology. The information reported here was supplied by the vendors and not independently verified by BioCycle editors.

THE BIG PICTURE

The big picture that emerges from the survey is that there is a wide range of technologies to choose from, and that many of these technologies have been around for quite a few years. The greatest number of years on the market is 30 years, for both Rotocom's rotating drum, and Christiaens Group's aerated tunnels. The average number of years on the market for all 19 vendors is 12 years. There are three newcomers: BioSystem Solution's horizontal and vertical agitated system with less than one year on the market; X-ACT System's rotating drum with two years; and Environmental Products & Technologies Corporation's rotating drum with three years.

Total number of plants or sites with the various technologies is over 587 worldwide, with Green Mountain Technology's Earth Tub leading with more than 200 sites, mostly for food waste, a number that reflects the ability to install a unit at a hotel, university or office complex cafeteria. The GORE Cover System comes in second, with 150 installations worldwide for composting biosolids, yard trimmings, MSW, food and agricultural waste streams. BW Organics lists 60 rotating drum facilities worldwide, mostly on farms, followed by RotoCom's 45 rotating drums, 43 of which are in Japan processing animal manure, meat by-products and food waste. VCU's passively aerated vertical chamber is reportedly installed at 38 locations.

Looking back over the past 10 years, there has been a continual evolution of in-vessel composting technology designs and vendors. BioCycle's 1997 Directory, "Equipment and Systems For Composting and Recycling Organics," listed 39 vendors under the Composting Systems category. Technologies were not divided into subcategories, so it is unclear exactly how many were actual "vessels." What is clear is that well over half of those companies are not in the 2007 directory, which, as noted, had 40 vendors under Composting Systems. (That is an increase of nine from 2002 to 2007, which also indicates a steady growth. Additionally, there has been far less turnover in the technology vendors.)

Although more costly than open air composting, in-vessel appears to be gaining ground as more food waste projects are implemented. This is due to a number of very good reasons, particularly control of the process, odor, leachate, vermin, weather and final product quality. Most state and provincial composting regulations call for control of these environmental factors, something in-vessel systems can provide to a greater degree than lower technology systems.

Another trend is toward modular systems since many composting projects start small (especially those processing food waste), and then expand as the program grows. Most of the in-vessel systems described here are considered modular, and either the unit can be lengthened, or additional units added. The survey also reveals several vendors who have added vermicomposting, either as a stand-alone technology, or as an add-on to in-vessel systems.

ENCLOSED AERATED STATIC PILES

The eight vendors who responded to the survey offer two different approaches to aerated static pile (ASP) composting contained in some type of vessel. The simplest systems are those that use some type of plastic bag or a breathable fabric cover to contain the organic material, and provide mechanical (as opposed to passive) aeration. Compared to nonenclosed aerated static piles, these systems are better able to keep out moisture from precipitation, maintain pile temperatures, and control odors. Windrows "in a bag" originated with agricultural applications where silage is mechanically pushed into plastic bags, or sausages, for storage. This technology has been adapted to composting by a number of companies that include pipes and blowers to aerate the material, enhancing the rate of degradation and reducing odor.

The other subgroup is mechanically aerated rigid containers, such as a metal rolloff container modified for composting, or a larger concrete or metal chamber or tunnel. These containers got their start in the mushroom growing industry. There are also vertical containers, with one vendor offering a passively aerated system, and the other a mechanically aerated system. The eight vendor systems in this category are described below.

Christiaens Group

Based in The Netherlands, this tunnel composting system got its start in the mushroom industry 30 years ago, and was introduced into the solid waste market in 1990. In just the last three years, the company reports development of four facilities in Canada, three in the United Kingdom, two in France, and four in Germany. These facilities process between 10,000 and 100,000 tons/year of biowaste, yard trimmings, MSW and/or biosolids. The tunnels are as large as 26.2 feet wide by 184 feet long, and are equipped with an aerated floor system designed to support a front-end loader as it moves material in and out of the tunnel. The tunnels also can be designed for loading with an automated conveyor system, or with a walking floor.

Each tunnel is loaded with one batch of organic material, the door is closed, and the PLC (programmable logic controller) tunnel climate control system is activated. The composting process is controlled based on temperature, oxygen and moisture readings that determine the amount of air to blow through the tunnels. Retention time depends upon local regulatory requirements, but is typically at least 14 days. To control the compost process, fans push air into the plenum beneath a floor designed to provide even air distribution. Air flows up through the organic matter and into the head space at the top of the tunnel where it is captured, mixed with fresh air, and then recirculated into the plenum at the base of the tunnel. Exhaust air is treated in a humidification scrubber, then a biofilter. The temperature of the biofilter is monitored, and can be maintained at optimum ranges through use of a damper and pressure controlled blower system. Air flow to the tunnels and the biofilter is controlled by a PLC, with remote monitoring by Christiaens if desired.

Depending on the size of the installation, labor requirements are a minimum of one operator and two front-end loader operators. The primary maintenance item is to grease the 22 kW to
55 kW fans. More maintenance is obviously required for those facilities that utilize an automated loading/unloading system. To minimize corrosion, stainless steel aeration fans are used, as well as aluminum duct work.

Christiaens also has developed a smaller container composting system. Most of these units are used for research purposes. The company has developed a working relationship with Maple Reinders, a Canadian company, in order to provide turnkey project development.

Engineered Compost Systems

ECS offers three variations of its in-vessel systems. The SV Composter™ is described as an insulated and stationary system designed for medium to large facilities, processing between 15 and 500 tons/day (tpd) of feedstocks. The system is designed to operate in a wide range of ambient temperature, from 40°C down to -30°C. The vessel walls and ceilings are constructed with insulated concrete, and the doors are gasketed and insulated. Stainless steel is used on the interior door surfaces of the vessel. The aeration floor is designed to provide uniform air distribution; leachate is collected in the aeration floor and drained to a sealed sump.

Some of the installations, such as Hutchinson, Minnesota, process source separated organic waste, while other plants, such as West Yellowstone, Montana and Mariposa, California, process mixed MSW. Several SV Composter systems, e.g., Granby, Colorado, are composting biosolids. A semi-automated conveyor loading system is available, or the units can be filled with a front-end loader. The in-slab aeration floor is compatible with loading and unloading with a front-end loader, and is reportedly "plug-resistant."

The aeration system provides reversing and recirculating process air through motorized dampers in order to achieve uniform temperatures of the biomass in the vessel. All components in contact with the air stream are constructed from either stainless steel or polymeric materials. The aeration system is designed to conserve energy with variable speed fans and a low friction aeration floor. All process air is treated in a site-built biofilter.

Air flow to each vessel is regulated by the ECS Comptroller™ based on temperature probes inserted into the compost bed once the vessel is filled. The control system requires minimal operator intervention during composting and automatically records temperature and other data for each batch. Aeration rates to each vessel are automatically controlled through setpoints, and can be set low to conserve moisture and fan power, or higher for increased drying. ECS can remotely provide technical assistance through this system.

A variation of the system is the CV Composter™, designed for 2 to 20 tpd applications. The CV vessels are fabricated with stainless steel interiors and stainless or galvanized metal exteriors. Vessels contain 20 to 50 cubic yards in one batch, and are built on a rolloff chassis so they can be moved and handled with a rolloff truck. The vessels are loaded with a conveyor, and unloaded with a rolloff truck tipping the vessel. CV vessels are composting source separated organics in Walla Walla, Washington and Ottawa, Ontario, and biosolids at several other sites.

The third, newest ECS system option is the AC Composter™ (Covered ASP) which uses a UV resistant, waterproof fabric to cover windrows up to 30 feet wide and 60 feet in length. Negative aeration of the piles is used to hold the fabric in place, with aeration pipes built into the slab; the Comptroller governs aeration. ECS also offers a less expensive above grade aeration option. The cover is removed manually for piles up to 60 feet in length, or with commercially available tarp rollers for larger piles. The negative aeration system and tarp are designed to minimize fugitive odors, with exhaust air directed to a biofilter. AC Composters were recently installed in Tenino, Washington for a 60,000 tons/year (tpy) source separated organics facility; pilot projects are being conducted at two other locations.

GORE Cover System

With over 150 installations in 15 years, W.L. Gore and Associate's GORE™ Cover System is employed in a large variety of feedstock applications - most recently for mechanical-biological treatment (MBT) of organic waste prior to waste to energy, as well as posttreatment of solids produced by anaerobic digestion. The system is centered on a membrane laminate technology similar to the company's GORE-TEX® fabric. The company does not sell just the fabric for composting, but an integrated system that includes the fabric covers, in-floor aeration, aeration blowers, oxygen and temperature sensors, controllers, computers, software, cover handling systems, training, engineering guidance and installation support.

The fabric has a microporous membrane that is laminated between two ultraviolet resistant support fabrics. The cover is waterproof and windproof to protect composting material from the elements, but it is also permeable to water vapor, allowing moisture to be released, along with CO_2 generated from composting. The cover also provides some insulating properties that help maintain composting temperatures.

Odor control from the fabric covers performs as follows: Many odor compounds are soluble in water, and therefore are trapped in the condensate that builds up under the cover. The condensate falls back into the composting mass to be further degraded. The company claims that the covers can achieve 90 to 97 percent reduction in odor concentrations, and that the small pore size of 0.2μ is an effective barrier for dust, aerosols, and microbes which could be released to the environment, impacting workers and neighbors.

Brian Fuchs, GORE's North American representative, explains that another advantage of the system is its ability to keep leachate separate from precipitation since the leachate is collected in a trenching system and can be stored for reuse on the compost. Precipitation is shed off the covers and also can be reused or discharged per local regulatory standards.

The covers are handled in two ways. A wall-mounted winder can serve up to 16 piles located next to each other. For larger installations, a mobile winder straddles the piles, moving slowly along while winding the tarp onto a spool above the piles.

Regarding projects on this continent, Fuchs says that although GORE only entered the North American market in the early 2000s, there are seven installations in North America treating over 315,000 tpy. "Our most recognized and the world's largest GORE™ Cover System is the Cedar Grove Composting facility in Everett, Washington with a design capacity of 160,000 tpy. More recently we installed a small 3,000 tpy plant for the Delaware Solid Waste Authority, which demonstrates our ability to supply systems of any size," he says.

The GORE system operates on a treatment time of eight weeks in total, from input to finished compost. As for it being considered an in-vessel system, he says "the system is internationally recognized as an enclosed or in-vessel system in Hungary, USA, UK, Spain, Sweden, Italy, Ireland, Finland, Estonia, Germany, and Canada."

A recent cold weather innovation was developed by the Greater Moncton Sewerage Authority in Moncton, New Brunswick, for use with their biosolids composting facility. The Authority installed pipes with glycol circulating through them (heating loops) in the compost pads to capture the heat generated under the compost piles. This heated glycol is then piped to areas of the compost pad where snow and ice have weighted down the GORE covers, thawing the ice so that they can be removed. A more detailed article on the Greater Moncton facility will appear in a future issue of BioCycle.

NaturTech

The NaturTech® Composting System has been on the market for 13 years, and is offered by Renewable Carbon Management LLC. The modular units are constructed from modified intermodal shipping containers using either a 20- or 40-foot long box. An aeration system is installed that operates based on temperature probes in the composting material. Process monitoring is done either manually or with a timer and data logger to a PLC. The containers are filled by a front-end loader, and then emptied with a rolloff truck for either remixing or curing in another container.

The system has been installed at 11 locations in the U.S., including a military base. Wastes composted at existing facilities include raw primary wastewater solids, DAF (dissolved air flotation) solids, food residuals, forest products, poultry feathers, chicken manure and dairy manure. Systems can be designed to process from 1 tpd up to 600 tpd.

A new feature for the units is a plastic aerated floor strong enough to drive a front-end loader on. The aeration system is dual negative and positive using differential pressure sensing with actuated valves. For curing containers, negative aeration is used. Leachate is handled with a patented quick couple drain and recirculation system. Odor control is through proper mixing and aeration, coupled with a containerized biofilter.

Corrosion control is accomplished by making the containers with Cor-Ten® Steel and epoxy coating, an abrasion resistant carbon steel designed for 15-year exposure to sea water. A replaceable insulation liner protects the container sidewalls; the plastic floor has an estimated life of 30 years.

Poly-Flex

Poly-Flex recently introduced an acquired technology that offers a patented waste management solution for composting organics. Sold under Poly-Flex CompostingTM, the system utilizes large plastic tubes that are mechanically loaded with organic waste by a moving press. Two perforated plastic pipes are inserted into the tube by the same press during the progressive filling of the tube. The aeration pipes are then connected to a blower to provide forced aeration during the composting process. The flexible plastic pipes are available in two different diameters, 5- and 10-foot, and in lengths of 200 feet.

In addition to the composting technology, Poly-Flex Composting sells biodegradable and compostable bags under the national distributed EcoGuardTM brand for residential and commercial collection. "We are extremely excited to continue to develop and offer full solutions," says Morris Jett. "We believe Poly-Flex Composting is the first company to offer the complete solution that addresses the full lifecycle of 'organic/green' waste from safe, sanitary collection systems to the self-contained in-vessel composting technology that meets EPA and wastewater regulations (controls odor and leachate) while producing high quality compost materials for reuse."

Transform Compost Systems

Transform Compost Systems is the only vendor responding to the survey with an in-vessel technology in two categories, Enclosed Aerated Static Pile and Agitated Bed. The company's Aerated Bunker System utilizes an aerated concrete bunker custom designed for each application. After two to three weeks in one aerated bin, the material is mixed and placed into a second aerated bin for another two to three weeks. The process is designed to maintain temperatures above 55°C for at least 14 days throughout the composting material. Bins are loaded with a conveyor system or front-end loader, and emptied with a loader.

An aerated bunker system is installed at the District of Kent, British Columbia.

The bins are equipped with a patented Airfloor™ aeration system embedded in a concrete floor that also allows for leachate collection. Aeration blowers are controlled by a computerized timer and temperature feedback system, with compost batches tracked through the bunkers, and time vs. temperature graphs produced for the entire process.

After the composting phase, material is screened and placed in curing piles for another six to eight weeks. The system can be designed for installation within a building that has a receiving and mixing area, allowing for collection of odors and treatment in a biofilter. The company also introduced the AirPhaser, a new, nonthermal plasma odor control system that destroys odor compounds by passing them through a high frequency and high voltage field. Its installation requires a small amount of space.

VCU Technology International

VCU Technology International Ltd. has been marketing a "modular vertical passively aerated aerobic in-vessel composter" for the past 10 years, with 38 installations in Australia, New Zealand, United Kingdom, Finland, Spain, Scotland and Canada. The Canadian installation is at Halton Waste Recycling in Newmarket, Ontario and processes 20,000 tpy of green waste and digestate from an anaerobic digester. Most of the other facilities process source separated organics and yard trimmings, with others handling fish waste, slaughterhouse and poultry by-products, wastewater treatment plant grit and sludge. One of the larger VCU installations processes 20,440 tpy of household green and food waste for the Merseyside Waste Disposal Authority in Gillmoss, England.

Processing capacities range from 4.5 to 8 tons per chamber per day. Each chamber is 9.8 feet by 9.8 feet by 16.4 feet tall, and is loaded from a blender/mixer to an inclined conveyor, which takes homogenously mixed material to the top of the chamber and then distributes it by another conveyor to the chosen cell in multicell systems. The fresh material is spread evenly at the top of the chamber by a proprietary mechanism. Compost product is harvested daily from the bottom of the cell, and the column then slumps down the chamber to an automatically controlled level. Leachate can be directed to the municipal sewer.

Paul Brown, coinventor and company founder, describes some improvements that have been made in the last few years. "We have changed some mechanical handling components since the Newmarket facility, which has allowed us to increase input volumes per hour. We have also changed the process a little where we are getting steeper heating curves in shorter time periods, postharvest and filling each day. This is enabling us to get the cells (chambers) back into process stasis [steady-state] sooner and be stabilized for 18 to 20 hours/day. Bugs with more hours per day in stasis, before their habitat and conditions are changed again, do more efficient work."

Typical retention times vary between seven and 14 days. Heat from the composting process rises through the chamber pushing temperatures in the top of the chamber to over 70°C, complying with regulatory requirements. Brown explains that gaining full accreditation under the Animal By-Products Regulation (ABPR) of any government is an involved process that takes at least six months. VCU works with its clients to prove that its process meets the requirements of the ABPR.

In Manchester, England, the modular nature of the system has allowed the facility to expand from a single cell chamber five years ago, to three chambers a couple of years later; it now has six chambers. The facility processes fruit, vegetable and flower wastes, combined with green waste and cardboard. It is located on the site of the market in Manchester.

Brown reports that two new size models will come on the market within the next three months. "They are small systems for the remote resort/island community/corporate campus sector," he says. "They will come with a solar cell/ 24-volt operating option and process up to 1 tpd."

Versa Corporation

This elongated plastic bag composting system was first developed in 1990, and was purchased by Versa Corporation in 2004. The Versa CTI System is a patented technology that uses a low cost containment vessel with forced aeration. The bags are 10 to 14 feet in diameter and up to 350 feet in length. Perforated pipe connected to an electric blower runs inside the length of the bag. Raw material is placed into the bag with a machine developed for the agricultural feed storage industry and has been manufactured in the U.S. for the last 25 years. Bags are unloaded by a front-end loader of some type. Four Versa systems are installed in Minnesota, California (2), and British Columbia, and process MSW, yard trimmings, food residuals, wood waste and biosolids. Versa also recommends the bags for storage of finished compost.

AGITATED BEDS AND VESSELS

As summarized in Table 2, six vendors responded from this category. A variety of machines have been developed over the last 20 years to mechanically stir and mix organic material in a horizontal or vertical container of some type. There are basically two subgroups in this category; horizontal concrete beds or bays with an agitator that travels along the top mixing the material below, and containers with an internal mixing paddle or shaft. Some of these systems are also aerated with a blower system.

Backhus

Backhus Kompost-Technologie, which manufactures windrow turners, has developed the Lane Turner (LT), previously model 9.45, to operate on concrete walls 16.4 feet wide, with a pile height up to 8.9 feet. The turning machine is only 5 feet tall above the wall and therefore allows for a low head space above the walls, reducing the amount of air to be collected and treated.

The concrete bunkers are loaded and unloaded with a conveyor, hopper-car or front-end loader. The units can be manually or automatically operated. The company notes that it is advantageous to the composting process to include an aerated floor. Backhus also has a bridge turner to span and turn much larger quantities of material inside a building.

BioSystem Solutions
Founded in 2002, BioSystem Solutions spent two years in R&D, and introduced a small, school cafeteria-sized vermicomposting unit, BioSafe™, to process up to 20 lbs/day of food waste, producing worm castings. After more R&D focused on large-scale composting, BioSystem launched three new models in 2007, two of which are agitated bed technologies.
The BioChamber™ is a self-contained, automated, agitated, in-vessel composting system designed to process food waste (including meat and dairy), manure and biosolids. The unit provides automated loading, turning and compost discharge. It is a stackable modular system constructed with stainless steel. Agitators inside the unit turn and move the material through the container in seven to 21 days. Process controls measure and record temperature, oxygen and moisture content. All exhaust air is treated through a biofilter. Leachate is also captured for reuse.
A vertical variation is offered in the BioTower™ for use in space-restricted locations, and is designed to process from one to 20 tpd. The third new product, BioLane™, is an automated, self-contained, stackable vermicomposting device.

Green Mountain Technology
More than 200 Earth Tub units have been installed in schools, restaurants, hospitals and supermarkets in the ten years they have been on the market. Described as a continuous batch process for 50 to 150 lbs/day of food residuals, manure or yard trimmings, a person manually rotates the cover while an internal auger shreds and mixes the material in the 4-foot high, 7.5 foot diameter plastic tub. Feedstocks are manually added through top and side doors until the unit is full, and then discharged after three to four weeks of active composting through the discharge door. An aeration system draws air through the compost and forces the exhaust air through a biofilter. Leachate is collected and disposed to a sewer system or holding tank.
The company reports that the system works best with two side-by-side units, which allows the product in one tub to complete composting while fresh compost is added to the adjacent tub. When fresh material is added, the 12-inch diameter stainless steel auger is turned on while the lid is manually rotated.
GMT recently redesigned the lid, which features a prop to hold up the loading hatch when food waste is being added (previously it had to be held up manually while loading). A metal cross bar was added to reinforce the plastic lid and rollers have been added to the ends of the cross bar to make the lid easier to turn. As for new applications, a number of units have been sold to biodegradable plastics manufacturers for use in product testing.

HotRot Exports
The HotRot in-vessel composting unit is a U-shaped vessel, enclosed with removable lids for inspection and maintenance, with a central tine-bearing shaft running longitudinally through the unit. The shaft rotates periodically to provide mixing and aeration. The HotRot 1811 represents the third generation unit, and is designed for 2.5 tpd of food waste and yard trimmings. Each unit is 42 feet long by 7.2 feet wide by 7.8 feet high. A much larger model, HotRot 3518 is constructed from precast concrete, and is designed to process up to 150 tpd using multiple units. Each unit is 72 feet long by 16 feet wide by 14 feet high, and has a capacity of 12 tpd. For some feedstocks, shredding is recommended to reduce particle size prior to loading in the vessel. The units, which typically are located outside, are intended to run in a continuous mode, with weekend storage capacity built into the hopper that feeds the unit via a shaftless auger or conveyor. The tines on the shaft are designed to break up clumps of materials. If biosolids and bulking agent are added separately, the internal shaft can mix them. The rotation of the shaft along with feed rate is used to regulate processing times. Net forward rotation affects retention time, with as little as ten days to achieve significant volume reductions, and 18 to 25 days to produce a more stable product, according to the manufacturer.
Air flow is counter to material flow, and the units are maintained under negative pressure, with biofilters used to treat odors. Temperatures of the process are monitored and recorded. Ancillary equipment such as augers, conveyors and dewatering units can also be supplied as part of a turnkey installation.
A new application of the technology is processing sewage treatment plant grit and screenings, in some cases without the addition of a bulking agent. HotRot has also been used to compost standard disposable diapers. Eight in-vessel sites are listed on the company website.

Siemens Water Technologies
Twenty years ago, at a plant nursery in Lebanon, Connecticut, the Sellew family created a compost company, Earthgro, and an in-vessel compost system designed to process chicken manure for use at their nursery. The composting technology was named International Process Systems (IPS), and was used at the Lebanon site to process manure, yard trimmings and food waste. The innovative design used a rail-mounted machine on top of two concrete walls that traveled the length of the bay, agitating and mixing the organic matter with a series of tines attached to a spinning drum. Eventually, the technology license was sold to a waste management company, who subsequently

sold it to Siemens Water Technologies. Twenty-two of the 27 IPS installations process biosolids, usually with sawdust or yard trimmings as the bulking agent. However, the two most recent facilities under construction, in Tyre, Lebanon and Mindarie, Australia, will process sorted organic food residuals.

The processing capacity of the installations ranges from 10 tpd of food waste at the Rikers Island , New York correctional facility, to over 500 tpd at the Burlington County, New Jersey biosolids and yard trimmings composting facility.

A new, optional feature is a dolly chute for automated off-loading to a conveyor system, with Delaware County, New York having the first installation (see "Composting Mixed MSW And Biosolids To Extend Landfill Life," November 2006). Most installations use a front-end loader to scoop up the compost that the turning machine pushes out at the end of the bay. With the dolly system, the compost can be conveyed to the curing area of the facility, eliminating use of a loader for that job.

Most IPS installations accomplish moisture addition to the bays with overhead sprinklers, or a sprinkler system built onto the turning machine with a reel to hold the water hose as the machine moves down the bay. A new option is to have sprinkler heads installed at the intersection of the rail and the top of the wall. The Rapid City, South Dakota and Mont De Marsan, France facilities utilize this feature, spraying the surface of the piles just prior to agitation.

Siemens/IPS recently added a "mini" agitator for a narrower bay than either the 10-foot or 6-foot wide standard designs. At only 5-feet wide, the miniagitator is small enough to ship in a standard container. It is a more simple design, and does not have some of the features of the larger machines. Barbara Petroff of Siemens observes that the company has recently proposed on several MBT facilities in Europe, an evolving market due to European Union mandates to divert organics from landfills.

Transform Compost Systems

The Transform Agitated Aerated Channel System is similar in many respects to the company's aerated bunker system described earlier in this article, but includes a self-tracking agitator that rides directly on top of a 10-foot wide by 8-foot high concrete bunker wall with no special rail required. The turner utilizes an "Artex" bed chain on an inclined conveyor to move the material 12 feet with each pass. An optional conveyor allows the material to be moved 24 feet with each pass. A transfer carriage moves the compost turner from one bunker to another. The 120 hp agitator is remotely operated. The bunker can be installed within a secondary cover that allows for collection of gasses from a much smaller area than the entire building. This air can then be treated in a biofilter, or the company's AirPhaser nonthermal plasma odor control system.

Transform also has developed a warning system to alert operators when temperature probes are unintentionally left inside the composting material so as to avoid damage to the compost turner.

The accompanying directory lists contact information and websites for the systems described in this article. Part II of What's New? In-Vessel Composting will run in the June 2007 issue of BioCycle. It will focus on rotating drum systems.

Robert Spencer is a Contributing Editor to BioCycle. An environmental planning consultant, he is based in Vernon, Vermont.

IN-VESSEL SYSTEMS DIRECTORY

Backhus Kompost-Technologie
c/o North America Inc.
[redacted]
www.backhus.us

BioSystem Solutions, Inc.
[redacted]
www.biosystemsolutions.com

Christiaens Group
[redacted]
www.christiaensgroup.com

Engineered Compost Systems (ECS)
[redacted]
www.compostsystems.com

Gore Cover Systems - North America
[redacted]
www.gorecover.com

[redacted]

Green Mountain Technologies
[redacted]
www.gmt-organic.com

HotRot Exports Ltd.
[redacted]
www.hotrotsystems.com

NaturTech Composting
[redacted]
www.composter.com

Poly-Flex Composting
[redacted]
www.poly-flex.com

Siemens Water Technologies
[redacted]
www.siemens.com/ips-composting

Transform Compost Systems
[redacted]
www.transformcompost.com

VCU Technology, Ltd.
[redacted]
www.vcutechnology.com

Versa Corporation
[redacted]
www.versacorporation.com

[redacted]

Cornell Waste Management Institute

Compost Air Emissions Health Studies

http://cwmi.css.cornell.edu/composthealth.pdf

Summary of the literature by:

Ellen Z. Harrison
Director

July 2007

Department of Crop and Soil Sciences • [redacted]
http://cwmi.css.cornell.edu

Summary of Articles on Compost Air Emissions Health Studies

This paper is an abridged version of a more comprehensive document. This paper summarizes only those articles that deal specifically with health impacts, while the full paper includes papers that address air emissions as well as health (see http://cwmi.css.cornell.edu/compostairemissions.pdf).

The summaries below are arranged chronologically. They indicate that workers show health effects (note that the Millner article that concludes that compost facilities do not pose significant health risks is based on a lack of impacts to workers predates these articles that demonstrate worker health impacts). Few studies of health of nearby residents have been done. Herr et al have shown respiratory and general health complaints in neighbors. Browne et al studying the Islip composting facility did not assess whether nearby residents had greater incidence of illness, but rather their work did assessed the relationship between neighbor's reports of symptoms and *A.fumigatus* concentrations. They did not find a correlation between symptoms reported and concentrations of *A.fumigatus.* However, large temporal variations in *A.fumigatus* concentrations were noted, and other bioaerosols were not monitored.

- Bunger, J., B. Schappler-Scheele, R. Hilgers, and E. Hallier. 2006. A 5-Year Follow-Up Study on Respiratory Disorders and Lung Function in Workers Exposed to Organic Dust from Composting Plants. International Archives of Occupational and Environmental Health. Online: http://www.springerlink.com/content/82u23r2371414873/fulltext.pdf

Conclusion: exposure to organic dust at composting workplaces is associated with adverse acute and chronic respiratory health effects. Compost workers were compared to controls at 41 German compost facilities (mixed household biowaste plus yard wastes). Exposure measurements revealed high concentrations of fungi and actinomycetes. Compost workers report significantly higher prevalence of mucosal membrane irritation of eyes and upper airways as well as more conjunctivitis. A significant decline in forced vital capacity was measured. Results differ from workers exposed to organic dust in other facilities, maybe due to thermotolerant fungi and bacteria in compost plants.

- Muller, T., R. A. Jorres, E. M. Scharrer, H. Hessel, D. Nowak, and K. Radon. 2006. Acute Blood Neutrophilia Induced by Short-Term Compost Dust Exposure in Previously Unexposed Healthy Individuals. International Archives of Occupational and Environmental Health. 79:477-482.

Conclusion: Short-term exposure of healthy young subjects to organic dust at composting facilities had mild but measurable effect in eliciting acute systemic alterations. 17 healthy subjects not working with wastes were exposed to a composting facility for 2 hrs doing moderate exercise. Changes in white blood cell counts, an increase in neutrophils and decrease in eosinophils was measured.

- Herr, C. E. W., A. zur Nieden, H. Seitz, S. Harpel, D. Stinner, N. I. Stilianakis, and T. F. Eikmann. 2004. Bioaerosols in Outdoor air - Statement of Environmental Medical Assessment Criteria on the Basis of an Epidemiological Cross Sectional Study. Gefahrstoffe Reinhaltung Der Luft. 64(4):143-152.

Total bioaerosols (total bacteria, molds and thermophilic actinomycetes) were found at $>10^5$ CFU/m^3 in outdoor air in the vicinity of an outdoor composting facility, dropping to **background concentrations within 550 m. There was an association between irritative respiratory symptoms and general health complaints and distance to the site.** There was no higher prevalence of reported allergies or infectious diseases. Individual odor annoyance was not associated with symptoms.

- Herr, C. E. W., A. zur Nieden, N. I. Stilianakis, and T. F. Eikmann. 2004. Health Effects Associated With Exposure to Residential Organic Dust. American Journal of Industrial Medicine. 46:381-385.

Significantly higher than background concentrations of thermophilic actinomycetes, total bacteria and molds were measured in air down wind 200 m from an outdoor composting site, dropping to near background within 300 m. These levels are similar to occupational composting exposures**. A physician-administered survey found airway symptoms but not odor annoyance were observed in residents in highest exposure (150-200 m downwind) vs further away (400-500 m). An association was demonstrated between residential bioaerosol pollution and irritative airway complaints as well as excessive fatigue and shivering (which symptoms are** reported at workplaces handling such materials). Residents reporting odors did not "overreport" health disturbances.

- Herr, C. E. W., A. Zur Nieden, R. H. Bodeker, U. Gieler, and T. F. Eikmann. 2003. Ranking and Frequency of Somatic Symptoms in Residents Near Composting Sites With odor Annoyance. International Journal of Hygiene and Environmental Health. 206:61-64.

This brief paper reports results of an epidemiologic study of people living in the vicinity of three composting plants**. Residents living near one of the sites at which concentrations of microorganisms were high experienced increased symptoms relative to the control population. Nausea was associated with strong odors.**

- Browne, M. L., C. L. Ju, G. M. Recer, L. R. Kallenbach, J. M. Melius, and E. G. Horn. 2001. A Prospective Study of Health Symptoms and *Aspergillus fumigatus* Spore Counts Near a Grass and Leaf Composting Facility. Compost Science and Utilization. 9(3):241-249.

Aspergillis fumigatus spore concentrations are higher in vicinity of 40 acre yard waste composting site than background. **Participant diaries showed no correlation between symptoms and *A. fumigatus* concentrations.** However there are caveats: large short term variations in concentrations of *A. fumigatus* were measured and the spore counts used were averages and were taken at sampling locations not specific to personal exposures.

- Bunger, J., M. Antlauf-Lammers, T. Schulz, G. Westphal, M. Muller, P. Ruhnau, and E. Hallier. 2000. Health Complaints and Immunological Markers of Exposure to Bioaerosols Among Biowaste Collectors and Compost Workers. Occupational and Environmental Medicine. 57:458-464.

Compost workers had significantly more symptoms and diseases of the airways and skin than control subjects. Some workers quit due to airway complaints leading possibly to underestimation of health effects. Increased anti-body concentrations against fungi and actinomycetes were found in compost workers. There was an association between the diseases and increased antibody concentrations in compost workers. A “healthy worker” effect is indicated by the under representation of atopic (allergic) diseases among compost workers.

- Douwes, J., I. Wouters, H. Dubbeld, L. v. Zwieten, P. Steerenberg, G. Doekes, and D. Heederik. 2000. Upper Airway Inflammation Assessed by Nasal Lavage in Compost Workers: A Relation With Bio-Aerosol Exposure. American Journal of Industrial Medicine. 37(5):459-468.

“Compost workers are at risk of developing acute and possibly chronic inflammatory responses in the upper airways…” Workers in compost plant that stored and processed source-separated food and yard waste indoors were studied using nasal lavage (NAL) (in which fluid is inserted in the nose and then removed and analyzed for various markers). The study included two time periods, one before and one after process improvements were made to try and decrease exposure to bioaerosols in the facility. **Compared with controls, before the facility improvements the workers had higher indicators inflammatory markers** even on Monday morning before work. Comparing pre and post-shift, workers showed an increase in markers.

- Ivens, U. I., J. Hansen, N. O. Breum, N. Ebbehoj, M. Nielsen, O. M. Poulsen, H. Wurtz, and T. Skov. 1997. Diarrhoea Among Waste Collectors Associated With Bioaerosol Exposure. Annals of Agricultural and Environmental Medicine. 4:63-68.

A survey of Danish waste collectors demonstrated an association between the level of exposure of workers to fungal spores and self-reported diarrhoea. However, the group with high exposure to either total fungi or total microorganisms reported fewer symptoms compared to the less exposed group.

- Marth, E., F. F. Reinthaler, K. Schaffler, S. Jelovcan, S. Haselbacher, U. Eibel, and B. Kleinhappl. 1997. Occupational Health Risks to Employees of Waste Treatment Facililties. Annals of Agricultural and Environmental Medicine. 4:143-147.

Several measures of allergy, inflammation and lung function were measured in 117 workers at 2 composting and 3 waste sorting facilities and compared with a control group. **Although elevated IgE was detected, no statistically significant increase in allergic diseases was found. Eye and mucous membrane irritation, coughing and decreased lung function were measured**.

- Cobb, N., P. S. Sullivan, and R. A. Etzel. 1995. Pilot Study of Health Complaints Associated with Commercial Processing of Mushroom Compost in Southeastern Pennsylvania. Journal of Agromedicine. 22(2):13-25.

In response to residents’ complaints, a symptom questionnaire was administered to 100 residents living within 3000 feet and living between 3000 and 5000 feet from a mushroom composting facility and to a control group. Local physicians were interviewed and some air and water testing were performed**. No statistically significant impact on health was found**.

- Millner, P. D., S. A. Olenchock, E. Epstein, R. Rylander, J. Haines, J. Walker, B. L. Ooi, E. Horne, and M. Maritato. 1994. Bioaerosols Associated with Composting Facilities. Compost Science and Utilization. 2(4):6-57.

This paper is a review based on a workshop.

Conclusion "Composting facilities do not pose any unique endangerment to the health and welfare of the general public" is based primarily on "the fact that workers were regarded as the most exposed part of the community and where worker health was studied.., no significant adverse health impacts were found. .. [and] in most cases the measured concentrations of the targeted aerobic bacteria, thermophilic (heat loving) fungi, and AF bioaerosols in the residential zones around composting facilities showed that the airborne concentrations of bioaerosols were not significantly different from background."

There are few data on bioaerosol concentrations, particularly for yard waste composting sites. Some of the non-yard waste studies have down-wind monitoring far away (like half mile and 1 mile). Slightly elevated levels of *Aspergillus fumigatus* at nearest monitoring station (500 feet) downwind of compost pad (WSSC Site 2, Clayton Environmental Consultants, Ltd., 1983) were detected in one study.

Current data are not sufficient to resolve questions regarding the potential health impacts of siting a large yard waste composting facility in relatively close proximity to neighbors.

Recommendations to minimize impacts:

- Design
  - Material handling processes downwind or maximum distance from receptors
  - Forest buffer
- Siting
  - Consider meterorologic and topographic features
  - Proximity can be mitigated with enclosure, good management practices, increased mechanization
- Operation/Mgmt
  - Minimize handling and time it when
    - potential for off-site movement is minimal
    - receptor population is least
  - Minimize disturbance of dusty areas by vehicles
  - Add moisture to minimize dust

References Cited Listed Alphabetically

Browne, M. L., C. L. Ju, G. M. Recer, L. R. Kallenbach, J. M. Melius, and E. G. Horn. 2001. A Prospective Study of Health Symptoms and *Aspergillus fumigatus* Spore Counts Near a Grass and Leaf Composting Facility. Compost Science and Utilization. 9(3):241-249.

Bunger, J., M. Antlauf-Lammers, T. Schulz, G. Westphal, M. Muller, P. Ruhnau, and E. Hallier. 2000. Health Complaints and Immunological Markers of Exposure to Bioaerosols Among Biowaste Collectors and Compost Workers. Occupational and Environmental Medicine. 57:458-464.

Bunger, J., B. Schappler-Scheele, R. Hilgers, and E. Hallier. 2006. A 5-Year Follow-Up Study on Respiratory Disorders and Lung Function in Workers Exposed to Organic Dust from Composting Plants. International Archives of Occupational and Environmental Health. http://www.springerlink.com/content/82u23r2371414873/fulltext.pdf.

Cobb, N., P. S. Sullivan, and R. A. Etzel. 1995. Pilot Study of Health Complaints Associated with Commercial Processing of Mushroom Compost in Southeastern Pennsylvania. Journal of Agromedicine. 22(2):13-25.

Douwes, J., I. Wouters, H. Dubbeld, L. v. Zwieten, P. Steerenberg, G. Doekes, and D. Heederik. 2000. Upper Airway Inflammation Assessed by Nasal Lavage in Compost Workers: A Relation With Bio-Aerosol Exposure. American Journal of Industrial Medicine. 37(5):459-468.

Herr, C. E. W., A. Zur Nieden, R. H. Bodeker, U. Gieler, and T. F. Eikmann. 2003. Ranking and Frequency of Somatic Symptoms in Residents Near Composting Sites With odor Annoyance. International Journal of Hygiene and Environmental Health. 206:61-64.

Herr, C. E. W., A. zur Nieden, H. Seitz, S. Harpel, D. Stinner, N. I. Stilianakis, and T. F. Eikmann. 2004. Bioaerosols in Outdoor Air - Statement of Environmental Medical Assessment Criteria on the Basis of an Epidemiological Cross Sectional Study. Gefahrstoffe Reinhaltung Der Luft. 64(4):143-152.

Herr, C. E. W., A. zur Nieden, N. I. Stilianakis, and T. F. Eikmann. 2004. Health Effects Associated With Exposure to Residential Organic Dust. American Journal of Industrial Medicine. 46:381-385.

Ivens, U. I., J. Hansen, N. O. Breum, N. Ebbehoj, M. Nielsen, O. M. Poulsen, H. Wurtz, and T. Skov. 1997. Diarrhoea Among Waste Collectors Associated With Bioaerosol Exposure. Annals of Agricultural and Environmental Medicine. 4:63-68.

Marth, E., F. F. Reinthaler, K. Schaffler, S. Jelovcan, S. Haselbacher, U. Eibel, and B. Kleinhappl. 1997. Occupational Health Risks to Employees of Waste Treatment Facililties. Annals of Agricultural and Environmental Medicine. 4:143-147.

Millner, P. D., S. A. Olenchock, E. Epstein, R. Rylander, J. Haines, J. Walker, B. L. Ooi, E. Horne, and M. Maritato. 1994. Bioaerosols Associated with Composting Facilities. Compost Science and Utilization. 2(4):6-57.

Muller, T., R. A. Jorres, E. M. Scharrer, H. Hessel, D. Nowak, and K. Radon. 2006. Acute Blood Neutrophilia Induced by Short-Term Compost Dust Exposure in Previously Unexposed Healthy Individuals. International Archives of Occupational and Environmental Health. 79:477-482.

The Dispersion of Flies by Flight

Authors: BISHOPP, F. C.; LAAKE, E. W.
Source: Journal of Economic Entomology, Volume 12, Number 2, April 1919 , pp. 210-211(2)
Publisher: Entomological Society of America

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Abstract:

Up to very recent years it has been generally held by entomologists that flies are comparatively limited in the distances which they will go from breeding places. Dr. Parker's work in Montana indicated that the house-fly is normally migratory in habit and he succeeded in obtaining specimens nearly two miles from the point of liberation. In 1916. the authors conducted some preliminary experiments in which colored flies were liberated in the vicinity of packing houses and a considerable number of these were recovered quite promptly in traps placed in the yard of the packing establishments, a flight of about three-fifths of a mile. The flies liberated in this experiment consisted largely of blowflies of the species *Chrysomyia rnacellaria* and *Phormia regina*. Later in the same summer a series of experiments was carried out to determine the distance of flight of several species of blowflies and house-flies under rural conditions. The flies were liberated at a point near the intersection of two roads and four traps were placed at given distances in the four cardinal directions from the point of liberation. A total of 1,745 colored flies were recovered in the sixteen recovery traps and a considerable number of these were in the outer ring of traps which was approximately three miles from the point of release. Another experiment was conducted immediately following this in which the traps were moved outward in the four directions to points approximately 2, .3, 4 and 5 miles from the point of liberation. House-flies, screw-worm flies and the Anthomyid, *Ophyra leucostoma*, were recovered in some of the most distant traps.

In 1918 it was determined to make more extensive tests of the dispersion tendencies of various species of flies. The same general

plan was followed as in the previous experiment, four traps being set in each of the cardinal directions from the point of liberation at distances approximately 4 1/2 6, 7 and 8 miles. About 60,000 colored flies were liberated, approximately 58 per cent being screw-worm flies, 39 per cent house-flies and the remainder *Phormia regina*, Sarcophagids and other species. As in previous experiments the flies in the various traps were killed daily and examined carefully for marked individuals. The day following liberation a considerable number of marked house-flies and screwworm flies were recovered in several of the traps. Even in those located 8 miles in each direction from the point of release, some screw-worm flies were taken. Following this experiment the traps were removed to points east and west approximately 9 1/2, 11, 13, 15 and 17 miles, two traps to the north 13 and 17 miles, and two traps to the south 8 and 10 miles from point of release. A trap was also placed about 7 miles east of south and another about 10 miles south of west of the point of liberation. About 80,000 flies were released in this test. The greatest distance from the point of liberation at which marked flies were recovered was: House-flies, 13 miles; screw-worm flies, 15 miles; *Phormia regina*, 11 miles and *Ophyra leucostoma*, 7 miles.

It is believed that the following of vehicles by flies in these experiments was unimportant. In general the experiments suggested that there is a natural tendency toward dispersion exhibited by both sexes of all species used in the tests. Many apparently favorable feeding and breeding places were passed in the course of migration. The relationship between direction of travel and the direction of the wind appeared not to be very close.

The many practical bearings of the question of distance and rapidity of travel of flies cannot be discussed here, but are apparent to all. It might be pointed out that this is the first series of experiments in which flight studies have been made with flies other than *Musca domestica*.

Document Type: Research article

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[redacted]

Key: F - Free Content N - New Content S - Subscribed Content T - Free Trial Content

Am. J. Trop. Med. Hyg., 13(6), 1964, pp. 881-886

Fly Dispersion from a Rural Mexican Slaughterhouse*

Bernard Greenberg† AND **Alexis Arroyo Bornstein**

We have recently reported on the extensive distribution of salmonellae among the flies of a rural Mexican slaughterhouse. The present study concerns the dispersion of these flies throughout the town and peripheral areas. A total of 543 fluorescein-tagged flies belonging to 6 species were recovered from residential sites, market place, dairy and a neighboring village, up to 3 miles from their origin. Flies spread across town within one day. The ready dispersion of *Salmonella*-contaminated houseflies, blowflies and other species constitutes a health hazard for the 100,000 inhabitants of the town and outlying communities.

* This study was supported by PHS research grant E-3498 C2, from the National Institute of Allergy and Infectious Diseases, Public Health Service, and conducted at the Instituto de Salubridad y Enfermedades Tropicales, Mexico, D.F. The interest and cooperation of Dr. Gerardo Varela, Director, in facilitating this study, is gratefully acknowledged.

† University of Illinois College of Pharmacy, Chicago 12, Ill.

[redacted]

Los Angeles Times | California | Local

Archive for Saturday, April 25, 1998

Firm Ordered to Stop Spreading Sewage Sludge

By Sharon Bernstein
April 25, 1998 *in print edition B-4*

Bio Gro, the firm that has proposed trucking sewage sludge to the High Desert and composting it for use as fertilizer, was dealt a setback this week when state water regulators ordered it to cease current operations.

The Oakland firm, whose proposal for a 67-acre composting facility is scheduled to come before the Board of Supervisors on Tuesday, was told to stop spreading sludge from L.A.'s Hyperion sewage plant on a farm near Lancaster, where the mixture is used in its wet, uncomposted form to fertilize fields.

In a letter dated April 17 and received by the company this week, the Lahontan Regional Water Quality Control Board gave the company until June 15 to submit a plan for avoiding water pollution from the sewage, which was washed from the fields during flooding from last winter's rains.

"The ranch was inundated by flood water during February's storm event, resulting in runoff," said Harold J. Singer, executive officer of the Lahontan board. "There is a continued threat of violations until Bio Gro institutes adequate flood control measures."

The proposal to build a composting facility–which would take in 500 tons of treated sewage and 1,000 tons of other waste each day –has sparked strong opposition from neighbors and local officials, including County Supervisor Mike Antonovich, who represents the area.

Opponents contend that baking sewage in the desert sun and turning it periodically into compost would lead to air pollution and odor problems as the strong High Desert winds blow the drying waste toward nearby homes.

The plan has drawn fire from local air quality officials, as well as neighbors and the city of Lancaster.

The latest action by the water board, which last month cited Bio Gro both for allowing the flooding and failing to report it, marks a second black eye for the proposal, which until recently was considered a shoe-in despite Antonovich's opposition.

It was not clear Friday whether the supervisors would go forward or delay action until the water issues are resolved. The vote on the composting plan–originally scheduled for last month –has already been put off once

[redacted]

because of concerns about water pollution.

The proposal was turned down by the Regional Planning Commission, but Bio Gro appealed to the county supervisors last year. The board voted last summer to approve the project in concept, but final approval was delayed after last winter's flood problems.

"This issue that came up has thrown a little confusion on it," said William Cotter, vice president and general manager for the Bio Gro Division of Wheelabrator Water Technologies.

Still, Cotter said, most of the supervisors continue to express support for the project.

"They're looking at it as another potential outlet for recycling and handling some of their organic wastes and diverting it from the landfill," Cotter said. "We still expect the [positive] vote that we would have expected last month."

Cotter said the company plans to address the water board's concerns about its present operations by digging a ditch or building a berm around the fields where the sludge is spread.

"We've agreed to work with [water quality regulators] to find a solution, and we expect it to be a very quick solution," Cotter said.

The fields won't need to be fertilized again, Cotter said, until June, and by then the company hopes to have permission to start work again.

Related Articles
- Riverside's Sludge Ban Puts O.C. in Tough Spot Jun 27, 2001
- Sewage Sludge Dioxins Safe, EPA Contends Oct 18, 2003
- Riverside Bans Sewage Sludge as Farm Fertilizer Jun 27, 2001
- Orange County Finds Distant Taker for Sludge Mar 11, 2002
- Antonovich Decries Levels of Chromium in Well Tests Sep 22, 2000

More articles by Sharon Bernstein

More articles from the California | Local section

COMPOST OPERATION RED-LIGHTED ONCE AGAIN.

Byline: Karen Maeshiro Daily News Staff Writer

For the second time in a month, county supervisors Tuesday delayed granting final approval for a sewage composting operation near Antelope Acres because storm water flowed over the property in February.

State water officials have told Maryland-based BioGro that it cannot spread any sludge as fertilizer for its farming operation until it comes up with a plan by June 15 to protect against flooding and to control runoff
, which occurred during El Nino-spawned rainstorms.

``This is to ensure BioGro submits to the state its flood mitigation plans,'' said Dave Vannatta, an aide to Supervisor Michael D. Antonovich. ``Behind that, it is our belief that BioGro is unable if not unwilling to comply with conditions of approval in general.''

Antonovich had sought to delay the decision until October to make sure BioGro submitted a plan and had flood control improvements in place, but he failed to get a second to his motion.

The board then approved on a 4-1 vote, with Supervisor Gloria Molina dissenting, to postpone the decision until June 23, Vannatta said.

Article Details

Publication: Daily News (Los Angeles, CA)
Date: Apr 29, 1998
Words: 645

Previous Article: SHERIFF'S DEPUTY, FIREFIGHTER OF YEAR; A.V. HONOREES MAKE A DIFFERENCE.(News)
Next Article: X-33 FLIGHT ON HOLD; GLITCHES PUSH BACK INITIAL TEST IN JULY.(News)

Related Articles

IN SPRING, A GROWER'S THOUGHTS TURN TO COMPOST.(L.A. Life)
COUNTY BACKS WASTE PLANT; DISSENTING ANTONOVICH HAD SOUGHT ENCLOSURE FOR SITE.(News)
CONCERNS RAISED ABOUT SLUDGE SITE; SUPERVISORS SCHEDULED TO VOTE ON COMPOST FACILITY TUESDAY.(News)
COMPOST PILE BURNS; SMOLDERING FIRE BREAKS OUT AGAIN IN RECYCLING YARD.(News)
WASTE-USE HOPES RISE.(News)(Statistical Data Included)
PUTTING BUGS TO WORK : HOMEOWNERS GET TIPS ON COMPOSTING.(NEWS)
SHORT ON COMPOST? LET FINGERS DO THE WALKING.(U)
IT'S TIME TO CUT BRUSH, WEED, START PLANTING.(News)
FALLEN FOLIAGE ON ITS WAY OUT.(Environment)(Autumn gold's slow fade to

[redacted]

BioGro, a division of Maryland-based Wheelabrator Clean Water Systems Inc., is seeking to establish a composting operation on 67 acres on its farm south of Avenue A and west of 140th Street West.

The company plans to pile sewage sludge and grass clippings or other plant waste in rows 7 feet tall, 18 feet wide and 850 feet long.

The county Regional Planning Commission had rejected BioGro's project, but BioGro appealed to county supervisors, who gave it a tentative go-ahead in June 1997.

BioGro officials said they were disappointed with the board's decision to delay the matter further.

``We know it's a good project,'' said company spokeswoman Linda Novick. ``We're confident we will resolve the issues relating to flood control and runoff.''

The supervisors earlier this month delayed voting on the project to hear testimony from representatives from the Lahonton Regional Water Quality Control Board about complaints that sludge used as farm fertilizer flowed off the property in February.

Water officials said BioGro violated its permit by not having adequate flood control measures in place, which resulted in runoff. Vannatta said BioGro did not notify regional water officials of the runoff, as required by the permit.

In an April 17 letter to BioGro, regional water officials ordered the company to stop applying sludge at the site until it comes up with a plan to deal with flooding and runoff.

BioGro can construct adequate flood control protection, formally change the permit to allow some flooding under certain acceptable conditions or stop land application of sludge at the site, water officials said.

Lyle Talbot, a member of Desert Citizens Against Pollution, testified at the meeting and challenged BioGro's ability to follow rules set forth in its permit.

``If they can't meet the conditions of their present permit, it would seem unwise to grant a new (conditional-use permit) inside the boundaries of that same piece of property,'' Talbot told the supervisors.

Of the two-month delay, Talbot said after the meeting, ``It's better than them passing it.''

Opponents want the project stopped outright or, failing that, to see the entire facility enclosed. Enclosing the site, they say, is the only way to keep the material from being blown off the site and to reduce the possibility of groundwater contamination.

BioGro officials rejected the idea of putting up barriers around the plant, saying it would cost $78.6 million - a figure critics say is inflated. Critics put the price tag at closer to $35 million.

Backers of the project say it will provide a low-cost way of recycling and would help Los Angeles County meet state-mandated goals of reducing the waste going into landfills.

brown is a sign that leaf pickup soon will begin)

Why the universe would think giving grades in school is stupid, if the universe thought of such things.(Poem)

Critics say the sludge contains industrial chemicals, including cancer-causing substances that can be carried great distances by the wind.

CAPTION(S):

Map

MAP: Proposed composting site

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ISSN: 1093-4529 (Print); 1532-4117 (Online)
DOI: 10.1080/10934520701304757

Accumulation of heavy metals in plants and potential phytoremediation of lead by potato, *Solanum tuberosum* L.

GEORGE F. ANTONIOUS[1] and JOHN C. SNYDER[2]

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The use of sewage sludge as a source of nutrients in crop production is increasing in the United States and worldwide. A field study was conducted on a 10% slope at Kentucky State University Research Farm. Eighteen plots of 22 × 3.7 m each were separated using metal borders and the soil in six plots was mixed with sewage sludge, six plots were mixed with yard waste compost, and six unamended plots were used for comparison purposes. During a subsequent 3-year study, plots were planted with potato (year 1), pepper (year 2), and broccoli (year 3). The objectives of this investigation were to: (i) characterize chemical properties of soil-incorporated sewage sludge and yard waste compost; (ii) determine the concentration of seven heavy metals (Cd, Cr, Ni, Pb, Zn, Cu, and Mo) in sewage sludge and yard waste compost used for land farming; and (iii) monitor heavy metal concentrations in edible portions of plants at harvest. Concentrations of heavy metals in sewage sludge were below the U.S. EPA limits. Analysis of potato tubers, peppers, and broccoli grown in sludge-amended soil showed that Cd, Cr, Ni, and Pb were not significantly different from control plants. Concentrations of Zn, Cu, and Mo were significantly greater in tubers and peppers grown in sludge compared to their respective controls. Zn and Mo in broccoli heads were higher than their control plants. The ability of potato to accumulate lead needs additional investigation to optimize the phytoremediation of this pollutant element.

Keywords: Biosolids, yard waste compost, soil conditioners, pepper fruits, broccoli heads.

Introduction

The increased production of sewage sludge in the United States has led many municipalities to consider the application of sewage sludge to agricultural land as a means of sludge and nutrient recycling. The U.S. Environmental Protection Agency (U.S. EPA) promotes beneficial use of municipal solids because it decreases dependence on chemical fertilizers and provides significant economic advantages. Sewage sludge (biosolids) contains organic matter, and macro and micronutrients important for plant growth. Sixteen elements out of the 90 found in plants, known to be essential for plant growth, are present in biosolids. Some of these elements, however, can be detrimental to human, plant or animal life if they are present above certain limits. These detrimental elements are regulated by respective statute.

The value of biosolids is their ability to improve the soil by providing plant nutrients and by improving soil structure and other characteristics. The potential value of these to the farmlands cannot be questioned. Efficient and effective use of these materials as soil conditioners provides one of the best means we have for maintaining and restoring soil productivity. Biosolids from different origins have unique properties that should be thoroughly investigated in the soil/water/plant ecosystem. In addition, the simultaneous use of soil conditioners to enhance soil physical, chemical, and microbial conditions could also enhance soil bioremediation.

The sharply escalating production costs associated with the increasing costs of energy and fertilizers to U.S. farmers and the problems of soil deterioration and erosion associated with intensive farming system have generated considerable interest in less expensive and more environmentally compatible production alternatives such as recycling wastes from several processing operations to produce high-quality organic amendments for soil improvement and crop production. On the other hand, accumulation of heavy metals by plants grown on sewage sludge-treated soils[1,2] requires a better understanding. Elevated Cd concentrations in soil, resulting from the application of biosolids has been perceived as a potential environmental hazard.[3,4]

The primary Cd risk posed by the agricultural use of biosolids is the increased dietary Cd intake of people consuming crops grown on these soils. There is limited

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information on heavy-metal absorption by vegetable crops from sludge-treated soil. The extent of heavy metal accumulation in plant tissue appears to be affected by many soil-, plant-, and sludge-related factors. The rate of release of heavy metals in sewage sludge into soil solution and subsequent uptake by plants could result in phytotoxicity. Elevated concentrations of heavy metals in harvested plant tissue could expose consumers to excessive levels of potentially hazardous chemicals. Identifying management strategies that meet crop nutrition needs, support crop production, and protect food quality is the focus of this investigation.

The objectives of this investigation were to (1) characterize chemical properties of soil incorporated sewage sludge and yard waste compost; (2) determine the concentration of seven heavy metals (Cd, Cr, Ni, Pb, Zn, Cu, and Mo) in sewage sludge and yard waste compost; and (3) monitor heavy metal concentration in edible portions of plants at harvest.

Materials and methods

Field study

A field study was conducted on a Lowell silty loam soil (2.8% organic matter, pH 6.9) located at Kentucky State University Research Farm, Franklin County, KY. The soil has an average of 12% clay, 75% silt, and 13% sand. Eighteen (18) universal soil loss equation (USLE) standard plots of 22×3.7 m each were established on a soil of 10% slope. Plots were separated using metal borders 20 cm above ground level to prevent cross-contamination between adjacent treatments. Three soil management practices were used: (1) sewage sludge (obtained from Nicholasville Wastewater Treatment Plant, Versailles, KY) was mixed with native soil at 30 t acre^{-1} (on dry weight basis) with a plowing depth of 15 cm, (2) yard waste compost made from yard and lawn trimmings, and vegetable remains (obtained from Kentucky State University Research Farm, Franklin County) was mixed with native soil at 30 t acre^{-1} (on dry weight basis) with a plowing depth of 15 cm, and (3) a no-mulch (NM) control treatment (roto-tilled bare soil) was used for comparison purposes.

In year 1, potato (*Solanum tuberosum* cv. Kennebec) seed pieces were planted in 10 rows plot^{-1} (10 plants row^{-1}). Plots were irrigated by drip tape (Rainbird Corporation, Glendora, CA) and no fertilizer was applied. Trifluralin (Treflan; 430 g liter^{-1} EC) was sprayed on the soil surface at the rate of 0.75 lb acre^{-1} and incorporated into the soil. In year 2, sweet pepper (*Capsicum annuum* L. cv. Aristotle-X3R) seedlings 60 days old, were planted at 10 rows plot^{-1} along the contour of the land slope at 10 plants row^{-1}and napropamide (Devrinol 50-DF; 4 lbs formulated product acre^{-1}) was sprayed on soil as a pre-emergent herbicide. In year 3, broccoli (*Brassica oleracea* L. cv. Packman F1) seedlings 45 days old, were planted at 10 rows plot^{-1} along the contour of the land slope at 10 plants row^{-1} and napropamide was used.

Soil and plant tissue analysis

Soil and soil-incorporated sewage sludge and yard waste samples were collected to a depth of 15 cm from field plots using a soil core sampler equipped with a plastic liner (Clements Associates, Newton, IA, USA) of 2.5 cm i.d. Soil samples were oven-dried at 65°C for 48 hours and then sieved to a size of 2 mm. pH was determined using a glass electrode in a soil: distilled water slurry (1:5, w/v). Soil organic matter was calculated as dry weight minus ash content. Nitrogen was determined by the Kjeldahl method. Quantitative analyses of Mehlich-3 extractable Cd, Cr, Ni, Pb, Zn, Cu, and Mo were conducted using an inductively coupled plasma[5] (ICP, Varian Vista-Pro) spectrometer. Detection limits (mg/kg) were Cd 0.02, Cr 0.04, Cu 0.04, Mo 0.1, Ni 0.2, Pb 0.3, Zn 0.04 at wavelengths (nm) 226.502, 267.716, 324.754, 202.032, 231.604, 220.353, and 213.857, respectively.

At harvest 25 potato tubers, pepper fruit or broccoli heads of comparable size were collected at random from each of the 18 field plots (six replicates for each soil treatment), washed with tap and deionized water and dried in an oven at 65°C for 48 hours. The dried samples were ground manually with ceramic mortar and pestle to pass through 1 mm sieve. Samples were re-dried to constant weight using an oven. To 1 g of each dry sample, 10 mL of concentrated nitric acid was added and the mixture was allowed to stand overnight, and then heated for 4 hour at 125°C on a hot plate. The mixture was then diluted to 50 mL with double distilled water and filtered through filter paper No.1. Concentrations of Cd, Cr, Ni, Pb, Zn, Cu, and Mo were determined using ICP spectrometry.

Results and discussion

Sewage sludge application altered the chemical and physical properties of soil, which in turn affected soil nurient balance (Table 1). Addition of sludge also increased the soil pH about 1.5 units compared to native soil. Soil pH affects ion availability.[6]An increase in pH can bring about strong adsorption on soil particles or in some cases, precipitation of Cu and Zn among other metals, which in turn allows for lower accumulation of these metals in plant tissues.[7]

Sewage sludge contains great amounts of nutrients especially N, P, and Ca (Table 1) that plants require. P concentrations in sewage sludge reached levels comparable with super-phosphate fertilizer.

As expected, total N and C were greater in the 1–15 cm soil horizon as a result of the addition of sewage sludge. Total C was 3.8 vs. 1.6% and total N was 0.4 vs. 0.1% in the unamended vs. sludge-amended soils, respectively.

Table 1. Chemical characteristics of sewage sludge, yard waste compost, and soil incorporated with sewage sludge or yard at Kentucky State University Research Farm, Franklin County, Frankfort, Kentucky, USA, 2001

Soil parameters	*Sewage sludge*	*Yard waste compost*	*Native soil*	*Sewage sludge incorporated with native soil*	*Yard waste incorporated with native soil*
pH*	12.33 ± 0.77 a	7.05 ± 0.17 c	6.99 ± 0.02 c	8.48 ± 0.13 b	7.31 ± 0.22 c
Organic Matter** %	30.26 ± 1.15 a	21.07 ± 0.16 b	2.72 ± 0.51 d	7.27 ± 0.42 c	7.60 ± 0.33 c
C %	17.05 ± 0.56 a	13.02 ± 1.36 b	1.59 ± 0.06 d	3.77 ± 0.35 c	3.84 ± 1.03 c
N %	2.16 ± 0.13 a	1.02 ± 0.07 b	0.15 ± 0.01 d	0.39 ± 0.02 c	0.32 ± 0.07 c
C/N ratio	7.90 ± 0.24 d	12.74 ± 0.44 a	10.54 ± 0.53 b	9.54 ± 0.47 c	11.78 ± 0.68 a
P %	1.23 ± 0.32 a	0.66 ± 0.02 b	0.18 ± 0.06 c	0.31 ± 0.13 c	0.24 ± 0.12 c
K %	0.20 ± 0.01 b	0.67 ± 0.16 a	0.25 ± 0.07 b	0.23 ± 0.06 b	0.28 ± 0.10 b
Ca %	19.10 ± 1.28 a	5.18 ± 0.10 b	0.40 ± 0.15 d	2.85 ± 1.19 c	1.04 ± 0.54 d
Mg %	0.38 ± 0.08 b	0.57 ± 0.03 a	0.19 ± 0.08 c	0.22 ± 0.11 bc	0.25 ± 0.09 bc
Cd ppm	0.13 ± 0.04 a	0.30 ± 0.09 a	0.25 ± 0.06 a	0.25 ± 0.05 a	0.18 ± 0.03 a
Cr ppm	0.40 ± 0.12 a	0.08 ± 0.02 c	0.15 ± 0.03 bc	0.30 ± 0.08 ab	0.13 ± 0.02 c
Ni ppm	6.0 ± 0.8 a	0.28 ± 0.06 c	0.63 ± 0.05 c	1.73 ± 0.06 b	0.85 ± 0.14 c
Pb ppm	0.50 ± 0.10 b	4.65 ± 0.92 a	0.85 ± 0.12 b	0.70 ± 0.09 b	1.53 ± 0.22 b
Zn ppm	66.93 ± 5.22 a	24.18 ± 2.74 b	3.95 ± 0.98 e	20.13 ± 2.50 c	7.78 ± 1.25 d
Cu ppm	94.75 ± 7.85 a	2.25 ± 0.55 c	1.28 ± 0.42 c	17.23 ± 2.66 b	1.98 ± 0.75 c
Mo ppm	0.63 ± 0.05 a	0.01 ± 0.00 b	0.08 ± 0.02 b	0.09 ± 0.01 b	0.06 ± 0.03 b

Each value in the table is an average obtained from analysis of six samples. Values within a row followed by the same letter(s) are not significantly different ($P < 0.05$) (SAS Institute, 2001; Duncan's multiple range test).[15] *pH was determined using a glass electrode in a soil: distilled water slurry (1:5, w/v). **Soil organic matter was calculated as dry weight minus ash content. †Sewage sludge and yard waste compost were each mixed with native soil at 30t acre^{-1} on dry weight basis.‡ Nitrogen was determined by Kjeldahl method. All other elements were determined using an Inductively Coupled Plasma Spectrometer.

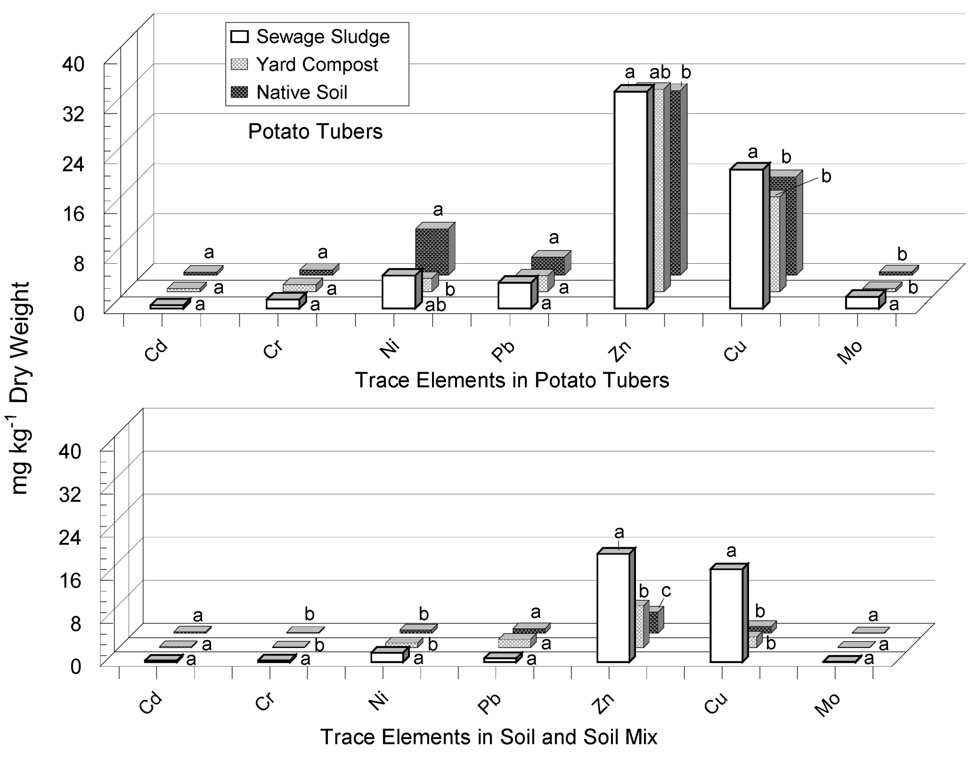

Fig. 1. Mean concentrations of Cd, Cr, Ni, Pb, Zn, Cu, and Mo in tubers of potato plants grown under three management systems (upper graph) at Kentucky State University Research Farm and concentrations of heavy metals in soil amended with sewage sludge or yard waste compost compared to native soil (lower graph). Statistical comparisons ($P < 0.05$) were carried out between three soil management practices for each element. Bars for an element accompanied by the same letter(s) are not significantly different using the ANOVA procedure.[15]

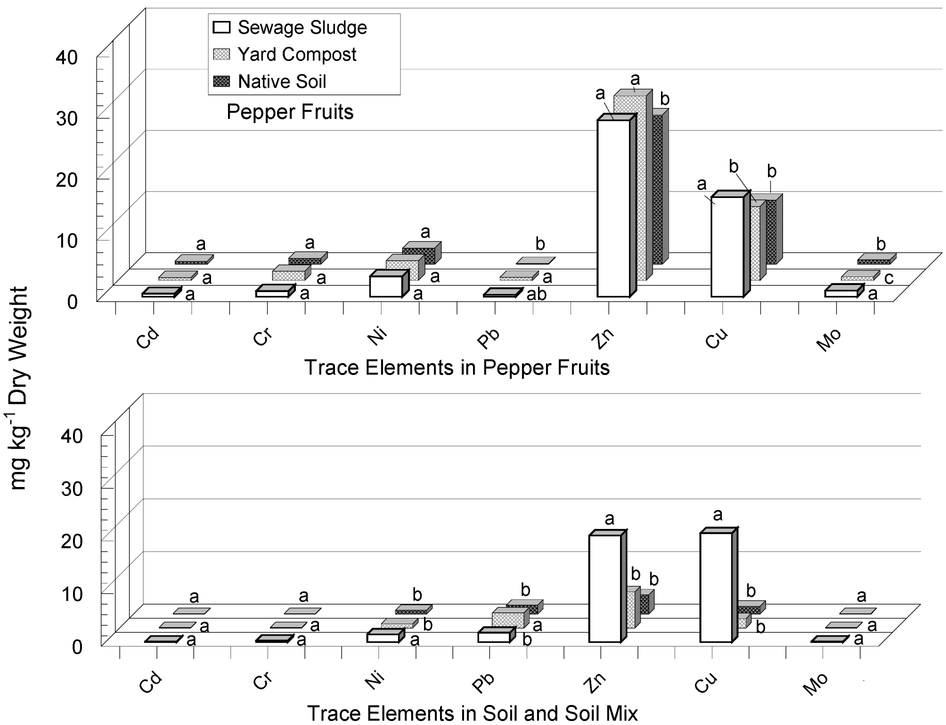

Fig. 2. Mean concentrations of Cd, Cr, Ni, Pb, Zn, Cu, and Mo in fruits of pepper plants grown under three management systems (upper graph) at Kentucky State University Research Farm and concentrations of heavy metals in soil amended with sewage sludge or yard waste compost compared to native soil (lower graph). Statistical comparisons ($P < 0.05$) were carried out between three soil management practices for each element. Bars for an element accompanied by the same letter(s) are not significantly different using the ANOVA procedure.[15]

However, sludge can also contain toxic metals, although at what level and when such metals might cause harmful effects are largely unknown.[8] The U.S.EPA has defined clean sludge in terms of its heavy metal content (mg kg^{-1}; Zn 1400, Cu 1500; Ni 420, Cd 39; Pb 300; Cr 1200; Mo 75). Unlimited amounts of sludge could be added to land if all these metals were below their limit.

Generally, the concentrations of heavy metals in sewage sludge used in this study were below the allowable limits and therefore this sludge has potential for agricultural use. However, results in Figure 1 (upper graph) indicated that Zn and Cu were accumulated in potato tubers grown even in the no-mulch soil. These data are consistent with Morrison et al.[9] who found that plants rapidly accumulate Cu. Soil analysis during the 3 years of the study revealed that Zn and Cu have increased significantly in soil as a result of sludge addition.

Plant uptake is one of the main pathways through which metals enter a food chain. This pathway transfers the metals through higher trophic levels to humans. Although Zn has relatively low toxicity to humans, studies have shown allergies and zinc poisoning could occur along the food chain, which may also interfere with copper metabolism.[10] Zn and Cu concentrations in sewage sludge obtained from the Nicholasville Wastewater Plant were extremely high (66.9 and 94.7 mg kg^{-1}, respectively) compared to other trace metals in sewage sludge. However, these concentrations are below the pollutant concentration limit in sewage sludge.[8] Zn and Cu concentrations were significantly reduced to 20.1 and 17.2 mg kg^{-1}, respectively when sludge was incorporated with native soil (Table 1). Generally, Zn and Cu levels in sludge and plants were of no major concern in the present study.

Cd and Pb are the heavy metals of greatest concern to human health since plants can take them up and introduce them into the human food chain. Levels of Cd and Pb in soil amended with sewage sludge averaged 0.25 and 0.7 mg kg^{-1}, respectively. These levels are much lower than the limits in the U.S. guidelines for using sewage sludge in land farming. Thus there was no major concern posed by Cd and Pb levels in sewage sludge for use as agricultural fertilizer. Our results revealed that concentrations of Cd in potato tubers, pepper fruits, and broccoli heads were 0.50, 0.49, and 0.04 mg kg^{-1}, respectively (Figs.1–3). Data for all crops analyzed in this investigation are expressed on dry weight basis. Considering that water content of potato was 85% and that of pepper was 95%, the Cd concentrations were near their Codex-established maximum limit[11] of 0.1 mg kg^{-1} for potato and 0.05 mg kg^{-1} for pepper.

Pb is defined by USEPA as potentially toxic to most forms of life. According to Codex Standard 230-2001, Revision 1-2003,[12] the maximum level for lead in most vegetables, including peeled potatoes, is 0.1 mg kg^{-1}. For

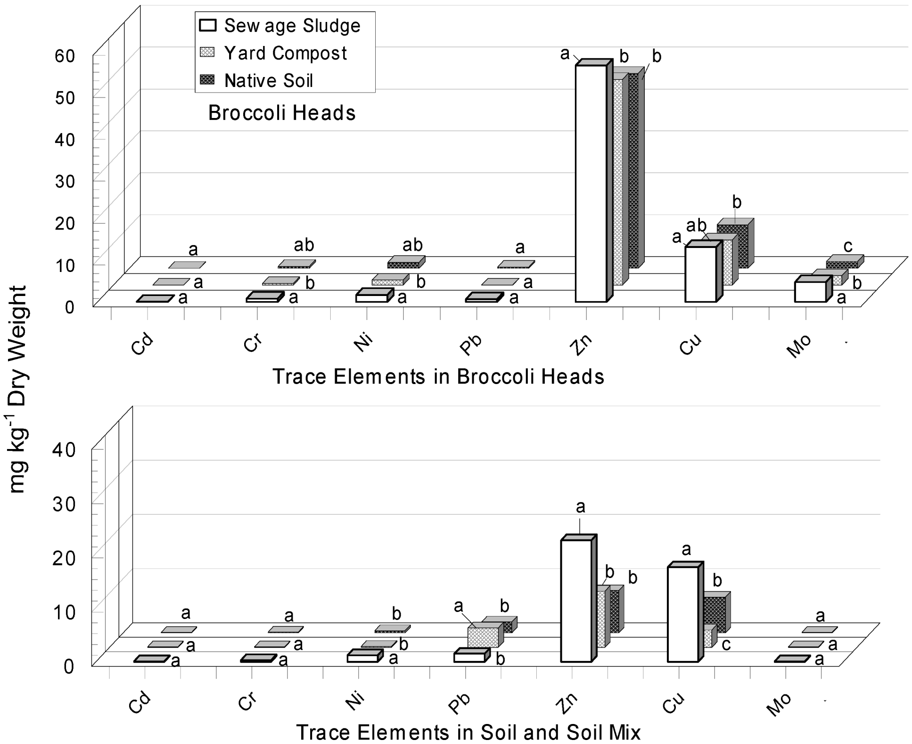

Fig. 3. Mean concentrations of Cd, Cr, Ni, Pb, Zn, Cu, and Mo in heads of broccoli plants grown under three management systems (upper graph) at Kentucky State University Research Farm and concentrations of heavy metals in soil amended with sewage sludge or yard waste compost compared to native soil (lower graph). Statistical comparisons ($P < 0.05$) were carried out between three soil management practices for each element. Bars for an element accompanied by the same letter(s) are not significantly different using the ANOVA procedure.[15]

cruciferous vegetables such as broccoli, the maximum level is 0.3 mg kg^{-1}. Based on water content calculations obtained for potatoes and peppers, the maximum lead levels were exceeded regardless of soil composition in potatoes, but not in peppers. However, the potatoes analyzed for this study were not peeled, and peeled potatoes may have reduced lead levels.

Accumulation of the seven heavy metals varied between plant species. The different absorption pattern of heavy metals among the three vegetables (potato, peppers, and broccoli) investigated in this study could be attributed to individual plant characteristics. There was a significant increase in concentrations of Zn and Cu in potato tubers grown under the three soil management practices investigated in this study even in potato grown in native soil. A comparison of heavy metal accumulation among the three vegetable species was not an objective of the study. Different crops were grown in different years, which makes valid statistically comparisons difficult. With these cautionary statements in mind, a post-hoc analysis indicated that Pb concentrations were significantly higher in potatoes 3.19 $\pm$ 0.20, compared to pepper 0.31 $\pm$ 0.14 and broccoli 0.33 $\pm$ 0.16 mg kg^{-1} dry wt. It is possible that potato will accumulate Pb, and could serve as a species useful for bioremediation. This needs additional investigation.

There is an urgent need to develop long-term, low-energy, biological, self-sustainable systems of farming. Recycling wastes from several processing operations for production of high quality organic amendments is simple, inexpensive, energy conserving, and effective for erosion control (data not shown) and nutrient recycling. Our previous studies have also indicated that the use of sewage sludge in land farming can become a useful technique for trapping pesticides such as trifluralin[13]and may reduce surface and groundwater contamination by other commonly used pesticides. On the other hand, research has indicated that increased dissolved organic carbon (DOC) in sewage sludge decreases the adsorption of metals to soil surfaces through the formation of organometalic complexes,[14] thereby increasing the bioavailability of metals to plants.

The impact of potentially toxic trace metals in sludge applied to cropland can be reduced by growing crops that do not accumulate these metals in their edible portions, or by increasing soil pH to bring about strong adsorption of metals on soil particles,[6,7] and by reducing the rate at which sludge is applied. Future research should consider variations in uptake between different plant species, the level of trace metals present in the atmosphere surrounding the study area, and explore plant genetic resources for nutritional improvement and phytoremediation. Additionally, the long-term effect of sewage sludge compost on the accumulation of heavy metals in edible plants should also be investigated to prevent elevated concentrations of heavy metals from reaching the consumer.

Acknowledgments

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Effect of Temperature on Composting of Sewage Sludge

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The effect of temperature on the composting reaction of sewage sludge was investigated at 50, 60, and 70°C. The total amount of CO_2 evolved and the final conversion of volatile matter were maximum at 60°C., suggesting that the optimal temperature for composting was around 60°C. The specific CO_2 evolution rate (moles of CO_2 evolved per hour per viable cell) was maximum at 70°C. The isolated thermophilic bacterium which was dominant at 60°C but did not grow at 70°C showed that the rate of O_2 consumption measured on the agar plate at 70°C was four times higher than that at 60°C. This showed that the energy yielded from catabolism is rather uncoupled with the anabolism at 70°C in the metabolism of microorganisms indigenous in the compost. A higher respiratory quotient was observed at 70°C than at any other temperature.

A high temperature during the composting of various materials is effective for the pasteurization of pathogenic microorganisms in the materials, for the promotion of water evaporation from the composting solid materials, and for the acceleration of the rate of degradation of organic matter in the composting materials. Because microbial activity is influenced by temperature, several researchers have tried to define the optimal temperature for composting (2, 5, 6, 10, 12, 13). Golueke (3) showed that the range of optimal temperature for the composting process as a whole is broad, from 35 to 55°C, because various microorganisms are involved in the decomposition of organic matter. Waksman et al. (13) stated that the amount of organic matter degraded per unit of time was maximum at 65°C in the composting of horse manure and wheat straw. Schultze (10) demonstrated that a linear relationship exists between the rate of O_2 consumption and temperature up to 70°C in municipal refuse composting. Recently, Bach et al. (2) found that the optimal temperature for sewage sludge composting was around 60°C as observed from the CO_2 evolution rate. McKinley and Vestal (6) stated that the microbial activity deduced from the chemical analysis of the solid component of compost was maximum at less than 55°C in the composting of sewage sludge. However, there have been only a few investigations concerning the optimal temperature under a controlled reaction environment.

In our previous papers (7, 9), we showed that the reaction rate of composting as measured by the CO_2 evolution rate is related to microbial succession, and we estimated the specific activity for thermophilic bacteria and actinomycetes. In this paper, the effect of temperature was investigated by the same procedure as in our previous papers, under controlled environmental conditions.

MATERIALS AND METHODS

Composting. The composting temperatures were kept at 50, 60, and 70°C as long as possible by controlling the rate of airflow. The operation of the reactor and the composting procedure were the same as those described in our previous paper (7). Two experimental series of runs were performed. In one series, raw sludge and the seed which was the compost product previously prepared in our laboratory were mixed at a ratio of 79 to 21% on a dry weight basis. These runs were denoted as Runs T1-50, T1-60, and T1-70, for the three different temperatures. In the other series, raw sludge and a compost product sterilized with gamma irradiation were mixed in the same ratio as in the Run T1 series. These runs were named T2-50, T2-60, and T2-70. The difference between the two series was in the initial number of thermophilic bacteria and actinomycetes.

Analytical method. The changes in CO_2 and O_2 concentrations in exhaust gas from the reactor during composting were measured with an infrared analyzer and a paramagnetic analyzer, respectively.

Isolation of microorganisms. Media and procedures for the isolation of the microorganisms which are responsible for the degradation of organic matter in compost were the same as described in our previous paper (7). Incubation temperatures were 30°C for mesophilic microorganisms and 60°C for thermophilic microorganisms.

Glucose uptake of thermophilic bacterium BH1. The glucose uptake rate of the isolated bacterium BH1, dominant in the thermophilic stage of composting, was measured in a Trypticase (BBL Microbiology Systems) medium containing Trypticase peptone (17 g), phyton peptone (3 g), glucose (2.5 g), K_2HPO_4 (2.5 g), and NaCl (5 g) in 1 liter. Preliminary characteristics of BH1 were given in our previous paper (8). Preculture was performed for 12 h at 60°C on a Trypticase medium. Precultured suspension (10 ml) was mixed with 90 ml of fresh Trypticase medium, and then the mixture was incubated at 60 and 70°C. Culture broth (5 ml) was sampled intermittently and centrifuged at 10,000 rpm for 10 min. The supernatant liquid was used for the analysis of glucose by the Glu-DH method (Merck & Co., Inc.). The viable cell numbers in the broth were determined on agar plates containing Trypticase medium.

O_2 consumption of thermophilic bacterium BH1. The oxygen uptake rate of the thermophilic bacterium, BH1, was measured by using a plastic box attached to an oxygen electrode, as described in our previous paper (8). The agar plate in which colonies of the BH1 cells were formed was placed in the box, and the change in O_2 concentration in the box was measured for 12 h at 60°C and for 4 h at 70°C. After the measurement, the viable cell number on the plate was determined.

RESULTS

Time course of composting at different temperature. The change in temperature, CO_2 evolution rate, conversion of volatile matter (VM), and microbial numbers are shown in

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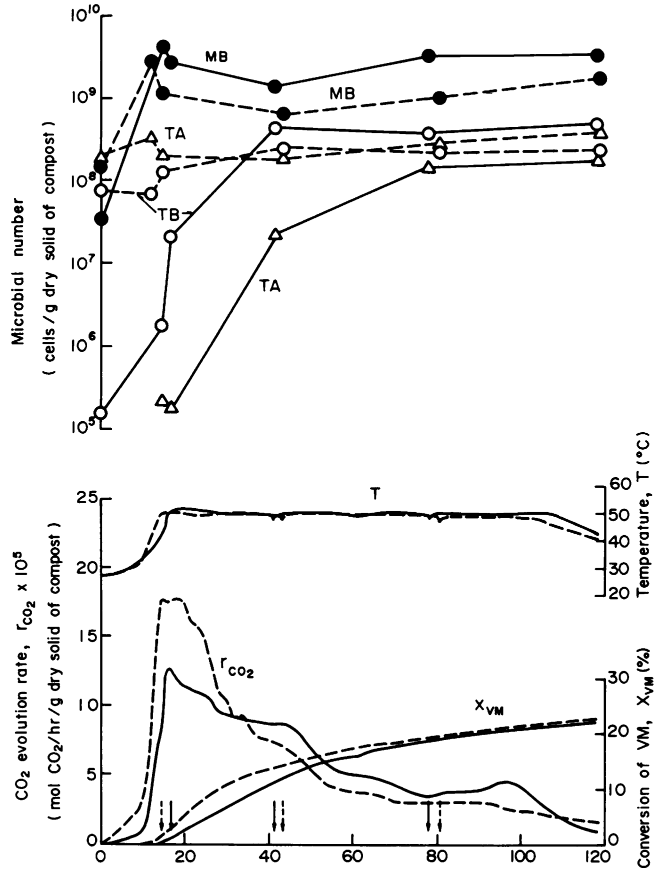

FIG. 1. Time courses of temperature (T), CO_2 evolution rate (r_{CO_2}), cell number of isolated microorganisms, and conversion of VM, X_{VM}, during composting at 50°C (Runs T1-50 and T2-50). Key for cell number: ●, mesophilic bacteria (MB); ○, thermophilic bacteria (TB); △, thermophilic actinomycetes (TA). The arrows on the abscissa in the lower panel indicate the points at which the compost was turned. Solid lines are for the composting containing 21% of sterilized compost product. Broken lines are for the composting containing 21% of compost product as a seed.

Fig. 1 to 3. The significant difference between Runs T1 and T2 was in the initial numbers of thermophilic bacteria and thermophilic actinomycetes. The CO_2 evolution rate and peak pattern were rather similar for the seeded T1 series composting and nonseeded T2 series composting at 60 and 70°C. At 50°C, the nonseeded composting had a lower rate of CO_2 evolution at the initial stage because of a lower rate of growth for thermophilic bacteria. The isolated dominant microorganisms were the same irrespective of operating temperature. In the nonseeded series, the rapid increase in the number of thermophilic bacteria was observed at the initial stage of composting, followed by an increase in the number of thermophilic actinomycetes at 50 and 60°C. At 70°C, the thermophilic bacteria at first increased up to 10^8 cells per g (dry solid) of compost and then decreased to 10^7. The thermophilic actinomycetes increased only when the temperature went below 70°C. In the seeded T1 series, the number of thermophilic bacteria and actinomycetes was constant at both 50 and 60°C, but there was a remarkable decrease on the order of 10^7 at 70°C. The change in the number of mesophilic bacteria showed the same tendency between the Run T1 and T2 series, i.e., the number increased to 10^9 in the period of rising temperature, and the decrease in number depended on the temperature. To reach the conversion of 15% of VM, 49 h were needed at 50°C, 40 h were needed at 60°C, and 53 h were needed at 70°C. This means that the average degradation rate of the organic matter in the compost material was highest at 60°C.

The total amount of CO_2 evolved, the final conversion of the VM of raw sludge, and the amount of time needed to maintain the setting temperature are shown in Table 1. The total CO_2 evolved and the final conversion of VM were maximum at 60°C. Although the change in microbial numbers showed different patterns between the seeded and nonseeded runs at each constant temperature, the data shown in Table 1 are almost the same. This result coincided with that obtained from the experiment on the effect of seeding in our previous paper (9).

The CO_2 evolution rates of the seeded T1 series were plotted against VM conversion of raw sludge (Fig. 4). The solid lines indicate CO_2 evolution rates in a range in which the setting temperatures of 50, 60, and 70°C were kept constant. At the region of low conversion, the difference in CO_2 evolution rates was slight, but as conversion increased, the CO_2 evolution rate was remarkably high at 60°C and lowest at 70°C. This trend was also observed in the nonseeded T2 series experiment. Based on these results, 60°C is an optimal temperature for the composting of sewage sludge.

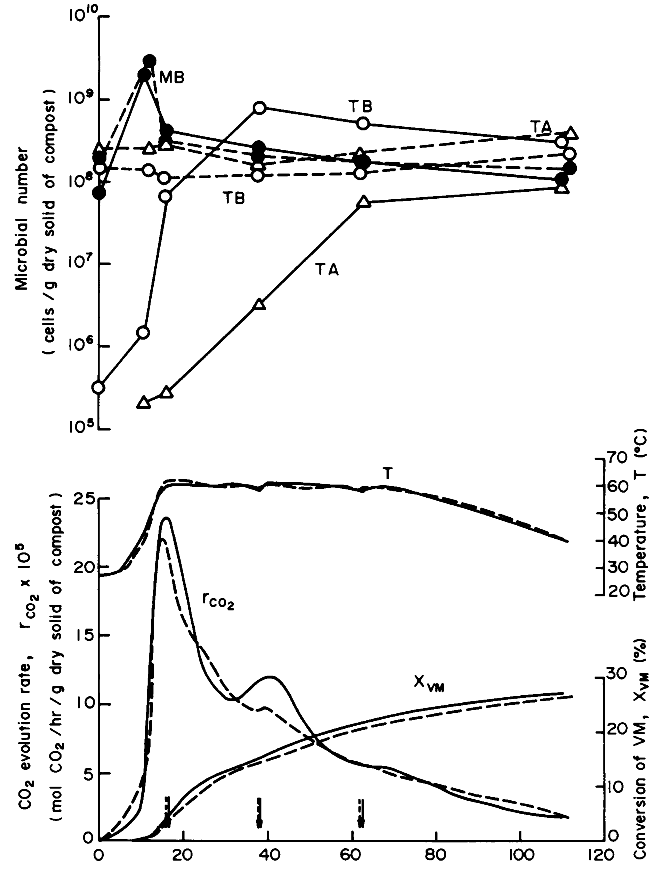

FIG. 2. Time courses of composting at 60°C (Runs T1-60 and T2-60). For the key to cell numbers and remarks, see the legend to Fig. 1.

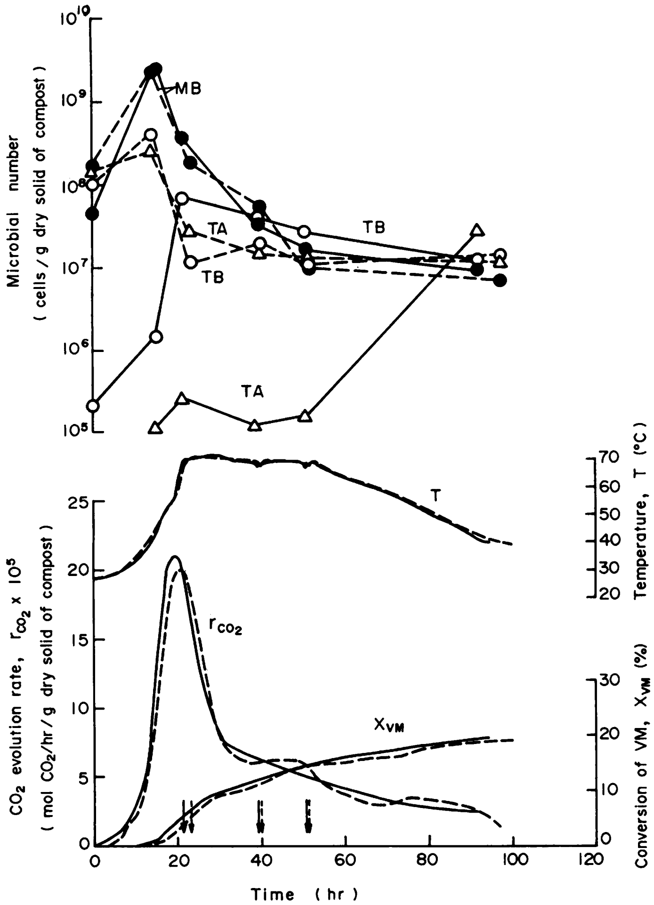

FIG. 3. Time courses of composting at 70°C (Runs T1-70 and T2-70). For the key to cell numbers and remarks, see the legend to Fig. 1.

Characteristics of thermophilic bacterium BH1. The experimental results of growth and glucose consumption of the thermophilic bacterium, BH1, in the Trypticase medium at 60 and 70°C are shown in Fig. 5. At 60°C, the cell number increased for 8 h and then declined. At 70°C, the viable cell number rapidly decreased. Glucose consumption lasted for 2 h, but no glucose consumption was detected after that. The initial rate of glucose consumption was the same at 60 and 70°C.

When the cells grown on the agar plate were placed in the plastic box to detect O_2 concentration, a linear decrease in O_2 concentration was observed at 60°C, and the specific

TABLE 1. Experimental results for composting at three different temperatures

Run	% Final conversion of VM (dry wt)	Amt (mol) of CO_2 evolved	Amt of time (h) required to maintain setting temperatures
T1-50	22.5	7.90	88
T2-50	21.6	7.35	91
T1-60	25.7	9.21	53
T2-60	27.2	9.82	56
T1-70	19.5	6.12	29
T2-70	19.2	6.43	28

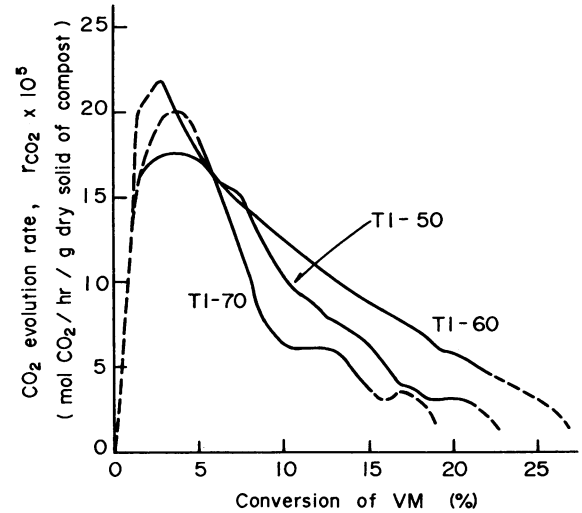

FIG. 4. CO_2 evolution rate versus conversion of VM at three different temperatures. The broken lines show the region where this temperature was below the setting temperature.

oxygen consumption rate was measured as 4.5×10^{-13} (mol of O_2 per h per cell). At 70°C, the decrease in oxygen concentration was observed for 4 h, but later no O_2 consumption was detected. The average value of the specific O_2 consumption rate for 4 h was 1.7×10^{-12} (mol of O_2 per h per cell).

DISCUSSION

Several reports on the optimal temperature for the composting of various materials have already been published (2, 5, 6, 10, 12, 13). However, the results were not necessarily obtained from well-defined and controlled reactor systems. Bach et al. (2) showed that the optimal temperature for the composting of a mixture of sewage sludge and rice husk that was used as a bulking agent was around 60°C in a laboratory-scale reactor, that is, a continuously mixed isothermal reactor. However, this reactor system is not applicable on a larger scale. The autothermal packed-bed reactor

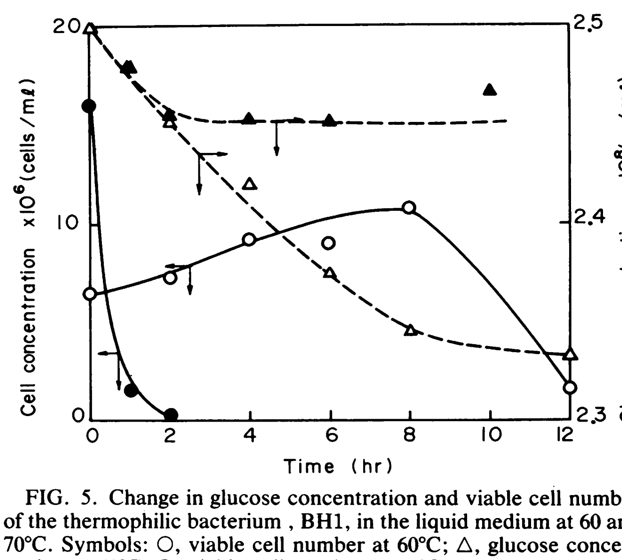

FIG. 5. Change in glucose concentration and viable cell number of the thermophilic bacterium , BH1, in the liquid medium at 60 and 70°C. Symbols: ○, viable cell number at 60°C; △, glucose concentration at 60°C, ●, viable cell number at 70°C; ▲, glucose concentration at 70°C.

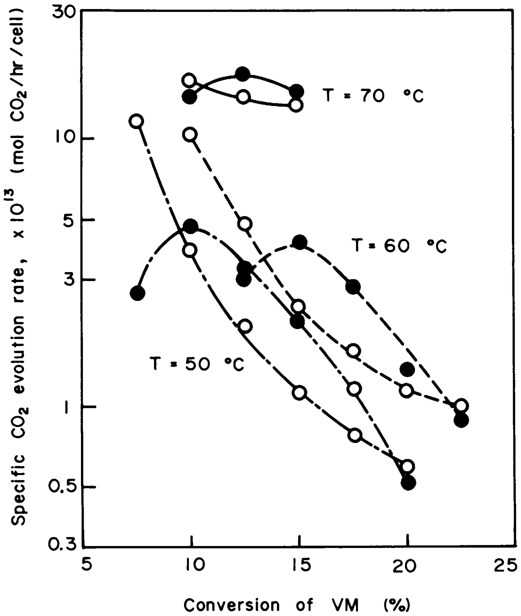

FIG. 6. The estimated specific CO_2 evolution rate at three different temperatures. Symbols: ○, thermophilic bacteria; ●, thermophilic actinomycetes; –·–, 50°C; -----, 60°C; ——, 70°C.

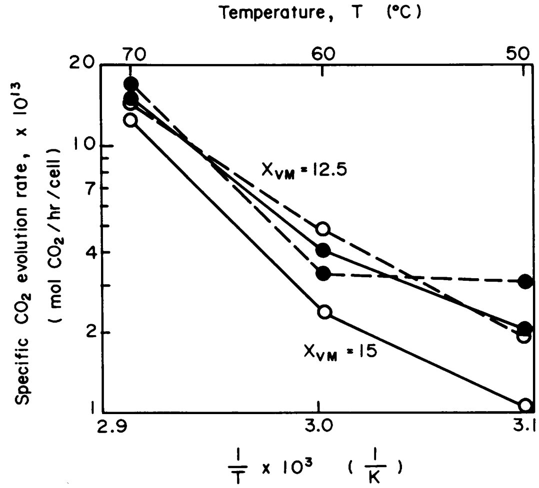

FIG. 7. Arrhenius plot of specific CO_2 evolution rate for thermophilic bacteria (○) and thermophilic actinomycetes (●). The ordinate was obtained from the data shown in Fig. 6 for each conversion of VM. Symbols, ——, 15%; -----, 12.5%.

we used in this work, the temperature of which is controlled by the rate of airflow, is practically applicable. In our experiment, the raw sewage sludge used was collected at the same wastewater treatment plant as that used by Bach et al. (2), but to simplify the reaction environment no bulking agent was added. As a result, the optimal temperature was 60°C. This means that the degradation of organic matter in the raw sludge, measured as the rate of CO_2 evolution, is most efficient at 60°C irrespective of the addition of a bulking agent or of the reactor systems used.

The specific CO_2 evolution rate for thermophilic bacteria and actinomycetes at three different temperatures estimated by the procedure described in our previous paper (7) is shown in Fig. 6. Of particular interest is that the rate of specific CO_2 evolution of the thermophiles was highest at 70°C, although the average number of viable cells at 70°C was smaller than those at 50 or 60°C. To elucidate this point, we investigated the activity of the isolated thermophilic bacterium, BH1. The rate of specific O_2 consumption of the bacterium at 70°C was four times higher than that at 60°C. This corresponds to the higher rate of CO_2 evolution at 70°C in the compost. Glucose was consumed by BH1 in the liquid medium even under conditions in which the cell number decreased remarkably at 70°C (Fig. 5). The initial rate of glucose consumption, however, was almost the same at 60°C. This was mainly because the reaction rate was limited by oxygen diffusion into the liquid phase. Therefore, the specific activity of glucose consumption between 60 and 70°C cannot be compared. The Arrhenius plot of the specific CO_2 evolution rate shown in Fig. 6 is presented in Fig. 7. Although the average slope in the range from 50 to 70°C gave an activation energy of 22 kcal (ca. 92,048 J), and similar values for the activation energy of thermophilic bacteria (4), thermophilic communities (6), and mesophilic bacteria (1, 11) were reported, the activation energy in Fig. 7 appears to be higher in the range of 60 to 70°C than in the range of 50 to 60°C. This suggests that CO_2 is evolved during composting from two parallel reactions, i.e., catabolism and anabolism with different activation energies. The one having a higher activation energy becomes dominant at the higher temperature. If the fraction between anabolism and catabolism is variable at different temperatures, the respiration quotient (RQ) will depend on the temperature. Because the elementary analysis of raw sewage sludge gave the formula $CH_{2.12}N_{0.09}O_{0.52}$, the following equation will be obtained when raw sludge is degraded only by catabolism.

$$[CH_{2.12}N_{0.09}O_{0.52} + 1.2\ O_2 \rightarrow CO_2 + 0.93\ H_2O + 0.09\ NH_3]$$

Consequently, the value of RQ is 0.83. The change in RQ calculated from the measured rates of CO_2 evolution and O_2 consumption during composting is shown in Fig. 8. It is obvious that the RQ value is higher at 70°C as compared with 50 or 60°C. This may be interpreted as indicating that catabolism is dominant at higher temperatures.

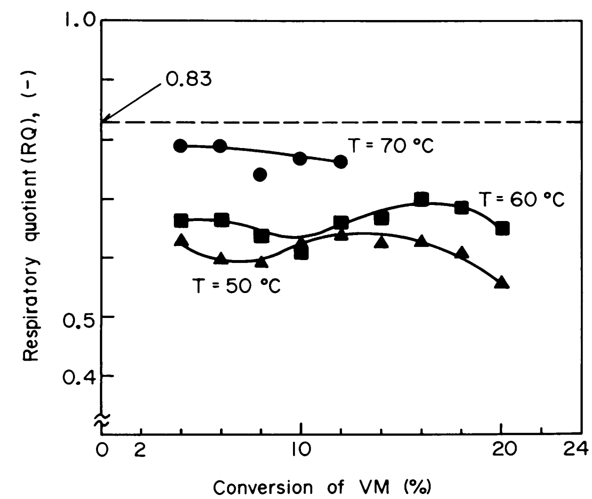

FIG. 8. RQ for each conversion of VM at three different temperatures. Symbols: ▲, 50°C; ■, 60°C; ●, 70°C.

Senez (11) showed a similar result for mesophilic bacteria. He measured the rate of O_2 uptake of the mesophilic bacterium *Aerobacter aerogenes*, showing that the respiratory activity of the bacterium was 175.6 (microliters of O_2 consumed per hour per milligram of cells) at the optimal temperature of 37.6°C, but that the activity still increased to 199.2 at 41.8°C and finally became 146.3 at 47°C, at which point no growth was observed. This result was interpreted as indicating an energy uncoupling between energy-yielding metabolism and cell synthesis. Our results reflect the case of thermophilic bacteria. So far, no data are available concerning energy uncoupling of thermophilic microorganisms.

It must be emphasized that the measured CO_2 evolution rate during the composting process as shown in Fig. 1 to 4 was the product of the specific CO_2 evolution rate and the cell number. Therefore, even though the specific CO_2 evolution rate was higher at 70°C, the optimal temperature should be the temperature that gives the maximum CO_2 evolution rate value.

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United States
Environmental Protection
Agency

Biosolids Technology Fact Sheet

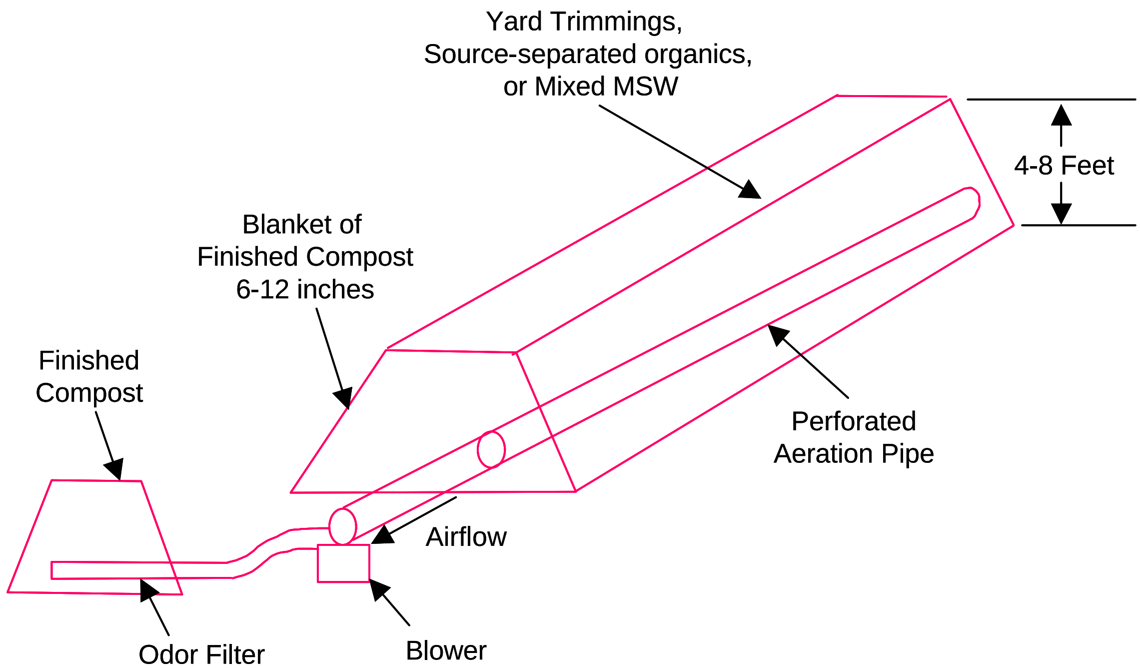
Use of Composting for Biosolids Management

DESCRIPTION

Composting is one of several methods for treating biosolids to create a marketable end product that is easy to handle, store, and use. The end product is usually a Class A, humus-like material without detectable levels of pathogens that can be applied as a soil conditioner and fertilizer to gardens, food and feed crops, and rangelands. This compost provides large quantities of organic matter and nutrients (such as nitrogen and potassium) to the soil, improves soil texture, and elevates soil cation exchange capacity (an indication of the soil's ability to hold nutrients), all characteristics of a good organic fertilizer. Biosolids compost is safe to use and generally has a high degree of acceptability by the public. Thus, it competes well with other bulk and bagged products available to homeowners, landscapers, farmers, and ranchers.

Three methods of composting wastewater residuals into biosolids are common. Each method involves mixing dewatered wastewater solids with a bulking agent to provide carbon and increase porosity. The resulting mixture is piled or placed in a vessel where microbial activity causes the temperature of the mixture to rise during the "active composting" period. The specific temperatures that must be achieved and maintained for successful composting vary based on the method and use of the end product. After active composting, the material is cured and distributed. The three commonly employed composting methods are described in the following paragraphs. A fourth method (static pile) is not recommended for composting wastewater solids based on a lack of operational control.

Aerated Static Pile - Dewatered cake is mechanically mixed with a bulking agent and stacked into long piles over a bed of pipes through which air is transferred to the composting material. After active composting, as the pile is starting to cool down, the material is moved into a curing pile.



Source: Hickman, 1999.

FIGURE 1 SCHEMATIC OF A STATIC-PILE FORCED-AIR COMPOSTING PROCESS

The bulking agent is often reused in this composting method and may be screened before or after curing so that it can be reused.

Windrow - Dewatered wastewater solids are mixed with bulking agent and piled in long rows. Because there is no piping to supply air to the piles, they are mechanically turned to increase the amount of oxygen. This periodic mixing is essential to move outer surfaces of material inward so they are subjected to the higher temperatures deeper in the pile. A number of turning devices are available, including: (1) drums and belts powered by agricultural equipment and pushed or pulled through the composting pile; and (2) self-propelled models that straddle the composting pile. As with aerated static pile composting, the material is moved into curing piles after active composting. Several rows may be laced into a larger pile for curing. Figure 2 shows a typical windrow operation.

Source: Parsons, 2002.

FIGURE 2 WINDROW OPERATIONS ARE TURNED TO PROVIDE ADEQUATE AERATION FOR ACTIVE COMPOSTING

In-Vessel - A mixture of dewatered wastewater solids and bulking agent is fed into a silo, tunnel, channel, or vessel. Augers, conveyors, rams, or other devices are used to aerate, mix, and move the product through the vessel to the discharge point. Air is generally blown into the mixture. After active composting, the finished product is usually stored in a pile for additional curing prior to distribution. A typical composting vessel is shown in Figure 3. This technology is discussed in greater detail in the fact sheet entitled *In-Vessel Composting of Biosolids* (EPA 832-F-00-061).

Source: Parsons, 2002.

FIGURE 3 TYPICAL COMPOSTING VESSEL

All three composting methods require the use of bulking agents, but the type of agent varies. Wood chips, saw dust, and shredded tires are commonly used, but many other materials are suitable. The U.S Composting Council lists the following materials as suitable for use as bulking agents:

- Agricultural by-products, such as manure and bedding from various animals, animal mortalities, and crop residues.
- Yard trimmings, including grass clippings, leaves, weeds, stumps, twigs, tree prunings, Christmas trees, and other vegetative matter from land clearing activities.
- Food by-products, including damaged fruits and vegetables, coffee grounds, peanut hulls, egg shells, and fish residues.
- Industrial by-products from wood processing, forestry, brewery and pharmaceutical operations. Paper goods,

paper mill residues, and biodegradable packaging materials are also used.

- Municipal solid waste.

If municipal solid waste is used in compost, it is put through a mechanical separation process prior to its use to remove non-biodegradable items such as glass, plastics and certain paper goods (USCC, 2000).

The length of time biosolids are composted at a specific temperature is important in determining the eventual use of the compost end product. 40 CFR Part 503, *Standards for the Use and Disposal of Sewage Sludge* (Part 503) defines time and temperature requirements for both Class A and Class B products (Table 1). The production of a Class B product is not always economically justified since the product cannot be used without restrictions and the additional expense to reach Class A requirements can be marginal.

TABLE 1 PART 503 TIME AND TEMPERATURE REQUIREMENTS FOR BIOSOLIDS COMPOSTING

Product	Regulatory Requirements
Class A	**Aerated static pile or in-vessel**: 55 C for at least 3 days **Windrow**: 55 C for at least 15 days with 5 turns
Class B	40 C or higher for five days during which temperature exceed 55 C for at least four hours

Source: 40 CFR Part 503.

If the compost process conforms with the time and temperature requirements to produce a Class A product and the maximum pollutant levels of Part 503 are met, the material is considered “Exceptional Quality” (EQ) biosolids. If used in accordance with sound agronomic and horticultural practices, an EQ biosolids product can be sold in bags or bulk and can be used in household gardens without additional regulatory controls. Class A and EQ biosolids typically have greater marketing success than Class B biosolids. Control of industrial waste streams to wastewater treatment plants (through pretreatment programs) greatly reduces the presence of metals in pre-processed wastewater residuals, enabling compost to meet the stringent EQ standards of Part 503.

If the compost produced is Class B, it can be used at agronomic sites with no public contact, with additional site restrictions. Class A biosolids can be used in home gardens with public contact and no site restrictions. Consistent and predictable product quality is a key factor affecting the marketability of compost (U.S. EPA, 1994). Successful marketing depends on a consistent product quality.

Stability is an important characteristic of a good quality compost. Stability is defined as the level of biological activity in the compost and is measured as oxygen uptake or carbon dioxide production. Oxygen uptake rates of 50 to 80 mg/L are indicative of a stable product with minimal potential for self-heating, malodor generation, or regrowth of pathogen populations. Stability is also indicated by temperature decline, ammonia concentrations, chemical oxygen demand (COD), number of insect eggs, change in odor, and change in redox potential (Haug, 1993).

Stable compost consumes little nitrogen and oxygen and generates little carbon dioxide. Unstable compost consumes nitrogen and oxygen and generates heat, carbon dioxide, and water vapor. Therefore, when unstable compost is applied to soil, it removes nitrogen from the soil, causing a nitrogen deficiency that can be detrimental to plant growth and survival. In addition, if not aerated and stored properly, unstable compost can emit nuisance odors (Epstein, 1998, Garcia, 1991).

APPLICABILITY

The physical characteristics of most biosolids allow for their successful composting. However, many characteristics (including moisture content, volatile solids content, carbon content, nitrogen content, and bulk density) will impact design decisions for the composting method. Both digested and raw solids can be composted, but some degree of digestion (or similar stabilization) is desirable to reduce the potential for generation of foul odors from the composting operation. This is particularly important for aerated static pile and windrow operations. Carbon and nitrogen content of the wastewater solids must be balanced against that of the bulking agent to achieve a suitable carbon to nitrogen ratio of between 25 and 35 parts carbon to one part nitrogen.

Site characteristics make composting more suitable for some wastewater treatment plants than others. An adequate buffer zone from neighboring residents is desirable to reduce the potential for nuisance complaints. In urban and suburban settings, in-vessel technology may be more suitable than other composting technologies because the in-vessel method allows for containment and treatment of air to remove odors before release. The requirement for a relatively small amount of land also increases the applicability of in-vessel composting in these settings.

Another important consideration before selecting the technology to be used for composting is the availability of adequate and suitable manpower. Composting is typically labor-intensive for the following reasons:

- Bulking agents must be added.
- Turning, monitoring, or process control is necessary.
- Feed and finished material(s) must be moved with mechanical equipment.
- Storage piles must be maintained for curing and distribution.
- Bulking agents recovery adds another step.

Finally, proximity to the markets for the resulting compost is desirable, although the usefulness of the final product in home gardening and commercial operations generally makes the material marketable in urban as well as rural areas. This is especially true for good quality material that does not emit foul odors.

ADVANTAGES AND DISADVANTAGES

Biosolids composting has grown in popularity for the following reasons (WEF, 1995):

- Lack of availability of landfill space for solids disposal.
- Composting economics are more favorable when landfill tipping fees escalate.
- Emphasis on beneficial reuse at federal, state, and local levels.
- Ease of storage, handling, and use of composted product.
- Addition of biosolids compost to soil increases the soil's phosphorus, potassium, nitrogen, and organic carbon content.

Composted biosolids can also be used in various land applications. Compost mixed with appropriate additives creates a material useful in wetland and mine land restoration. The high organic matter content and low nitrogen content common in compost provides a strong organic substrate that mimics wetland soils, prevents overloading of nitrogen, and adsorbs ammonium to prevent transport to adjacent surface waters (Peot, 1998). Compost amended strip-mine spoils produce a sustainable cover of appropriate grasses, in contrast to inorganic-only amendments which seldom provide such a good or sustainable cover (Sopper, 1993).

Compost-enriched soil can also help suppress diseases and ward off pests. These beneficial uses of compost can help growers save money, reduce use of pesticides, and conserve natural resources. Compost also plays a role in bioremediation of hazardous sites and pollution prevention. Compost has proven effective in degrading or altering many types of contaminants, such as wood-preservatives, solvents, heavy metals, pesticides, petroleum products, and explosives. Some municipalities are using compost to filter stormwater runoff before it is discharged to remove hazardous chemicals picked up when stormwater flows over surfaces such as roads, parking lots, and lawns. Additional uses for compost include soil mulch for erosion control, silviculture crop establishment, and sod production media (U.S. EPA, 1997a).

Limitations of biosolids composting may include:

- Odor production at the composting site.
- Survival and presence of primary pathogens in the product.
- Dispersion of secondary pathogens such as *Aspergillus fumigatus*, particulate matter, other airborne allergens.
- Lack of consistency in product quality with reference to metals, stability, and maturity.

Odors from a composting operation can be a nuisance and a potential irritant. Offensive odors from composting sites are the primary source of public opposition to composting and have led to the closing of several otherwise well-operated composting facilities. Although research shows that biosolids odors may not pose a health threat, odors from processing facilities have decreased public support for biosolids recycling programs (Toffey, 1999). Many experts in the field of biosolids recycling believe that biosolids generating and processing facilities have an ethical responsibility to control odors and protect nearby residents from exposure to malodor.

Composting odors are caused by ammonia, amine, sulfur-based compounds, fatty acids, aromatics, and hydrocarbons (such as terpenes) from the wood products used as bulking agents (Walker, 1992). A properly designed composting plant, such as the one shown in Figure 4, operated at a high positive redox potential (highly aerobic) will reduce, but not necessarily eliminate, odors and odor causing compounds during the first 10 to 14 days of the process (Epstein, 1998). Control of odors is addressed in further detail in the fact sheet entitled Odor Management in Biosolids Management (EPA 832-F-00-067).

In addition to odors, other bioaerosols, such as pathogens, endotoxins, and various volatile organic compounds, must also be controlled. Biofilters are often used to control odors, but the biofilters themselves can give off bioaerosols.

Pathogens, such as bacteria, viruses, and parasites (helminth and protozoa), are present in untreated wastewater residuals. These organisms can potentially invade a normal, healthy human being and produce illness or debilitation. Composting reduces bacterial and viral pathogens to non-detectable levels if the temperature of the compost is maintained at greater than 55 C for 15 days or more. Additionally, it has been demonstrated that viruses and helminth ova do not regrow after thermal inactivation (Hay, 1996).

Regrowth of *Salmonella* sp. in composted biosolids is a concern, although research shows that salmonellae reach a quick peak during regrowth, then die off. Composting is not a sterilization process and a properly composted product maintains an active population of beneficial microorganisms that compete against the pathogenic members. Under some conditions, explosive regrowth of pathogenic microorganisms is possible. A stabilized product with strict control

Source: Parsons, 2002.

FIGURE 4 ODOR CONTROL EQUIPMENT CAN BE A SUBSTANTIAL PART OF CAPITAL INVESTMENT

of post-composting handling and addition of amendments coupled with four to six weeks of storage will mitigate *Salmonella* regrowth (Hay, 1996).

Compost workers may be exposed to a common fungus known as *Aspergillus fumigatus*, endotoxins, or other allergens. *A. fumigatus* is common in decaying organic matter and soil. Inhalation of its airborne spores causes skin rashes and burning eyes. While healthy individuals may not be affected, immunocompromised individuals may be at risk. The spores of *A. fumigatus* are ubiquitous and the low risk of exposure is not a significant health concern. However, spore counts at composting facilities are high, and the risk of operators and persons handling composted biosolids being exposed to these spores is also high (Epstein, 1998). Inhalation of spores, particulates, and other matter can be reduced or prevented by:

- Wearing masks and other protective devices.
- Equipping front end loaders with filters or air conditioners.
- Thoroughly ventilating composting halls.
- Installing biofilters or other odor scrubbing systems in composting halls (Epstein 1998).

Organic dust (such as pollen) is another nuisance that must be controlled at composting operations. These contaminants are primarily a concern to workers at the composting facilities and are generally not present in quantities that would cause reactions in most individuals that are not exposed outside of the facilities.

Environmental Impact

Potential environmental impacts may result from both composting operations and use of the compost product.

Composting Process

Dust and airborne particles from a composting operation may affect air quality. The impact to adjacent areas may need to be mitigated and permitted.

To protect area ecology and water quality, run-off from application sites must be controlled. The potential nitrogen and phosphorus rich run-off (or leachate) can cause algal growth in surface water and render groundwater unfit for human consumption.

Land Application of Compost Products

Excess nitrogen is detrimental to soil, plants, and water, so care must be taken when choosing application sites, selecting plant/crop types, and calculating the agronomic rate for biosolids land application. It should be noted that the most plant-available form of nitrogen in biosolids (ammonium ion (NH_4^+)) is converted to nitrate (NO_3^-) by the composting process. Improper use of biosolids can result in the contamination of water resources with leached nitrogen, because nitrate is more mobile than ammonium, and is taken up less easily by plants. However, applying compost in accordance with the Part 503 Regulations poses little risk to the environment or public health (Fermante, 1997). In fact, the use of compost can have a positive impact on the environment in addition to the soil improving characteristics previously discussed. Reduced dependence on inorganic fertilizers can significantly decrease nitrate contamination of ground and surface waters often associated with use of inorganic fertilizers.

PERFORMANCE

Composting is a viable, beneficial option in biosolids management. It is a proven method for pathogen reduction and results in a valuable product. According to a 1998 survey in *Biocycle, The Journal of Composting and Recycling,* 274 biosolids composting facilities were operating in the United States (Goldstein, 1999). Nearly 50 additional facilities were in various stages of planning, design, and construction. A large number of these facilities (over 40 percent) use the aerated static pile composting method.

Since 1984, EPA has encouraged the beneficial use of wastewater residuals through formal policy statements. The implementation of Part 503 enhanced the acceptance of biosolids as a resource by standardizing metal and pathogen concentrations. Moreover, Part 503 officially identifies composting as a method to control pathogens and reduce vector attraction.

Discussions of the specific performance factors of the three primary composting methods are provided below.

Aerated static pile systems are adaptable and flexible to bulking agents and production rates. Aerated static pile is mechanically simple, thus with lower maintenance than other cost method. Conversely, this configuration can be labor intensive and may produce nuisance odors and dust. Cover, negative aeration, chemically scrubbing, or use of a well-maintained biofilter may be required to minimize off-site odor migration. The popularity of the aerated static pile method is based on the ease of design and operation and lower capital costs associated with facility construction. Selection of an appropriate method requires an assessment of the physical facility, process considerations, and operation and maintenance costs (WEF, 1995).

Windrow composting is adaptable, flexible and relatively mechanically simple. However, the windrow configuration requires a large area and can result in release of malodor, dust, and other airborne particles to the environment during natural processing, ventilation, and windrow turning.

In-vessel systems are less adaptable and flexible compared with aerated static pile and windrow systems. However, in-vessel composting requires a smaller area. Because the reactor is completely enclosed, the potential for odor and the need for controls is increased. Due to the greater complexity of in-vessel mechanical systems, trouble can be encountered meeting peak flows, breakdowns are more frequent, and repairs are more difficult and costly. Failure of aeration devices, under- designed aeration systems, or lack of a back-up aeration method may cause large quantities of product to become anaerobic, and therefore, unacceptable. Often the compost residence time in in-vessel composting systems is inadequate to produce a stable product, particularly where the depth of the composting mass is great, (e.g., more than 3 m [10 feet]) and mixing does not occur. In addition, bridging sometimes occurs within these systems. Finally, depending upon the configuration and direction of air flow, the worker environment can be very hostile. However, in-vessel composting requires a smaller area and generates relatively little dust outside the facility.

Table 2 compares the three methods and highlights key features of each.

COSTS

The capital costs of aerated static pile or windrow configuration may be lower than in-vessel composting configurations, but costs increase markedly when cover is required to control odors. More highly mechanized in-vessel systems are often more costly to construct, but tend to be less labor intensive. On the other hand, in-vessel systems tend to be less flexible in their ability to adapt to changing properties of biosolids and bulking agent feedstocks.

Capital costs of in-vessel systems range from $33,000 to $83,000 per dry metric ton ($30,000 to $75,000 per dry ton) per day processing capacity. A typical aerated static pile facility costs approximately $33,000 per dry metric ton ($30,000 per dry ton) per day of processing capacity (Harkness, 1994; U.S. EPA, 1989).

Typical operation and maintenance (O&M) costs for in-vessel systems range from $150 per dry ton per day to greater than $200 per dry ton per day. Aerated static pile O&M costs average $150 per dry ton per day (Harkness, 1994; U.S. EPA, 1989). Costs for windrow systems fall between the costs for in-vessel and aerated static pile. The selling price for compost ranges from $5 to $10 per cubic yard or $10 to $20 per ton. Some facilities allow landscapers and homeowners to pick up compost for little or no charge.

TABLE 2 COMPARISON OF COMPOSTING METHODS

Aerated Static Pile	Windrow	In-Vessel
Highly affected by weather (can be lessened by covering, but at increased cost)	Highly affected by weather (can be lessened by covering, but at increased cost)	Only slightly affected by weather
Extensive operating history both small and large scale	Proven technology on small scale	Relatively short operating history compared to other methods
Large volume of bulking agent required, leading to large volume of material to handle at each stage (including final distribution)	Large volume of bulking agent required, leading to large volume of material to handle at each stage (including final distribution)	High biosolids to bulking agent ratio so less volume of material to handle at each stage
Adaptable to changes in biosolids and bulking agent characteristics	Adaptable to changes in biosolids and bulking agent characteristics	Sensitive to changes in characteristics of biosolids and bulking agents
Wide-ranging capital cost	Low capital costs	High capital costs
Moderate labor requirements	Labor intensive	Not labor intensive
Large land area required	Large land area required	Small land area adequate
Large volumes of air to be treated for odor control	High potential for odor generation during turning; difficult to capture/contain air for treatment	Small volume of process air that is more easily captured for treatment
Moderately dependent on mechanical equipment	Minimally dependent on mechanical equipment	Highly dependent on mechanical equipment
Moderate energy requirement	Low energy requirements	Moderate energy requirement

Source: Parsons, 2002.

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Other Related Fact Sheets

In-Vessel Composting of Biosolids
EPA 832-F-00-061
September 2000

Odor Management in Biosolids Management
EPA 832-F-00-067
September 2000

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EPA 832-F-00-053
September 2000

Belt Filter Press
EPA 832-F-00-057
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Other EPA Fact Sheets can be found at the following web address:

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Via U.P.S. Overnight Delivery

November 13, 2006

Carrie Hyke
San Bernardino County Land Use Services Department
Advanced Planning Division
[redacted]

Re: Comments on the Draft Environmental Impact Report for Nursery Products Hawes Composting Facility: State Clearinghouse Number 2006051021.

Dear Ms. Hyke,

I am submitting this letter on behalf of the Center for Biological Diversity ("Center"), a non-profit organization with over 25,000 members across the United States, many of whom reside in San Bernardino County. The Center is dedicated to protecting imperiled species and their habitats through science, policy, and environmental law. As described below, the Center objects to approval of the proposed project based on its impacts to the environment and inadequacy of the current environmental documents.

The Nursery Products Hawes Composting Facility Project will significantly alter the existing landscape and environment. The project will be comprised of an office building, parking lot, scale, composting windrows, screening area, equipment, finished product storage area and a 2,000 gallon above-ground fuel tank. It will destroy 160 acres of occupied Desert Tortoise habitat and process 400,000 tons of sewage sludge per year. The project will require between 96 and 174 truck trips daily from unspecified locations in San Bernardino County and the Inland Empire.

The primary concerns with the Draft EIR noted in this comment letter are its inadequate analysis and mitigation of impacts the project will create to biological resources (particularly the Desert Tortoise), air quality, water quality, hazards and hazardous materials, as well as the lack of analysis and mitigation of greenhouse gas emissions and issues of environmental justice.

I. THE DRAFT EIR FAILS TO MEET THE REQUIREMENTS OF THE CALIFORNIA ENVIRONMENTAL QUALITY ACT

An EIR is a detailed statement, prepared under the California Environmental Quality Act, Public Resources Code §§ 21000-21178 ("CEQA"), describing and analyzing the significant environmental effects of a project and discussing ways of avoiding or mitigating those effects. 14 Cal Code Regs § 15362. The purposes of an EIR are to provide decision making bodies and the public with detailed information about the effect a proposed project is likely to have on the environment, to list ways in which the significant effects of a project might be minimized, and to indicate alternatives to the project. Pub. Res. Code § 21061; 14 Cal Code Regs. § 15002. The following purposes have also been enumerated by California Courts: an EIR should provide disclosure of all relevant facts; should provide a balancing mechanism whereby decision makers and the public can weigh the costs and benefits of a project; should provide a means for public participation; should provide increased public awareness of environmental issues; should provide for agency accountability; and should provide substantive environmental protection. Because of the shortcomings discussed below, the Draft EIR for the project is inadequate to meet both the procedural and substantive mandates of CEQA.

II. THE DRAFT EIR FAILS TO DISCLOSE INFORMATION THAT ADEQUATELTY DEFINES THE PROPOSED PROJECT

CEQA mandates that the project description be accurate because an accurate description is necessary to determine the scope of environmental review. *County of Inyo v. City of Los Angeles,* 71 Cal App. 3d 185, 199 (1977). If the description of the project is inadequate because it fails to completely discuss and accurately portray the project, the environmental analysis will likely reflect these shortcomings. *Laurel Heights Improvement Ass'n v. Regents Univ. of Cal*. 47 Cal. 3d 376, (1988).

The Draft EIR fails to meet the disclosure requirements of CEQA. In order to understand and analyze the proposed project it is imperative to know exactly where the sewage sludge is coming from. The Draft EIR gives a vague and inadequate explanation of where the sludge will derive from, stating that the project will compost waste for the County of San Bernardino and the Inland Empire. Draft EIR at ES-1. It is impossible to sufficiently analyze the project's impacts without knowing exactly where the waste will derive from. The impact on traffic and air quality due to truck emissions, and hazards created by transporting sewage sludge cannot be adequately assessed without knowing the precise location of departure. Failure to disclose this information compromises the entire Draft EIR, rendering it inadequate under CEQA and therefore, invalid.

III. THE DRAFT EIR'S ANALYSIS OF BIOLOGICAL RESOURCES IS INADEQUATE

The proposed project will result in significant habitat loss, developing 160 acres of habitat occupied by endangered and sensitive species. The project threatens to attract ravens, a natural predator of the Desert Tortoise, to the area and introduce invasive plant species into the adjacent habitat, threatening both protected plant and animal species. Construction activity and vehicle traffic from the project also threaten the existence of the Desert Tortoise and other sensitive species. Further, the project threatens to significantly affect threatened and sensitive species by impacting air quality, water quality and creating hazards such as leaks or spills of toxic sludge into the environment.

The Biological Resources section of the Draft EIR fails to adequately disclose, analyze, avoid, minimize, and mitigate impacts to the biological resources of the project site. While the Draft EIR discloses that the endangered Desert Tortoise, as well as a host of other state-listed and sensitive species, will be impacted by the project, the Draft EIR fails to adequately analyze the significant impacts to these species, fails to address alternatives to avoid such impact, and relies on insufficient mitigation measures to reduce the effects of the project.

The direct and indirect effects of the project will impact a number of rare, sensitive, threatened and endangered species, including, but not limited to, the following: Desert Tortoise (*Gosepherus agassizi)*, Mojave Ground Squirrel (*Spermophilus mohavensis)*, Barstow Woolly Sunflower (*Eriophyllum mohavense)*, California Horned Lark (*Eremophilia alpestris actia)*, Northern Harrier (*Circus cyaneus),* Bell's Sage Sparrow (*Amphispiza belli).* Draft EIR 4-31; App. C 3.2.4. The species identified above are acknowledged in the Draft EIR and qualify for heightened scrutiny under CEQA.

The Legislature and the Secretary of Resources have determined that certain kinds of impacts are necessarily significant. "Mandatory findings of significance" are required for the following circumstances:

> The project has the potential to… substantially reduce the habitat of a fish or wildlife species, cause a fish or wildlife population to drop below self-sustaining levels, threaten to eliminate a plant or animal community, [or] reduce the numbers or restrict the range of an endangered, rare or threatened species.

CEQA Guidelines § 15065 [emphasis added]; *see also* Pub. Resources Code § 21083. Additionally, the State CEQA Guidelines Appendix G defines an impact significant if it would "interfere substantially with the movement of any native resident or migratory fish or wildlife species." Section 15065 applies "to the contents of an EIR once it is determined an EIR must be prepared." *Los Angeles Unified School Dist. V. City of Los Angeles* 58 Cal.App.4th 1019, 1024, fn.6.

The mandatory findings of significance control "the identification of effects to be analyzed in depth in the EIR, the requirement to make detailed findings on the feasibility of alternatives and mitigation measures to reduce or avoid the significant effects, and when found to be feasible, the making of changes in the project to lessen the adverse environmental impacts." Discussion following CEQA Guidelines § 15065. The drafters of the guidelines realized that this section was necessary to assure agencies follow the concerns of the Legislature to determine whether effects are significant. *Id*. Courts have determined that impacts to habitat for rare flora and fauna are significant under section 15065 and require full evaluation and recirculation prior to approval. *Mira Monte Homeowners Association v. Ventura County* 165 Cal.App.3d 357, 363-364 (1985). The failure to assess rare, threatened, and endangered species identified in the Biological Report renders the Draft EIR inadequate.

The Draft EIR failed to adequately address significant impacts to species found on or near the project site. Specifically, the Draft EIR did not sufficiently analyze significant impacts to the Desert Tortoise, the Mojave Ground Squirrel and the Burrowing Owl, as well as others. Failure to discuss a significant environmental impact is a violation of CEQA.

CEQA demands that an EIR identify both feasible alternatives and mitigation measures that could avoid or reduce the project's significant environmental effects. Pub. Res. C §21002, 21002.1(a), 21100(b)(4), 21150. The EIR must describe a reasonable range of alternatives to the project or its location that would feasibly attain most of the objectives while avoiding significant effects. 14 Cal. Code Regs §15126.6(a). The EIR must discuss alternatives even if the significant impacts will be avoided or reduced by mitigation. *Laurel Heights Improvement Ass'n v. Regents of Univ. of Cal*. 47 Cal. 3d at 376. Additionally, the EIR must briefly identify alternatives rejected as infeasible and explain why they were rejected. 14 Cal. Code. Reg. §15126.6 (c).

The Draft EIR fails to adequately address alternatives and therefore does not sufficiently seek to avoid the project's significant environmental impacts to biological resources. As discussed below, the Draft EIR completely fails to address building an enclosed composting facility close to the sewage treatment plants rather than trucking the sludge out to the proposed site and significantly impacting the endangered and sensitive species that live there. Further, even if the lead agency found such an alternative infeasible, it is required to explain the infeasibility and has failed to do so. The Draft EIR notes that the Reduced Capacity Alternative would reduce the amount of replacement habitat necessary to mitigate the significant impacts created by the project but fails to state whether such land is available or sufficient to replace the existing habitat. The Fort Cady site offered as an alternative is also habitat to rare plant and animal species which would bear the impact of the project and proposed mitigation measures are inadequate to reduce the impact to insignificant.

Contrary to CEQA guidelines and relevant case law, the Draft EIR erroneously concluded that the suggested mitigation measures, if implemented, will sufficiently reduce the project's impact to less than significant. The Draft EIR fails to include necessary measures that would mitigate many of the project's impacts, namely those impacts which were not analyzed, below the level of significance. Additionally, the Draft EIR fails to distinguish between the mitigation measures suggested by the project proponents and those proposed by the lead agency. CEQA Guidelines, §15126.4, subd. (a)(1)(A).

A. Desert Tortoise

The project is subject to the Endangered Species Act ("ESA"), and must fully comply with the ESA's provisions. Section 9 of the Endangered Species Act of 1973, and Federal regulations issued pursuant to section 4(d) of the ESA, prohibit take of endangered and threatened species without a special exemption. 16 U.S.C. §1531 *et seq*. Section 7 of the Act requires Federal agencies to consult with the United States Fish and

Wildlife Service ("USFWS") should it be determined that their actions may affect federally listed threatened or endangered species or adversely modify critical habitat. Take is defined as harass, harm, pursue, hunt, shoot, wound, kill, trap, capture or collect, or attempt to engage in any such conduct. Harm is further defined by USFWS to include significant habitat modification or degradation that actually kills or injures a listed species by significantly impairing essential behavioral patterns, including breeding, feeding, or sheltering. Harass is defined by USFWS as an action that creates the likelihood of injury to a listed species by annoying it to such an extent as to significantly disrupt normal behavioral patterns which include, but are not limited to, breeding, feeding, or sheltering. Incidental take is defined as take that is incidental to, and not the purpose of, the carrying out of an otherwise lawful activity. Under the terms of section 7(b)(4) and section 7(o)(2), such incidental taking is not considered to be a prohibited taking under the ESA only if it is in compliance with the Incidental Take Statement.

The Desert Tortoise (*Gopherus agassizii*) is a threatened species under the Endangered Species Act. The Mojave population of the Desert Tortoise was listed because numbers are declining precipitously in many areas. These declines are mainly attributed to direct and indirect human caused mortality. Exhibit 1, Fish and Wildlife Service. 1994. Desert Tortoise (Mojave population) Recovery Plan at i. Impacts such as the destruction, degradation, and fragmentation of desert tortoise habitat result from urbanization, agricultural development, livestock grazing, and roads. Exhibit 1, *Id*. Human predation, either by direct mortality or removal from habitat, is also a major factor. Exhibit 1, *Id*. It is estimated that Desert Tortoise populations have declined by up to 59% per year. Exhibit 1, at 3. These declines have been attributed to direct take by humans (e.g., collection for pets or food, shooting, killing and injuring with motor vehicles; habitat loss, degradation, and fragmentation (e.g. due to roads, agriculture, residential development). Sievers et al. 1988, Luckenbach 1982, Coombs 1977a and b); FWS at 6.

Approval of the tentative project will result in harm and harassment of the Desert Tortoise. The Desert Tortoise habitat onsite will be destroyed and adjacent habitat will be modified by the unmitigable significant effects to air quality in addition to the other changes in habitat created by the project. To obtain a permit, the applicant must develop a Habitat Conservation Plan (HCP), designed to offset any harmful effects the proposed activity might have on the species. No incidental take statement has been issued, and no Habitat Conservation Plan is present to allow for take of threatened species. The project cannot proceed in violation of the ESA.

The project has the potential to reduce the numbers or restrict the range of an endangered species. Therefore impacts to the Desert Tortoise represent a mandatory finding of significance. The project will destroy occupied habitat and also result in additional recognized threats to the Desert Tortoise, including, but not limited to, impacts from: construction activity, diminished air quality, vehicle traffic, habitat loss, attraction of predators, introduction of invasive plants, increased fire potential. These impacts must be recognized as significant. Therefore, all feasible mitigation measures should be addressed in order to adequately assess the potential for reducing the impact to less than significant. Further, the Draft EIR fails to address impacts in relation to the goals of the Desert Tortoise Recovery Plan, Mojave Population ("Recovery Plan"). Exhibit 1. The Recovery Plan is a crucial document guiding the protection and recovery of the species under the ESA. Failure to assess threats and mitigation as it relates the Recovery Plan is a fatal flaw because the Recovery Plan is the oversight agencies' analysis of what is necessary to conserve and recover the species as required under the ESA.

The Draft EIR recognizes that the project would lead to significant impact on the Desert Tortoise. However, the Draft EIR is deficient because it fails to adequately analyze the impacts addressed and to recognize several additional impacts the project would have on the Desert Tortoise population. These impacts must be considered significant under CEQA and therefore must be sufficiently addressed and properly mitigated.

The Draft EIR recognizes that the project will create unmitigable significant impacts on air quality. Such impact will harm the Desert Tortoise and its ability to both survive and recover. The Draft EIR failed to adequately address the increase of particulate matter from windrows and the way it will likely impact the respiratory-disease prone Desert Tortoise. The Draft EIR briefly mentioned this risk and dismissed it as an insignificant impact because some Desert Tortoise will be removed from the site and the windrows will not be turned during high wind situations. Regardless of these two factors, the risk of particulate matter affecting the Desert Tortoise on the project site and adjacent lands is significant in that it may substantially affect an endangered species and should therefore be analyzed and, if necessary, sufficiently mitigated.

The Draft EIR fails to address the indirect effects of wind-borne biosolids over large areas of desert tortoise critical habitat which are a foreseeable, significant concern. These effects are of concern because biosolid-derived pollutants are likely to negatively impact the food chain, become concentrated in food plants, and then upon being eaten, becoming even more concentrated in animals. A revised version of the EIR must consider this potentially significant effect and analyze and mitigate accordingly.

The Draft EIR suggests that purchasing 800 acres and designating the land as protected habitat, in order to compensate for loss of the 160 acres of occupied Desert Tortoise habitat that would be utilized by the project, will serve as an adequate mitigation measure to reduce the impact to less than significant. However, there is no mention of whether sufficient land is available for purchase or the quality of that habitat. Mitigation measures cannot be remote and speculative. *Federation of Hillside & Canyon Ass'ns v. City of Los Angeles*, 83 Cal. App. 4th 1252, 1260 (2000). The final EIR must explain which lands the project proponent intends to purchase as mitigation habitat and the feasibility of purchasing such land.

The Draft EIR claims the project area is within the planning area of the proposed West Mojave Coordinated Management Plan ("WMP"). Additionally, the Draft EIR uses the WMP as a mitigation measure. Draft EIR at 4-36. However, the WMP has not been passed and implemented in San Bernardino County and there is no evidence to support the assumption that such approval will occur.[1]

"An adequate EIR must respond to specific suggestions for mitigating a significant environmental impact unless the suggested mitigation is facially infeasible." *Los Angeles Unified School District v. City of Los Angeles*, 58 Cal. App. 4th at 1029. The Draft EIR failed to adopt many suggested mitigation measures which are not facially infeasible and address significant impacts. For example, as mentioned in the comments submitted by the Desert Tortoise Preserve Committee and the Desert Tortoise Council, the entire project must be enclosed within a solid, roofed structure. Additionally, all roads to the site within the Desert Tortoise DWMA that will be used by truck traffic generated by the project must be permanently fenced on both sides with tortoise barrier fencing and all green waste should be sterilized prior to being hauled to the project site to eliminate the risks of wind blown spread of exotic plant and weed seeds.

B. Other Species

Impacts to sensitive species and their habitat must also be fully analyzed, avoided, and minimized or mitigated where unavoidable. Species are categorized as sensitive because of their potential to become threatened or endangered in the future. Impacts from human development, urbanization, habitat alteration and fragmentation, are some of the biggest threats to fish and wildlife. As discussed above CEQA requires a mandatory finding of significant impact if a project has the potential to reduce the numbers or restrict the range of an endangered, rare or threatened species. CEQA Guidelines § 15065. Direct mortality of sensitive species is a significant impact to a threatened species and must be analyzed in depth as a significant impact. In order to determine the significance of the impact to sensitive species, the EIR should disclose a quantified analysis of impacts to species populations resulting from project activities. Additionally, the results of numerous individual projects eliminating small habitat fragments are cumulatively considerable. The project cannot rationalize impacts to sensitive species and their habitat as insignificant without analysis and without proposing specific mitigation measures. The Draft EIR must fully mitigate the impacts of habitat destruction.

The Draft EIR fails to adequately analyze impacts to species with habitat on the project site that were not found during surveys. Negative surveys do not mean that the species does not utilize the habitat on the project site; it simply means that the species was not present at the time of the survey. The project will eliminate suitable habitat for sensitive species and contribute to continued habitat fragmentation, and destruction. The elimination of marginal or immature habitat, because it presently does not meet the ideal habitat for sensitive species, will prevent the species from ever using that habitat in the future during dispersal and/or colonization. These impacts must be addressed and mitigated.

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[1] *See* Record of Decision, West Mojave Plan: Amendment to the California Desert Conservation Area Plan, March 2006 (approving a BLM only plan).

Even if it were proper to assume that no rare, threatened or endangered species currently occupy the project area, which it is not, that would not relieve the County from the duty to identify and analyze impacts to these species due to the fact that the project area contains valuable high quality habitat that these species will need in the future in order to adequately recover. In other words, just because habitat is not currently occupied does not mean the habitat is unnecessary or inessential to conservation of the species which includes both survival and recovery of the species. To the contrary, every acre of habitat that is left is critically important to the future recovery of the sensitive species such as the Burrowing Owl. Therefore, without adequate current surveys to the contrary, the Draft EIR must assume that species associated with the project area are present and that, even if these species are not present, the loss of high quality unoccupied habitat to development may directly, indirectly, and cumulatively impact the conservation of these species.

The Draft EIR fails to adequately address impacts to the Mojave Ground Squirrel (*Spermophilius mohavensis*) and its habitat. The Mojave Ground Squirrel, as acknowledged in the Draft EIR, Appendix C at 3-4, is listed by California as a threatened species. The Draft EIR recognizes the potentially significant impact construction activity may have on the Mojave Ground Squirrel but claims that surveys to determine the presence of the Squirrel within the project area will reduce that impact to less than significant. This is an inadequate mitigation measure because surveys alone do not mitigate for impacts to the species. Moreover, as stated above, absence of the species at the time of the survey does not mean that that the species does not utilize the habitat at the project site, but rather that it is not utilizing the habitat at the time of the survey. The species' presence at the time of the survey can not guarantee whether or not the species will be present during the entire span of construction activities. Further, additional construction activities may take place at times other than those designated for initial construction.

The Draft EIR fails to address impacts to the Burrowing Owl (*Athene cunicularia*) and its habitat. The Burrowing Owl is listed by California as a species of special concern. The Draft EIR recognizes that construction activities and vehicle traffic from the project could possibly directly harm the Burrowing Owl. However, the Draft EIR fails to adequately analyze the potential impacts to the species and its habitat. The project's activities will result in habitat modification, increased traffic, introduction of new species and human disturbance, these impacts and other must be addressed under CEQA.

The Draft EIR fails to adequately address impacts to the Barstow Woolly Sunflower (*Eriophyllum mohavense*) and its habitat. The Barstow Woolly Sunflower, as noted in the Draft EIR, Appendix C at 3-4, is a federal species of special concern. The Sunflower generally blooms in April or May and may have not yet bloomed when the April 2006 survey was conducted. Citing that the species was not detected, the Draft EIR did not analyze the potential significant impacts to this species; this is insufficient. If adequate surveys are not conducted, the lead agency must assume that this species may be found on the project site and, under CEQA the Draft EIR must analyze, avoid, and if necessary mitigate, any potentially significant impacts to the Barstow Woolly Sunflower.

The Draft EIR fails to address impacts to the California Horned Lark (*Eremophilia alpestris actia*) and its habitat. The California Horned Lark, as noted in the Draft EIR, Appendix C at 3-5, is listed as a state species of special concern and was observed on the project site during the April 2006 survey. Yet, the Draft EIR fails completely to analyze potential impacts to the species, such as the introduction of non-native species into adjacent natural habitat. The potential impacts to the California Horned Lark must be fully analyzed and avoided, or minimized and mitigated.

The Draft EIR fails to address impacts to the Northern Harrier (*Circus cyaneus*) and its habitat. The Northern Harrier, as recognized in the Draft EIR, Appendix C at 3-5, is protected under the federal Migratory Bird Treaty Act and listed as a state species of special concern. The Northern Harrier was observed on the project site during the April 2006 survey. Harriers have declined in California in recent decades and the disturbances at the project site will likely affect the species. The Draft EIR must fully analyze, avoid, minimize, and mitigate the impacts to the Northern Harrier.

The Draft EIR fails to address impacts to the Bell's Sage Sparrow (*Amphispiza belli*) and its habitat. The Bell's Sage Sparrow, as noted in the Draft EIR, Appendix C at 3-4, is a state species of special concern. Yet, the Draft EIR fails completely to analyze the impacts to this species. Under CEQA the Draft EIR must analyze any potentially significant impacts to the Bell's Sage Sparrow and avoid or minimize and mitigate those impacts.

There is a complete lack of analysis regarding the project's impact on surrounding dairy barns. Many dairy barns are in fairly close vicinity of the project site. Bioaerosols, viruses, bacteria, dust, odor and flies from the site may migrate over to the barns, impacting the dairy cattle and impose respiratory and other risks. The revised EIR must address the impact to these biological resources and proper mitigation.

IV. THE DRAFT EIR'S ANALYSIS OF AIR QUALITY IS INADEQUATE

The proposed project will create significant impacts to the quality of the air at the project site and the throughout the region. The construction and operation of the facility will result in air pollution which threatens the well-being of endangered and sensitive species, nearby residents, and employees. Additionally, the project will result in greenhouse gas emissions that will contribute to global climate change and foul odors.

Although the Draft EIR recognizes that the proposed project will cause air pollution, and that it will have a significant, negative effect on local and regional air quality, it underestimates the scope of those negative impacts, and inadequately analyzes ways to avoid or mitigate them. The Draft EIR explains the state and federal Clean Air Act regulatory framework, but then fails to conduct a complete analysis of the project's air quality impacts. The fact that other agencies have regulatory control over some aspects of air pollution pursuant to other statutes in no way lessens the County's responsibility to fully disclose, analyze, avoid, minimize, and mitigate all air quality impacts of the proposed project.

The Draft EIR recognizes that the proposed project lies within the Mojave Desert Air Basin ("MDAB"), and consults data from the Barstow monitoring station in determining whether recorded levels of gases exceed federal and state standards. As stated in the Draft EIR, the MDAB currently does not meet State and Federal ambient air quality standards for ozone and PM10. In addition to already existing emissions, the Draft EIR discusses the types and levels of air pollutants likely to emanate from the project site during construction and "operations," and concludes that such emissions will have significant negative impacts on air quality. Draft EIR at 4-21. The project will also generate offensive odors and significant dust.

The impacts of air pollution are much more far-reaching and dangerous than the mere violation of an air quality standards might suggest. Polluted air causes short and long term health problems for people and other species, and affects the environment locally, regionally and globally.[2] Regionally, air pollution affects human health and the environment. Air pollution causes a litany of problems, from poor visibility to health problems to nitrogen deposition.

Globally, human-induced air pollution is causing climate change. This fact is no longer subject to credible debate. In 2001, the Intergovernmental Panel on Climate Change ("IPCC") concluded that over the next century, average global temperatures will rise between 2.5 and 10.5 degrees Farenheit.[3] Dr. Rajenda Pachauri, chairman of the IPCC, has stated that the world has "already reached the level of dangerous concentrations of carbon dioxide in the atmosphere," and that "[w]e are risking the ability of the human race to survive."[4] Tangible evidence that the world is getting warmer can be found in the Arctic, where the sea ice has been declining (melting and not re-freezing) a staggering 9% per decade. Polar bears and other Arctic species are dwindling as their habitat literally melts from under them. Even under conservative estimates, scientists say Arctic winter temperatures could rise as much as eighteen degrees Fahrenheit, eliminating year-round ice completely by the end of the century.[5]

In discussing the air quality impacts, the Draft EIR concludes that projected emissions from the proposed project will violate state and federal air quality standards. However, it falls far short of a complete discussion of the impacts. The CEQA Guidelines provide that, in discussing the environmental effects of a project, an EIR must include "a sufficient degree of analysis to provide decision makers with information which enables them to make a decision which intelligently takes account of

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[2] Environmental Working Group: Sharp, R. and B. Walker. *Particle Civics: How Cleaner Air in California Will Save Lives and Save Money.*

[3] 4 IPCC, *Climate Change 2001: The Scientific Basis.* Cambridge University Press. (2001)

[4] The Independent, *Global Warming Approaching Point of No Return, Warns Leading Climate Expert*, January 23, 2005.

[5] ACIA. 2004. *Impacts of a Warming Climate: Arctic Climate Impact Assessment*. Cambridge University Press. (2004)

environmental consequences." 14 Cal. Code Regs. § 15151. The Draft EIR fails to do so.

The Draft EIR correctly states that the U.S. EPA regulates six criteria pollutants under the Clean Air Act: ozone (O3), carbon monoxide (CO), oxides of nitrogen (NOx), oxides of sulfur (SOx), particulate matter (PM) and lead. Under the California Clean Air Act, the California Air Resources Board (CARB) regulates these same six criteria pollutants, in addition to sulfate, hydrogen sulfide, vinyl chloride, and visibility (a measure of air quality rather than a pollutant).

Ozone (O3) is the chief component of the common pollutant known as "smog." Ozone is formed when emissions including reactive organic gases (ROG) and oxides of nitrogen (NOx) undergo photochemical reactions in sunlight and are transformed to O3. Ozone irritates lung airways and causes inflammation of the skin resembling sunburn. Ozone causes wheezing, coughing, pain when taking a deep breath, and breathing difficulties during outdoor activities. Repeated exposure to ozone pollution for several months may cause permanent lung damage. Children, the elderly, and those with respiratory problems are at the most risk, but anyone who spends time outdoors may be affected. Even at very low levels, ozone triggers a variety of health problems including aggravated asthma, reduced lung capacity, and increased susceptibility to pneumonia and bronchitis. Ozone also interferes with the ability of plants to produce and store food, which makes them more susceptible to disease, insects, and weather, and damages the leaves of trees and plants, ruining the appearance of cities, national parks, and recreation areas. Ozone also reduces crop yields, and is, in fact, responsible for 98% of air quality related crop damage in California.[6] A revised EIR must discuss the proposed project's production of ozone precursor emissions and the direct, indirect, and cumulative impact both on human health and on vegetation and wildlife habitat, especially habitat for threatened, endangered, and sensitive species.

The Draft EIR concludes that the MDAB does not meet the State and Federal air quality standards for Ozone (O3) and PM10. Further, the project's emissions would exceed all thresholds during project operations and this impact was found to be significant and unmitigable. Under CEQA, the Draft EIR must discuss the lead agency's reasons for choosing to tolerate these impacts rather requiring an alternative design. The Draft EIR fails to do this and also fails to adequately address possible mitigation measures for project emissions.

Particulate matter (PM) is a category of pollutant which includes the respirable particles suspended in the air. PM is classified into "coarse" particles, PM10, or those under 10 microns in diameter, and "fine" particles, PM2.5, or those under 2.5 microns in diameter, and comes from a variety of sources including diesel exhaust, windblown dust from agriculture and construction and motor vehicles. Because the human respiratory system's ability to filter out harmful particles decreases as particles size decreases, the smallest particles lodge deepest in the lungs and are especially dangerous. PM can

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[6] Environmental Working Group: Sharp, R. and B. Walker. Particle Civics: How Cleaner Air in California Will Save Lives and Save money.

contain at least 40 toxic chemicals including heavy metals, nitrates, sulfates, and aerosols, as well as soot, soil, and dust. PM is associated with extreme health consequences. PM causes premature death, causes and aggravates asthma, increases coughing, painful breathing, and chronic bronchitis, and decreases lung function. Lung inflammation caused by inhaling PM can also lead to changes in heart rhythm, constriction of blood vessels, blood coagulation, and increased risk of heart attacks. Unlike what is believed about some other air pollutants, there is no "safe" level of PM pollution: even very low levels of PM lead to health impacts.[7]

The Draft EIR fails to adequately address Particulate Matter, particularly the impact it creates for asthmatics and children. In discussing mitigation by way of placing the project area in an enclosed facility, the Draft EIR dismisses such a measure because it will not reduce emissions to an amount that will make the impact less than significant. However, just because enclosing the project will not make the project's emissions less significant does not mean there is no mitigation value in implementing such a measure – minimizing impacts is also required under CEQA.

An EIR must reflect a good faith effort to evaluate and disclose environmental impacts, address mitigation measures to reduce the impacts, and discuss alternatives to avoid the impact if it is unmitigable. 14 Cal Code Regs §15362. The Draft EIR fails to adequately address alternatives for unmitigable significant impacts to air quality and therefore does not sufficiently seek to avoid the project's significant environmental impacts. As discussed below, the Draft EIR completely fails to address building an enclosed composting facility either on this site or close to the sewage treatment plants rather than trucking the sludge out to the proposed site and significantly impacting the air quality of the MDAB with the plant's operations and truck emissions. Further, even if the lead agency found such an alternative infeasible, it is required to briefly explain the infeasibility and has failed to do so.

The lead agency fails to adequately analyze the No Project Alternative in relation to air quality impacts. The Draft EIR claims that the sewage sludge will have to be sent elsewhere if the project is not developed and that impacts to air quality may be "less than, comparable to or greater than those predicted for the proposed Project." Draft EIR at 4-27 (4.3.4.1). However, there is no information provided in the Draft EIR to support or clarify these claims and thus, the analysis of the No Project alternative is inadequate under CEQA. The Reduced Capacity alternative fails to mitigate the impacts of the project to insignificant levels and the Fort Cady site would produce emissions virtually identical to the proposed project. Therefore, the Draft EIR fails to provide an environmentally superior alternative apart from the No Project alternative, as required by CEQA. 14 Cal Code Regs §15126.6(e)(2).

The proposed project will do nothing to improve local, regional or global air quality, and everything to further degrade them all. The City must consider alternatives as

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[7] American Lung Association, American Lung Association State of the Air, 2002

well as adequate mitigation options. Mitigation measures may not be voluntary, and they must be effective.

The City must consider requiring alternative energy sources to be integrated into the proposed project, including such elements as solar power and using vehicles that run on alternative fuels like biodiesel for employee and sewage transportation.

Methane is a leading greenhouse gas. According to NASA, methane's effect on warming the global climate may be double what it is currently believed to be. Methane leads to increased air pollution and smog, which in turn effects the world's climate. [8]

The Draft EIR fails to adequately address Methane Capture as a mitigation measure. The proposed project will likely emit 34.5 lbs. of methane per ton of sewage processed at the facility. Acknowledging that in order to eliminate emissions the project must employ a system of capture and thermal destruction by a control device, the Draft EIR simply concludes that such mitigation measures would render the project economically infeasible. Besides a brief mention, the Draft EIR failed to adequately discuss methane capture and explain why this mitigation measure is economically unfeasible. Indeed other facilities use captured methane for co-generation of energy. This alternative is not mentioned at all and no explanation is provided for this oversight. The revised EIR must fully address methane capture and, if necessary, explain why the County believes that this option is infeasible.

The Draft EIR fails to adequately address composting requirements for windrow composting set forth by the EPA, particularly in the 503 Regulations.[9] The requirements set out in 503 are in accordance with the time-temperature relationship between the sludge and the turning of the windrows. The requirements were created to limit emissions and permanent effects they may have. In order to comply with federal and state law, the Draft EIR must fully address the 503 Regulations and assure that the project conforms to them.

In regards to the issue of odor, the Draft EIR fails to adequately address alternatives that would avoid this impact or minimization and mitigation measures. The mitigation measures suggested fail to include the option of completely enclosing the facility, which would significantly aid in controlling the offensive odors generated by the project.

The Draft EIR fails to address adequate mitigation measures for truck and automobile emissions which will result from the project. The trucks used to haul the waste to and from the project area, as well as the trucks used to construct the facility could potentially run on biodiesel fuels, reducing the emissions that contribute to the

[8] National Aeronautics and Space Administration (NASA), *Methane's Impacts on Climate Change May Be Twice Previous Estimates*. 2005.
[9] EPA 503 Regulation, 40 CFRPT 503, 1993

project's overall impact to air quality. This alternative that could avoid many of the project's impacts to air quality and greenhouse gases must be analyzed in the DEIR.

III. THE DRAFT EIR'S ANALYSIS OF HYDROLOGY AND WATER QUALITY IS INADEQUATE

The proposed composting facility will utilize limited water resources and potentially contaminate surface water with runoff from the windrows. Construction and operation of the project will create risks of significant impact to water quality, which will affect the local ecosystem and residents.

The Draft EIR fails to adequately address significant impacts created by the proposed project and to suggest adequate alternatives or proper measures to minimize or mitigate such impacts. As recognized by the Draft EIR, the project site is located in the Mojave groundwater basin – an area in sever overdraft. As such, the EIR must evaluate the project to determine whether it will have any impact on the groundwater, and consequently, on the health and safety of residents who depend on that water.

CEQA guidelines establish that a significant impact is expected if the project substantially downgrades water quality. CEQA Guidelines, §15064. The relocation of hundreds of thousands of tons of sewage waste over an aquifer creates the risk of contamination and therefore presents potential significant impacts. The Draft EIR fails to adequately analyze the potential impact of the project by considering only the lesser potential impact rather than the worse case scenario in each assessment. 14 Cal Code Regs §15126.2(a).

The Draft EIR fails to adequately address alternatives and therefore does not sufficiently seek to avoid the project's significant impacts to water quality. As discussed below, the Draft EIR completely fails to address building an enclosed composting facility on this site or close to the sewage treatment plants rather than trucking the sludge out to the proposed site and significantly impacting the ground and surface water in the area, which the residents of Hinkley as well as native species and migrating birds rely upon. Further, even if the lead agency found such alternatives infeasible, it is required to explain the infeasibility and has failed to do so.

The Draft EIR improperly defers identification and analysis of many of the project's impacts, as well as formulation of mitigation measures, to a later time. This deferral frustrates informed decision-making and violates CEQA. "An EIR should be prepared with a sufficient degree of analysis to provide decision-makers with information which enables them to make a decision which intelligently takes account of environmental consequences." CEQA Guidelines § 15151. *See Concerned Citizens of Costa Mesa, Inc. v. 32nd District Agricultural Association*, 42 Cal. 3d 929 (1986) ("the EIR must contain facts and analysis, not just the agency's bare conclusions or opinions."); *Berkeley Keep Jets Over the Bay Committee v. Board of Port Commissioners*, 91 Cal.App.4th 1344 (2001); *Stanislaus Natural Heritage Project v. County of Stanislaus*, 48 Cal. App. 4th 182 (1996).

CEQA guidelines require environmental analysis "as early as feasible in the planning process to enable environmental considerations to influence the project program and design." CEQA Guidelines, § 15004, subd. (b). The Courts have consistently reiterated that concern:

> [e]nvironmental problems should be considered at a point in the process "where genuine flexibility remains." A study conducted after approval of a project will inevitably have diminished influence on decision-making. Even if the study is subject to administrative approval, it is analogous to the sort of post hoc rationalization of agency actions that has been repeatedly condemned in decisions construing CEQA.

Sundstrom v. County of Mendocino (1988) 202 Cal.App.3d 296,307 (citations omitted).

One of the mitigation measures proposed is to prepare a Storm Water Pollution Prevention Plan ("SWPPP") in order to obtain coverage under a National Pollution Discharge Elimination System ("NPDES") permit. The DEIR states that the SWPPP shall be prepared and implemented prior to disturbing a site.[10] However, while compliance with the NPDES permitting is necessary, it does not excuse the County to from analyzing impacts to water resources in the EIR. Under CEQA those impacts must be fully addressed in the EIR, the commitment to obtain a permit notwithstanding.

The Draft EIR provides an inadequate analysis of the use of water for the project and its potential impact. There is no specification whether the project will use the groundwater or import water to the site. Draft EIR at 2-18. If a well is installed, the Draft EIR suggests that 1,000 gallons will be used per day but fails to explain how that figure was calculated. Does this figure account for the water which will be used by employees to clean their hands and shower? Does it account for water which must be kept on hand and potentially used for fire firefighting? Moreover, the DEIR fails to analyze the impacts of such extractions on the local aquifer that is already over-drafted and fails to clearly state that the needed water may not be available for the life of the proposed project. If imported water is needed, the impacts of taking that water from other areas must be fully addressed in this DEIR as well.

The Draft EIR concludes that the quantity of water needed for the project would be considered a very small amount but gives no basis or support for claiming that the use of water by the project will be insignificant and certainly provides no cumulative analysis that would support this claim. The project site exists in a desert climate where the surrounding region relys almost entirely on groundwater for its water supply. To conclude that any new use of groundwater will be insignificant without supporting figures is insufficient. Further the only "mitigation measure" is monitoring, collecting a

[10] National Pollutant Discharge Elimination System General Permit for Storm Water Discharges Associated with Construction Activity (general permit) Water Quality Order 99-08-dWQ

sample from the groundwater well for only one year even though there is potential for the project to expand over time. Draft EIR at 4-61. This is inadequate under CEQA.

The Draft EIR fails completely to address the issue of truck cleaning and the subsequent water runoff. The trucks carrying the sewage waste will have to be cleaned and the water used to clean the trucks will consequently contain runoff from the biosolids that may contain pathogens that could contaminate surface waters. The revised EIR must address this aspect of the project and all necessary alternatives to avoid, minimize or mitigate such impacts. For example, the EIR must address whether the retention basins, proposed as a measure to mitigate runoff from the windrows during rains, will also be sufficient contain runoff from the cleaning of trucks or any other vehicle containing possible contaminants. Additionally, the amount of water needed to perform the service of cleaning trucks which come to and from the project site is sure to number in the thousands of gallons. This affects the water use analysis, which as stated above, was inadequate to begin with.

IV. THE DRAFT EIR'S ANALYSIS OF HAZARDS AND HAZARDOUS MATERIAL IS INADEQUATE

Numerous impacts are posed by the hazards and hazardous materials resulting from the construction and operation of the proposed project. Potential impacts include, fuel leaks and spills, exposure to pathogens and allergens, fire danger and risks from seismic activities.

The analysis of impacts and mitigation measures regarding hazards and hazardous materials is insufficient under CEQA. The Draft EIR fails to adequately analyze all likely hazards created by the project, rendering it invalid. Under CEQA guidelines, the project will result in a significant impact if it will "create a significant hazard to the public or the environment through the routine transport, use, or disposal of hazardous materials" and "creates a significant hazard to the public or the environment through reasonable foreseeable upset and accident conditions involving the release of hazardous materials into the environment." CEQA Guidelines, Appendix G.

The Draft EIR fails to adequately address alternatives and therefore does not sufficiently seek to avoid the project's significant environmental impacts resulting from hazards and hazardous materials. As discussed below, the Draft EIR completely fails to address building an enclosed composting facility close to the sewage treatment plants rather than trucking the sludge out to the proposed site and significantly impacting the habitat, residents, and species both at this site and along the truck route with the hazards and hazardous materials due to the project. Further, even if the lead agency found such an alternative infeasible, it is required to explain the infeasibility and has failed to do so.

The Draft EIR fails to adequately analyze leaks and spills resulting from storage, transfer or fueling activities. The analysis of potential materials that could leak or spill is limited to a general reference of "hazardous materials" without fully delineating the particular materials, what hazards they present and where they could potentially spill or leak. Biosolids, which will be transported to the project site, may contain human pathogens (i.e. viruses, bacteria, and parasites). Draft EIR at 4-49. Should the truck transporting the biosolids spill any of the material on or off site, or the drums storing the biosolids or fuel should leak or spill, a significant hazard to the public and environment is created. Therefore, the project creates a significant impact which the Draft EIR must adequately address, seek to avoid and minimize or mitigate if unavoidable.

The Draft EIR fails to adequately address mitigation measures for the storage and transfer of hazardous materials by improperly deferring identification and analysis of the Spill Prevention, Control and Countermeasure Plan and the Emergency Contingency Plan to a later time. This deferral frustrates informed decision-making and violates CEQA. CEQA guidelines require environmental analysis "as early as feasible in the planning process to enable environmental considerations to influence the project program and design." CEQA Guidelines, § 15004, subd. (b). The Draft EIR must address the measures that will be undertaken to avoid or minimize and mitigated this significant impact by including precise information concerning elements of the Plan such as; evacuation procedures, guidelines for transfer operations, containment, clean-up, reporting of spilled liquids containing hazardous materials, inspections of containers and secondary containment areas. In addition, the DEIR must explain how the project proponents will ensure that there are sufficient resources to handle spills that may occur along the truck routes.

In its discussion of the fire danger created by the project, the Draft EIR fails to adequately analyze all of the ways the project may contribute to such a danger and fails to analyze sufficient mitigation measures. The Draft EIR discusses the fire danger created by the heat of materials being composted in the windrows but completely fails to analyze the fire danger elevated by increased non-native weeds which will result from the project. The sludge, which contains high levels of phosphorus and nitrogen, can increase the growth of plants, including invasive weeds which, when they die off, elevate the fire danger. The revised Draft EIR must analyze this fire danger and appropriate mitigation measures. Additionally, one of the mitigation measures for fire hazard is keeping an adequate water supply on site for fire suppression. Because the Draft EIR fails to account for the amount of water required, the analysis of hydrology and water quality is rendered inadequate.

The Draft EIR falsely claims that the potential hazard to human health, created by exposure to the fungus Aspergillus, is limited because the site is not open to the general public. Draft EIR at 4-49. However, the Draft EIR does not mandate that workers' clothing must be left on site and properly cleaned. Nor does it mandate that workers properly shower and disinfect themselves before leaving the site. Because of this, the fungus and other allergens may reach and effect high-risk individuals, particularly in the nearby town of Hinkley. In addition, high winds which are not unusual in this area, are likely to create a risk of exposure downwind.

As the County is well aware, the town of Hinkley suffered toxic contamination of their water supply from the chemical Chromium 6, which imperiled residents with incapacitating and fatal illnesses. The community and environment is still recovering from the contamination of the water. The Draft EIR acknowledges that those who are immuno-compromised may be at greater risk of infection from the fungi and allergens introduced into the area by the project. Draft EIR at 4-49. Thus, the project poses a potentially harmful effect on the residents of Hinkley and this significant impact must be adequately analyzed and mitigated.

The Draft EIR completely fails to address the seismic risk created by the location of the project site. This is an area of high seismic activity and the disruption of the soil and cracks in containment facilities need to be considered. The revised Draft EIR must include an analysis of this risk and proper mitigation measures.

V. THE DRAFT EIR COMPELTELY FAILS TO ADDRESS ISSUES OF ENVIRONMENTAL JUSTICE

According to the EPA,

> Environmental Justice is the fair treatment and meaningful involvement of all people regardless of race, color, national origin, or income with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies. EPA has this goal for all communities and persons across this Nation. It will be achieved when everyone enjoys the same degree of protection from environmental and health hazards and equal access to the decision-making process to have a healthy environment in which to live, learn, and work.

http://www.epa.gov/environmentaljustice/index.html

The Draft EIR does not explain where the sewage sludge is coming from, yet it is clear who is bearing the cost. The people of Hinkley and those living in the general area of the project site are the ones who will suffer the negative impact of having a waste facility so near to their homes. The significant impact the project will have on the air quality of this desert environment, which already suffers from poor air quality, will in turn have a significant impact on the respiratory health of the citizens who reside nearby.

The project calls for open air composting, which is prohibited in many areas of California. The project will likely sacrifice the health and standard of living of Hinkley's residents so that a cheaper facility can be built and the people of wealthier communities in the County and of other Counties, like Los Angeles and Orange County, do not have to suffer the ill effects of having such a facility in their community. All areas should be processing and managing their own sewage waste in enclosed facilities, which can be equipped with biofilters and air quality controls. Hauling sludge to rural communities that are not equipped to defend themselves and their environment is an example of environmental injustice and should not be permitted. The Draft EIR should evaluate this aspect of the project.

This project is not the first time Nursery Products has attempted to operate a composting facility in a rural desert town. The sludge composting facility built in Adelanto, which was significantly smaller than the project proposed here, generated numerous complaints of illness, flies, dust, and odor and, in a settlement agreement, was ultimately forced to stop receiving sludge and close. Nursery Products was cited by the city for violating the Adelanto Municipal Code, the Uniform Building Code. The Adelanto City Council found that Nursery Products had presented the project incorrectly, such that the EIR may have been inadequate, and the project had not complied with conditions of approval and mitigation measures. [11] Some residents were so ill they had to abandon their homes altogether.

The population of Hinkley is 38% Hispanic and yet there is no version of the Draft EIR available in Spanish. [12] Therefore, Spanish speaking citizens have been unable to equally participate in the process or submit comments on the Draft EIR. Furthermore, the recent letter notifying those concerned that the comment period has been extended was in both English and Spanish, thus the County has acknowledged the need to post any information concerning the project in both languages. The County should re-issue and re-circulate an adequate Draft EIR in both English and Spanish.

VI. THE DRAFT EIR'S ANALYSIS OF ALTERNATIVES IS INADEQUATE

CEQA demands that an EIR identify both feasible alternatives and mitigation measures that could avoid or reduce the project's significant environmental effects. (Pub. Res. C §21002, 21002.1(a), 21100(b)(4), 21150). The EIR must describe a reasonable range of alternatives to the project or its location that would feasibly attain most of the objectives while avoiding significant effects. (14 Cal. Code Regs §15126.6(a)). CEQA requires that the Draft EIR contain sufficient information about each alternative in order for the alternative to be adequately evaluated. 14 Cal Code Regs §15126.6(a). The analysis of each alternative must contain concrete information about each alternative in order for a fact-based comparison to be drawn between the project and the alternative. 14 Cal Code Regs §15126.6 (d). The EIR must discuss alternatives even if the significant impacts will be avoided or reduced by mitigation. *Laurel Heights Improvement Ass'n v. Regents of Univ. of Cal*. 47 Cal. 3d 376 (1988). Additionally, the EIR must briefly identify alternatives rejected as infeasible and explain why they were rejected. 14 Cal. Code. Reg. §15126.6 (c).

The Draft EIR recognizes three System Alternatives: Modifying or expanding current management practices, Conversion technologies, and Alternative composting technology. However, these alternatives are not analyzed in sufficient detail, making the Draft EIR inadequate in its analysis of alternatives as required by CEQA.

Within "current management practices" there are three potential alternatives that could compost "green materials": development of composting operations at one of the

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[11] Battersby, M. City Attorney for the City of Adelanto: Letter to Daniel Avera/Nursery Products Composting Facility, City of Adelanto (Nov. 7, 2003).
[12] http://www.co.san-bernardino.ca.us/demographics.htm

major County landfills; promoting the expansion of one or more of the existing private composting operations; or relying on the new facility in Rancho Cucamonga. The Draft EIR acknowledges that all three of these alternatives are possible but claims that none of them are capable of handling the amount of biosolids necessary, within a reasonable time frame and in a comparably remote location, as the proposed Project. This assertion is unsupported by sufficient data, namely any evidence to dismiss that possibility that existing facilities could *potentially* accommodate the necessary composting. Claiming these options are insufficient also undermines the Draft EIR's analysis of a Reduced Capacity alternative, which recognizes a project that processes less waste as a feasible option.

The Draft EIR acknowledges that alternative conversion technologies for waste, such as hydrolysis, gasification and anaerobic digestion, are possible. The County notes that these conversion technologies result in fuels rather than compost. Draft EIR at 3-4. The DEIR claims that the Inland Empire is in need of compost but fail to explain why there is no need for fuels – given the high consumption of fuels in the region, this statement makes no sense whatsoever. Furthermore, it should be noted that Nursery Products, the company proposing the project, is a company that processes and sells compost and has current customers who rely on their compost. Draft EIR at 3-5. However, the proponent's business model cannot be allowed to control the alternatives studied in the EIR. If fuel production is a feasible alternative, it must be examined.

The Draft EIR discusses three potentially feasible Project Specific alternatives: No Project alternative, Reduced Capacity alternative, and Fort Cady site alternative. These three alternatives do not represent a reasonable range as required by CEQA. The EIR must "give reasonable consideration to alternatives in light of the nature of the project." *City of Rancho Palos Verdes v. City Council,* 59 Cal. App. 3d 869 (1976). The Draft EIR completely fails to address the alternative of placing an enclosed composting facility near the treatment plants where the waste is originating, or enclosing the facility at this site both of which should be considered in light of the nature of the project. If the County considered these alternatives and rejected detailed review for some reason (such as economic infeasibility), the Draft EIR fails explain that any such consideration was undertaken in violation of CEQA.

The Draft EIR fails to adequately analyze the three proposed project specific alternatives and therefore does not sufficiently seek to avoid the project's significant environmental impacts as required under CEQA.

The analysis of the No Project alternative fails to meet the requirements mandated under CEQA by not adequately discussing the existing conditions at the site or projecting what would reasonably be expected to occur in the foreseeable future if the project was not approved. 14 Cal Code Red §15126.6(e)(2) and (3)(3)(C). The lead agency alludes to rejection of the No Project alternative because increasing amounts of sewage waste must be composted and if it is not processed at the proposed site it will be processed elsewhere. Draft EIR at 3-5. However, there is no information included in the Draft EIR to support the claim that there is a growing need to treat and manage biosolids for composting (and not, for example, for fuel production) or that there is a need to have the treatment occur so far from the plants that produce the waste. Therefore a fact-based comparison between the project and no project is not possible.

The Reduced Capacity alternative proposes to reduce the project's capacity from 400,000 to 320,000 tons of sewage per year and reduce the project site from 160 acres to 80 acres. This alternative will still present significant impacts to protected species like the Desert Tortoise and create emissions that would add to the problems already facing the air quality in the MDAB.

The Fort Cady site presented as an alternative would create comparable significant impacts, and therefore, is not an adequate alternative. The purpose of requiring the EIR to discuss alternatives is to identify ways that significant environmental effects can be avoided or mitigated. *Laurel Heights Improvement Ass'n v. Regents of Univ. of Cal*. 47 Cal. 3d at 403. The alternatives that are addressed by the EIR should be ones that present a substantial environmental advantage over the proposed project. *Citizens of Goleta Valley v. Board of Supervisors*, 52 Cal. 3d 533, 566 (1990). The Fort Cady site is not a suitable alternative to meet these requirements, and as such, the range of alternatives is not reasonable, as required under CEQA.

VII. THE DEIR FAILS TO ANALYZE AND MITIGATE GREENHOUSE GAS EMISSIONS FROM THE PROJECT

The Draft EIR fails to sufficiently mention and discuss climate change, greenhouse gases or global warming. This is a significant omission and must be remedied in a revised EIR.

A. Global Warming is one of the Greatest Problems Facing California and the World

Concentrations of greenhouse gases are increasing in the earth's atmosphere, primarily from society's burning of fossil fuels for energy and destruction of forests for other human activities. These gases cloak the earth like a blanket, absorbing solar radiation that would otherwise be radiated back into space, causing the earth's climate to warm much like the interior of a greenhouse. This phenomenon is called global warming and is leading to profound changes in the earth's climate. The world's leading scientists agree that society's production of greenhouse gases, including carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), is responsible for the unprecedented rate of warming observed over the past century. (ACIA 2004; IPCC 2001).

Carbon dioxide accounts for approximately 85% of total emissions, and methane and nitrous oxide together account for almost an additional 14%. Because of the persistence and mixing of these gases in the atmosphere, emissions anywhere in the world impact the climate everywhere equally. Therefore, the impact of greenhouse gas emissions produced in California (the 12th largest emitter in the world) will impact not only California, but the rest of the world as well. In the absence of substantial reductions in greenhouse gas emissions, global warming and its impacts on human health, the environment, and the economy will rapidly worsen in this century.

1. Rising Global Average Temperatures

The Intergovernmental Panel on Climate Change ("IPCC") has concluded that the global average temperature has risen by approximately 0.6° C ± 0.2 C during the 20th Century (IPCC 2001). There is an international scientific consensus that most of the warming observed has been caused by human activities (ACIA 2004; IPCC 2001). Carbon dioxide emissions, carbon dioxide concentrations, and temperature over the last 1,000 years are all correlated (ACIA 2004). Mean temperatures during the 20th century were the highest in 1,000 years (Albritton et al. 2001). Global climate has changed in other ways as well. For example, precipitation has increased by 0.5 to 1% per decade in the 20th century over most mid- and high latitudes of the Northern Hemisphere continents, and to a lesser degree over the tropical land areas in the Northern Hemisphere (IPCC 2001).

Global average temperature increases mask significant regional variation. Due to a number of positive feedback mechanisms, warming in the Arctic has been and will be greater and more rapid than in the rest of the world (ACIA 2004). Warming in the Arctic is in many ways a harbinger of what is to come in other areas. Changes already observed in some areas of the Arctic dwarf global averages. In extensive areas of the Arctic, air temperature over land has increased by as much as 5° C (9° F) over the 20th century (Anisimov et al. 2001).

All climate models predict significant warming in this century, with variation only as to the rate and magnitude of the projected warming (ACIA 2004). Determining the degree of future climate change requires consideration of two major factors: (1) the level of future global emissions of greenhouse gases, and (2) the response of the climate system to these emissions ("climate sensitivity") (ACIA 2004a). Global warming will continue and accelerate if greenhouse gas emissions are not reduced.

As hard data are not available for events that have not yet occurred, the future level of society's greenhouse gas emissions must be projected. The IPCC has produced a Special Report on Emissions Scenarios ("SRES") (Nakićenović et al. 2000) that describes a range of possible emissions scenarios based on how societies, economies, and energy technologies may evolve, in order to study a range of possible scenarios (ACIA 2004a; Albritton et al. 2001).

Climate models make different assumptions regarding how various aspects of the climate system will respond to increased greenhouse gas concentrations and warming temperatures. These differing assumptions are expressed as "climate sensitivity," defined as the equilibrium response of global mean temperature to doubling levels of atmospheric carbon dioxide (Stainforth et al. 2005). The IPCC (2001) used climate sensitivities of 1.3-5.8K for projections of warming from 1990-2100 (Stainforth et al. 2005).

Using the SRES emissions scenarios and the world's leading climate models, the IPCC predicts that the global average temperature will warm between 1.4 and 5.8°C by the end of this century. Warming will be greater in the Arctic, where the annual average temperatures will rise across the entire Arctic, with increases of approximately 3-5° C over the land areas and up to 7° C over the oceans. Winter temperatures are projected to rise even more significantly, with increases of approximately 4-7° C over land areas and approximately 7-10° C over oceans (ACIA 2004a). Year-to-year variability is also projected to be greater in the Arctic than in other regions (ACIA 2004a).

For a number of reasons, IPCC (2001) and ACIA (2004) projections may be significant underestimates of the amount and rate of warming. First, the planet is already committed to an additional 1° F warming from the excess solar energy already in our climate system, due to lag time in the climate response (Hansen 2005). Second, actual worldwide greenhouse gas emissions may be on the high end or above the range of the IPCC scenarios. All scenarios utilized by the IPCC assume that energy use will shift away from fossil fuels to a greater percentage of sustainable energy sources and that worldwide greenhouse gas emissions will begin to decline during this century (IPCC 2001). Yet the most recent energy projections show that if current policies continue, worldwide greenhouse gas emissions will be 52% higher in 2030 than they are today (IEA 2005).

Third, climate sensitivity may be substantially greater than the levels used by IPCC (2001). Results from the *climateprediction.net* experiment indicate that much larger climate sensitivities of up to 11.5K are possible (Stainforth et al. 2005). Chapin et al. (2005) studied the warming amplification caused by the expansion of shrub and tree cover in the Arctic and resulting increase in solar absorption. This amplification could be as much as two to seven times (Chapin et al. 2005), and is not accounted for in the climate models used in IPCC (2001) (Foley 2005).

Recent data on the unexpectedly fast rate of warming in the Arctic also reinforces the likelihood that the IPCC (2001) projections will need to be revised upwards. (Overpeck et al. 2005) concluded that the Arctic is on a trajectory towards an ice-free summer state within this century, a state not witnessed in at least the last million years (Overpeck et al. 2005). These scientists conclude that there are few, if any processes or feedbacks within the arctic system that are capable of altering the trajectory toward this ice-free summer state. In September, 2005, scientists reported a new record Arctic sea-ice minimum for the month of September (NSIDC 2005). These scientists called the sea ice reduction "stunning" and concluded that Arctic sea ice is likely on an accelerating, long-term decline (NSIDC 2005).

2. The Impacts of Global Warming Generally

Global warming consists of more than just increases in global average temperature. In 2001 the IPCC predicted a 90-99% chance of the following weather changes:

- Higher maximum temperature and more hot days over nearly all land areas;
- Higher minimum temperatures, fewer cold days and frost days over nearly all land areas;
- Reduced diurnal temperature range over most land areas;
- Increase of heat index over land areas;
- More intense precipitation events.

Albritton et al. 2001.

The IPCC also predicted a 66-90% chance of the following:

- Increased summer continental drying and associated risk of drought;
- Increased in tropical cyclone (hurricane) peak wind intensities;
- Increase in tropical cyclone mean and peak precipitation intensities.

Albritton et al. 2001.

Greenland ice cores indicate that the climate can change very abruptly. Scientists caution that thresholds may be reached that trigger rapid and extreme climatic changes that are difficult to predict but could be devastating. Examples include the shut down of the North Atlantic thermohaline circulation, which transfers heat from the equatorial regions to the Arctic, which could plunge northern Europe into a new ice age. The more rapid melting of the Greenlandic ice sheet, once thought to be several centuries away, could trigger this impact and also result in global sea level rise of up to six meters, completely eliminating many coastal areas. As in the case of the shift to an ice-free Arctic summer, scientists warn that we may be very close to crossing thresholds of rapid climate change from which there is no return.

Increased intensity of precipitation events due to global warming has long been predicted by climate models and remains a consistent result of the most advanced modeling efforts (Cubasch and Meehl 2001). In global simulations for future climate, extreme precipitation events over North America are predicted to occur twice as often (Cubasch and Meehl 2001).The impacts of global warming, once envisioned to be experienced by future generations, are already upon us, bringing profound climactic and ecological changes, great loss of human life, and likely extinction for many of the planet's non-human species. As written recently in the New England Journal of Medicine,

> Since [the release of the *Third Assessment Report* in] 2001, we've learned substantially more. The pace of atmospheric warming and the accumulation of carbon dioxide are quickening; polar and alpine ice is melting at rates not thought possible several years ago; the deep ocean is heating up, and circumpolar winds are accelerating; and warming in the lower atmosphere is retarding the repair of the protective "ozone shield" in the stratosphere….Given the current rate of carbon dioxide build-up and the projected degree of global warming, we are entering uncharted seas.

> As we survey these seas, we can see some of the health effects that may like ahead if the increase in very extreme weather events continues. Heat waves like the one that hit Chicago in 1995, killing some 750 people and hospitalizing thousands, have become more common. Hot, humid nights, which have become more frequent with global warming, magnify the effects.

Epstein 2005.

In 2002, more than 1,000 people died in a spring heat wave in India (Gelbspan 2004). In the spring of 2003, 1,400 people died in another heat wave in India and Pakistan. Also in 2003, a summer heat wave in Europe killed between 21,000-35,000 people (Epstein 2005).

In 1998, Hurricane Mitch dropped six feet of rain on Central America in three days, and was followed by soaring incidences of malaria, dengue fever, cholera, and leptospirosis (Epstein 2005). In 2000, after rain and three cyclones hit Mozambique over a six week time period, the incidence of malaria rose by five times (Epstein 2005). In June, 2001, Houston suffered the single most expensive storm in modern history when tropical storm Allison dropped thirty-five inches of rain in one week, resulting in $6 billion in damages (Gelbspan 2004). In November, 2001, record flooding killed more than 1,000 people in Algeria (Gelbspan 2004). Also in 2002, more than 12 million people were displaced by severe flooding in South Asia (Gelbspan 2004).

In the Eastern United States, the effect of sea level rise over the last century (primarily from thermal expansion as the oceans warm) has also exacerbated the beach erosion and flooding from modern storms that would have been less damaging in the past (Folland and Karl 2001). In August, 2005, Hurricane Katrina killed hundreds and destroyed the city of New Orleans (Epstein 2005). Katrina was quickly followed by Rita, and then Wilma, putting 2005 on track to setting a new record for hurricane season destruction.

While it may not be possible to link individual episodes to global warming, this overall pattern of increasingly violent weather is very likely linked to human-caused warming. But even more subtle, gradual changes can profoundly damage public health (Epstein 2005). During the past two decades, the prevalence of asthma in the United States has quadrupled, at least in part because of climate-related factors (Epstein 2005). Increased levels of plant pollen and soil fungi may also be involved, as experiments have shown that ragweed grown in twice the ambient levels of carbon dioxide produces 60% more pollen (Epstein 2005). High carbon dioxide levels also promote the growth and spore production of some soil fungi, and diesel particles then help to deliver these aeroallergens deep into human lungs (Epstein 2005).

Widening social inequities and changes in biodiversity caused by global warming have also contributed to the resurgence of many infectious diseases (Epstein 2005).

Global warming is credited with the current spread of Lyme disease, as well as malaria, hantavirus, and West Nile virus (Epstein 2005). Floods are also frequently followed by disease clusters, as downpours can drive rodents from burrows, deposit mosquito-breeding sites, foster fungus growth in houses, and flush pathogens, nutrients, and chemicals into waterways (Epstein 2005). Droughts also weaken trees' defenses against infestations and promote wildfires, which can cause injuries, burns, respiratory illness, and deaths (Epstein 2005).

Shifting weather patterns are jeopardizing water quality and quantity in many countries, where groundwater systems are overdrawn (Epstein 2005). Most montane ice fields are predicted to disappear during this century, further exacerbating water shortages in many areas of the world (Epstein 2005).

An even greater threat to human health comes from illnesses affecting wildlife, livestock, crops, forests, and marine organisms (Epstein 2005). One recent report found that 60% of resources examined, from fisheries to fresh water, are already in decline or being used in unsustainable ways (Epstein 2005). This is a grim prognosis indeed as global population continues to rise even as global warming accelerates.

As discussed further below, global warming will also have profound impacts on the earth's biological diversity and threatens many thousands of species. The primary prevention and mitigation of all of these climate impacts is to reduce the nation's energy use and halt the extraction, mining, transport, refining and combustion of fossil fuels (Epstein 2005). Experts believe that a substantial reduction in energy use would have innumerable health and environmental benefits along with stabilizing the climate (Epstein 2005).

3. The Impacts of Global Warming on Threatened, Endangered, Rare, and Special Species

Climate change is a leading threat to California and the world's biological diversity. Species have already been profoundly impacted by the worldwide average temperature increase of 1° Fahrenheit (.6° Centigrade) since the start of the Industrial Revolution (IPCC 2001). Yet the warming experienced to date is small compared with the 2.5- 10.4° F (1.4-5.8° C) or greater warming projected for this century. The ways in which climate change threatens species are varied and sometimes complex. Below we present an overview of impacts observed to date and projections for the future.

Scientists have predicted three categories of impacts from global warming: (1) earlier timing of spring events, (2) extension of species' range poleward or upward in elevation, and (3) a decline in species adapted to cold temperatures and an increase in species adapted to warm temperatures (Parmesan and Galbraith 2004). A recent survey of more than 30 studies covering about 1600 hundred species summarized empirical observations in each of these three categories and found that approximately one half of the species were already showing significant impacts, and 85-90% of observed changes were in the direction predicted (Parmesan and Galbraith 2004). The statistical probability of this pattern occurring by chance, as opposed to being caused by climate change, is less than one in a billion (Parmesan and Galbraith 2004).

Changes in the life cycles and behaviors of organisms such as plants blooming and birds laying their chicks earlier in the spring were some of the first phenomena to be observed. These changes may not be detrimental to all species, but depending on the timing and interactions between species, may be very harmful.

The Edith's checkerspot butterfly, which occurs along the west coast of north America, has been severely impacted by such changes in the lifecycles of organisms. The Edith's checkerspot's host plant, *Plantago erecta*, now develops earlier in the spring while the timing of caterpillar hatching has not changed. Caterpillars now hatch on plants that have completed their lifecycle and dried up, instead of on young healthy plants (Parmesan and Galbraith 2004). The tiny caterpillars are unable to move far enough to find other food and therefore starve to death (Parmesan and Galbraith 2004). Because of this, many Edith's checkerspot butterfly populations have become extinct. Many more populations have been lost in the southern portion of the species' range than in the northern portion, resulting in a net shift of the range of the species northward and upwards in elevation. All these changes have occurred in response to "only" 1.3° Fahrenheit regional warming (Parmesan and Galbraith 2004).

The southernmost subspecies, the Quino checkerspot butterfly, already listed as endangered under the Endangered Species Act due to habitat destruction from urban development and other impacts, has disappeared from nearly 80% of otherwise suitable habitat areas due to global warming (Parmesan and Galbraith 2004). The Bay checkerspot and Taylor's checkerspot butterflies, also listed under the Endangered Species Act, have been similarly impacted (Parmesan and Galbraith 2004).

Butterfly species are impacted in other ways as well. The northward expansion of the treeline into alpine meadow butterfly habitat can impede dispersal, fragment habitat, and increase mortality via bitterly collisions with the trees (Krajick 2004; Ross et al. 2005).

While theoretically some species can adapt by shifting their ranges in response to climate change, species in many areas today, in contrast to migration patterns in response to paleoclimatic warming, must move through a landscape that human activity has rendered increasingly fragmented and inhospitable (Walther 2002). When species cannot shift their ranges northward or to increased elevations in response to climate warming, they will become extinct (Parmesan and Galbraith 2004). Therefore, the least mobile species will be the first to disappear.

The pika is a small, vegetarian relative of the rabbit, which is adapted to life on high, treeless mountain peaks. Because pikas need cold, bare habitat, it is not surprising that their numbers are plummeting all over the globe (Krajick 2004). Fossil evidence shows that pikas once ranged widely over North America but their range has contracted to a dwindling number of high peaks during the warm periods of the last 12,000 years

(Krajick 2004). Alpine species like the pika are unable to shift their ranges as warming temperatures and advancing treelines, competitors, and predators impact their mountain habitat (Krajick 2004). Pikas are further limited by their metabolic adaptation to their cold habitat niche, which allows them to survive harsh winters but also causes them to die from heat exhaustion at temperatures as low as 77.9° F (25.5° C) (Krajick 2004).

American pika populations at seven of twenty-five previously recorded localities in the Great Basin of the western United States have disappeared in recent years (Beever 2003). Based on work conducted in the late 1990s, researchers documented that the average elevation of surviving pika populations was 8,310 feet, up from a pre-historic average of about 5,700 feet between 7,500 and 40,000 years ago (Beever 2003; Grayson 2005). Most recently, researchers announced in December, 2005, that at least 2 additional populations have become extinct, and the average elevation of surviving populations has increased by another 433 feet.

In the Yukon, collared pikas declined 90% between 1999 and 2000, when unprecedented midwinter snowmelts, rain, and refreezing eliminated the insulating snow and then iced over the pika's forage plants (Krajick 2004). A pika species endemic to the mountains of northwest China, discovered only in 1986, was not located in extensive surveys in 2002 and 2003 and may be extinct.

Alpine dwelling marmots which rely upon the treeless tundra to visually spot and avoid predators, are also at risk as treelines advance, providing cover for predators like wolves and cougars.

Alpine plants, which have little or no capability to shift their range to higher elevations as the climate warms, may be most at risk. One study predicts that a 3° Centigrade temperature rise over the next century will eliminate eighty percent of alpine island habitat and cause the extinction of between a third and a half of 613 known alpine plants in New Zealand (Krajick 2004).

A study of 15,148 North American vascular plants found that 7%-11% of all species (1,060 to 1,670 plants) could be entirely out of their climate envelopes with just a 5.4° F (3° C) warming, the lower limit of climate change predicted for this century by the IPCC (Morse et al. 1995). At the upper boundary of climate change predicted for this century, 10.4° F (5.8° C), the percentage of plants completely outside their envelope increases to 25-40% (Morse et al. 1995). By contrast, about 90 North American plant species are believed to have become extinct in the past two centuries (Morse et al. 1995).

Species are also at great risk because climate change can alter conditions for diseases and their vectors in a way that allows the incidence of disease to increase and spread. Global warming can exacerbate plant disease by altering the biological processes of the pathogen, host, or disease-spreading organism (Harvell et al. 2002). For example, cold winter temperatures limit disease in some areas because the cold kills pathogens. Warmer winter temperatures can decrease pathogen mortality and increase disease (Harvell et al. 2002). Warmer temperatures can also increase pathogen growth through longer growing seasons and accelerated pathogen development (Harvell et al. 2002). The most severe and least predictable disease outbreaks will likely be when climate change alters host and pathogen geographic ranges, so that pathogens introduced to new and vulnerable hosts (Harvell et al. 2002).

Climate change will also influence wildlife diseases by affecting the free-living, intermediate, or vector stages of pathogens (Harvell et al. 2002). Many vector-transmitted diseases are currently climate limited because the parasites cannot complete development before the vectors are killed by cold temperatures (Harvell et al. 2002). Well studied vector borne human diseases such as malaria, Lyme disease, tick-borne encephalitis, yellow fever, plague, and dengue fever have expanded their ranges into higher latitude areas as temperatures warm (Harvell et al. 2002). Given the sensitivity of the Desert Tortoise to pathogens, this impact of climate change must be considered in the Draft EIR for this project.

Increased ocean temperatures also cause marine pathogen range expansions. One example is the spread of eastern oyster disease on the east coast of the United States from Long Island to Maine during a winter warming trend in which the cold-water barrier to pathogen growth was removed (Harvell et al. 2002).

A study published in *Nature* has linked the extinction of dozens of amphibian species in the tropical highland forests of Central and South America to global warming due to the creation of ideal conditions for growth of the chytrid fungus, a disease which kills frogs by growing on their skin and attacking their epidermis and teeth, as well as by releasing a toxin (Pounds et al. 2006). Seventy-four of the 110 species of brightly colored harlequin frogs of the genus *Atelopus* have disappeared in the past 20 years due to the spread of the fungus (Pounds et al. 2006). The study's lead author stated "Disease is the bullet killing frogs, but climate change is pulling the trigger" (Eilperin 2006). The golden toad (*Bufo periglenes*), endemic to the same tropical mountain forests, was also driven extinct by climate change. These amphibian extinctions from the Monteverde Cloud Forest are one of the largest recorded vertebrate extinction events of at least the last 100 years.

Projected increases in atmospheric carbon dioxide and temperature over the next 50 years will rapidly and substantially exceed the conditions under which coral reefs have flourished over the past 500,000 years (Hughes et al. 2003). Coral reefs are already experiencing a major decline (Hughes et al. 2003). Thirty percent of reefs are already severely damaged, and sixty percent of reefs could be gone by 2030 (Hughes et al. 2003). The link between increased greenhouse gases, climate change, and regional-scale bleaching of corals, questioned by some researchers as recently as ten to twenty years ago, is now incontrovertible (Hughes et al. 2003). In the face of elevated ocean temperatures, corals "bleach" by expelling the symbiotic algae that provide them nourishment. Such bleaching events are often fatal, and as they become more frequent with global warming, threaten not just individual coral species but the entire reef ecosystem.

Corals face an additional threat from greenhouse gas emissions: increasing levels of dissolved carbon dioxide in the oceans from society's fossil fuel use reduces the rate of calcification corals need for growth. The frequency and intensity of hurricanes is also projected to continue to increase, leading to a shorter time for recovery between damaging storm events (Hughes 2003). Two species of Caribbean coral, the elkhorn coral (*Acropora palmata*) and staghorn coral (*Acropora cervicornis*) have been listed under the Endangered Species Act, in part due to elevated ocean temperatures from global warming and ocean acidification from anthropogenic carbon dioxide emissions. U.S. Fish and Wildlife Service (USFWS) 2006.

Species in areas of the globe experiencing more rapid warming than the average, such as the Arctic, are also particularly vulnerable to climate change. The Arctic has warmed at over twice the rate of the rest of the world and has been impacted particularly early and intensely by climate change. Winter temperatures in parts of the Arctic have increased by as much as 3-4° C (5-7° F) in just the past 50 years. Over the next 100 years, under a moderate emissions scenario, annual average temperatures are projected to rise 3-5° C (5-9° F) over land and up to 7° C (13° F) over the oceans. Winter temperatures are projected to rise by 4-7° C (5-9° F) over land and 7-10° C (13-18°) over the oceans (ACIA 2004b:2).

The disproportionate regional warming is caused by several unique characteristics and feedback mechanisms in the Arctic. Chief among these is the decrease in Arctic snow and ice cover and northward expansion of boreal forests and shrubs as temperatures warm. These changes greatly decrease the amount of solar radiation reflected back into space and speed regional warming in a positive feedback loop of enormous magnitude. As temperatures go up, Arctic sea ice melts. Summer sea ice extent is already declining at up to 10% per year, and experienced a new record minimum in September 2005 (NSIDC 2005). An area of sea ice of about half a million square miles, or roughly twice the size of Texas, has been lost (NSIDC 2005). If current trends continue, the Arctic will be ice free in the summer in just a few decades. Decreases in winter sea ice extents in the Arctic have also been documented, approaching reductions of 3% per decade (Meier et al. 2005). The Arctic may already be on a trajectory towards a summer ice-free, "super interglacial" state that has not existed for at least a million years (Overpeck et al. 2005). There appear to be no feedback processes in the Arctic system capable of altering this trajectory towards dramatically less permanent ice than at present (Overpeck et al. 2005).

The rapid warming threatens the entire Arctic web of life, including the polar bear (*Ursus maritimus*), the largest of the world's bear species and an icon of the North. Polar bears live only in the Arctic where sea ice is present for substantial portions of the year. Polar bears are the Arctic's top predator and completely dependent upon the sea ice for all of its essential behaviors. Polar bears are specialized predators of seals in ice-covered waters. Polar bears also use the sea ice to travel, to mate, and some mothers even give birth to their cubs in snow dens excavated on top of the sea ice. The polar bear's dependence on sea ice is so complete that, like whales and seals, they are classified as a marine mammal by scientists and the federal government.

Due to the overwhelming risk to polar bears caused by global warming, in February, 2005, the conservation organization Center for Biological Diversity submitted a Petition to the U.S. Fish and Wildlife Service to list polar bears as a threatened species under the Endangered Species Act. *See* *http://biologicaldiversity.org/swcbd/species/polarbear/petition.pdf*. In February, 2006, the Fish and Wildlife Service found that listing of polar bears "may be warranted," and the listing process is currently ongoing. 71 Fed.Reg. 6,745 (February 9, 2006).

The number and magnitude of the impacts already recorded from a 1° F increase in average global air temperature is profoundly disturbing. And the projected increase, even under moderate greenhouse gas scenarios, for this century of 2.5- 10.4° F (1.4-5.8° C) is many times the warming already experienced. Not surprisingly, the projections for the future are more disturbing still.

The leading study on the quantification of risk to biodiversity from climate change, published in 2004 in *Nature*, included over 1,100 species distributed over 20% of the earth's surface area (Thomas et al. 2004). Under a relatively high emissions scenario, 35%, under a medium emissions scenario 24%, and under a relatively low emissions scenario, 18% of the species studied would be committed to extinction by the year 2050 (Thomas et al. 2004). Extrapolating from this study to the earth as a whole reveals that over a million species may be at risk. The clear message is that immediate reductions in greenhouse gas emission may save preserve many thousands of species. It is also clear that some impacts from climate change are inevitable, and thus adaptation strategies will be an essential component of any comprehensive strategy to manage the impacts of climate change.

4. The Impacts of Global Warming on California

California is extremely vulnerable to the impacts of global warming and is also responsible for a significant portion of the U.S. and global emissions of greenhouse gases. The significant risks climate change poses to California as well as the considerable benefits the state could realize if it addresses these risks prompted Governor Schwarznegger to issue Executive Order S-3-05 on June 1, 2005. *See* F.Chung et al. 2006 at Appendix 1.7. The Executive Order called for specific emissions reductions and a periodic update on the state of climate change science and its potential impacts on sensitive sectors, including water supply, public health, coastal areas, agriculture and forestry. The Executive Order established the following greenhouse gas (GHG) emissions targets: by 2010, reduce GHG emissions to 2000 levels; by 2020, reduce GHG emissions to 1990 levels; and by 2050, reduce GHG emissions to 80 percent below 1990 levels. A recent piece of legislation, the California Global Warming Solutions Act of 2006 (AB 32), places a cap on California's greenhouse gas emissions from utilities, oil refineries, and other major global warming polluters and thus brings the state closer to meeting these targets.

In response to Executive Order S-3-05, the California Environmental Protection Agency (CalEPA) formed a Climate Action Team with members from various state agencies and commissions, The Team has issued a series of reports, including a March 2006 Climate Action Team Report to Governor Schwarznegger and the Legislature. This and other reports issued by CalEPA, the California Energy Commission (CEC), Department of Water Resources and other California agencies are available at http://www.climatechange.ca.gov/documents/index.html and should be used by local jurisdictions like the City of Banning in preparing environmental documents under CEQA.

Some of the major impacts identified in recent reports include:

- Reduction of Sierra snowpack up to 90 percent during the next 100 years threatens California's water supply and quality as the Sierra accounts for almost all of the surface water storage in the state.

- Impacts to the health of Californians due to increases in the frequency, duration, and intensity of conditions conducive to air pollution formation, oppressive heat, and wildfires. Increasing temperatures from 8 to 10.4°F, as expected under the higher emission scenarios, will cause a 25 to 35 percent increase in the number of days Californians are exposed to ozone pollution in most urban areas. This will slow progress toward attainment of air quality standards and impede many of the state's efforts to reduce air pollution. Temperature increases are likely to result in an increase in heat-related deaths. Children, the elderly, and minority and low-income communities are at greatest risk.

- Potential impacts from limited water storage, increasing temperatures, increased carbon dioxide concentrations, pests and weeds threaten agriculture and its economic contribution to the state. Direct threats to the structural integrity of the state's levee system would also have immense implications for the state's fresh water supply, food supply, and overall economic prosperity.

- Erosion of our coastlines and sea water intrusion into the state's delta and levee systems may result from a 4 to 33-inch rise in sea level during the next 100 years. This will further exacerbate flooding in vulnerable regions.

- Increasing temperatures and pest infestations would make the state's forest resources more vulnerable to fires. Large and intense fires threaten native species, increase pollution, and can cause economic losses.

- Increasing temperatures will boost electricity demand, especially in the hot summer season. By 2025 this would translate to a 1 to 3 percent increase in demand resulting in potentially hundreds of millions of dollars in extra energy expenditures

CalEPA 2006; Cayan et al. 2006; Chung 2006; Drechsler et al. 2006.

The precise nature of the impacts over the next decades will depend upon whether global greenhouse gas emissions continue to increase at current rates, or whether the current rate of increase is slowed, and emissions actually reduced. Scientists model future impacts based on different emissions scenarios (Cayan et al. 2006). Under a low emissions scenario, by the end of this century heat waves and extreme heat in Los Angeles will quadruple in frequency and heat-related mortality will increase two to three times (Hayhoe et al. 2004). Alpine and subalpine forests are reduced by 50-75%, and Sierra snowpack is reduced 30-70% (Hayhoe et al. 2004). Under a higher emissions scenario, heat waves in Los Angeles will be six to eight times more frequent, with heat-related excess mortality increasing five to seven times (Hayhoe et al. 2004). Alpine and subalpine forests would be reduced by 75-90%, and snowpack would decline 74-90%, with impacts on runoff and streamflow that, combined with projected declines in winter precipitation, could fundamentally disrupt California's water rights system (Hayhoe et al. 2004).

As of 2002, California's main source of greenhouse gases was the transportation sector (41.2%) followed by the industrial sector (22.8%), electric power sector (19.6%), agriculture & forestry sector (8.0%), and other sources (8.4%) (Cal EPA 2006). Mitigation of the state's emissions, therefore, will result from addressing each of the sources.

5. Tipping Point

The science of global warming is now sufficiently well understood that experts can accurately predict the future changes that will occur if greenhouse gas emissions and atmospheric concentrations continue to increase. Dr. James E. Hansen, Director of the NASA Goddard Institute for Space Studies, and NASA's top climate scientist, and others have recently published a paper stating that additional global warming of 2°C would push the earth beyond a "tipping point" and cause dramatic climate impacts including eventual sea level rise of at least several meters, extermination of a substantial fraction of the animal and plant species on the planet, and major regional climate disruptions (Hansen et al. 2006).

In order to limit future temperature increases to below 2°C, society must follow the "Alternative" scenario, rather than the "Business as Usual" scenario, with respect to emissions (Hansen et al. 2006). In the Business as Usual scenario, CO_2 emissions continue to grow at about 2% per year, and other greenhouse gases such as CH_4 and N_20 also continue to increase (Hansen et al. 2006). In the alternative scenario, by contrast, CO_2 emissions decline moderately between now and 2050, and much more steeply after 2050, so that atmospheric CO_2 never exceeds 475 parts per million (Hansen et al. 2006). The Alternative scenario would limit global warming to less than 1°C in this century (Hansen et al. 2006). However, CO_2 emissions have continued to increase by 2% per year since 2000 (Hansen et al. 2006). If this growth continues for just ten more years, the 35% increase of CO_2 emissions between 2000 and 2015 will make it implausible to achieve the Alternative scenario (Hansen et al. 2006). Moreover, the "tripwire between keeping global warming less than 1°C, as opposed to having a warming that approaches the range of 2-3°C, may depend upon a relatively small difference" in anthropogenic greenhouse gas emissions (Hansen et al. 2006). This is because warming of greater than 1°C may induce positive climate feedbacks, such as the release of large amounts of methane from thawing arctic permafrost, that will further amplify the warming. (Hansen Dec. ¶ 39).

Based on these warnings, it is imperative that we seize all opportunities to reduce emissions.

6. The Economic Cost of Carbon

The economic cost of greenhouse gas pollution is the estimated cost of the net impact on economies and societies of long term trends in climate conditions related to anthropogenic greenhouse gas emissions (Downing et al. 2005). The economic cost is often expressed as the marginal cost of climate change impacts, and is usually estimated as the net present value of the impact over the next 100 years (or longer) of one additional ton of carbon emitted to the atmosphere today, and is expressed in dollars (or other currency) per ton of carbon (tc).[13]

The recently released Stern Review on the Economics of Climate Change has conducted one of the most comprehensive reviews to date of the economic costs of climate change, and has concluded that the cost of each ton of carbon emitted into the atmosphere is at least $85 (Stern 2006.) The clear finding of the Stern Review is that the costs of inaction with regard to greenhouse gas emissions far exceed the costs of controlling them. According to one measure, the benefits of measures to shift to a low carbon economy will be on the order of $2.5 trillion per year.

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Estimating the economic cost of greenhouse gas pollution is a rapidly developing field, and very few studies conducted to date have included any non-market damages such as species extinction, or the risk of potential extreme weather such as hurricanes, droughts, and floods (Watkiss et al. 2005). None have included socially contingent effects, or the potential for longer-term effects and catastrophic events (Watkiss et al. 2005). This indicates that values in the literature are a sub-total of the full economic (or social) cost of greenhouse gas pollution, and therefore by definition an underestimate, though researchers cannot yet say by how much (Watkiss et al. 2005).

A report released at the end of 2005 Researchers have concluded that $64/tc (year 2000) is a reasonable figure for decision makers to use as a lower benchmark of the

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[13] The cost can also be expressed per ton of carbon dioxide, where 1tc=3.664t CO_2.
[14] The cost can also be expressed per ton of carbon dioxide, where 1tc=3.664t CO_2.

economic cost of greenhouse gas emissions (Downing et al. 2005). An upper benchmark is more difficult to deduce from the current literature but the risk of higher values for the social cost of carbon is significant (Downing et al. 2005, Watkiss et al. 2005). Decision makers should use the best available range of values displayed in Table 1.

Table 1: Economic Cost of Carbon: Values for Use in Project Appraisal (USD per ton carbon) (Source: Adapted from Watkiss et al. 2005:ix)[15]

Year of Emission	Central guidance	Lower Central Estimate	Upper Central Estimate
2000	$101	$64	$238
2010	$119	$73	$293
2020	$146	$91	$375
2030	$183	$119	$475
2040	$256	$165	$603
2050	$384	$238	$768

Using the central guidance figure and the year 2010 baseline, the cost per ton of CO_2 would be $32.48. This measure, as well as qualitative measures of environmental and social impacts must be analyzed in the DEIR and taken into consideration when determining what is and is not a feasible mitigation measure or alternative.

B. The Draft EIR Entirely Overlooks the Project's Greenhouse Gas Emissions

The DEIR is inadequate because it neglects to analyze global warming and the project's greenhouse gas emissions. The project will result in foreseeable and quantifiable emissions of carbon dioxide, methane, and other greenhouse gases during both construction and the lifetime of the project. These emissions, although relatively small in comparison to worldwide greenhouse gas emissions, will contribute directly and cumulatively to the increase in atmospheric greenhouse gases, and will thus contribute directly and cumulatively to global warming.

Under CEQA, it is irrelevant that the fact that the project's emissions associated with the project are small in comparison tomay be a small component of the state's total emissions does not relieve the County of its obligation to fully analyze them. On the contrary, CEQA's cumulative impact analysis requirement exists to capture precisely this type of impact that may be individually small but cumulatively significant. *Kings County Farm Bureau v. City of Hanford* (1990) 221 Cal. App. 3d 692, 721. ("The EIR improperly focused upon the individual project's relative effects and omitted facts relevant to an analysis of the collective effect this and other sources will have upon air quality.") Here, the EIR quantifies the project's cumulative contribution to the emissions of other pollutants, and includes some mitigation measures for those impacts as well as

[15] Figures from Watkiss et al. 2005:ix were converted from GBP (£) to USD ($) with the exchange rate calculator at http://coinmill.com/GBP_USD.html on July 18, 2006 and rounded to the nearest dollar.

ultimate conclusions of unavoidable significance. The EIR must similarly conduct an analysis for the project's greenhouse gas emissions. A revised DEIR must calculate the project's greenhouse gas emissions, and then propose measures to avoid, minimize, and mitigate them to the maximum extent feasible. In fact, many of the actions to avoid, minimize, and mitigate greenhouse gas emissions may also save the project proponent money on operating costs the project proponent and homeowners in the long run.

The greenhouse gas emissions of each component and phase of the project must be calculated. For example, the construction phase would include, but not be limited to: (1) the greenhouse gas emissions of construction vehicles and machinery; (2) the greenhouse gas emissions from manufacturing and transporting the project's building materials. ; (3) the greenhouse gas emissions of the project's planning and design. The operation phase would include but not be limited to: (1) the greenhouse gas emission from the heating, cooling, and lighting the office; and (2) the greenhouse gas emissions from the vehicle trips to transport the sewage sludge; and (3) the methane emissions from the composting project itself.

The Draft EIR's Air Quality Section (4.3) does not adequately analyze greenhouse gas emissions, and the document as a whole contains insufficient information for the reader to estimate the project's total greenhouse gas emissions. Section 2.5 (Traffic Numbers and Types of Vehicles) provides that the project will generate 96 daily trips on an average day and will increase to 174 daily truck trips on a peak day. DEIR at 2-18. The revised EIR, once discussing the precise location the waste will originate from, should estimate average trip length and average fuel efficiency of the vehicles and then calculate their carbon dioxide emissions. For example assuming an average trip length of 10 miles and average fuel efficiency of the vehicles equating to .44 kg/per mile of carbon dioxide emissions (Each gallon of gasoline consumed releases approximately burning one gallon of fuel releases 26 pounds of carbon dioxide into the atmosphere.), the project will result in 15,164 x 10mi x .44kgCO_2/mi = 66,722 kg CO_2/ day, which equates to 73.5 tons CO_2/day and approximately 26,845 tons CO_2/year. The EPA has many different tools available for calculating emissions. They are available at: http://yosemite.epa.gov/oar/globalwarming.nsf/content/ResourceCenterToolsCalculators.html; *see also* http://pubs.wri.org/pubs_description.cfm?PubID=3756 (which contains calculators for CO_2emissions from fuel used for heating and transportation, CO_2emissions from purchased electricity, CO_2emissions from business travel by air, train, bus and car, and CO_2 emissions from employee commuting etc.). Calculation of the project's greenhouse gas emissions is the first step to then analyzing and mitigating them.

Luckily, there are many avoidance and mitigation measures available to the project proponent. Adopting these measures will benefit the environment, take the state closer to meeting its greenhouse gas emissions reduction targets, and demonstrate responsible development. These measures may also save the project proponent and future residents of the project site money. Measures to minimize greenhouse gas emissions include:

- Enclosing the facility and capturing methane emissions
- Following the U.S. Green Building Council's LEED (Leadership in Energy and Environmental Design) or comparable standards for energy- and resource-efficient building during pre-design, design, construction, operations and management. *See* http://www.usgbc.org and links; Alameda County 2005
- Minimizing and recycling construction-related waste
- Using salvaged and recycled-content materials for building
- Installing the maximum possible solar energy array on the building roofs and/or on the project site to generate solar energy for the facility
- Using passive heating, natural cooling, solar hot water systems, and reduced pavement;
- Landscaping to preserve natural vegetation and maintain watershed integrity
- Installing electric vehicle charging stations at the facility
- Constructing the most energy-efficient buildings possible, to decrease heating and cooling costs
- Utilizing the combination of construction materials with the lowest carbon footprint
- Utilizing only Energy Star heating, cooling, and lighting devices, and appliances
- Ensuring that public transportation will serve the site, by constructing bus stops or other facilities and funding the transportation agency if necessary
- After all avoidance and minimization measures have been incorporated, purchasing offset credits for the project's lifetime greenhouse gas emissions

Once all measures to avoid and minimize greenhouse gas emissions have been adopted, the project's remaining greenhouse gas emissions should be calculated, and offsets purchased to mitigate for them. There are many options for purchasing carbon offsets (or credits), including but not limited to the following:

- The Chicago Climate Exchange (http://www.chicagoclimatex.com/)
- Climate Care (http://www.climatecare.org/)
- My Climate (http://www.myclimate.org)
- Climate Friendly (http://www.climatefriendly.com/)
- The Carbon Neutral Company (http://www.carbonneutral.com/)
- The Climate Trust (http://www.climatetrust.org/)
- Renewable Choice Energy (http://www.renewablechoice.com/m/index.php)

Purchasing mitigation credits to offset the project's unavoidable greenhouse gas emissions is entirely feasible, and is in fact becoming quite common. Early in 2006, Whole Foods announced that it would buy wind energy credits from Renewable Choice Energy to offset 100% of its electricity use (other companies purchasing these credits include Johnson & Johnson, DuPont, Starbucks, IBM, and Safeway), FedEx Kinkos announced it would will increase its "green power" commitment by 67.5 percent to an estimated 40 million kilowatt-hours per year, and Walgreens announced it will install solar-power systems at 96 stores and two distribution centers in California. There is no reason why this Project cannot mitigate for 100% of its greenhouse gas emissions once all avoidance and minimization measures have been incorporated.

A wealth of additional resources on calculating, avoiding, and mitigating greenhouse gas emissions is available on the internet. Several options include the David Suzuki Foundation at http://www.davidsuzuki.org/Climate_Change/What_You_Can_Do/carbon_neutral.asp and the World Resources Institute at http://pubs.wri.org/pubs_description.cfm?PubID=3756.

Because the project's greenhouse gas emissions are likely to be significant after calculation given even high number of vehicle trips generated and the methane emissions, a revised EIR must consider and adopt feasible mitigation measures and/or an alternative that reduces the project's contribution of greenhouse gases to the maximum extent feasible. Not only is this required by CEQA, but it will also demonstrate the project proponent and County of San Bernardino's commitment to environmental and community leadership.

C. The Draft EIR fails to address legislation AB 32

AB 32 is a bill recently passed by the California legislature and signed by the Governor to reduce California's emissions and in turn, combat global warming. This bill requires the California Air Resources Board (CARB) to adopt procedures and protocols by 2008 to reduce greenhouse gas emission to 2000 levels by 2010, and to 1990 levels by 2020. The bill requires the CARB to provide an annual report to the Governor and the Legislature on the progress of greenhouse gas emissions, develop compliance and enforcement procedures, and coordinate with state agencies to implement green house gas reduction standards. The County should be taking a pro-active role in this process by limiting greenhouse gas emissions in all new projects and requiring off-sets as well as by encouraging retro-fit of older projects.

In order for AB 32 to be implemented, newly proposed projects that will emit greenhouse gases must consider how the project will abide by the new standards. The project proposed by Nursery Products is especially subject to such considerations since the area where it is proposed to be developed has poor air quality and the project itself will create significant emissions due to truck travel, business operations. and composting.

VIII. THE DRAFT EIR FAILS TO ADEQUATELY ANALYZE OTHER IMPACTS

The Draft EIR is invalid because it fails to adequately analyze and mitigate impacts to the following: aesthetics, agricultural resources, geology, soils, land use, mineral resources, noise, population, housing, public services, recreation and transportation/traffic.

IX. THE DRAFT EIR'S ANALYSIS OF CUMULATIVE IMPACTS IS INADEQUATE

The list of other current or future projects, presented in order to determine cumulative effects, is underinclusive for the purpose of satisfying CEQA requirements for the EIR. The Draft EIR provides mere conclusory statements. However, CEQA requires that the discussion must be more than a conclusion "devoid of any reasoned analysis." *Whitman v. Board of Supervisors* 88 Cal.App.3d 397, 411 (1979). The MDAB already suffers from environmental degradation due to poor air quality. Additionally, it is habitat to a number of endangered and sensitive species. There are a number of other projects located in the nearby vicinity of the proposed project and its alternatives that also contribute or will contribute significant impacts to the local environment. However, these impacts are not listed in the Draft EIR and the list of cumulative projects that is provided simply concludes that most impacts as not applicable. Other proposed projects in the area that should have been analyzed for their cumulative impacts include, but are not limited to, the following: expansion of the Barstow landfill; the Barstow casino proposal, and the P&V Enterprises proposal. Each of these projects will also have significant impacts on air quality, water resources and water quality, biological resources, and traffic.

X. CONCLUSION

In summary, the project cannot proceed in violation of local and State laws. The current Draft EIR has not adequately disclosed, analyzed, avoided, or minimized and mitigated the environmental impacts of the proposed project. Because of the document's shortcomings, the public and decision makers cannot make informed decisions about the proposed project's impacts in areas including biological resources, air quality, water resources and water quality, global warming, or cumulative impacts. Should the County wish to move forward with the proposed project, the Center hopes to receive a revised Draft EIR.

Please include the Center for Biological Diversity, on all mailing lists for all information about this project. Notices and documents should be addressed to: The Center for Biological Diversity, 1095 Market St. Suite 511, San Francisco, CA. 94103, Attn: Lisa Belenky. If you have any questions please do not hesitate to contact Lisa Belenky, Staff Attorney, at (415) 436-9682. Thank you very much for your consideration of these comments.

Sincerely,

Hallie Albert
Legal Fellow
Center for Biological Diversity

cc: (without exhibits)

Field Supervisor
USFWS- Ecological Services
[redacted]

State Water Resources Control Board
Division of Water Rights
[redacted]

California Department of Fish and Game
Eastern Sierra – Inland Deserts Region
[redacted]

California Department of Fish and Game
Eastern Sierra – Inland Deserts Region
[redacted]

List of Exhibits and References:

EXHIBITS:

Exhibit 1: Fish and Wildlife Service. 1994. Desert Tortoise (Mojave population) Recovery Plan. U.S. Fish and Wildlife Service, Portland, Oregon.

Exhibit 2: Battersby, Marguerite, City Attorney for the City of Adelanto: *Letter to Daniel Avera/Nursery Products Composting Facility, City of Adelanto* (Nov.7, 2003).

Exhibit 3: Albritton, D.L., L.G. Meira Filho, U. Cubasch, X. Dai, Y. Ding, D.J. Griggs, B. Hweitson, J.T. Houghton, I. Isaksen, T. Karl, M. McFarland, V.P. Meleshko, J.F.B. Mitchell, M. Noguer, B.S. Nyenzi, M. Oppenheimer, J.E. Penner, S.Pollonais, T. Stocker and K.E. Trenberth. 2001. Technical Summary. Pp. 21-83 *In*: *Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the*

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Exhibit 4: Parmeson, C. and H. Galbraith. 2004. Observed impacts of global climate change in the U.S. Pew Center on Global Climate Change. 56 pp.

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Exhibit 9: Stern Review: The Economics of Climate Change, 2006.

Exhibit 10: Assembly Bill, 32.

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VIA EMAIL

Carrie Hyke
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PUBLIC COMMENTS ON THE DRAFT SUPPLEMENTAL ENVIRONMENTAL IMPACT REPORT FOR NURSERY PRODUCTS HAWES COMPOSTING FACILITY

Pursuant to the County of San Bernardino's ("County") Notice of Availability for the Draft Supplemental Environmental Impact Report for Nursery Products Hawes Composting Facility, the Center for Food Safety ("CFS") submits the following comments. CFS is a nonprofit membership organization that works to protect human health and the environment by curbing the proliferation of harmful food production technologies and by promoting organic and other forms of sustainable agriculture. CFS represents members in California and throughout the country that are opposed to the use of sewage sludge[1] in compost for agriculture.

I. THE COUNTY'S ISSUANCE OF THE SUPPLEMENTAL ENVIRONMENTAL IMPACT STATEMENT IS IMPROPER.

The California Environmental Quality Act ("CEQA") is a procedural statute mandated for "projects," which are "[activities] directly undertaken by any public agency" that "may cause either a direct physical change in the environment, or a reasonably

[1] Also known as and used interchangeably in this document as "Biosolids."

foreseeable indirect physical change in the environment."[2] A project is either "undertaken by a public agency, undertaken by a person with assistance from a public agency," or an "activity that involves the issuance of a lease, permit, etc., for use by one or more public agencies.[3]

> CEQA is implemented through initial studies, negative declarations and EIR's. CEQA requires a governmental agency to prepare an EIR whenever it considers approval of a proposed project that may have a significant effect on the environment. . . [T]he Supreme Court has recognized that CEQA requires the preparation of an EIR whenever it can be fairly argued on the basis of substantial evidence that the project may have significant environmental impact.[4]

"A significant effect on the environment is defined as a substantial, or potentially substantial, adverse change in the environment."[5] CEQA defines "environment" as the "physical conditions which exist within the area which will be affected by a proposed project, including land, air, water, minerals, flora, fauna, noise, objects of historic or aesthetic significance."[6] An Environmental Impact Report (EIR) "provide[s] public agencies and the public in general with detailed information about the effect which a proposed project is likely to have on the environment; to list ways in which the significant effects of such a project might be minimized; and to indicate alternatives to such a project."[7]

Here, the project is the proposed Nursery Products Hawes Facility, which will compost sewage sludge and green material on 80 acres of a 160 acre parcel located within an unincorporated area in the County of San Bernardino.[8] The project proposes to combine this sludge and green waste to create Class A compost.[9] In December, 2005, Nursery Products, LLC ("Nursery Products") submitted an application with the County seeking approval of the Hawes sludge composting facility. Pursuant to CEQA, the final EIR was issued in November, 2006 and certified by the planning commission in early 2007.

The Center for Biological Diversity and HelpHinkley.org jointly filed a lawsuit in Superior Court outlining the inadequacies of this EIR and asking the court to invalidate the EIR.[10] In *Center for Biological Diversity v. County of San Bernardino*, Judge Feer ruled that the initial EIR was flawed, vacated all permits given in association with the

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[2] CAL PUB. RES. CODE § 21065; *Sherwin Williams, Co. v. South Courst Air Quality Management Dist.*, 86 Cal.App.4th 1258 (Cal.App. 2d Dist., 2001).
[3] CAL PUB. RES. CODE § 21065.
[4] *California Sportfishing Protection Alliance v. State Water Resources Control Board,* 160 Cal.App.4th 1625 1642 (CalApp. 1 Dist 2008) (internal citations omitted).
[5] *Id.*
[6] CAL PUB. RES. CODE § 21060.5.
[7] *Id.* at § 21061.
[8] Draft Supplemental Impact Report Nursery Products LLC Hawes Composing Facility, State Clearinghouse No. 2006051021, at ES-1 (July 2009).
[9] Draft Supplemental Impact Report Nursery Products LLC Hawes Composing Facility, State Clearinghouse No. 2006051021, at ES-1 (July 2009).
[10] *Center for Biological Diversity v. County of San Bernardino*, Case No. BCV 09950 (Super. Ct. 2008).

document, and held that "[n]o part of the project is severable."[11] CFS firmly believes that the issuance of this Supplemental Environmental Impact Report ("SEIR") directly contradicts the Judge's Order. An SEIR is appropriate only for the following reasons: where there have been substantial changes to the project that require major revisions of the EIR; there are substantial new circumstances surrounding the project; or new information of substantial importance became available.[12] However, the decision clearly requires the County to vacate the previous EIR, therefore issuing the SEIR violates the decision of the court.

This decision was stayed when the county appealed. However, only two possible outcomes can result from the appeal: the county loses and must prepare an entirely new EIR, or the county prevails, and the original EIR is reinstated. Under either scenario, the SEIR is unnecessary. CFS believes that the SEIR will ultimately be vacated by the District Court if the County proceeds with its appeal. In the event that this is not the case, CFS comments on the inadequacies of the SEIR.

II. THE SUPPLEMENTAL ENVIRONMENTAL IMPACT REPORT FAILED TO ASSESS THE ENVIRONMENTAL IMPACTS OF SEWAGE SLUDGE COMPOST.

The County failed to assess the environmental impacts of composing sewage sludge. Sewage sludge contains a number of contaminants not addressed by the governing federal regulatory scheme. These contaminants can and will be released into the environment. Therefore, the County must assess the effects.

A. Federal Sewage Sludge Regulations are Inadequate to Address the Overwhelming Number of Contaminants in Sewage Sludge and Sludge Compost.

Sewage sludge is a combination of industrial waste and household sewage, both of which are routed for treatment through municipal sewage treatment plants.[13] This sewage "contains not only human fecal wastes from homes and businesses but also products and contaminants from homes, industries, businesses, stormwater, and landfill leachate (in some locals) and contaminants leached from pipes."[14] At treatment plants, wastewater is treated to remove chemicals, pathogens, and toxic metals from the effluent and these materials are concentrated in the byproduct, sewage sludge.[15] The resulting sewage sludge is replete with toxic chemicals. For example, it has been estimated that 90% of the dioxins in the incoming water routed thought the treatment plant will end up in sewage sludge.[16]

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[11] *Id.* at 4.
[12] California Environmental Quality Act, CAL PUB. RES. CODE § 21166 (2009).
[13] *R.A. McElmurray v. U.S. Dep't Agric*, 535 F.Supp.2d 1318, 1321 (S.D.Ga. 2008).
[14] Ellen Z. Harrison et al., *Land Application of Sewage Sludges: An Appraisal of the US Regulations*, 11 INT'L. J. ENV. & POLLUTION 1, 2 (1999).
[15] *McElmurray*, 535 F.Supp.2d at 1321.
[16] Harrison et al., *supra*, n.14.

Sewage sludge contains a variety of organic wastewater contaminants ("OWCs"), which are compounds produced to offer improvements in industrial, medical and household products and applications.[17] "Compounds that can be classified as OWCs include pharmaceuticals, hormones, detergent metabolites, fragrances, plasticizers, and pesticides."[18] Sewage sludge can also contain a variety of other contaminants, such as flame retardants and metals. In a recent EPA survey of sewage sludge, samples from across the US found that sewage sludge can contain heavy metals, pathogens, steroids, hormones, flame retardants, pharmaceuticals and endocrine disruptors.[19] Particularly alarming is that almost all the samples contained 27 metals, 10 different flame retardants, 12 pharmaceuticals, and high levels of known endocrine disruptors.[20] There are as many as 100,000 chemicals used in American industry, with about a thousand new chemical compounds put to commercial use each year.[21] Any of these can enter the wastewater stream and if they do, they will ultimately be found in sludge.

Sewage sludge is regulated by the Environmental Protection Agency ("EPA") by what is commonly known as the "Part 503 Rule."[22] Part 503 requires the treatment of sewage sludge so that it can be land applied and used in agriculture. The rule includes concentration limits for nine metals and pathogens, as well as for vector attraction and reduction.[23] Sewage sludge can be Class A, in which pathogens are essentially eliminated, or Class B, in which pathogens have been reduced but not eliminated.[24] However, sewage sludge contains a diverse collection of wastewater contaminants of emerging and known toxicological concern not addressed whatsoever by the Part 503 Rule.[25] Despite EPA's own study indicating high levels of a variety of toxins other than the nine metals and pathogens that sewage sludge is treated for, no additional federal requirements exist to eliminate these toxins.

A recent federal court decision indicates not only that EPA's regulations are inadequate, but that EPA actively hidden and subverted critical information concerning the dangers of sewage sludge. In *McElmurray v. US*, a Georgia judge stated that EPA's sludge program has ignored scientific dissent indicating that sewage sludge is harmful to humans and the environment. In this case, a Georgia dairy farmer entered into an agreement with the City of Augusta in 1979 to allow the city to apply local sewage sludge.[26] Over the next

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[17] Chad A. Kinney et al., *Survey of Organic Wastewater Contaminants in Biosolids Destined for Land Application*, 40 ENVTL SCI. TECH. 7202, 7207 (2006).
[18] *Id.*
[19] EPA, Targeted National Sewage Sludge Survey, EPA-822-R-08-014, 7 (January 2009) available at http://www.epa.gov/waterscience/biosolids/tnsss-overview.pdf.
[20] *Id.*; Josh Harkinson, *Sludge Happens*, MOTHER JONES, April 21, 2009, at 1, available at http://www.motherjones.com/environment/2009/05/sludge-happens.
[21] Robert C. Hale and Mark J. Laguardia, *Have Risks Associated with the Presence of Synthetic Organic Contaminants in Land-Applied Sewage Sludges Been Adequately Addressed?*, 12 NEW SOLUTIONS J. ENV. & OCCUPATIONAL HEALTH POLICY 371, 372 (2002).
[22] 40 C.F.R. § 503.
[23] Harrison et al., *supra*, n.14 at 3.
[24] *Id.*
[25] Mark J. La Guardia et al., *Organic Contaminants of Emerging Concern in Land-Applied Sewage Sludge (Biosolids)*, 1 J. OF RESIDUALS SCI. & TECH. 111, 119 (2004).
[26] *McElmurray*, 535 F.Supp.2d at 1321.

decade, McElmurray began having trouble with his crops and about half of his 700 cows died from severe diarrhea.[27] McElmurray hired an expert to test his soil, who opined that McElmurray's fields were contaminated by heavy metals, and that there was a correlation between the cattle eating silage produced from the field and the cattle mortality.[28] McElmurray submitted an application to the USDA for disaster relief, and when denied, sued in federal court.[29] The district court found the USDA's denial to be arbitrary and capricious and ruled in favor of McElmurray.[30] Additionally, the court indicated that "[o]ther evidence of record calls into question the fairness and objectivity of the EPA's opinions with respect to the sludge land application program. The administrative record contains evidence that senior EPA officials took extraordinary steps to quash scientific dissent, and any questioning of the EPA's biosolids program."[31]

Thus, sewage sludge contains many harmful chemicals, which are inadequately regulated. EPA's Part 503 Rule is an inadequate tool for protecting the public from the various harmful toxins in sewage sludge.

B. Composting Sewage Sludge Does Not Effectively Eliminate Toxins and Poses Direct Harm to the Public.

Sewage sludge poses severe threats to human health, and while composting sludge may eliminate pathogens, it wholly fails to eliminate toxic chemicals. "Treated" sewage sludge, renamed "biosolids" by the EPA, finds its way into agriculture, either by direct land application, as an ingredient in industrial and processed fertilizer, or as "compost." According to the EPA, composting is one of several methods for treating sewage sludge to "create a marketable end product that is easy to handle, store and use."[32] The end product is considered "Class A" compost that can be and is applied as "a soil conditioner and fertilizer to gardens, crops and rangelands."[33] This "compost" is often given away to area residents, community gardeners, even schools for application on school gardens.[34] EPA claims that Class A sludge compost is without a detectible level of pathogens. While composting may reduce pathogens, it does not reduce or eliminate the variety of other toxins commonly found in sewage sludge.

Kinney et al. studied the effects of adding plant material (green material) to sewage sludge as proposed at the Nursery Products facility. The results indicated that composting does not reduce OWC concentrations.

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[27] *Id.*; Josh Harkinson, *Sludge Happens*, MOTHER JONES, April 21, 2009, at 1, available at http://www.motherjones.com/environment/2009/05/sludge-happens.
[28] *McElmurray* at 1327.
[29] *Id.* at 1322-24.
[30] *Id.* at 1321.
[31] *Id.* at 1333.
[32] EPA, Biosolids Technology Fact Sheet: Use of Composting for Biosolids Management, available at http://www.epa.gov/owm/mtb/combioman.pdf.
[33] *Id.*
[34] *See* SFPUC's Big Blue Bucket Eco Fair, available at http://sfpucbigbluebucket.eventbrite.com/.

> The addition of plant material effectively dilutes biosolids samples, while possibly increasing the organic matter content of the biosolid production. Composting has been recognized as an effective means to limit or eliminate some organic contaminants, but when the biosolids that are composted are compared to the unamended sludges and granulated biosolid products, the comparable concentrations observed in this study suggest that composting is relatively ineffective at reducing OWC concentrations.[35]

Toxins found in sewage sludge can leach into the soil on site, or become food safety hazards when the compost is used on gardens, farms, or rangelands. For instance, EPA recognizes that 27 metals are present in almost all sludge samples taken for their most recent risk assessment.[36] "Toxic metals do not breakdown in the treatment process or in the environment. As a consequence they can build up in the soil upon repeated application."[37] Since the US standards for metals in sewage sludge are among the most lenient in the world, and since the US only regulates 9 of the 27 metals found in sewage sludge, it is inevitable that metals will be released from sludge and expose humans to their harmful effects.

Plants fertilized with sludge or sludge compost often contain increased levels of metals. A 2007 study found that, for potatoes and peppers grown in soil spread with sewage sludge, the cadmium concentration was almost at the "Codex-established maximum limit"[38] and the lead concentration in potatoes exceeded the maximum level.[39] Further, research indicates that increased dissolved organic carbon (DOC) in sewage sludge decreases the adsorption of metals to soil surfaces through formation through formation of organometalic complexes, thereby increasing the bioavailability of metals to plants.[40] Adverse health effects from heavy metals have been recognized for a long time. For instance, arsenic is a well known toxin and carcinogen.[41] Adults chronically exposed to lead can experience seizures, anorexia, abdominal disorders and personality changes.[42] Children exposed to lead suffer a far worse fate, brain damage.[43] Mercury can also cause brain damage, even in adults.[44] Cadmium and lead are of the greatest concern, because plants actively take them up and introduce them into the human food chain.[45] Even though the health effects of these metals are well-known, the County failed to assess the

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[35] Kinney et al., *supra*, n.17 at 7212.
[36] EPA, Sewage Sludge Survey, *supra*, n. 19.
[37] Hale and Laguardia, *supra*, n.21 at 373.
[38] George F. Antonious & John C. Snyder, *Accumulation of Heavy Metals in Plants and Potential Phytoremediation of Lead by Potato, Solanum tuberosum* L., A 42 J. ENVT'L. SCI & HEALTH 811, 814 (2007).
[39] *Id.*
[40] *Id.*
[41] Heavy Metals in the Environment and Their Effects, July 21, 2009, http://soil-environment.blogspot.com/2009/07/heavy-metals-and-their-health-effects.html
[42] The Hazards of Heavy Metals, http://www.physics.ohio-state.edu/~wilkins/energy/Companion/E14.2.pdf.xpdf.
[43] *Id.*
[44] *Id.*
[45] Antonious and Snyder, *supra*, n.38 at 814.

impact of the release of heavy metals on the environment and potential exposure to the population.

Furthermore, there are a variety of other toxic agents found in sewage sludge with known and unknown consequences to human health and the environment. Poly-brominated diphenal ethers (PBDEs), for example, are commonly found in sewage sludge and are recognized for their impact on human health and the environment.[46] They are chemically related to PCBs and PBBs and replaced them in chemical applications.[47] Chronic exposure to PBDEs or exposure during development can compromise the endocrine and nervous systems.[48] Numerous additional organic pollutants have been found to be present in US sludge, such as polycyclic aromatic hydrocarbons, PCBs, DDT degradation products, chlordadanes, synthetic musk products, triclosan, and tributytin.[49] The presence of these compounds at the Hawes Composting Facility site presents severe human health and environmental risks that must be addressed. Further, the use of sludge compost in local home gardening and in agriculture presents unstudied and unacceptable food safety risks.

The County did not assess the impacts of the release of the above toxins in the environment via the Hawes Composting facility. As a matter of public policy, the County's failure to analyze the human health and environmental risk associated with sewage sludge is inexcusable. As a matter of law, this failure violates the most basic requirements of CEQA to review the environmental impacts of this project.[50]

III. CONCLUSION

The County's issuance of the SEIR was improper. Regardless, this document is inadequate because the County did not assess the environmental impacts of sewage sludge compost. Specifically, the SEIR did not take into account the release of heavy metals, OWCs and other contaminants on the environment. For the above reasons, the County must vacate the current SEIR and prepare an EIR that addresses these and other environmental impacts.

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[46] *See* Hale and Laguardia, *supra* ,n.21.
[47] *Id.* at 376.
[48] *Id.*
[49] *Id.* at 382.
[50] CAL PUB. RES. CODE § 21061.

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Review

Organic chemicals in sewage sludges

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Abstract

Sewage sludges are residues resulting from the treatment of wastewater released from various sources including homes, industries, medical facilities, street runoff and businesses. Sewage sludges contain nutrients and organic matter that can provide soil benefits and are widely used as soil amendments. They also, however, contain contaminants including metals, pathogens, and organic pollutants. Although current regulations require pathogen reduction and periodic monitoring for some metals prior to land application, there is no requirement to test sewage sludges for the presence of organic chemicals in the U. S. To help fill the gaps in knowledge regarding the presence and concentration of organic chemicals in sewage sludges, the peer-reviewed literature and official governmental reports were examined. Data were found for 516 organic compounds which were grouped into 15 classes. Concentrations were compared to EPA risk-based soil screening limits (SSLs) where available. For 6 of the 15 classes of chemicals identified, there were no SSLs. For the 79 reported chemicals which had SSLs, the maximum reported concentration of 86% exceeded at least one SSL. Eighty-three percent of the 516 chemicals were not on the EPA established list of priority pollutants and 80% were not on the EPA's list of target compounds. Thus analyses targeting these lists will detect only a small fraction of the organic chemicals in sludges. Analysis of the reported data shows that more data has been collected for certain chemical classes such as pesticides, PAHs and PCBs than for others that may pose greater risk such as nitrosamines. The concentration in soil resulting from land application of sludge will be a function of initial concentration in the sludge and soil, the rate of application, management practices and losses. Even for chemicals that degrade readily, if present in high concentrations and applied repeatedly, the soil concentrations may be significantly elevated. The results of this work reinforce the need for a survey of organic chemical contaminants in sewage sludges and for further assessment of the risks they pose.

Keywords: Sludge; Biosolids; Land application

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1. Introduction

Sewage sludges are residues generated at centralized wastewater treatment plants (WWTPs) as a result of the treatment of wastes released from a variety of sources including homes, industries, medical facilities, street runoff and businesses The use of these sludges as soil amendments is widely practiced in the U.S., where more than 60% of the 6.2 million dry metric tons (MT) of sludge produced annually are applied to land (U.S. Environmental Protection Agency, 1999). Since 1991 when ocean dumping was banned, both the quantity produced and the percentage land-applied have increased (U.S. Environmental Protection Agency, 1999).

Sewage sludges contain nutrients and organic matter that can provide soil benefits, but they also contain contaminants including metals, pathogens, and organic pollutants. The fate of chemical contaminants entering a WWTP depends on both the nature of the chemical and the treatment processes (Zitomer and Speece, 1993). Organic chemicals may be volatilized, degraded (through biotic and/or abiotic processes), sorbed to sludge, or discharged in the aqueous effluent. Degradation results in the creation of breakdown products that can be either more or less toxic than the original compound.

For many hydrophobic organic chemicals, sorption to the sewage sludge solids is the primary pathway for their removal from wastewater. This is especially true of persistent, bioaccumulative toxics that may enter the waste stream (Petrasek et al., 1983). Even volatile chemicals, such as benzene, are commonly found in sewage sludges as a result of sorption to organic substances in the sludge matrix (Wild et al., 1992). After they have been separated from wastewater, land-applied sludges must be treated to reduce pathogens through one of a number of processes including anaerobic digestion, lime stabilization, or composting. Each of these processes has effects on the fate of both pathogens and the organic contaminants in the sludge (Rogers, 1996).

The information available on the concentration of organic chemicals in sewage sludges arises largely from academic reports or from the national sewage sludge survey (NSSS) which was conducted by the U.S. Environmental Protection Agency (EPA) in 1988 (U.S. Environmental Protection Agency, 1990). The NSSS was performed by analyzing samples of the final sludge product collected from approximately 180 wastewater plants for the presence of 411 chemicals. This survey was used in the development of the U.S. regulations (U.S. Environmental Protection Agency, 1996).

Very few countries have rules limiting the concentration of any organic chemicals in sewage sludges (Beck et al., 1995). The European Union is considering establishing limits for a handful of organic chemicals. Under the Clean Water Act, (CFR Section 405 (d)), the rules regarding the concentration of pollutants permitted in land-applied sewage sludges in the U.S. are mandated to be protective of human health and the environment. A biennial review is called for to determine if there are additional chemicals that might pose a risk and should thus be subject to regulatory review.

To date, EPA has not established regulations for any organic chemicals and there is no federal requirement to monitor the type or concentration of organic chemicals in sludges. When promulgating the original rules in 1993 (CFR 40 Part 503), the EPA declined to include any organic contaminants. There were three criteria that led to the elimination of all of those considered: 1. the chemical was no longer in use in the U.S.; 2. the chemical was detected in 5% or fewer of the sludges tested in the NSSS; or 3. a hazard screening showed the chemical to have a hazard index of one or greater (Beck et al., 1995). Where sufficient data were lacking to evaluate the hazard, for example the lack of fate and transport data, that chemical and pathway were also eliminated from further consideration (U.S. Environmental Protection Agency, 1996).

Concerns with this process include the persistence of some chemicals in the environment despite their elimination in commerce, the high detection limits for some chemicals, and the potential risks posed by chemicals that were eliminated from consideration merely due to a lack of data (National Research Council, 2002). In a court-ordered review of additional contaminants, the EPA reconsidered regulation of some organic chemicals. In that review, it eliminated chemicals that were detected in 10% or fewer of the sludges in the NSSS. Of the 411 analytes in the NSSS 269 were not detected and 69 were detected in fewer than 10% of the sludges. Fifteen of the 73 remaining chemicals were eliminated due to lack of toxicity data (U.S. Environmental Protection Agency, 1996). Hazard screening analysis was conducted on the remaining chemicals. Dioxins, furans and co-planar PCBs were the only organic chemicals that remained and a risk assessment was then conducted (U.S. Environmental Protection Agency, 2002). Based on the assessment, EPA decided not to extend regulation to dioxins or any other organic pollutant (U.S. Environmental Protection Agency, 2003a). The Round 2 review conducted by the EPA in 2003 was not limited to the chemicals analyzed in the

NSSS. It considered 803 chemicals and resulted in the selection of 15 chemicals as candidates for regulation based on available human health or ecological risk end points but not on concentration data from sludges. Among those were 9 organic chemicals (U.S. Environmental Protection Agency, 2003b).

The National Research Council of the U.S. Academy of Sciences (NRC) conducted two reviews of the land application of biosolids (National Research Council, 1996; 2002). Their 2002 report included a comparison of the limits of detection for samples analyzed in the NSSS to EPA soil screening limits (SSLs) and pointed out that high limits of detection for many chemicals in the NSSS were a concern. The SSLs are conservative risk-based soil concentrations of selected industrial pollutants (93 organic and 16 inorganic compounds) that are used in determining whether a site specific risk assessment is required at a Superfund site (U.S. Environmental Protection Agency Superfund, 1996).

The SSLs were used by the NRC as an indicator of concentrations that might pose a risk requiring remediation. For 5 of 8 organic chemicals examined in the NRC report, most sludge samples analyzed in the NSSS had limits of detection that were higher than the EPA-established SSLs. Thus the NSSS results were not sensitive enough to detect pollutant concentrations that, if present in soil at a Superfund site, would have triggered a risk assessment. For example, in the case of hexachlorobenzene (HCB), the NSSS did not detect HCB in any of the 176 samples tested, thus prompting EPA to exclude it from regulatory consideration. The NSSS limits of detection exceeded 5 mg/kg for the majority of samples and was greater than 100 mg/kg for 4 samples (National Research Council, 2002). Depending on the pathway of exposure being considered, the SSLs for HCB range from 0.1 to 2 mg/kg. Only one of the NSSS samples reached a limit of detection of 0.1 mg/kg. Analysis of the data compiled in this paper revealed that 9 of the 13 reports of HCB concentrations in sewage sludges exceeded 0.1 mg/kg and 3 exceeded 2 mg/kg. Thus the majority of samples exceeded an SSL for HCB.

In addition to concerns regarding analytical limitations, the introduction of new chemicals into commerce, suggests that there is a need for a new survey in order to better characterize sludges with respect to the presence and concentration of contemporary organic chemicals. Flame retardants, surfactants, chlorinated paraffins, nitro and polycyclic musks, pharmaceuticals, odorants, as well as chemicals used in treating sludges (such as dewatering agents) are among the chemical categories suggested by the NRC as compounds requiring additional data collection and consideration in future risk assessments (National Research Council, 2002).

Although the EPA conducted a limited survey of sludges in 2001 to determine the concentration of dioxins, furans and co-planar PCBs, and plans to conduct a survey of sludges to test for the 9 organic chemicals being considered for regulation, it is not proposing a broader survey of organic chemicals in sludges (U.S. Environmental Protection Agency, 2003b).

2. Methods

To help fill the gaps in knowledge regarding the presence and concentration of organic chemicals in sewage sludges, we examined the peer-reviewed literature and official governmental reports to compile available data on the concentration of organic chemicals reported in sludges. In some cases sources did not contain sufficient information to permit comparison of chemical concentrations as a function of sludge dry weight and were therefore not included. One hundred and thirteen usable data sets were obtained. Reports were inconsistent in providing individual versus average or median values so we have reported the ranges detected and are not able to offer averages. Where available, average values from a specific report are noted (supporting information 1). There are several important aspects of wastewater and sludge treatment that can affect the fate of organic chemicals. Unfortunately many reports do not include such information. Where available, the type of treatment is noted (supporting information 1). Similarly, most reports did not include information on the type of catchment area or on significant non-domestic inputs that might contribute particular chemicals.

The chemicals were grouped into 15 classes and the range of concentrations reported for each chemical was recorded. Data were found for 516 chemicals and the range of concentrations detected in each of the sources was recorded (supporting information 1). For ease of presentation, this list was reduced to 267 chemicals through the grouping of congeners and isomeric compounds. The range of concentrations for compounds that have been reported in sewage sludges and the sources from which these data were obtained are shown in Table 1.

To provide a context for the sludge concentration data, we sought soil pollutant concentration standards with which to compare the sludge concentrations. We found that the U.S. SSLs, soil clean-up standards in Ontario and Dutch Intervention values were supported

Table 1
Concentrations of organic chemicals reported in sewage sludges and sources of those data

	Range mg/kg dry wgt	Data sources [a]
Aliphatics—short chained and chlorinated		
Acrylonitrile	0.0363–82.3	[1]
Butadiene (hexachloro-1,3-)[SSL]	ND–8	[1–4]
Butane (1,2,3,4-diepoxy)	ND–73.9	[5]
Butanol (iso)	ND–0.165	[5]
Butanone (2-)	ND–1540	[5]
Carbon disulfide[SSL]	ND–23.5	[5]
Crotonaldehyde	ND–0.358	[5]
Cyclopentadiene (hexachloro) [SSL]	<0.005	[2]
Ethane (hexachloro)[SSL]	0.00036–61.5	[3]
Ethane (monochloro)	ND–24	[3]
Ethane (pentachloro)	0.0003–9.2 g	[3]
Ethane (tetrachloro)	<0.1–5.0	[6]
Ethane (trichloro) isomers[SSL]	ND–33	[7]
Ethylene (dichloro)[SSL]	<0.01–865	[3,8]
Ethylene (monochloro)	<0.025–110	[2,3]
Ethylene (tetrachloro)[SSL]	ND–50	[1–3,5,7,8]
Ethylene (trichloro)[SSL]	ND–125	[2,3,5,7]
Hexanoic acid	ND–1960	[5]
Hexanone (2-)	ND–12.7	[5]
Methane (dichloro)[SSL]	ND–262	[3,5,8,9]
Methane (monochloro)	ND–30	[5]
Methane (tetrachloro)[SSL]	ND–60	[2,3,5–7]
Methane (trichloro)[SSL]	ND–60	[2,5–7]
Methane (trichlorofluoro)	ND–3.97	[5]
N-alkanes (polychlorinated)	1.8–93.1	[10]
N-alkanes	ND–758	[5]
Organic halides absorbable (AOX) and extractable (EOX)	1–7600	[7,11–13]
Pentanone (methyl)	ND–0.567	[5]
Polyorganosiloxanes	8.31–5155	[14–18]
Propane (dichloro) isomers[SSL]	ND–1230	[1,3,5]
Propane (trichloro)	0.00459–19.5	[1,3]
Propanenitrile (ethyl cyanide)	ND–64.7	[5]
Propanone (2-)	ND–2430	[5]
Propen-1-ol (2-)	ND–0.0312	[5]
Propene (trichloro)	<0.0010–167	[1]
Propene chlorinated isomers[SSL]	0.002–1230	[3,5]
Propenenitrile (methyl)	ND–218	[5]
Squalene	ND–16.7	[5]
Sulfone (dimethyl)	ND–0.784	[5]
Chlorobenzenes		
Benzene (dichloro) isomers[SSL]	ND–1650	[2,3,5,8, 19,20]
Benzene (hexachloro)[SSL]	ND–65	[1,2,4,7,11, 20–22]
Benzene (monochloro)[SSL]	ND–846	[3,5,19]

Table 1 (*continued*)

	Range mg/kg dry wgt	Data sources [a]
Chlorobenzenes		
Benzene (pentachloro)	<0.005–<0.01	[2,20]
Benzene (tetrachloro)	<0.001–0.22	[2,20]
Benzene (trichloro) isomers[SSL]	ND–184	[2,3,5,19,20]
Flame retardants		
Brominated diphenyl ether congeners (BDEs)	<0.008–4.89	[23–30]
Cyclododecane (hexabromo) isomers	<0.0006–9.120	[31]
Tetrabromobisphenol A	<0.0024–3322	[32]
Tetrabromobisphenol A (dimethyl)	<0.0019	[32]
Monocyclic hydrocarbons and heterocycles		
Acetophenone	ND–6.92	[5]
Aniline (2,4,5-trimethyl)	ND–0.220	[5]
Benzene[SSL]	ND–11.3	[3,5,33]
Benzene (1,4-dinitro)	ND–4.4	[5]
Benzene (ethyl)[SSL]	ND–65.5	[3,5]
Benzene (mononitro)[SSL]	ND–1.55	[2,5]
Benzene (trinitro)	12	[34]
Benzenethiazole (2-methylthio)	ND–64.4	[5]
Benzenethiol	ND–3.25	[5]
Benzoic acid[SSL]	ND–835	[5]
Benzyl alcohol	ND–156	[5]
Analine (chloro) (P-)[SSL]	ND–40.2	[5]
Cymene (P-)	ND–84.3	[5]
Dioxane (1,4-)	ND–35.3	[5]
Picoline (2-)	ND–365	[5]
Styrene[SSL]	ND–5850	[3,5]
Terpeniol (alpha)	ND–2.56	[5]
Thioxanthe-9-one	ND–19.6	[5]
Toluene[SSL]	ND–1180	[3,5,6,8,9, 34,35]
Toluene (chloro)	1.13–324	[5]
Toluene (2,4-dinitro)[SSL]	ND–10	[2,5,34]
Toluene (para nitro)	100	[34]
Toluene (trinitro)	12	[34]
Xylene isomers[SSL]	ND–6.91	[5,8,33, 35–37]
Nitrosamines		
***N*-nitrosdiphenylamine[SSL]**	ND-19.7	[5]
N-nitrosodiethylamine	ND–0.0038	[38]
N-nitrosodimethylamine	0.0006–0.053	[38]
N-nitrosodi-*n*-butylamine	ND	[38]
N-nitrosomorpholine	ND–0.0092	[38]
N-nitrosopiperdine	ND–trace	[38]
N-nitrosopyrrolidine	ND–0.0042	[38]
Organotins		
Butylitin (di)	0.41–8.557	[39–44]
Butyltin (mono)	0.016–43.564	[39–44]

Table 1 (*continued*)

	Range mg/kg dry wgt	Data sources [a]
Organotins		
Butyltin (tri)	0.005–237.923	[9,39–44]
Phenyltin (di)	0.1–0.4	[42,43]
Phenyltin (mono)	0.1	[42,43]
Phenyltin (tri)	0.3–3.4	[42,43]
Personal care products and pharmaceuticals		
Acetaminophen	0.0000006–4.535	[45]
Gemfibrozil	ND–1.192	[45]
Ibuprofen	0.000006–3.988	[45]
Naproxen	0.000001–1.022	[45]
Salicylic acid	0.000002–13.743	[45]
Antibiotics		
Ciprofloxacin	0.05–4.8	[46,47]
Doxycycline	<1.2–1.5	[47]
Norfloxacin	0.01–4.2	[46,47]
Ofloxacin	<0.01–2	[47]
Triclosan (4-chloro-2-(2,4-dichloro-phenoxy)-phenol and related compounds	ND–15.6	[25,48–50]
Fluorescent whitening agents		
BLS (4,4'-bis(4-chloro-3-sulfostyryl)-biphenyl)	5.4–5.5	[51]
DAS 1 (4,4'-bis[(4-anilino-6-morpholino-1,3,5-triazin-2-yl)-amino] stilbene-2,2'-disulfonate)	86–112	[51]
DSBP (4,4'-bis (2-sulfostyryl)biphenyl)	31–50	[51]
Fragrance material		
Acetyl Cedrene	9.0–31.1	[52]
Amino Musk Ketone	ND–0.362	[37]
Amino Musk Xylene (AMX)	ND–0.0315	[37]
Cashmeran (DPMI) (6,7-dihydro-1,1,2,3,3-pentamethyl-4(5H)-indanone)	ND–0.332	[34,37]
Celestolide (1-[6-(1,1-Dimethylethyl)-2,3-dihydro-1,1-methyl-1H-inden-4-yl]-ethanone)	0.010–1.1	[34,37,53,54]
Diphenyl Ether	ND–99.6	[5,52]
Galaxolide (HHCB) (1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[g]-benzopyran)	ND–81	[25,34,37, 52–56]
Galaxolide lactone (1,3,4,6,7,8-Hexahydro-4,6,6,7,8,8-hexamethylcyclopenta[g]-2-benzopyran-1-one)	0.6–3.5	[54]
Hexyl salicylate	Trace–1.5	[52]

Table 1 (*continued*)

	Range mg/kg dry wgt	Data sources [a]
Fragrance material		
Hexylcinnamic Aldehyde (Alpha)	4.1	[52]
Methyl ionone (gamma)	1.1–3.8	[52]
Musk Ketone (MK) (4-tertbutyl-3,5-dinitro-2, 6-dimethylacetophenone)	ND–1.3	[37,52,57]
Musk Xylene (1-*tert*-butyl-3, 5-dimethyl-2,4,6-trinitrobenzene)	ND–0.0325	[57]
OTNE (1-(1,2,3,4,5, 6,7,8-octahydro-2, 3,8,8-tetramethyl-2-naphthalenyl))	7.3–30.7	[52]
Phantolide (1-[2,3-Dihydro-1,1,2,3,3,6-hexamethyl-1H-inden-5-yl]-ethanone)	0.032–1.8	[34,37, 53,54]
Tonalide (1-[5,6,7,8-Tetrahydro-3,5,5,6,8,8-hexamethyl-2-naphthalenyl]-ethanone)	ND–51	[25,37, 52–55]
Traseolide (ATII) (1-[2,3-Dihydro-1,1,2,6-tetramethyl-3-(1-methyl-ethyl)-1H-inden-5-yl] ethanone	0.044–1.1	[53,54]
Pesticides		
Aldrin[SSL]	ND–16.2	[1–5,21,22, 33,58,59]
Azinphos Methyl	ND–0.279	[5]
Benzene (pentachloronitro)	ND–8.83	[5]
Captan	ND–0.968	[5]
Chlordane[SSL]	ND–16.04	[1,3,5]
Chlorobenzilate	ND–0.104	[2,5]
Chloropyrifos	ND–0.529	[5]
Ciodrin	ND–0.093	[5]
Cyclohexane isomers (lindane and others[SSL]**)**	ND–70	[1–7,9,11,21, 22,59–62]
DDT and related congeners[SSL]	ND–564	[1–5,7,9, 11,21,22,33, 58,60–62]
Diallate	ND–0.394	[2,5]
Diazinon	ND–0.151	[5]
Dicrotophos (Bidrin)	ND–0.550	[5]
Dieldrin[SSL]	ND–64.7	[1–7,21,22, 33,60,61]
Dimethoate	ND–0.340	[2,5]
Disulfotone	<0.0050	[2]
Endosulfans	ND–0.280	[2,4,5,21]
Endrin[SSL]	ND–1.17	[1,2,4,5,21, 22,59]
Famphur	<0.0050–0.400	[2]

(continued on next page)

Table 1 (*continued*)

	Range mg/kg dry wgt	Data sources [a]
Pesticides		
Heptachlor epoxides[SSL]	ND–0.780	[1,2,5,21]
Heptachlor[SSL]	ND–16	[2,3,5,21,22]
Isobenzan	ND–0.130	[4]
Isodrin	ND	[4]
Isophorone[SSL]	<0.0050–0.08294	[2]
Leptophos	ND–0.319	[5]
Methoxychlor[SSL]	<0.015–0.330	[2]
Mevinphos (phosdrin)	ND–0.148	[5]
Naled (Dibrom)	ND–0.484	[5]
Naphthoquinone (1,4-)	<0.0050	[2]
Nitrofen	ND–0.195	[5]
Parathion (ethyl)	<0.0050–0.380	[2]
Parathion (methyl)	<0.0050–0.070	[2]
Permethrin isomers	<0.15–163	[20,63]
Phenoxy herbicides[SSL]	ND–7.34	[1,2,5]
Phenoxypropanoic acid (trichloro)	ND–0.121	[5]
Phorate (*O*,*O*-diethyl *S*-[(ethylthio) methyl] phosphorodithioate)	<0.0050–0.200	[2]
Phosphamidon	ND–0.232	[5]
Pronamide (dichloro (3,5-)-*N*-(1,1-dimethylpropynyl) benzamide)	<0.0050–0.008	[2]
Pyrophosphate (tetraethyl)	ND–20	[5]
Quintozene	ND–0.100	[4]
Safrol (iso)	<0.0050–0.750	[2]
Safrole (EPN)	ND–0.545	[2]
Toxaphene[SSL]	51	[3]
Trichlorofon	ND–2.53	[5]
Trifluralin (Treflan)	ND–0.235	[5]
Phenols		
Bisphenol-A (BPA)	0.00010–32,100	[18,49,64,65]
Hexachlorophene (HCP)	0.0226–1.190	[49]
Hydroquinone	0.14–223	[3]
Hydroxybiphenyls	ND–0.172	[64]
Phenol[SSL]	ND–920	[2,3,5,7, 8,36,66]
Phenol chloro congeners[SSL]	<0.003–8490	[1–3,5–9, 33,35,49, 61,66–68]
Phenol chloro methyl congeners	ND–136	[2,3,5,8,9, 61,64]
Phenol methyl congeners[SSL]	ND–1160	[2,3,5,7–9, 34,66]
Phenol nitro methyl congeners	0.2–187	[5]
Phenols nitro congeners[SSL]	<0.003–500	[2,3,8]

Table 1 (*continued*)

	Range mg/kg dry wgt	Data sources [a]
Phthalate acid esters/plasticizers		
Bis(2-chloroethyl) ether[SSL]	<0.020–0.130	[2]
Bis(2-chloroisopropyl) ether	<0.150–5.700	[2]
Bis(2-cloroethoxy) methane	<0.020–0.240	[2]
Di(2-ethylhexyl) adipate	<0.100–0.450	[2]
Phthalates[SSL]	ND–58,300	[2,3,5–9, 28,33,36, 58,69–73]
Polychlorinated biphenyls, naphthalenes, dioxins and furans		
Aroclor 1016	0.2–75	[6,74]
Aroclor 1248	ND–5.2	[5,6,33,58]
Aroclor 1254	0.0667–1960	[1,5]
Aroclor 1260	ND–433	[1,5,6,58,60]
Biphenyl (decachloro)	0.11–2.9	[1]
Biphenyls (polybrominated)	431	[3]
Dibenzofuran	ND–59.3	[5]
Dioxins and furans (polychlorinated dibenzo)	ND–1.7	[5,8,72, 75–81]
PCB congeners	ND–765	[2–5,7,11, 13,21,22,28, 35,53,59, 61,71,72, 79,81–87]
Phenylether (chloro)	<0.020	[2]
Terphenyls and naphthalenes (polychlorinated)	ND–11.1	[2,3,5,9, 28,53]
Polynuclear aromatic hydrocarbons		
Acenaphthene[SSL]	ND–6.6	[2,5,8,21,53, 82,88]
Acenaphthylene	0.00360–0.3	[2,8,21,53]
Anthracene[SSL]	ND–44	[2,3,5,8,21, 28,31,53, 74,88,89]
Benzidine	12.7	[3]
Benzo(*a*)anthracene[SSL]	ND–99	[2,3,5,8, 21,53, 82,88–90]
Benzo[*ghi*]perylene	ND–12.9	[1,2,5–8, 21,22,28, 53,88–91]
Benzofluoranthene congeners[SSL]	0.006–34.2	[3,89]
Benzofluorene congeners	ND–8.1	[62,89]
Benzopyrene congeners[SSL]	ND–24.7	[1–3,5–8, 11,21,22,28, 33,53,62, 82,88–91]

Table 1 (*continued*)

	Range mg/kg dry wgt	Data sources [a]
Polynuclear aromatic hydrocarbons		
Biphenyl	ND–15,300	[3,5,53]
Chrysene[SSL]	ND–32.4	[3,5,8,21,53, 82,88,90]
Chrysene+triphenylene	0.01–14.7	[2,89]
Dibenzoanthracene congeners[SSL]	ND–13	[2,3,8,21,53, 88,89,91]
Dibenzothiophene	ND–1.47	[5]
Diphenyl amine	ND–32.6	[5]
Fluoranthene[SSL]	ND–60	[1–3,5–8,21, 22,28,33,53,62, 82,88–90]
Fluorene[SSL]	<0.01–8.1	[2,8,21,53, 82,88]
Fluorene (nitro)	0.941	[28]
Indeno(1,2,3-c,d) pyrene[SSL]	ND–9.5	[2,7,8,21,22, 28,53,88–91]
Naphthalene[SSL]	ND–6610	[2,3,5,6,8,21, 36,53,62,88]
Naphthalene methyl isomers	ND–136	[2,5,28,53]
Napthalene methyl congeners		
Napthalene nitro congeners	ND–0.0798	[28]
Perylene	ND–69.3	[3,5,53,89,91]
Phenanthrene	<0.01–44	[2,3,5,6, 8,21,28,53, 62,82,88–90]
Phenanthrene methyl isomers	ND–37.4	[5,53]
Pyrene[SSL]	0.01–37.1	[2,3,5,6, 8,21,53, 82,88–90]
Pyrene (phenyl)	0.06–6.86	[1]
Retene (7-isopropyl-1-methylphenanthrene)	0.260	[28]
Total PAH	ND–199	[9,11,28, 72,86]
Triphenylene	ND–15.4	[5]
Sterols, stanols and estrogens		
Campestanol (5a+5b)	3.0–14	[55]
Campesterol	6.3	[55]
Cholestanol (5a-)	22.7	[49,87]
Cholesterol	57.4	[55]
Coprostanol	216.9	[55]
Estradiol (17b)	0.0049–0.049	[92,93]
Estrone	0.016–0/0278	[92,93]
Ethinylestradiol (17a)	<0.0015–0.017	[92,93]
Sitostanol (5a-b+5b-b-)	14.1–93.9	[55]
Sitosterol (b-)	29.6–31.1	[55]
Stigmastanol (5a-+5b)	1.9–12.9	[55]
Stigmasterol	6.7	[55]

Table 1 (*continued*)

	Range mg/kg dry wgt	Data sources [a]
Surfactants		
Alcohol ethoxylates	ND–141	[70,94,95]
Alkylbenzene sulfonates	<1–30,200	[6,7,9, 70–72,74, 85,94,96–98]
Alkylphenolcarboxylates	10–14	[92]
Alkylphenolethoxylates	ND–7214	[2,7,25,28, 49,69,71,72, 85,90,92, 94,99–101]
Alkyphenols (nonyl and octylphenol)	ND–559,300	[2,6,9,18,25, 28,36,49,64, 69,74,92, 95,99–107],
Coconut diethanol amides	0.3–10.5	[70]
Poly(ethylene glycol)s	1.7–17.6	[70]
Triaryl/alkyl phosphate esters		
Cresyldiphenyl phosphate	0.61–179	[3]
Tricresyl phosphate	0.069–1650	[3]
Tricresyl phosphate	<0.020–12.000	[2]
Tri-*n*-butylphosphate	<0.020–2.400	[2]
Triphenylphosphate	<0.020–1.900	[2]
Trixylyl phosphate	0.027–2420	[3]

See Supporting Information 1 for further detail.

Boldfaced = one or more reported concentrations exceed an SSL. SSLs may be established only for a particular congener. Table 1 groups congeners and where any one of the congener concentration exceeds an SSL for that congener, the group of congeners is shown in bold. Available data for specific congeners is shown in supporting information 2.

[SSL] indicates that SSLs have been established for one or more congener in this group.

ND indicates not detected where the lower limit of detection is not specified. >*XX* indicates not detected at the specified (*XX*) limit of detection.

[a] The data sources for this table are identified by number and cited below as a part of this table.

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by risk-based analyses. The Ontario regulatory maximum soil concentration limits address several different land uses and pathways of exposure for 118 chemicals (Ontario Ministry of the Environment, 2004). The Dutch system includes target values that seek to prevent harm to human and ecological systems as well as intervention values where predicted harm requires clean-up to be implemented. The Ontario and Dutch values are generally comparable to the U.S. SSLs, but values for specific chemicals are not identical, presumably due to differences in assumptions (Netherlands Ministry of Housing Spatial Planning and Environment, 2000).

For the purposes of this paper, we compared the reported sludge concentrations to the SSL values for those compounds for which EPA has established an SSL. The SSLs are not regulatory standards, but are guidelines used by EPA relative to cleaning up industrially-contaminated sites. Sites with soil concentrations lower than the SSLs are considered “clean,” while sites with higher concentrations require site-specific risk analysis. Using default values for a residential exposure scenario, the EPA risk-based SSLs address exposure pathways including direct ingestion of contaminated soil, inhalation, dermal exposure, drinking of groundwater contaminated by migration of chemicals through soil, and ingestion of homegrown produce contaminated via plant uptake (U. S. Environmental Protection Agency Superfund, 1996). The groundwater pathway includes two values, one assuming no dilution or attenuation (1 DAF) and the other assuming a 20-fold dilution/attenuation (20 DAF). SSLs do not include risks posed by ingesting animal products grown on contaminated soils, nor do they address environmental and ecologic risks. These human health SSLs are based on a 10^{-6} risk for carcinogens or a hazard quotient of 1 for non-carcinogens and separate SSL concentrations are listed for four different exposure pathways (ingestion, inhalation, groundwater 20 DAF, groundwater 1 DAF). For most organic contaminants, the groundwater SSL that assumes no attenuation or dilution is the most restrictive concentration (supporting information 2).

It is likely that the concentration of a chemical in a soil to which sludge has been applied would be lower than the concentration in the sludge itself due to mixing and subsequent dilution with soil as well as through degradation, volatilization and leaching processes. A single application of sludge tilled into the soil would be diluted approximately 100-fold, but concentrations would increase with repeated applications when losses are not as great as application rates and would also be higher in surface soils if sludge is not tilled into the soil such as in pasture application. Despite the differences between contaminated soils and sludges, the NRC (National Research Council, 2002) used SSLs as an EPA-established metric to suggest whether further evaluation might be warranted. We thus report sludge concentrations of organic contaminants that exceed an SSL (Table 1; supporting information 2).

Two other EPA-generated lists of chemicals were also used to evaluate the organic chemicals reported in sludges. The first is a list of chemicals generated in 1979 and modified in 1981 for which technology-based water effluent limitations were required (Keith and Telliard, 1979). These 126 chemicals, known as priority pollutants, reflect the knowledge of contaminants in industrial wastewater effluents during the 1970s. One hundred and eleven of these are organic chemicals. Although there are no federal requirements for monitoring these compounds in sewage sludges, some states, including New York (New York State Department of Environmental Conservation, 2003), require screening of land-applied sludges for these priority pollutants. The second list includes chemicals that laboratories performing analyses on Superfund site soils must be able to detect and quantify. These 143 chemicals are known as target compounds (U.S. Environmental Protection Agency, 2004). Table 2 provides a summary, by class, of the number of chemicals reported in sludges that fall into these groups.

3. Results and discussion

Tens of thousands of organic chemicals are currently in use, however sludge concentration data could only be found for 516 organic chemicals in the peer reviewed literature and official government reports (supporting information 1). Table 2 shows the number of compounds in each of the 15 classes for which concentration data were found, and the number of studies from which these data were obtained.

Ninety of the 111 organic priority pollutants and 101 of the 143 target compounds were reported in sludges (Table 2). No data were found for the other 21 organic priority pollutants or 42 target compounds. Eighty-three percent of the reported chemicals were not on the priority pollutant list and 80% were not on the target compounds list. Thus monitoring sludges for priority pollutants will not capture the vast majority of chemicals that may be present.

Six of the 15 chemical classes for which data were found did not contain compounds included among the priority pollutants, target compounds, or those compounds with SSLs (Table 2). This may be due in part to

Table 2
Number of chemicals reported in sludges in each class, number of studies from which data were obtained, number that are priority pollutants, target compounds or for which there are SSLs, and number for which maximum reported concentrations in sludges exceed an SSL

	# chem	# of studies	# PP chem	# TC chem	# chem with SSLs	# chem that exceed an SSL
Aliphatics	58	19	16	17	16	15
Chlorobenzenes	11	13	6	7	5	5
Flame retardants	29	11	0	0	0	
Monocyclic HC	34	12	7	12	11	10
Nitrosamines	7	1	2	1	1	1
Organotins	6	7	0	0	0	
PCPs	36	17	0	0	0	
Pesticides	71	20	18	19	18	15
Phenols	40	20	10	14	9	8
Phthalate	19	16	9	8	6	6
PCBs	108	38	5	6	0	
PAHs	52	25	18	18	13	8
Sterols and stanols	16	3	0	0	0	
Surfactants	23	33	0	0	0	
Triaryl/alkyl phosphate.esters	6	2	0	0	0	
Total	516	113 [a]	91	102	79	68

[a] Note: # of studies is not a sum of the list above because some studies include data for more than one class.

the fact that all three of these lists arose out of a response to a concern over the fate of industrial contaminants. Thus some chemicals, such as personal care products, that are present in sludges primarily as a result of non-industrial sources, do not appear on those lists. In addition, the priority pollutant list is 25 years old, so industrial chemicals of current and emerging concern, such as polybrominated diphenyl ethers, which were not in wide use at that time, were not included.

There are SSLs for 15% of the 516 organic chemicals reported in sludges. The reported maximum sludge concentration exceeded an SSL for 86% of the chemicals for which there are SSLs (Table 2, supporting information 2). This high proportion is observed in most classes, with PAHs as an exception.

The proportion of individual reports that exceed an SSL for a particular chemical was examined to determine whether such exceedances were the result of single high-concentration reports or whether most reported values exceeded an SSL. The data show that for chemicals in some classes such as aliphatics and monocyclic hydrocarbons, most reported concentrations for chemicals within that class exceed an SSL while for other classes including phthalates and polyaromatic hydrocarbons, a much smaller percentage of the reported concentrations were high enough to exceed an SSL (Table 3). However, even within these classes, there are some chemicals for which a high percentage of reports exceed an SSL (Fig. 1).

As a result of an evaluation of additional sludge-borne chemicals for which regulation should be considered, the EPA has suggested that it will conduct limited additional sludge testing including efforts to monitor the presence of 9 organic chemicals (acetone, anthracene, carbon disulfide, 4-chloroaniline, diazinon, fluoranthene, methyl ethyl ketone, phenol, and pyrene) (U.S. Environmental Protection Agency, 2003b). In the present work, no data were found for two of the 9

Table 3
The percentage of reported concentrations that exceed an SSL for chemicals within a class for which there are SSLs

	% for which 100% reports exceed SSL	% for which 75–99% reports exceed	% for which 50–74% reports exceed	% for which 25–50% reports exceed	% for which 0–25% reports exceed
Aliphatics	75	6	19	0	0
Chlorobenzenes	20	20	60	0	0
Monocyclic	75	8	0	0	17
Nitrosamines	100				
Pesticides	31	13	25	6	19
Phenols	22	22	33	11	11
Phthalate	17	0	17	17	50
PAHs	0	23	8	15	54

See Supporting Information 2 for the specific chemicals and SSLs.

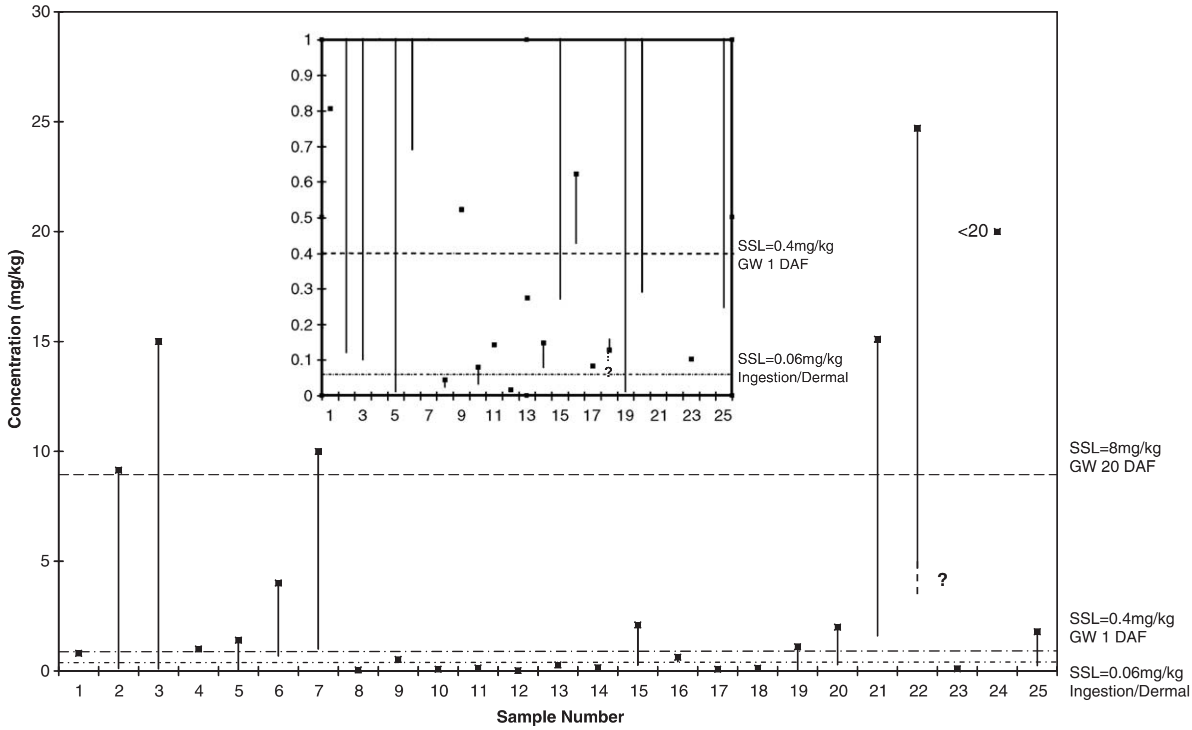

Fig. 1. Concentration (dry wgt) of benzo[a]pyrene in sewage sludges compared to soil screening levels. Note: ? means the report did not specify the concentration of values reported as non-detects.

compounds (acetone and methyl ethyl ketone). Data were found for the other 7 compounds (Table 1; supporting information 1; supporting information 2).

Anthracene was reported in 12 studies with a range from 0.0088 to 44 mg/kg. Six studies detected more than 1 mg/kg, but none exceeded an SSL. Only the NSSS reported concentrations for carbon disulfide, *p*-chloroaniline and diazinon, with maximum concentrations of 23.5, 40.2 and 0.15 mg/kg respectively. The carbon disulfide value exceeded the lower groundwater SSL and the *p*-chloroaniline value greatly exceeded both groundwater SSLs. There are no SSLs for diazinon. Fluoranthene was reported in 17 studies with concentrations ranging from 0.01 to 60 mg/kg, but none exceeded any SSL. Seven studies reported phenol ranging from 0.002 to 920 mg/kg, with concentrations of over 100 mg/kg reported in four studies, suggesting that these high concentrations were not a result of a particular source of contamination or analytic error. Six studies reported concentrations exceeding the lower groundwater SSL and four exceeded both groundwater SSLs. Eleven studies reported pyrene concentrations ranging from 0.1 to 36.8 mg/kg, but none exceeded any SSL. These data suggest that several of the contaminants that EPA proposes to study are not likely to be of concern since data on their concentration in sludges exist and demonstrate concentrations below SSLs indicating they are unlikely to be present in concentrations high enough to be of significant risk.

Benzo(a)pyrene and hexachlorobenzene were suggested as pollutants requiring further analysis by the NRC in a 1996 report (National Research Council, 1996). In the present work, 19 sources reported benzo(a)pyrene in sludges at concentrations from <0.01 to 25 mg/kg, with 24 of 27 reported concentrations exceeding one or more SSL (Fig. 1; supporting information 2). Hexachlorobenzene was reported by 9 sources. Nine of 13 reported concentrations exceed an SSL (Fig. 2; supporting information 2). These data suggest the value of assessing the risks posed by these chemicals in sludges.

Another group of compounds suggested as a possible concern is nitrosamines. Given the toxicity of nitrosamines and the potential for their formation during the wastewater treatment process, it is surprising that only two sources from the 1980s report nitrosamine concentration in sludges. Of the 7 compounds reported, there are SSLs for only one and the reported concentrations for that compound (*N*-nitrosdiphenylamine) exceed the groundwater and ingestion/dermal SSLs. The NSSS detected *N*-Nitrosodiphenylamine in 1% of the sludges tested and hence it was eliminated from regulatory consideration by EPA. The maximum concentration

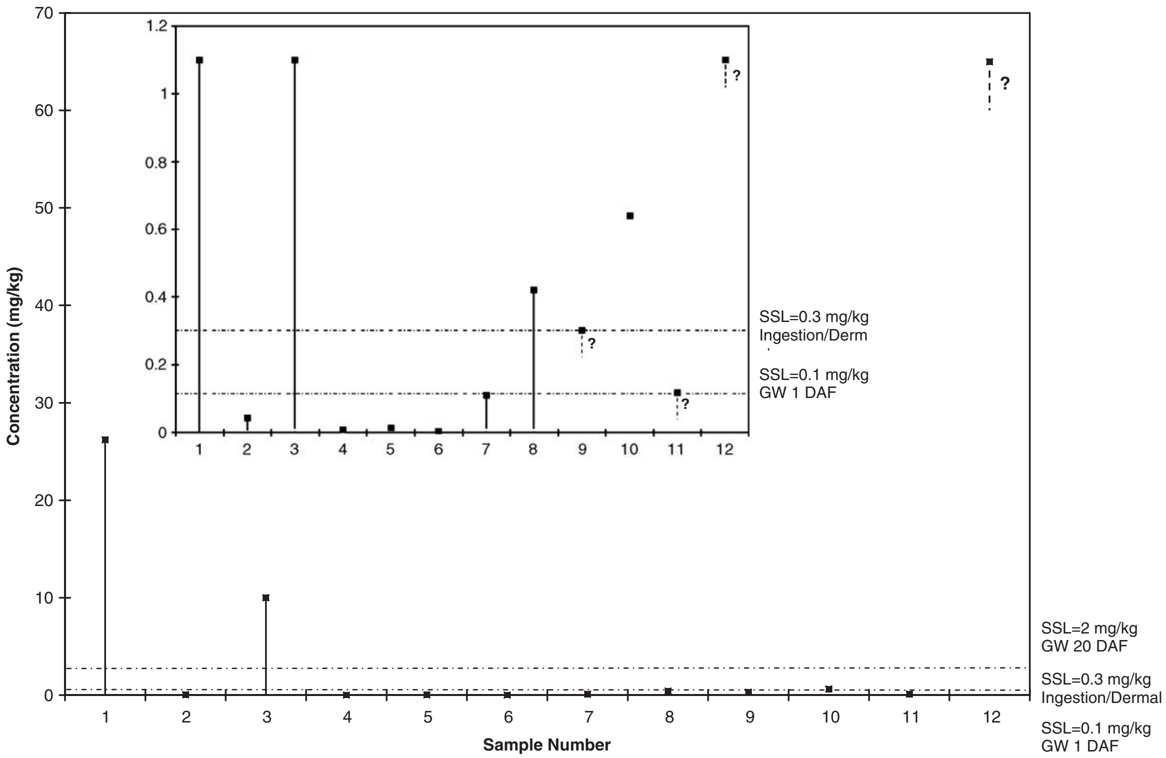

Fig. 2. Concentration (dry wgt) of hexachlorobenzene in sewage sludges compared to soil screening levels. Note: ? means the report did not specify the concentration of values reported as non-detects.

detected was 19.7 mg/kg. Most samples had a limit of detection exceeding 1 mg/kg although detection limits as high as 800 mg/kg were also reported. The high limits of detection in many cases helped prompt the NRC to speculate that *N*-Nitrosodimethylamine may be present in some sludges at concentrations of concern (National Research Council, 1996).

Reported concentrations exceeding an SSL should not be interpreted to indicate a significant risk, but rather indicate that the concentration of those chemicals would be sufficient to require further assessment if present in soil at the same level. While sludge management and environmental processes may alter the concentrations of these chemicals in field situations through mixing with soil, leaching, degradation and other processes, the number of SSL exceedences suggests that assessment of the potential risks may be warranted.

The use of SSLs as a screening tool, does not address some potential routes of human exposure that may represent significant risk (Wild and Jones, 1992), including food chain transfer through the consumption of animal products. For organic contaminants in land applied sludges, this has been suggested as one of the two exposure pathways representing the highest risk, the other being direct ingestion of soil and sludge by humans (Chaney et al., 1996). Application of sludge products to lawns, athletic fields and home gardens could provide a route for direct ingestion. The lipophilic nature of many organic chemicals found in sludges causes them to accumulate in the fat of exposed animals. Livestock may be exposed to sludge contaminants through sludge adhering to plant materials as well as through the ingestion of soil when sludges are applied to pasture (Fries, 1996).

Much of the work evaluating the potential risks posed by organic chemicals in sludges addresses human health risks. However, in addition to potential human impacts, organic chemicals in land applied sludges may pose environmental or ecological risks. The use of SSLs as a trigger does not account for these risks as most SSLs are currently based only on human health criteria. A number of the chemicals detected in sludges have been shown to function as endocrine disrupters. For example, nonylphenols which are present in sludges at relatively high concentrations (concentrations greater than 1000 mg/kg are not unusual), may be of concern because of their potential impact on wildlife (Environment Canada, 2004), even though they are unlikely to represent a major direct human health risk. Soil processes may also be impacted by organic chemical contaminants in land applied sludges as suggested by observed fungitoxic effects (Schnaak et al., 1997).

Specifying organic chemicals that should be monitored in sludges is not a simple task because it necessitates a degree of analytical competence that may not be widespread. The EPA has addressed this issue with respect to Superfund sites by developing a list of target compounds which includes priority pollutants in addition to other compounds. Certified laboratories performing analyses of Superfund samples are required to be able to test for these target compounds. As mentioned above, 80% of the organic chemicals reported in this paper, however, were not target compounds and could go undetected even in certified laboratories unless expensive mass spectral analyses were also performed. While the use of standardized methods that have been validated for individual chemicals is essential to ensure data quality, ongoing screening and validation efforts using generalized methods and robust detection technologies are required in order to identify chemicals of emerging concern.

For many compounds, there was wide variation in the reported concentrations found in sewage sludges. There are a number of potential sources of this variation. Discrepancies in analytical methods may account for some of the differences in the range of concentrations reported in this paper (Pryor et al., 2002). For most of the chemicals, no standard methods have been established for either sample extraction or analyte detection. The importance of methodological variation was clearly demonstrated in one report examining extraction efficiency, where a nearly five-fold difference was found in the concentration of several organic chemicals in sludge samples simply as a result of using different solvents (Bolz et al., 2001) and in another report where drying methods resulted in similarly large differences (Scrimshaw et al., 2004).

For some contaminants, differences in the source inputs to the WWTP may explain the range (Bodzek and Janoszka, 1999). For example, the high concentrations reported for some of the polynuclear aromatic hydrocarbons (PAHs) in one study (Constable et al., 1986) were likely due to inputs from local industry including two steel mills. Due to the large number of sludges sampled in the NSSS, that survey included a wide range of concentrations and yielded the highest reported concentrations for a number of contaminants (supporting information 1).

Another source of variability in chemical concentrations may be the type of treatment to which the sludges were subjected. The impact of this variable was difficult to gauge, however, as many reports did not provide information about wastewater and sludge processing methods. Where such information was available, it was noted (supporting information 1). Since pollutant concentrations have been found to vary significantly with different types of processing (Wild and Jones, 1989), some of the variation in concentrations may have been a result of the different treatments to which the sludges were subjected (Constable et al., 1986; Wild and Jones, 1989; Zitomer and Speece, 1993; Rogers, 1996) or to differences in sludge retention time (Ternes et al., 2004).

Changes in chemical use over time is another potential source of the large range in reported concentrations. The references from which data were obtained go back as far as 1976, though most were from the 1980s or later. Because of changes in chemical usage, including bans on some chemicals, the introduction of new chemicals and the increasing use of others, the use of old data can be problematic. A new survey of organic chemicals in sludges is needed since the NSSS dates back to 1988 (National Research Council, 2002). Due to the paucity of data, however, even older studies were included in this paper and the date of sampling was included when available (supporting information 1).

The vast majority of the data found were for sludges from the U.S. or Western Europe where chemical use and wastewater treatment are relatively similar, resulting in similar pollutant concentrations. There were, however, some noteworthy differences. In several European countries, for example, bans or the voluntary elimination of compounds such as penta-brominated diphenyl ethers and nonylphenol have been enacted. As a result, concentrations of these chemicals in sludges from those countries have decreased in recent years (Jobst, 1998).

There are also important differences between the European and U.S. approaches to the management of land application of sludges that would likely result in lower soil loadings of contaminants in most European countries. The soil concentration of a sludge-borne pollutant after land application is not only a function of the concentration of the chemical in the sludge, but also the amount of sludge applied. A number of European countries limit application rates either through direct limits on the number of dry MT/ha/yr or by limiting application to *P*-based agronomic rates, which are far more restrictive than the *N*-based rates used in the U.S. In Denmark, for example, no more than 30 kg/ha/yr of P can be applied (Ministry of Environment and Energy, 1997). This equates to an application rate of approximately 1 dry MT/ha/yr. While quantitative limits vary among the European countries, most limit application to a maximum of 1–4 dry MT/ha/yr (Schowanek et al., 2004). In conducting risk assessments, the European Commission assumes an application rate of 5 dry MT/ha/yr (European Commission Joint Research Centre, 2003). This compares to 10 dry MT/ha/yr which was the assumed high-end application rate used by EPA in developing the regulations for land application (U.S. Environmental Protection Agency, 1995). Another critical management strategy pertains to the prohibition of pasture-application in some countries, which could reduce the potential contamination of animal products.

Other management practices such as depth of mixing into the soil and losses through various environmental processes will also affect chemical concentrations in soils after land application. Degradation is an important component of loss, but may be incomplete or slow, even for relatively easily degraded chemicals such as linear alkyl benzene sulfonates (LAS). LAS is present at such high concentrations in sludges (up to 3% by weight) that incomplete degradation coupled with repeated applications could result in consistently elevated LAS concentrations in soils. This was demonstrated in one study that detected over 10 mg/kg six years after land application of sludge. Importantly, no further decrease was found after two more years, indicating that the residual LAS was resistant to degradation (Carlsen et al., 2002).

4. Conclusion

More data are needed on the chemicals that are in sludges today and on the temporal trends for those chemicals. Relying on existing lists of chemicals such as priority pollutants will not identify many chemicals of current concern.

To make more informed assessments about the impact of sludge processing on chemical concentrations, more information on the type of treatment (both of the wastewater and the sludge) and the sludge residence time as well as the nature of significant non-domestic inputs is needed. Detection methods and limits of detection need to be reported. Where multiple samples are analyzed, individual data points as well as median and means should be reported since averaging values among several sludges may obscure information relating to the differences due to inputs or treatment.

This paper demonstrates that there are groups of chemicals for which there are relatively abundant sludge concentration data (such as PCBs, pesticides and PAHs), while there are others for which few data have been collected (such as nitrosamines). Certain classes of chemicals also are shown to have high percentage of reported concentrations that exceed SSLs, suggesting that analysis of additional chemicals in those classes may be warranted. Few data exist on the fate of sludge-borne chemicals in field soils and such research is critical to assessing the risks posed by sludge application.

Evaluating the risks posed by individual chemicals, let alone mixtures requires multiple assumptions that can lead to unacceptably high levels of uncertainty. Current limitations in our knowledge base regarding the amount and type of chemicals in sludges exacerbate this problem, as does the limited availability of fate and toxicity data, for both human and non-human receptors. As sludge application occurs on farms, forests, and mines, as well as residential and recreational land, humans, wildlife and soil organisms may all be exposed to the organic contaminants present in sludges. Filling the gaps in knowledge regarding the concentration, fate and toxicity of sludge-borne contaminants is critical if the risks associated with land application are to be adequately characterized.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.scitotenv.2006.04.002.

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[redacted]

COMPOST FACT SHEET #6:

Compost Pads

COMPOST
FACT SHEET SERIES
2004/2005

For these fact sheets and other compost information:
http://cwmi.css.cornell.edu/Composting.html

Fact Sheet #1
Marketing Composts and Meeting Consumer Needs

Fact Sheet #2
Regulation and Certification of Composts

Fact Sheet #3
Improving and Maintaining Compost Quality

Fact Sheet #4
Testing Composts

Fact Sheet #5
Compost Bulking Materials

Fact Sheet #6
Compost Pads

Fact Sheet #7
Compost Equipment Choices

Ellen Z. Harrison, Director
Jean Bonhotal, Sr Extension Associate
Mary Schwarz, Research Support Aide

Cornell Waste Management Institute

Selecting, Siting, Sizing and Constructing Compost Pads

The surface on which outdoor compost facilities operate is an important part of the composting process and can influence the quality of the compost that is produced. When working on some soils with easy-to-manage feedstock, an improved pad may not be needed, but in many situations some kind of pad may be advisable or even required.

It is important to first find out whether there are relevant state regulations and to what kinds of composting operations they apply. These may be rules promulgated by the state environmental agency, the state agriculture department or possibly by a local agency. Even if there are no pertinent regulations, if a site causes pollution or generates significant neighbor concerns, it may be shut down or the operator may be liable for damages. Thus good planning and implementation is important. The U.S. Department of Agriculture Natural Resources Conservation Service (NRCS) has guidance and may provide technical and financial assistance for compost facilities on farms, including compost pads.

Why Build a Pad?

Pads have several purposes including water quality protection, providing a good working surface, allowing access through wet weather conditions and preventing the mixing of soil into the compost when it is turned. In dry conditions, most soil types provide a good working surface, but many will be problematic after a storm event or during spring thaw. Pads need to provide a solid working surface so that machinery can function throughout the year.

Siting & Sizing

An outdoor compost facility can be engineered so that it can be located on a wide variety of soils and sites. It is best to choose a site high on the landscape and

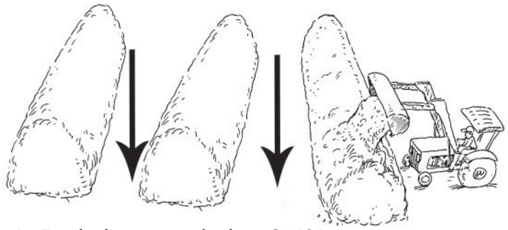


Figure 1. Pad slope graded to 2-4%.

well away from surface water bodies to reduce the chance that runoff from the site will enter surface water and reduce the chance that surface water will flow onto the pad. Moderate to well-drained, hard-packed soils with gentle slopes are well suited. A slope of about two percent is desirable to prevent ponding of water. Steep slopes are not satisfactory because of potential problems with erosion, vehicular access, and equipment operation. Compost windrows should run up and down the slope, rather than across, to allow runoff water to move between the piles rather than through them (see figure 1). The initial site preparation will usually require grading and may require surfacing (as discussed below).

Siting is very important to help avoid neighbor issues. Compost processing can generate odors (though these should be minimal in well-run operations), and odor is likely the main reason neighbors may complain about the operation. Determine the dominant wind direction, and if most air flow is directed toward populated areas, look for another site. In New York State, permitted compost facilities need to be at least 200 yards away from the closest dwelling. They cannot be sited in a floodplain or wetland, or where the seasonal high groundwater is less than 24 inches from the ground surface, or where bedrock lies less than 24 inches below the ground surface, unless provisions have been made to protect water quality (see text box below for URL for relevant NYS Part 360 rules). Composting of organic materials on the farm where they are generated is exempt from the regulations, as are some other facilities. Check the rules to determine whether a facility is covered under the regulations. NRCS also provides guidance for compost facilities (see text box on pg 4 for URL for relevant NRCS Guidelines).

A hedge row can be planted to help shield the facility from the road and may help filter the air between the compost piles and neighbors.

Siting facilities well can also help to avoid water quality problems. A high water table may lead to flooding of the site which will make equipment access and operation more difficult. Flooding can also promote anaerobic conditions in the compost which may lead to malodors. A high water table or flow of surface water onto the site also increases the likelihood of leachate contamination of groundwater or nearby surface water. The shorter the distance leachate percolates through unsaturated soil, the less it undergoes natural biological and physical treatment. Moderate to good soil percolation rates are desirable to avoid standing water and to minimize leachate and runoff. Well-drained sites allow equipment to operate even in wet weather. County soil surveys that provide information on depth to groundwater, percolation rates, and soil types are usually available at the local office of NRCS.

Site preparation avoids rutting.

Surface water runoff from storms and snow melt should be diverted away from the site by using a diversion ditch, an interceptor berm or drain so that excess water does not come onto the compost pad.

Determining the size of a pad is tricky. It is never big enough! Plan for space for active windrows and for curing piles, storage of bulking materials, and possibly a sales area

NYS Part 360 Rules:
www.dec.state.ny.us/website/regs/ch4.htm#360

(for screening and bagging) and space to store equipment. The area required for composting depends on the volume and types of material processed, the size and shape of piles, windrow or in-vessel technology used, and the time required to complete the process. Static piles and turned windrow methods require more land than the more intensive forced aeration and in-vessel system methods.

To download a free copy of the Co-Composter model, visit http://compost.css.cornell.edu/CoCompost.html

To aid in planning, a user-friendly computer model created in Microsoft Excel, called "Co-Composter" was developed at Cornell University as a planning and management tool for composting facilities. It was designed initially for dairy farms, but can be applied in other situations as long as you know the weight and some characteristics of the feedstock. Co-Composter asks an extensive series of questions relating to either an existing facility or a planned facility. Information requested includes feedstock type and quantity, bulking/bedding material, equipment type and age, and time available. There are default values built into the model, providing average values for certain parameters to use when site-specific information is not available. Co-Composter generates a detailed logistical and economic analysis to help compost managers look at facility planning, equipment, efficiency and feasibility. It includes calculations of the area needed for the facility. In addition, there is a section in the On-Farm Compost Handbook NRAES-54 <www.nraes.org/publications/nraes54.html>, which provides guidance on pad size.

Pad Types

One consideration in selecting the type of pad to construct is longevity. Some materials like concrete or asphalt are long lasting, but may require demolition if no longer desired. Other considerations are cost and availability of materials. Cost will vary depending on what is available in different areas. Many farms and communities have gravel banks and mine them to build roads and hard surfaces. In Vermont there is a pad made of white marble because it was a by-product from the local quarry. They paid only installation costs. Recycled asphalt is often available for trucking cost, and concrete millings generally cost less than gravel. New asphalt and concrete bear the highest costs. Local construction projects often need to dump excess asphalt and concrete at the end of a project. If your site is close enough, you may be able to take advantage. Some of the more common pad types include:

- **Filter Fabric and Gravel.** The combination of fabric and gravel makes a good working surface. A combination of sand and gravel can also make a good surface. Sand and gravel can be mixed or layered. In construction, place material with larger particle size in the layer above the cloth. Sand that is all one size can make an unstable surface as moisture conditions vary. Crusher run gravel with enough fines to bind the gravel into a smooth pad works well. A clean, poorly graded (all one size) rounded gravel will not compact very well. Fabric is available at farm implement and construction supply dealers. First the topsoil is removed from the surface. Then filter fabric is rolled out to cover the surface and 12"-18" of gravel are put on top of the cloth. The layers are then compacted and ready for use. The fabric is an important part of the pad. When gravel is spread out on soil without cloth, it works its way into the soil, particularly on soils containing a lot of clay. After years of use, additional gravel may be required to keep the surface in good shape. As you start using this type of pad you will tend to incorporate some gravel when turning, but as the pad settles, the amount incorporated will decrease.

Cloth and gravel pad.

- **Fabric and Sand.** These can work well especially on pads that need to avoid gravel in the completed compost but do not mind having sand in the completed compost. Of course, the sand will not be as durable as the gravel pad.

- **Lime Stabilized Earth.** Modification and stabilization of highway and airport pavement subgrades using lime is a well-established, time-tested practice in the United States. This technology may have applications in pad construction but has been tested very little. NRCS may be able to provide some guidance on this.

- **Compacted Soil.** Some soils are well enough drained that they can be compacted and used as a pad without adding gravel or other materials to make it more stable. This type of pad can be hard to work if precipitation rates are high, but can easily be eliminated if the pad is no longer needed.

- **Recycled Asphalt or Recycled Concrete.** Recycled materials are available in many communities and may be an economical alternative. Asphalt that is removed when roads are repaired is often collected until there is enough to reuse. Smaller communities rarely accumulate enough to reuse, therefore it becomes a waste product. Many highway departments are eager to find a disposal or reuse option. When put down in warm weather and rolled, recycled asphalt makes a good hard surface. If put down in cold weather the work is more difficult and the surface will not be smooth.

  Recycled cement is old cement that has been removed from a site and milled to a size that resembles gravel. This may be a less expensive substitute for gravel when some material is needed to firm up sites and roads.

- **Paved or Poured.** Pads can also be constructed out of asphalt or concrete, usually at sites where soils are highly permeable or where groundwater levels rise too close to the surface. A paved site offers some advantages in terms of access, equipment operation, and groundwater protection, but these advantages must also be weighed against added costs, as well as difficulties in managing runoff. Such paved pads are relatively permanent structures requiring significant effort to remove if composting ceases. If you are considering a paved pad, think about how it could be used if no longer needed for composting, e.g., a slab for a building project.

To access NRCS National Conservation Practice Standards go to: http://www.nrcs.usda.gov/technical/standards/nhcp.html.

Relevant sections include the Standards for: Composting Facility (317), Filter Strip (393), Nutrient Management (590), and Wastewater Treatment Strip (635).

Compost berm at Ohio State composting site. Collected runoff is treated in a wetland before disposal.

Ground and Surface Water Protection

An important part of choosing a pad surface is deciding how to manage water.

Leachate, formed when water percolates through the organic material, can be harmful to ground and surface water, because it can deplete oxygen and may contain unacceptably high levels of nitrogen phosphorus or pollutants. An initial bed of carbonaceous, bulking materials underneath the compost pile can help absorb excess moisture and keep it in the windrow. If the compost site is at the bottom of a slope, berms can be built to divert runoff water around the pad.

It is not difficult to compost outdoors in most climates; however, in climates with heavy precipitation it is best to keep finished product under cover to keep it from absorbing moisture. Commodity sheds, barns, compost covers and tarps work well.

When leachate is generated, some measures that can help prevent water pollution include:

- **Collection Lagoons.** Retention ponds can be constructed to hold runoff from normal operations as well as excessive runoff resulting from storms. Sand filtration of lagoon outlet waters can help to reduce pollutant loads. Discharge from a lagoon may require a permit even if passed through a sand filter. Lagoons need to be emptied before going into a wet season unless evaporation rate exceeds precipitation and runoff into the lagoon. Solids need to be removed periodically and can be put back into windrows for composting. The liquids can be used to irrigate appropriate field crops, to hydrate dry compost piles, or in some locations must be transported to a sewage treatment facility. Recovered solids often contain high moisture, so they may need to be dried out with carbonaceous material so they can efficiently compost.

- **Compost Berms/Compost Socks.** A berm of compost can be used to slow and/or control excess water from piles or storm events. A berm of finished compost 24" tall x 24" wide, triangular in cross section, and as long as needed down-slope of the pile and perpendicular to the slope will absorb moisture and help control leachate. Compost socks are long cloth tubes filled with compost. They are available in several diameters. There is specialized equipment that blows the compost into these tubes that are then tied off and laid or staked in place. They can be used as a berm and filter water before it goes into a lagoon, leach field or drain.

- **Tanks.** Leachate collection tanks can be buried below the pad surface. Grading of the pad can direct the leachate into the tank. When emptied, the liquid can be used to add moisture to the piles, irrigated on appropriate crops or disposed of at a sewage treatment plant. There needs to be a way to remove solids from the tank. If possible, solids can be mixed into suspension so that much of the solid material can be removed with the liquids. If solids are allowed to build up and the tank is not designed for easy removal, the tank could become useless. Solids can also be removed with a sewage collection truck. Be aware that these sediments are anaerobic and may have substantial odor.

- **Filter Strips.** A vegetated section of soil down-slope of the compost pad can help absorb nutrients and particulates that run off the pad surface. When possible, on unimproved surfaces, keep vegetation between the windrows as well to absorb additional leachate. NRCS has standards for filter strips for compost pads (see the box on page 4 for the web site).

Site Maintenance

Good housekeeping at the site is important. There should be no ruts, standing water or garbage on the site. Site perimeters should be mowed to avoid contaminating piles with weed seed that will blow in. Good maintenance keeps the operation running smoothly.

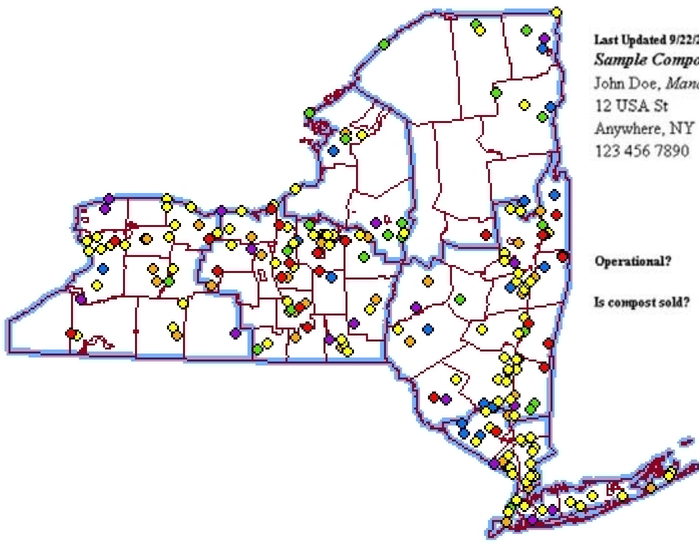
Cornell's compost site.

Acknowledgement

Thanks to Cornell Cooperative Extension, the NYS Energy Research and Development Authority, Empire State Development and the College of Agriculture and Life Sciences at Cornell for funding in support of CWMI compost work. Thanks also to the reviewers: Aldrich, Cornell University; Horvath, NRCS; Telega, Cornell University; Wright, NRCS. This fact sheet represents the best professional judgment of the authors and does not necessarily reflect the views of the funders or reviewers.

Maps of a database of NYS Compost Facilities can be accessed at: http://compost.css.cornell.edu/maps/simple-search.asp (see example below). **If you know of additional facilities** or have corrections to suggest, contact CWMI at: cwmi@cornell.edu or 607-255-1187.

New York State Compost Facilities Search



Last Updated 9/22/2004
Sample Compost Site
John Doe, *Manager*
12 USA St
Anywhere, NY 12345
123 456 7890

Operational? yes

Is compost sold? no

Compost Facility Search Results

Feedstocks

Leaves	yes	Paper Products	
Grass	yes	Floral Waste or Plant Trimmings	
Brush and Branches	yes	Animal Manures	
Logs, Stumps other Wood		Sewage Sludge	
Pre-consumer Food Waste	yes	Paper Sludge	
Post-consumer Food Waste	yes	Other Materials	

Composting Method? windrow piles

Is compost free? yes
If yes, to whom? residents

Select a map to view facilities

All Compost Facilities

Yardwaste Composts

Manure Compost Facilities

Foodscrap Compost Facilities

Biosolids Compost Facilities

Compost Research Farms

Small Scale Compost Demonstration Sites

Option #2

Select a county from the list below

None Selected

*Click "Submit" to send request

Submit

Composting Resources:

- **Farm-Based Composting: Manure & More - http://www.nraes.org/publications/nraes150.html**
- **Natural Rendering: Composting Livestock Mortality & Butcher Waste:**
  Fact Sheet - http://compost.css.cornell.edu/naturalrenderingFS.pdf
  Video - http://www.nraes.org/publications/nraes163.html
- **Co-Composter: http://compost.css.cornell.edu/CoCompost.html**
- **Compost...because a rind is a terrible thing to waste (video) - http://compost.css.cornell.edu/FoodCompostpr.html**

For other composting resources see the CWMI web site at: http://cwmi.css.cornell.edu/Composting.html

November 13, 2006

Carrie Hyke, Supervising Planner
San Bernardino County, Land Use Services Department,
[redacted]

RE: DRAFT ENVIRONMENTAL IMPACT REPORT FOR NURSERY PRODUCTS HAWES COMPOSTING FACILITY. Dated September 2006.
State Clearinghouse No. 2006051021

Dear Ms. Hyke:

I previously submitted scoping comments on the above project on behalf of the Desert Tortoise Preserve Committee and the Desert Tortoise Council. The proposed location of the project is habitat for the state- and federal-listed desert tortoise and the state-listed Mohave ground squirrel. The project will have long lasting, direct and indirect impacts on these species and likely result in their take.

The Draft Environmental Impact Report (DEIR) has not addressed a number of the comments I raised in my scoping letter of June 8, 2006. I have attached a copy of the June 8, 2006 scoping letter and incorporate the contents by reference into this comment letter. The final EIR should address all the issues that have been raised in the scoping letter. In addition, I would like to offer the following comments on the DEIR that should be addressed in the final EIR.

1. The DEIR characterizes the project not as a dump or landfill but as a composting facility thus: "*It is important to note that composting facilities have been inaccurately compared to landfills; however, that is not an accurate comparison as the proposed composting activities will not likely attract ravens or other birds directly because the compost would not contain edible food or other garbage that would appeal to ravens and other scavengers (see photos in Section 2). Ravens were not recorded at a similar composting site in Adelanto over a recent 5-year monitoring period of the facility during monthly inspections by the San Bernardino County Environmental Health.*" The DEIR fails to support these categorical statements with any documentation. Documentation that projects such as this one will not enhance subsidized tortoise predators would certainly be useful and is required to support the claims made in the DEIR.

2. The two large ponds at the north end of the project must be covered year round to minimize beneficial impacts to the local raven population.

3. The location of the Fort Cady alternative is outside the current range of the Mohave ground squirrel. The EIR should note that both the "no project" and the Fort Cady alternatives would have no impact on the Mohave ground squirrel. In contrast, the proposed action will impact the Mohave ground squirrel. Both the "no project" and the Fort Cady alternatives pose significantly less environmental impacts to the desert tortoise and the Mohave ground squirrel than the proposed project.

4. In my scoping letter, I stressed the need for the project proponents to describe the likely wind plume from the project site. "*The EIR must also determine the likely wind plume for all the waste components, including the biosolids, proposed for dumping at the site.*" This was requested so that the area of desert tortoise critical habitat that will be impacted by airborne toxicants and project caused nitrification could be determined.

This information has not been presented in the document. However, Table 4.3.12 (page 4.25) predicts maximum offsite ammonia concentrations due to the composting windrows at the Nursery Products Hawes Composting Facility. The data that is provided is troubling and should be augmented and explained in greater depth.

The predicted acute levels at the site boundary (6906 $\mu g/m^3$) are more than twice the reference exposure level of 3,200 $\mu g/m^3$. As the DEIR notes, the immediate adjacent area is occupied desert tortoise critical habitat. The desert tortoises that are present on these federal lands will be exposed to ammonia levels that are predicted to be well above the reference exposure level. Acute ammonia exposure may lead to injurious effects to the respiratory and ocular systems. In addition to its direct toxicity, ammonia exposure is known to increase the pathologic conditions associated with *Mycoplasma pulmonis* infection in rats.[1] Desert tortoise populations have been devastated by related *Mycoplasma* species.[2] Any parameter that could enhance the risk of a new Upper Respiratory Tract Disease epidemic breaking out in West Mojave desert tortoises needs careful and thorough review.

The DEIR fails to provide any analysis of the impacts of this ammonia on desert tortoises and their habitat in the adjacent areas where ammonia concentrations well above the reference exposure level are predicted to occur. The DEIR must estimate the expected take of tortoises and the considerable area of critical habitat that will be modified by the ongoing release of ammonia from the project during the projects entire operation. Only then could appropriate mitigations be determined.

5. On a related note to point 4. Where is the analysis of potential threats to human health and safety for users of Highway 58 who will be driving through the ammonia plume? The eye is particularly sensitive to ammonia. What is the risk posed by driver's tearing as they drive through the area?

6. The Final EIR must provide a detailed account of the mitigation measures that will offset all the impacts of the projects operation including the habitat lost through airborne toxicity and nitrification. The DEIR only addresses replacement habitat for the project site itself and not all the habitat that will be impacted.

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[1] CHRONIC TOXICITY SUMMARY AMMONIA (Anhydrous ammonia; aqueous ammonia) CAS Registry Number: 7664-41-7

[2] Fish and Wildlife Service. 1994. Desert tortoise (Mojave population) recovery plan. U.S. Fish and Wildlife Service, Portland, Oregon. 73 pp. plus appendices.

7. The DEIR does not provide for adequate mitigation for take of tortoises on roads by the truck traffic generated. At a minimum, within the DWMA all roads leading to the site should be fenced with tortoise barrier fencing.

8. Monitoring for weeds while useful will not mitigate the impacts of nitrification unless the monitoring has associated triggers that will close the facility. These should be added.

9. The federal portion of the West Mojave Plan has been completed. The word proposed should removed where appropriate and the project reviewed for compatibility with the published plan.

I thank you for the opportunity to comment on this Draft Environmental Impact Report. Please keep us informed of any decisions or actions related to this or similar projects. If you require more information, please feel free to contact me by telephone at [redacted] mail at [redacted]

Sincerely,

Michael J. Connor, Ph.D.

Desert Tortoise Preserve Committee, Inc.
[redacted]

THE DESERT TORTOISE COUNCIL

June 5, 2006

Carrie Hyke, Supervising Planner
San Bernardino County, Land Use Services Department,
[redacted]

RE: NOTICE OF PREPARATION OF ENVIRONMENTAL IMPACT REPORT FOR NURSERY PRODUCTS LLC. APPLICATION FOR A CONDITIONAL USE PERMIT TO ESTABLISH A SITE FOR CO-COMPOSTING OF BIO-SOLIDS AND GREENWASTE ON APPROXIMATELY 160 ACRES LOCATED IN THE UNINCORPORATED COMMUNITY OF HINKLEY. Dated May 5, 2006

Dear Ms. Hyke:

The Desert Tortoise Preserve Committee and the Desert Tortoise Council would like to offer the following comments for consideration in the preparation of the Environmental Impact Report (EIR) for the above referenced proposal to locate a site for co-composting of bio-solids and green waste on a quarter square mile of desert just south of Highway 58. The project site is within habitat designated as critical to the conservation and recovery of the desert tortoise. The Desert Tortoise Council was established in 1976 to promote the conservation of the desert tortoise in the southwestern United States and Mexico. The Council organizes the Annual Desert Tortoise Council Symposium, the Annual Tortoise Handling Workshop, and has produced 21 volumes of Symposium Proceedings since 1976. The Desert Tortoise Preserve Committee has worked since 1974 to promote the welfare of the desert tortoise and the species that share its habitat through preserve development and management, and through education and research. The Desert Tortoise Preserve Committee has an ongoing tortoise barrier-fencing project at Harper Lake Road near to the project site and is well acquainted with the project area.

The proposed location of the project is habitat for a number of listed and sensitive species including the desert tortoise and the Mohave ground squirrel. Because the project will have long lasting, direct and indirect impacts on these listed species and likely result in their take, the project proponents will need to obtain incidental take permits from both the United States Fish and Wildlife Service (FWS) and from the California Department of Fish and Game (CDFG).

The *Guidelines for Implementation of the California Environmental Quality Act* (CEQA) defines an EIR is an informational document which will inform public agency decision-makers and the public generally of the significant environmental effect of a project, identify possible ways to minimize the significant effects, and describe reasonable alternatives to the project. In order to satisfy the CEQA Guidelines, the following concerns regarding the desert tortoise and Mohave ground squirrel should be addressed in the Environmental Impact Report:

(1) National Environmental Quality Act (NEPA) requirements.

The eastern boundary of the project site borders public lands managed by the Bureau of Land Management. This public land is designated critical habitat for the desert tortoise and is within the boundaries of the Fremont-Kramer Desert Wildlife Management Area (DWMA). The Fremont-Kramer DWMA is a conservation area for both the desert tortoise and the Mohave ground squirrel. The project details made available for our review are insufficient for us to determine if any permits or actions will be required from the Bureau of Land Management. Because of the environmental significance of this project, any requirements for action by the Bureau to facilitate this project would require preparation of an Environmental Impact Statement (EIS). If this is so, CEQA Guidelines require that preparation of the EIR should be combined with the EIS to facilitate the environmental review process.

(2) Take of the Federal- and California-listed threatened desert tortoise, *Gopherus agassizii*, on the site.

The project site is entirely within desert tortoise habitat. The Desert Tortoise Preserve Committee has records of numbers of desert tortoises along nearby Harper Lake Road. Tortoise sign was identified on nearby BLM lands during the survey efforts for the BLM's West Mojave Plan planning effort. Additional, detailed surveys are required to document the tortoise population, to develop take avoidance measures, and to devise an appropriate tortoise relocation plan to minimize take during development of the project.

(3) Take of the California-listed threatened Mohave ground squirrel, *Spermophilus mohavensis*, on the site.

The project site is within the boundaries of the Fremont-Kramer DWMA. This DWMA is designated as a Mohave ground squirrel habitat conservation area. Trapping surveys are required to document the presence or absence of Mohave ground squirrels at the site. In addition, the FWS is currently considering a petition to list the Mohave ground squirrel under the federal Endangered Species Act. This should be acknowledged in the EIR.

(4) Take of the Federal- and California-listed threatened desert tortoise, *Gopherus agassizii*, off-site and during the life of the project.

The project's sensitive location assures that if implemented, the project will have on-going impacts on the conservation and recovery of the desert tortoise for the long-term. The EIR should consider a range of reasonable alternatives such as choice of less sensitive locations for the project, and a project site that it is completely enclosed. The EIR should also review the contribution the project will make to all the threats to the desert tortoise that are outlined in the Fish and Wildlife Service's 1994 *Desert Tortoise (Mojave Population) Recovery Plan*.

Other ongoing specific threats posed by this project include:

(a) Indirect And Direct Effects Of Biosolids On Desert Tortoises:

There are numerous unanswered questions about the safety, environmental effect, and propriety of applying Biosolids or sewage sludge to open lands, even when applied

[redacted]

in accordance with federal and state regulations. Biosolids may contain a number of toxic substances including various heavy metal toxicants.

Biologists have known for many years that desert tortoises are at risk for metal-toxicity [e.g. Jacobson et al., 1991 J. Wildlife Diseases 27: 296-316] and mercury may accumulate in their livers. Heavy metals have been implicated as potential contributing factors in a dyskeratinizing disease that affects the species in some areas [e.g. see Jacobson et al., 1994 J. Zoo. Wildlife Med. 25: 68-81]. Heavy metals such as arsenic, lead, cadmium and nickel have been found in ill and dying wild tortoises and are linked to upper respiratory tract disease, shell lesions, bladder stones and other serious illnesses. These toxicants may have contributed to increased mortality rates in some tortoise populations. One of the likely sources is considered to be air-borne pollutants.

The EIR must review the composition and variability of composition of the biosolids in order to determine the likely environmental impacts of the project on the desert tortoise.

The EIR must also determine the likely wind plume for all the waste components, including the biosolids, proposed for dumping at the site.

(b) Indirect And Direct Effects Of Biosolids On Desert Tortoise Critical Habitat:

The Mojave Desert is notorious for its strong and persistent winds. Indirect effects of wind-borne biosolids over large areas of desert tortoise critical habitat are a foreseeable, significant concern.

Biosolid-derived pollutants are likely to negatively impact the food chain, become concentrated in food plants, and then when these plants are eaten become even more concentrated in animals. This must be addressed in the EIR.

The EIR must consider the impacts of the increased particulate matter from the projects “windrows” on the respiratory-disease prone desert tortoise.

The EIR must consider the likely contribution that biosolid dispersal will make on alien plant and weed invasions. Biosolids are a rich source of nitrogen, and nitrogen supplementation may accelerate the spread of noxious, exotic weeds that displace native plants. Dr. Matthew Brooks in his 1998 University of California, Riverside doctoral dissertation clearly established that nitrogen supplementation preferentially enhanced weed proliferation over native plant growth in Mojave Desert test plots. Weed proliferation has been recognized as an issue of national significance. The February 1999 Presidential Executive Order stated that invasion of exotic species was costing the government billions of dollars each year, and affecting agriculture, many endangered and threatened species, and other aspects of the environment. Desert tortoises are selective feeders. Weed invasions can seriously impact the quality and quantity of desert tortoise forage.

The EIR must consider the increased risk of desert fires posed by the project. Build up of noxious weeds is increasing the fuel load in the desert and has contributed to a dramatic increase in the extent and incidence of desert fires. Prevailing winds in the project area are such that weed proliferation would trend towards Harper lake Road and Highway 58. This is a special concern because most desert fires originate at roads, and composting piles themselves are known to spontaneously combust. Desert fires place both humans and animals at risk. Fires also destroy native desert shrubs that are not fire-

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adapted, and facilitate type-conversion of viable habitat to one dominated by alien weeds.

(c) Other Indirect And Direct Effects Of the Project On the Desert Tortoise and Mohave Ground Squirrel:

The project will operate round the clock. Deliveries of biosolids and other waste will be made by truck. The Checklists indicates that the site will receive up to 2,000 tons of waste in up to 522 truck trips each day. The Checklist does not indicate where these trucks will be coming from or what the route will be into the project site. Presumably, the bulk of the truck traffic will travel to the site from Highway 58. These trucks will travel along roads through desert tortoise and Mohave ground squirrel habitat. This will result in ongoing take of these two species throughout the entire life of the project. This impact must be fully analyzed in the EIR.

Truck traffic will also increase the amount road killed mammals, rodents and birds on desert roads in the area. This will increase opportunities for subsidized scavengers such as ravens allowing more of them to remain in the area year round. Ravens are known predators of hatchling and young desert tortoises. This foreseeable impact must be fully analyzed in the EIR.

(5) Impacts to the Fremont Kramer Desert Wildlife Management Area & Area of Critical Environmental Concern.

The project is located within the boundaries of the Fremont Kramer DWMA and Area of Critical Environmental Concern. For a number of reasons, including providing foraging opportunities for subsidized predators such as ravens, landfills are considered incompatible with desert tortoise recovery. The West Mojave Plan that established the Fremont Kramer DWMA specifies "counties and cities would ensure that no new landfills are constructed inside DWMAs or within five miles of them" (DT-27). This issue must be addressed in the EIR.

(6) Consistency with Regional Plans.

CEQA Guidelines require that an EIR discuss any inconsistencies between the proposed project and applicable general plans and regional plans. The project lies within the Bureau of Land Management's West Mojave Plan planning area. The federal portion of the WMP plan was completed in March 2006. As outlined in (5) above the project lies in the WMP's Fremont Kramer DWMA and is an incompatible use. The EIR should address both this issue and the implications of this project to the nascent HCP component of the WMP.

(7) Cumulative Impacts.

The EIR should fully analyze all the cumulative impacts to the desert tortoise and Mojave ground squirrel. We suggest the project proponents incorporate the cumulative impacts analysis from the West Mojave Plan as a starting point.

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The EIR should provide detailed mitigation measures to offset all identified environmental impacts to the desert tortoise in order to fulfill the "fully mitigated" requirement of the California Endangered Species Act. In formulating the appropriate measures to achieve this requirement, the EIR should consider the following:

[redacted]

(a) The project will effectively eradicate or make unsuitable for occupation 160 acres of desert tortoise and Mohave ground squirrel habitat. This acreage is the baseline for determination of replacement habitat.
(b) Consistent with the WMP Plan, the EIR should specify that the minimum compensation ratio for replacement habitat for this area is 5:1 i.e. 800 acres.
(c) Because the project is located in designated critical habitat and the project is an incompatible use, the mitigation ratio for replacement habitat used should be considerably higher than the minimum laid down in the WMP. A ratio of 10:1 i.e. 1600 acres or higher, would seem more in line with CDFG's requirements for other projects.
(d) Consistent with the WMP plan's prescription against landfills, the EIR should require the entire project to be enclosed within a solid, roofed structure. This would mitigate a number of the impacts outlined in (4) above.
(e) The project must incorporate adequate safeguards to manage impacts to desert tortoises from ravens and other subsidized predators. All artificial water sources and effluent should be closed or covered.
(f) All roads to the site within the DWMA that will be used by truck traffic generated by the project must be permanently fenced on both sides with tortoise barrier fencing. To avoid further habitat fragmentation in the area the project proponents must also install tortoise and wildlife culverts under fenced areas of road.
(g) The sensitive location of the project ensures that intensive management will be required to minimize the impacts from the project in perpetuity. Adequate funding provisions must be made to establish a management endowment sufficient to cover the costs of managing both the replacement habitat and monitoring and ameliorating the ongoing effects to the habitat surrounding the project.
(h) Given the sensitive nature of the location, the area and surrounding area should be fully surveyed for all the protected and sensitive species that are known to occur in the region. This would include burrowing owl surveys and surveys for rare plants. These surveys must be conducted during the appropriate growing seasons.
(i) All green waste should be sterilized prior to being hauled to the project site to eliminate the risks of wind blown spread of exotic plant and weed seeds.

We thank you again for this opportunity to provide scoping comments for preparation of this Environmental Impact Report. Please keep us informed of any decisions or actions related to this or similar projects. If you require more information, please feel free to contact me by telephone at [redacted]

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DESERT TORTOISE PRESERVE COMMITTEE
DESERT TORTOISE COUNCIL

[redacted]

Desert Tortoise Preserve Committee, Inc.
[redacted]

THE DESERT TORTOISE COUNCIL

June 5, 2006

Carrie Hyke, Supervising Planner
San Bernardino County, Land Use Services Department,
Advance Planning Division
[redacted]

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