Community Water Center's Health and Drinking Water Series

Water & Health in the Valley:

Nitrate Contamination of Drinking Water and the Health of San Joaquin Valley Residents

COMMUNITY WATER CENTER

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The Community Water Center, based in Tulare County, California, seeks to ensure that all communities have access to safe, clean, and affordable water. Our mission is to create community-driven water solutions through organizing, education and advocacy in California's San Joaquin Valley.

The San Joaquin Valley is the center of California's growing drinking water crisis. Five of its eight counties – Fresno, Madera, Merced, Kern, Kings, San Joaquin, Stanislaus, and Tulare – have some of the highest rates of water contamination per person in the state.[1] Contaminated drinking water causes many adverse human health effects, including gastrointestinal illnesses, nervous or reproductive system impacts, and chronic diseases such as cancer.[2]

This is the first of a series of reports that examine the prevalence of common drinking water contaminants in the San Joaquin Valley and the rates of related health indicators as outlined in public health literature. According to the Centers for Disease Control and Prevention, health indicators can "…provide information about a population's health status with respect to [environmental] factors that can influence health."[3] Our intention is to draw connections between contaminants in drinking water and the high rates of many diseases prevalent in the San Joaquin Valley.

It is *not* our intention to prove that certain diseases are a direct result of water contamination. Cause and effect can only be established through long-term longitudinal health studies with tests of the participants' drinking water. The health effects discussed here cannot be conclusively attributed to any contamination in the Valley's drinking water.

Despite these limitations, it is indisputable that San Joaquin Valley residents struggle with a wide range of diseases, as well as contaminated drinking water, and these facts should not be ignored or dismissed. Our goal with this series of health papers is to provide information that can begin to address these important issues.

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Nitrates: a Widespread Problem in the San Joaquin Valley

Nitrate is a natural and human-made contaminant.

Nitrate is an inorganic compound produced when nitrogen is introduced into the environment. Although nitrate occurs naturally at low levels, human activities, including the use or improper disposal of fertilizers, animal manure, or human waste, can elevate levels of nitrates in sources of drinking water.[4] At high levels, nitrates have been linked to a range of diseases, discussed below.[5]

Nitrate contamination of drinking water is widespread and increasing in California.

Nitrate is the largest source of well closures in the state.[6] An additional 10 to 15 percent of wells in California already exceed nitrate standards for drinking water.[7] According to the Lawrence Livermore National Laboratory Nitrate Working Group:

> The human activities that contribute nitrate to groundwater – animal operations, crop fertilization, wastewater treatment discharge, septic systems – are ongoing and essential to the industry and commerce of the State of California. Best management practices can mitigate source loading but not eliminate it. Furthermore, nitrate is expensive to remove from drinking water supplies, especially in public and private systems that rely on untreated groundwater and do not have the necessary water treatment infrastructure. These factors combine to make nitrate the greatest contaminant threat to California's drinking water supply.[8]

Unfortunately, the number of wells contaminated with nitrates in California is only increasing.[9] Furthermore, many wells have nitrate levels just below the legal limit leaving them highly vulnerable to any increases. In 2007, over a third of all groundwater samples taken by the State Water Resource Quality Control Board contained between 10 and 45 mg/L of nitrates (45 mg/L is the legal limit).[10] Another factor that may exacerbate levels of contamination are increasing drought conditions.[11] Drought conditions in California are expected to worsen in the coming years,[12] and researchers have found that low groundwater levels worsen well contamination.[13]

According to
UC Berkeley research:

Our findings show that in smaller water systems, communities with larger fractions of Latinos and renters are potentially exposed to drinking water with higher nitrate levels compared to communities with higher proportions of white residents and homeowners.

We found that in systems with fewer than 200 connections, those with higher fractions of people of color or fewer homeowners have higher nitrate levels.

Balazs, C. (2010). Just Water? Social Disparities in Nitrate Contaminated Drinking Water in California's Central Valley. Dissertation in preparation.

According to the
United States Geological Survey:

Ground water is the source of drinking water for most of the population of the eastern San Joaquin Valley. Each year, millions of pounds of nitrate (in fertilizer and manure) and pesticides are applied to cropland. Some of these chemicals infiltrate to the water table, degrade the water quality, and potentially cause a public health risk.

Dubrovsky, Neil, et al. (1998). Water Quality in the San Joaquin-Tulare Basins, California, 1992-95. U.S. Geological Survey Circular 1159.

The problem of nitrate-contaminated drinking water wells is most acute in the San Joaquin Valley.

The San Joaquin Valley is vulnerable to nitrate contamination because groundwater serves as the source of drinking water for almost 90 percent of its residents.[14] Groundwater contamination, in effect, becomes drinking water contamination.[15]

Many studies document the widespread, high levels of nitrate contamination in San Joaquin Valley groundwater:

- In 2009, 42 percent of wells tested near dairies exceeded health standards for nitrates.[16]
- In 2007, 74 percent of all nitrate health standard violations in the state were found in the San Joaquin Valley, impacting over 275,000 people.[17]
- In 2007, 61 percent of all people served drinking water from a community water system in the San Joaquin Valley received water with nitrate levels at least half of the state and federal health limit.[18]
- In 2003, 13 percent of drinking water from wells in the San Joaquin Valley groundwater basin exceeded nitrate health standards.[19]
- According to a United States Geological Survey (USGS) study of water quality in the San Joaquin Valley groundwater basin from 1992 through 1995:
  - » 24 percent of wells tested exceeded state health standards in the eastern San Joaquin Valley.
  - » 40 percent of wells near almond orchards exceeded drinking water standards in the San Joaquin Valley Basin.
  - » Nitrates were detected in 97 percent of wells sampled throughout the Valley.[20]

Photo by Erin Lubin

In the San Joaquin Valley, the largest sources of nitrate pollution are chemical fertilizer applications and manure produced at immense confined animal feeding operations throughout the region.

The San Joaquin Valley is California's agricultural heartland. California generates 13 percent of U.S. farming receipts, and the San Joaquin Valley accounts for over half of this agricultural production.[21] Fresno, Tulare, Kern, Merced, San Joaquin and Stanislaus are all among California's top seven agricultural counties.[22]

The USGS has found that nitrate pollution of both surface and ground water in the valley is due primarily to the region's intensive irrigated agriculture and its use of chemical fertilizer.[23] The San Joaquin Valley contains over 6.6 million acres of irrigated cropland.[24] One acre of irrigated cropland typically produces more than 80 pounds of nitrogen per acre per year that may leach into groundwater, usually as nitrate.[25]

Animal wastes produced by the region's confined animal feeding operations are a major source of nitrate pollution.[26] A typical dairy cow produces 32.77 tons of solid manure per year, and 1 to 2.5 percent of this amount is nitrogen.[27] In 2008, the San Joaquin Valley contained almost 1.6 million dairy cows and calves, and 161,000 beef cattle.[28] According to the Regional Board, "waste production at most sites is equivalent to that of a small city."[29] However, unlike a small city, these large animal facilities do not have extensive treatment systems.

According to the
Southwest Journal of Hydrology:

Agriculture's use of inorganic fertilizer and animal manure is the most dominant groundwater contaminant besides salt, both in the United States and globally. The major regions with high groundwater nitrate pollution are therefore not surprisingly the major agricultural regions: Imperial, Central, Salinas, and other coastal valleys in California.

Harter, Thomas. "Agricultural Impacts on Groundwater Nitrate." Southwest Hydrology (2009).

Photo by CWC

Health Impacts of Nitrate Contamination

Exposure to nitrates can cause immediate, or acute, health problems. Exposure over long periods of time can lead to many other dangerous health conditions.

In the short-term, nitrates can cause:

- Methemoglobinemia, or "Blue Baby Syndrome"[30]
- Indigestion and inflammation of the stomach and gastrointestinal tract (gastroenteritis), with abdominal pain, diarrhea, and blood in the urine and feces[31]

In the long-term, scientific and medical studies have linked nitrates to:[32]

- Multiple digestive tract impairments, including dyspepsia[33]
- Depression, headache and weakness[34]
- Miscarriage,[35] stillbirths or premature birth[36]
- Sudden Infant Death Syndrome (SIDS)[37]
- Mutagenicity (DNA damage) and tetragenicity[38]
- Impaired growth of fetuses *in utero*, leading to neural tube disabilities and other birth-related disabilities[39]
- Cancers of the digestive system,[40] stomach,[41] esophagus,[42] lungs,[43] colon,[44] bladder and ovaries,[45] testicles,[46] uro-genital tract,[47] and non-Hodgkins lymphoma[48]
- Nervous system disabilities[49]
- Dieresis (increased urination), increased starchy deposits and hemorrhaging of the spleen[50]
- Active ulcerative colitis and Crohn's disease[51]
- Pancreatitis,[52] which is highly associated with pancreatic cancer[53]
- Thyroid disruption, including hypertrophy and increased risk of thyroid cancer[54]

Photo by Bear Guerra

Children are especially vulnerable to the following health impacts of nitrates:

- Methemoglobinemia, or "Blue Baby Syndrome"[55]
- Inflammatory bowel disease[56]
- Acute respiratory tract infections[57]

These health impacts can be exacerbated if a person is consuming nitrate-contaminated water and that person has a preexisting gastrointestinal problem, such as inflammation. Health impacts can also be exacerbated if nitrate contamination is accompanied by bacterial contamination. Studies have shown that drinking water contaminated with both bacteria and nitrates can make methemoglobinemia more likely.[58] High nitrate levels can also be especially harmful to vulnerable populations, such as pregnant women and children.[59]

Nitrates can have indirect health impacts as well. In particular, diabetes may be indirectly linked,[60] because impaired pancreas functioning can lead to diabetes mellitus, and nitrates are associated with chronic pancreatitis. In fact, nitrate concentrations in blood have been recommended as a marker for diabetes.[61]

Wells with Nitrates Exceeding MCL

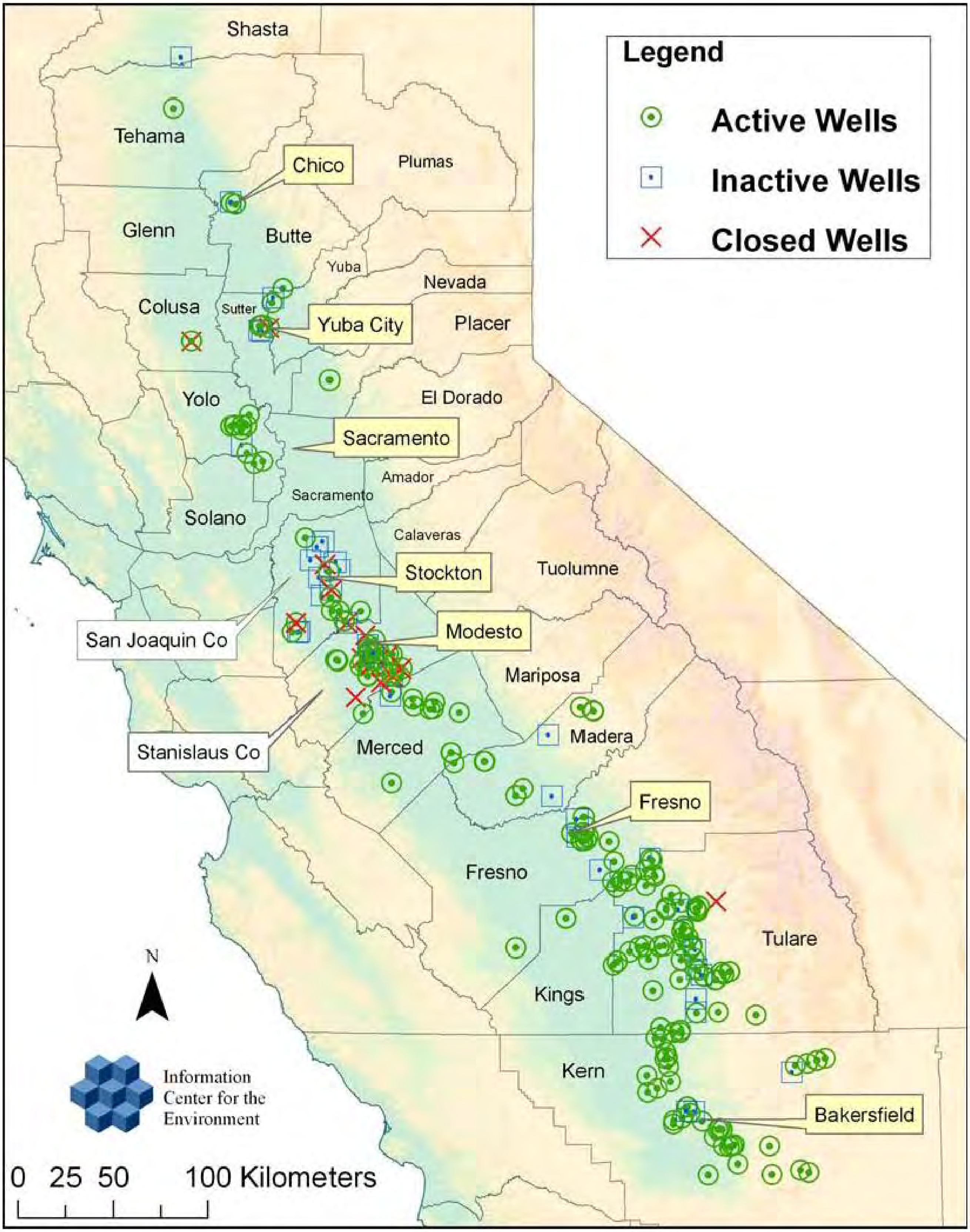

Figure 1 - Total number of wells in California's Central Valley with nitrate levels detected over the Maximum Contaminant Level (MCL).

Source: Presented at a public workshop at the Central Valley Regional Water Quality Control Board in 2009 as part of a larger presentation entitled "Nitrate Effects on Public Water System Wells" by Leah Godsey Walker, P.E., Chief Drinking Water Technical Programs Branch, California Department of Public Health.

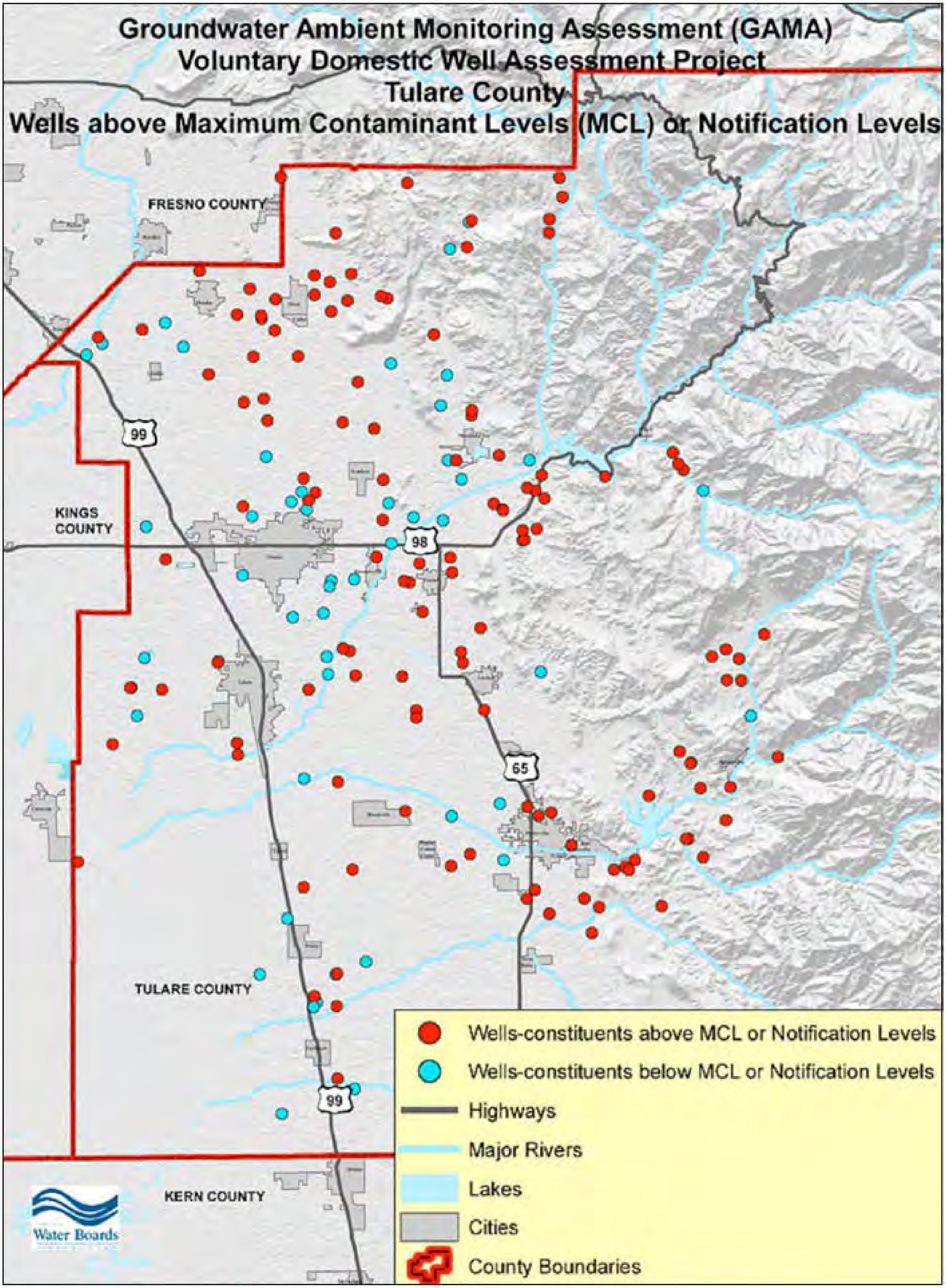

Figure 2: State Water Resource Control Board mapping of domestic wells with high levels of nitrate contamination (2006).

Case Study: Nitrates Impact Communities in Tulare County

Tulare County is at the center of the San Joaquin Valley's drinking water crisis. The number of drinking water systems with contaminant violations is particularly high. To explore the relationship between high levels of contamination and health outcomes, CWC has assembled detailed information on the rates of diseases in Tulare County associated with nitrates, as outlined in scientific and medical literature.

Tulare County is home to intensive agriculture and dairy production.

In 2007, close to 500,000 acres were fertilized in Tulare County.[62] While application rates across crops vary by many factors, such as grower, season, and soil type, average nitrogen application rates for the County's largest crops indicate that almost 8.5 million pounds of nitrogen are applied on an annual basis in Tulare County.[63]

In addition, Tulare County produces more animal waste than any other county in California.[64] In 2008, there were 483,500 milk cows and 28,000 beef cattle in Tulare County alone.[65] In 1997, the most recent year there is available data, Tulare County produced the most animal waste of any county in the state, a total of 7,800,000 tons, resulting in 83,000,000 pounds of nitrogen.[66]

Many studies document the high rates of nitrates in Tulare County's groundwater.

Over 90 percent of all Tulare County residents rely on groundwater as their source of drinking water, making the area particularly vulnerable to contamination.[67] The intensive agricultural and dairy production has resulted in high rates of nitrate contamination in groundwater:

- Over 20 percent of small public water systems serve water with nitrate levels that exceed federal health limits, according to 2006 data from the Tulare County Department of Environmental Health.[68]
- Nitrate levels in Tulare County wells ranged from 10 to 54 mg/L (45 mg/L is the state health standard), according to a 2003 Department of Water Resources study.[69]
- Over 40 percent of private wells tested in a recent study exceeded federal health standards for nitrates, according to the Groundwater and Ambient Monitoring Assessment 2006 data.[70]

Photo by Bear Guerra

Many of the health indicators associated with nitrate contamination have elevated rates in Tulare County.[71]

The following tables present information on health outcomes that occur at elevated levels within Tulare County and are associated with high nitrate levels. Information for health outcomes that occur at average statewide rates are not included. All statistics are expressed as "death rates," which refer to the rate of death for each associated disease per 100,000 people. The death rate for each disease varies depending on the health outcome, but in each outcome listed, Tulare County's death rate occurred at levels significantly higher than the state rate.

Reproductive and Infant Health Concerns

Residents in Tulare County face a variety of reproductive and infant health issues at levels that are significantly higher than elsewhere in the state. Given the strong connection between nitrate contamination, reproductive health and infant mortality, this is cause for alarm.

Tulare County's infant mortality rate is higher than the state average – 6.4 versus 5.3 (per 100,000 infants births).[72] These rates have remained consistently high since 1990.[73] Another cause for concern is that studies have shown that drinking water contaminated with both bacteria and nitrates can make methemoglobinemia (blue baby syndrome) more likely.[74] In private well testing in Tulare County, 15 percent of wells tested exceeded MCLs in both categories.[75]

Health outcome associated with high nitrate levels	***Death rate in Tulare County***
Sudden Infant Death Syndrome	146 to 252 percent of state rate (2003)
Methemoglobinemia, or "Blue Baby Syndrome"	140 percent of state rate, ranking Tulare County 42nd of all California counties (2006)
Congenital malformations, deformations and chromosomal abnormalities, including neural tube disabilities	109 percent of state rate (2003); leading cause of infant death in 2005
Certain Conditions Originating in the Prenatal Period	250 percent of state rate (2003)
Spontaneous abortion, miscarriage	211 percent of state rate (2001-2003)

Source: California Department of Public Health, Center for Health Statistics, Office of Health and Information Research.

Photos by Bear Guerra

Incidences of Cancers Associated with Nitrate Contamination

Health outcome associated with high nitrate levels	***Death rate in Tulare County***
Digestive System Cancers	125 percent of state rate
Pancreatic cancer	121 percent of state rate
Esophogus Cancer	Between 125 and 134 percent of state rate (2001 - 2005); as high as 153 percent for females
Stomach Cancer	#8 in state for deaths caused by stomach cancer (1988-2005)
Bladder Cancer	111 percent of state rate (2003)
Ovarian Cancer	116 percent of state rate (2001-2005)
Testicular Cancer	107 percent of state rate (2002 – 2006)
Colon Cancer	113 percent of state rate (2005)
Non-Hodgkin lymphoma	119 percent of state rate for females (2001-2005)
Lung Cancer	108 percent of state rate (2001-2005); as high as 115 percent in 2005

Source: California Department of Public Health, Center for Health Statistics, Office of Health and Information Research.

Gastrointestinal Illnesses

Many gastrointestinal illnesses are related to nitrates.[77] One of the acute impacts of consuming nitrate-contaminated water is a variety of gastrointestinal illnesses. Almost 17 percent of farm workers in Tulare experienced at least monthly bouts of diarrhea, vomiting, and/or stomach pains.[78] While these may or may not be linked to nitrates, gastrointestinal inflammation exacerbates the more serious health impacts of nitrate contamination, such as pancreatitis and cancers of the gastrointestinal tract.

Health outcome associated with high nitrate levels	***Death rate in Tulare County***
Diseases of the Digestive System	149 percent of state rate (2003)
Peptic Ulcer	140 percent of state rate (2003)
Chronic Liver Diseases and Cirrhosis	133 percent of state rate (2003)
Other Liver diseases	224 percent of state rate (2003)
Pancreatitis	180 percent of state rate (2003)

Source: California Department of Public Health, Center for Health Statistics, Office of Health and Information Research.

Additional Health Outcomes Associated with Nitrate Contamination

Several other health outcomes associated with nitrates occur at notably high rates in Tulare County. For example, consumption of water high in nitrates has been shown to increase hypertrophy, a condition marked by enlargement of the thyroid, which is responsible for many of the body's endocrine and hormonal functions.[79] Tulare County's rate of death for these diseases is exceptionally high. Another endocrine-related disease is diabetes mellitus, which is associated with the endocrine portion of the pancreas.[80] Nitrates are associated with chronic pancreatitis, and total nitrate concentrations in blood serum have been suggested as a prognostic marker for diabetes.[81]

Health outcome associated with high nitrate levels	*Death rate in Tulare County*
Endocrine, Nutritional and Metabolic Diseases (including thyroid disorders)	172 percent of the state rate (2003)
Respiratory problems; shortness of breath; acute respiratory infections	119 percent of state rate (2007)
Diabetes	148 - 158 percent of state rate (2003 - 2006)

Source: California Department of Public Health, Center for Health Statistics, Office of Health and Information Research.

What is the legal health limit for nitrate?

California Department of Public Health (CDPH) has set a legal limit of 45 miligrams per liter (mg/L) for nitrates in public drinking water supplies.[82]

In California, the Maximum Contaminant Level (MCL) for nitrates is 45 mg/L. Water that has a concentration higher than this limit is considered unsafe and a violation of the Safe Drinking Water Act. Many experts debate whether this limit is too low.[84] For example, the European Economic Community has set a more conservative health standard of 5.6 mg/L. The U.S. Environmental Protection Agency (EPA) regulates nitrates primarily for its link to methemoglobinemia but does not even list the many other potential health risks of nitrate contamination.[85]

What is the difference between California's and the federal government's health standards for nitrate?

The federal government and California have set equivalent health standards, but for different forms of nitrate. Nitrate is found in several chemical forms in drinking water – either with more oxygen, as NO_3, or simply as nitrogen, N. The federal Environmental Protection Agency (EPA) has set a health standard of 10 mg/L for N, which is equivalent to California's standard of 45 mg/L as NO_3.

In particular, the EPA does not consider nitrate's link to cancer, despite studies by both the National Academy of Sciences and the International Agency for Research on Cancer that indicate the connections.[86] According to a Working Group of the International Society for Environmental Epidemiology, the EPA has "not thoroughly considered chronic health outcomes….The few epidemiologic studies that have evaluated intake of nitrosation precursors and/or nitrosation inhibitors have observed elevated risks for colon cancer and neural tube defects associated with drinking water nitrate concentrations below the regulatory limit."[87]

Another concern with the EPA limit is that nearly all other chemical standards create a "buffer" between exposure and particularly vulnerable populations, so that even if they are exposed to the legal limits of a contaminant, they will be protected.[88] Nitrate health standards do not have such a "margin of safety," particularly for infants.[89] Studies of infants in Europe have found that three to four percent of methemoglobinemia cases in infants occurred at doses lower than the U.S. federal MCL of 10 mg/L.[90]

Cumulative Impacts: Examining the Range of Impacts Caused by Contaminated Drinking Water and Other Environmental Stressors

Exposure to nitrate contamination is compounded by poverty.

Nitrate contamination has many impacts on the health and quality of life of San Joaquin Valley residents that cannot be captured in health statistics. Research has consistently shown that low-income communities and communities of color have higher rates of a range of environmentally-related diseases, ranging from asthma to lead poisoning, and socio-economic factors such as income level can contribute to a person's vulnerability to disease.[91] The San Joaquin Valley is home to both low incomes and high rates of disease. Average per capita income in the San Joaquin Valley is around $20,000, significantly less than the California average.[92] Almost 19 percent of residents live below the poverty line, versus California's average of 13 percent,[93] and one fifth of the San Joaquin Valley's population lacks health insurance.[94] Death rates and cancer rates in the San Joaquin Valley regularly exceed state averages.[95] Tulare County has the 14th highest death rate of all California counties, higher than the state average.[96] Residents also face an increased risk of cancer. In 2007, the risk for all types of cancer was 106 percent of the state rate.[97]

Forcing residents to choose between covering basic household costs and buying additional water to supplement their contaminated tap water is a real threat in the San Joaquin Valley. Some people are unable to afford buying bottled water, leaving them no choice but to rely on contaminated tap water and thus face increased exposure to dangerous contaminants.

Nitrate contamination imposes an economic burden on Valley residents.

Because of the widespread nature of contamination in the San Joaquin Valley, many residents spend extra money to buy safe water.[98] For example, in the small town of Seville, in Tulare County, the elementary school spends between $5200 and $7200 a year on bottled water to avoid serving nitrate-contaminated water to local children. The average annual income in Seville is approximately $14,000 per year.[99] CWC calculates that many residents throughout the Valley spend up to 10 percent of their income on water, forced to buy safe bottled or vended water on top of monthly water bills. The EPA has established criteria for determining what is an "affordable" household cost for water; the agency considers spending over 2 percent of annual income to be unaffordable.[100]

Photos by Bear Guerra

According to the
California Department of Food and Agriculture:

Additional costs of nitrate in groundwater include land use restrictions, denial of loans for lack of a suitable water supply, and a reduced tax base. So the problem of increased nitrate levels in California's groundwater is both significant and persistent.

California Department of Food and Agriculture. (2010) "About Fertilizer".

There are additional economic consequences to nitrate contamination, as well. Towns throughout the San Joaquin Valley have been forced to close wells due to nitrate contamination.[101] Small water systems may also need to impose high water rates on their low-income customers to cover expensive treatment systems.[102]

Nitrate is not the only contaminant in the San Joaquin Valley.

Unfortunately, the health problems associated with nitrate contamination in drinking water may be exacerbated and/or compounded by many other environmental and health stressors.[103] While we have outlined the health indicators specifically related to nitrate contamination in drinking water according to classic toxicology and epidemiological literature, these approaches do not assess the danger of nitrates when combined with multiple sources and pathways of exposure from a wide variety of stressors.[104]

In recent decades, more attention has been placed on the idea of "cumulative risks and impacts." According to the National Environmental Justice Advisory Committee, this concept is "a matrix of physical, chemical, biological, social and cultural factors which result in certain communities and sub-populations being more susceptible to environmental toxins, being more exposed to toxins, or having compromised ability to cope with and/or recover from such exposure."[105]

As the National Academy of Sciences notes, multiple stressors, ranging from chemicals released from noxious land uses to socioeconomic factors, can exacerbate the impacts of one particular source. They recommend "that exposure assessment methods [for environmental hazards] be expanded to consider exposures to multiple chemicals with multiple routes of exposure...These models need to be able to assess the cumulative effects of chemicals that may have either synergistic or antagonistic actions."[106]

Photo by Bear Guerra

If cumulative risks make certain communities more vulnerable to stressors,[107] such as drinking water contamination, the residents in the San Joaquin Valley are extremely vulnerable. In addition to nitrate contamination, residents face a host of other drinking water pollutants, including pesticides, arsenic, disinfectant by-products, and gasoline additives.[108]

Residents of the San Joaquin Valley are also assaulted by some of the most polluted air in the U.S. According to the American Lung Association, five of the nation's top 25 cities most polluted by particle matter are in the San Joaquin Valley.[109] In addition, five San Joaquin Valley counties make the top 25 list of the most polluted counties for both ozone and particulate matter.[110]

Cumulatively, residents in the San Joaquin Valley face many challenges to overall health and quality of life. While many of these issues are complex and difficult to address, reducing the high rates of nitrate contamination in drinking water is an important part of strengthening the health of Valley residents.

Conclusion: Ensuring Safe, Clean, Affordable Water for the San Joaquin Valley

By outlining the many health indicators associated with nitrate contamination that have been researched and documented in scientific and medical publications, we hope to raise awareness for the potential health threats faced by residents in the San Joaquin Valley. The research presented here does not create a definitive "link" between nitrate contamination and rates of disease in any one place, nor does it fully address all the potential ways San Joaquin Valley residents are impacted by drinking water and other environmental health contaminants.

The research does show two things, however: the San Joaquin Valley has high rates of nitrate contamination from agriculture and large animal facilities, and San Joaquin Valley residents face many health problems at rates much higher than elsewhere in the state. We believe that these two facts alone should be enough to compel us – as water providers, as government regulators, as residents in the San Joaquin Valley, and as a society – to ensure that our drinking water sources are protected to the utmost of our ability and to prioritize reducing the number of people drinking contaminated water. Safe, clean water is a human right, not a privilege.

For more information, please visit our website or contact us!

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Photo by Bear Guerra

End Notes

[1] Ramos, P. (2003). *Promoting Quality, Equity, and Latino Leadership in California Water Policy*. San Francisco: Latino Issues Forum.

[2] U.S. Department of Health and Human Services. United States Surgeon General. (2009). *The Surgeon General's Call to Action to Promote Healthy Homes 2009*.

[3] Centers for Disease Control and Prevention. (2002). Occupational Health Indicators for Tracking Work-Related Health Effects and Their Determinants. *Morbidity and Mortality Weekly Report* 51: 1073-1074.

[4] Harter, T. (2009). Agricultural Impacts on Groundwater Nitrate. *Southwest Hydrology* 8: 22 – 35.

[5] Camargo, J. and A. Alonso. (2006). Ecological and toxicological effects of inorganic nitrogen pollution in aquatic ecosystems: A global assessment. *Environment International* 32: 831- 849.

[6] Saracino, A. and H. Phipps. (2008). Groundwater Contaminants and Contaminant Sources. In *Watersheds, Groundwater and Drinking Water: A Practical Guide,* edited by T. Harter and L. Rollins. Oakland: University of California, Agriculture and Natural Resources.

[7] Bianchi, M. and T. Harter. (2002). *Nonpoint sources of Pollution and Irrigated Agriculture.* Oakland: University of California Agriculture and Natural Resources.

[8] Esser, B. et al. (2002). *Nitrate Contamination in California Groundwater: An Integrated Approach to Basin Assessment and Resource Protection.* Lawrence Livermore National Laboratory. See also: Burton, C. and K. Belitz. (2008). *Ground-water Quality Data in the Southeast San Joaquin Valley, 2005-2006-Results from the California GAMA Program*. Reston: U.S. Geological Survey Data Series 351.

[9] Balazs, C. (2010). *Trends in Nitrate Violations: Maximum Contaminant Level (MCL) Violations Over Time in California and the San Joaquin Valley*, Appendix A from *Just Water? Social Disparities in Nitrate Contaminated Drinking Water in California's Central Valley* (Ph.D. in preparation). Based on raw data from California Department of Public Health, Permits, Inspections, Compliance, Monitoring and Evaluation database (PICME).

[10] Ekdahl, E., M. de la Paz Carpio-Obeso, and J. Borkovich. (2009). Using GeoTracker GAMA to Investigate Nitrate Contamination in California's Groundwater, 1980-2008. Presented at: *Groundwater Monitoring: Design, Analysis, Communication, and Integration with Decision Making Conference, Orange, CA, Feb. 25-26, 2009.*

[11] Davisson, M., and R. Criss. (2004). Fertilizers, Water Quality, and Human Health. *Environmental Health Perspectives* 112.

[12] California Energy Commission. (2010). Frequently Asked Questions About Global Climate Change. Retrieved June 18, 2010, from http://www.climatechange.ca.gov/publications/faqs.html#iia.

[13] Davisson and Criss (2004).

[14] Balazs (2010).

[15] Burow, K., J. Shelton, and N. Dubrovsky. (1998). Occurrence of nitrate and pesticides in groundwater beneath three agricultural land-use settings in the eastern San Joaquin Valley, California, 1993-1995. Sacramento: U.S. Geological Survey.

[16] Central Valley Regional Water Quality Control Board. (2009). "Dairy Domestic Wells Table, Draft." Provided to the Community Water Center.

[17] Balazs (2010).

[18] Ibid.

[19] U.S. Geological Survey. (2003). State Summary of California. Sacramento: U.S. Geological Survey. Retrieved September 11, 2009, from http://pubs.usgs.gov/sir/2007/5213/downloads/pdfLinks/CAstatesum.pdf.

[20] Dubrovsky, N., C. Kratzer, L. Brown, J. Gronberg, and K. Burow. (1998). Water Quality in the San Joaquin-Tulare Basins, California, 1992-95. Sacramento: U.S. Geological Society.

[21] California Rural Policy Task Force. (2003). *California Agriculture: Feeding the Future*. Sacramento: Governor's Office of Planning and Research.

[22] Ibid.

[23] Gronberg, J., C. Kratzer, K. Burow, J. Domagalski, and S. Phillips. (2004). Water-Quality Assessment of the San Joaquin–Tulare Basins—Entering a New Decade. Sacramento: U.S. Geological Survey. See also: Davisson, M. and R. Criss. (1993). Stable isotope imaging of a dynamic groundwater system in the southwestern Sacramento Valley, California (USA). *Journal of Hydrology.* 144: 213–246. Davisson, M., and R. Criss. (1996). Stable isotope and groundwater flow dynamics of agricultural irrigation recharge into groundwater resources of the Central Valley, California. In: International Symposium on Isotopes in Water Resources Management. IAEA-SM-336/14. Vienna: International Atomic Energy Agency, 405-418; Dubrovsky et al. (1998); Burow et al (1998).

[24] National Agricultural Statistics Service. (2007). The Census of Agriculture. Washington: United States Department of Agriculture.

[25] Harter (2009).

[26] Committee of Experts on Dairy Manure Management. (2006). *Groundwater Quality Protection: Managing Dairy Manure in the Central Valley of California*. Oakland: University of California Agriculture and Natural Resources.

[27] Ingels, C. (2000). Manure, Nutrient Planning Pays For Small Farms. Water Watch Newsletter 87. Retrieved June 4, 2010, from http://extension.agron.iastate.edu/waterquality/neidpmaterials/ww87-1.html.

[28] National Agricultural Statistics Service. (2002). County Profile, Tulare, California. The Census of Agriculture. Washington: United States Department of Agriculture.

[29] Ibid.

[30] U.S. Environmental Protection Agency. (2010). Basic Information about nitrate in drinking water. Retrieved June 4, 2010, from http://www.epa.gov/safewater/contaminants/basicinformation/nitrate.html. Knobeloch, L., B. Salna, A. Hogan, J. Postle, and H. Anderson. (2000). Blue Babies and Nitrate-Contaminated Well Water. *Environmental Health Perspectives* 108.

[31] Fassett, D. (1973). Nitrates and Nitrites. *Toxicants Occurring Naturally in Foods*. Washington: National Academy Press.

[32] Camargo and Alonso (2006).

[33] Fassett (1973).

[34] Ibid.

[35] Manassaram, D., L. Backer, and D. Moll. (2006). A review of nitrates in drinking water: maternal exposure and adverse reproductive and developmental outcomes. *Environmental Health Perspectives* 114:320-327. Fan, A., and V. Steinberg. (1996). Health implications of nitrate and nitrite in drinking water: an update on methemoglobinemia occurrence and reproductive and developmental toxicity. *Regulatory Toxicology and Pharmacology* 23:35-43.

[36] Manassaram et al (2006).

[37] U.S. EPA (2010).

[38] Camargo and Alonso (2006).

[39] Manassaram et al (2006). See also: Dorsch, M., R. Scragg, A. McMichael, P. Baghurst, and K. Dyer. (1984). Congenital Malformations and Maternal Drinking Water Supply in Rural South Australia: a Case-Control Study. *American Journal of Epidemiology* 119:473-86; Knox, E. (1972). Anencephalus and dietary intake. *British Journal of Preventive and Social Medicine.* 26: 219–23; Super, M., H. Heese, D. MacKenzie, W. Dempster, J. Du Plessis, and J. Ferreira. (1981). An epidemiological study of well-water nitrates in a group of South West African/Namibian infants. *Water Resources* 15:1265-1270. Croen, L., K. Todoroff, and G. Shaw. (2001). Maternal exposure to nitrate from drinking water and diet and risk for neural tube defects. *American Journal of Epidemiology*. 153:325–331.

[40] Powlson, D., T. Addiscott, N. Benjamin, K. Cassman, T. de Kok, H. van Grinsven, J. L'Hirondel, A. Avery, and C. van Kessel. (2003). When does nitrate become a risk for humans? *Journal of Environmental Quality* 37:291-5.

[41] World Health Organization International Agency for Research on Cancer Monograph Working Group. (2006). Carcinogenicity of nitrate, nitrite, and cyanobacterial peptide toxins. *Lancet Oncology*, 7:628-629.

[42] Zhang, X., Z. Bing, Z. Xing, Z. Chen, J. Zhang, S. Liang, F. Men, S. Zheng, X. Li, and X. Bai. (2003). Research and control of well water pollution in high esophageal cancer areas. *World Journal of Gastroenterology* 9:1187-90.

[43] Greenblatt, M., S. Mirvish, and B. So. (1971). Nitrosamine Studies: Induction of Lung Adenomas by Concurrent Administration of Sodium Nitrite and Secondary Amines in Swiss Mice. *Journal of National Cancer Institute* 46:1029-1034.

[44] Ward, M. (2006). Workgroup report: Drinking-water nitrate and health--recent findings and research needs. *Environmental Health Perspectives* 114:A458-9; A459-61. See also: Gulis, G., M. Czompolyova, and J. Cerhan. (2002). An ecologic study of nitrate in municipal drinking water and cancer incidence in Trnava District, Slovakia. *Environmental Resources* 88:182-187.

[45] Weyer, P., J. Cerhan, B. Kross, G. Hallberg, J. Kantamneni, G. Breuer, M. Jones, W. Zheng, and C. Lynch. (2001). Municipal drinking water nitrate level and cancer risk in older women: the Iowa Women's Health Study. *Epidemiology* 12:327-38.

[46] Moller, H. (1997). Work in agriculture, childhood residence, nitrate exposure, and testicular cancer risk: a case-control study in Denmark. *Cancer Epidemiology, Biomarkers and Prevention* 6:141-144.

[47] Lubin, F., H. Farbstein, A. Chetrit, M. Farbstein, L. Freedman, E. Alfandary, and B. Modan. (2000). The role of nutritional habits during gestation and child life in pediatric brain tumor etiology. *International Journal of Cancer* 86:139-143.

[48] Gulis et al (2002).

[49] Manassaram, D., L. Backer, and D. Moll. (2006). Ingested nitrate and nitrite, and cyanobacterial peptide toxins. *Monographs On The Evaluation Of Carcinogenic Risks To Humans*. International Agency for Research on Cancer 94.

[50] U.S. E.P.A. (2010).

[51] Kimura, H., S. Miura, T. Shigematsu, N. Ohkubo, Y. Tsuzuki, I. Kurose, H. Higuchi, Y. Akiba, R. Hokari, M. Hirokawa, H. Serizawa, and H. Ishii. (1997). Increased nitric oxide production and inducible nitric oxide synthase activity in colonic mucosa of patients with active ulcerative colitis and Crohn's disease. *Digestive Diseases and Science* 42:1047-54. See also: National Institute of Public Health and Environmental Protection. (2010). Nitrate. International Program on Chemical Safety. Retrieved April 5, 2010, from http://www.inchem.org/documents/jecfa/jecmono/v35je14.htm.

[52] Carmargol et al (2008).

[53] Coss, A., K. Cantor, J. Reif, C. Lynch, and M. Ward. (2004). Pancreatic Cancer and Drinking Water and Dietary Sources of Nitrate and Nitrite. *American Journal of Epidemiology* 159:693.

[54] van Maanen, J., A. van Dijk, K. Mulder, M. de Baets, P. Menheere, and D. van der Heide. (1994). Consumption of Drinking Water with High Nitrate Levels Causes Hypertrophy of the Thyroid. *Toxicology Let*ters 72:365-374. Ward, MH, BA Kilfoy, PJ Weyer, KE Anderson, AR Folsom and JR Cerhand. 2010. Nitrate intake and the risk of thyroid cancer and thyroid disease. Epidemiology 21:389-395.

[55] U.S. E.P.A. (2010). See also: Knobeloch, L., B. Salna, A. Hogan, J. Postle, and H. Anderson. (2000). Blue Babies and Nitrate-Contaminated Well Water. *Environmental Health Perspectives* 108.

[56] Levine, J., M. Pettei, E. Valderrama, D. Gold, B. Kessler, and H. Trachtman. (1998). Nitric oxide and inflammatory bowel disease: evidence for local intestinal production in children with active colonic disease. *Journal of Pediatric Gastroenterology and Nutrition* 26:34-8.

[57] Gupta, S., R. Gupta, A. Gupta, A. Seth, J. Bassin, and A. Gupta. (2000). Recurrent Acute Respiratory Tract Infections in Areas With High Nitrate Concentrations in Drinking Water. *Environmental Health Perspectives* 108.

[58] Fan and Steinberg (1996).

[59] McCasland, M., N. Trautmann, and S. Porter. (2008). Nitrate: Health Effects In Drinking Water. Natural Resources Cornell Cooperative Extension. Retrieved June 5, 2010, from http://psep.cce.cornell.edu/facts-slides-self/facts/nit-heef-grw85.aspx.

[60] Kostraba, J., E. Gay, M. Rewers, and R. Hamman. (1992). Nitrate Levels in Community Drinking Waters and Risk of IDDM, an Ecologic Analysis. *Diabetes Care* 15:1505-1508. See also: Parslow R., P. McKinney, G. Law, A. Staines, R. Williams, and H. Bodansky. (1997). Incidence of Childhood Diabetes Mellitus in Yorkshire, Northern England, is Associated with Nitrate in Drinking Water: an Ecologic Analysis. *Diabetologia* 40:550-556.

[61] Nunes, S., I. Figueiredo, P. Soares, N. Costa, M. Lopes, and M. Caramona. (2008). Semicarbazide-sensitive amine oxidase activity and total nitrite and nitrate concentrations in serum: novel biochemical markers for type 2 diabetes? *Acta Diabetologica* 46:135-140.

[62] United States Census of Agriculture. (2009). Fertilizer and chemicals applied: 2007 and 2002. Washington: National Agricultural Statistics Service.

[63] Tulare Agricultural Sealer. (2009). Tulare County Permanent Planting Acreage: 2008 Crop Report. Retrieved June 8, 2010, from http://agcomm.co.tulare.ca.us/pdf/2008%20Crop%20Report.pdf. The crops included in this calculation are: pasture, citrus, grapes, peaches/nectarines, almonds, walnuts, oranges, cotton, wheat, and barley.

[64] Scorecard. (2005). Animal Waste: Counties with Animal Waste. Retrieved October 1, 2008, from http://www.scorecard.org/env-releases/aw/rank-counties.tcl?animal_type_code=total&waste_type_code=tons&fips_state_code=06. Scorecard combines livestock population data from the U.S. Department of Agriculture with waste factors developed by the agricultural community to estimate the amount of animal waste that livestock operations produce. Scorecard reports on animal waste production in 1997.

[65] California Agricultural Production Statistics 2009-2010. (2010). Livestock and Dairy. Sacramento: California Department of Food and Agriculture.

[66] Scorecard (2005).

[67] Balazs (2009).

[68] Tulare County Department of Environmental Health. (July 17, 2007). County Of Tulare Agenda Item: Modification of the Membership of the Tulare County Water Commission and Authorization of Submission Of A Proposition 84 Grant Application. Tulare County.

[69] Department of Water Resources. (2003). California's Groundwater Update 2003: Lake Tulare Hydrologic Region. Sacramento: Department of Water Resources.

[70] State Water Resources Control Board. (2006). Groundwater Ambient Monitoring & Assessment Program Domestic Well Project: Groundwater Water Quality Data Report: Tulare County Focus Area. Retrieved June 8, 2010, from: http://www.swrcb.ca.gov/gama/domestic_well.shtml#tularecfa.

[71] We used the most recent health statistics available to compile these figures. All death rates were taken from the California Department of Public Health, Center for Health Statistics, Office of Health and Information Research. For each health indicator, the data cited here are the most recent we were able to find during the time the research was originally undertaken (2008-2009).

[72] California Department of Public Health. (2010). County Health Status Profiles. Retrieved June 8, 2010, from http://www.cdph.ca.gov/programs/ohir/Pages/CHSP.aspx.

[73] California Department of Health Services. (2005). Leading Causes of Infant Death, California Counties, 2005 (By Place of Residence). Sacramento: Center for Health Statistics.

[74] Fan and Steinberg (1996).

[75] State Water Resources Control Board (2006).

[76] California Department of Health Services (2005).

[77] Laboratory for Toxicology, National Institute of Public Health and Environmental Protection. (n.d.). Nitrate. National Institute of Public Health and Environmental Protection: International Programme on Chemical Safety. Retrieved January 21, 2009, from http://www.inchem.org/documents/jecfa/jecmono/v35je14.htm.

[78] Frisvold, G., R. Mines., and J. Perloff. (1988). The Effects of Job Site Sanitation and Living Conditions on the Health and Welfare of Agricultural Workers. *American Journal of Agricultural Economics* 70(4):875-85.

[79] Van Maanen et al (1994).

[80] Kostraba et al 1992. See also: Parslow et al (1997).

[81] Nunes et al (2008).

[82] Public Health Service. (1962). *Drinking Water Standards 1962*. Washington: U.S. Department of Health, Education, and Welfare.

[83] Safe Drinking Water Committee, National Research Council. (1977). *Drinking Water and Health: Volume 1*. Washington: National Academies Press.

[84] Simon, C., H. Manzke, H. Kay, and G. Mrowetz. (1964). Occurrence, pathogenesis, and possible prophylaxis of nitrite induced methemoglobinemia. *Zeitschr. Kinderheilk*. 91: 124-138.

[85] U.S. EPA (2010).

[86] Manassaram et al (2006). See also: Francis, A. (1995). Toxicity Profiles: Formal Toxicity Summary for NITRATES. Risk Assessment Information System: Department of Energy. Retrieved January 21, 2009, from: http://rais.ornl.gov/tox/profiles/nitrates_f_V1.html.

[87] Ward, M., T. deKok, P. Levallois, J. Brender, G. Gulis, B. Nolan, and J. VanDerslice. (2005). Workgroup Report: Drinking-Water Nitrate and Health—Recent Findings and Research Needs. *Environmental Health Perspectives* 113(11):1607–1614.

[88] Environmental Working Group. (1996). *Pouring It On: Health Effects of Nitrate Exposure*. Washington: Environmental Working Group.

[89] Safe Drinking Water Committee (1977).

[90] Simon et al (1964).

[91] Evans, G. and E. Kantrowitz. (2002). Socioeconomic Status and Health: The Potential Role of Environmental Risk Exposure. *Annual Review of Public Health* 23: 303-331; Morello-Frosch, R. and R. Lopez. (2006). The Riskscape and the Colorline: Examining the Role of Segregation in Environmental Health Disparities. *Environmental Research* 102(2): 181-196. Williams, D. and C. Collins. (1995). US Socioeconomic and Racial Difference in Health: Patterns and Explanations. *Annual Review of Sociology* 21: 349-389.

[92] U.S. Census Bureau. (2008). *American Housing Survey for the United States: 2007*. Washington: U.S. Government Printing Office.

[93] Ibid.

[94] Congressional Research Service. (2005). *California's San Joaquin Valley: A Region in Transition.* Washington: Library of Congress.

[95] California Department of Public Health (2008). See also: California Department of Public Health. (2007). 2005 Pop estimates. Sacramento: California Department of Public Health.

[96] California Department of Public Health (2008).

[97] California Department of Public Health, Center for Health Statistics, Office of Health and Information Research.

[98] Quintana, R. (May 4, 2010). Personal communication.

[99] Community Water Center. (2010). Seville: A System Abandoned in Disrepair. Factsheet available from Community Water Center.

[100] Congressional Budget Office. (2002). Future Investment in Drinking Water and Wastewater Infrastructure: Appendix C: The 4 Percent Affordability Benchmark for Affordability. Washington: The Congress of the United States.

[101] Davisson and Criss (1996).

[102] For example, the small community of Alpaugh, in Tulare County, has been forced to raise rates to cover the cost of arsenic treatment.

[103] Koppe, J., A. Bartonova, G. Bolte, M. Bistrup, C. Busby, M. Butter, P. Dorfman, A. Fucic, D. Gee, P. van den Hazel, V. Howard, M. Kohlhuber, M. Leijs, C. Lundqvist, H. Moshammer, R. Naginiene, P. Nicolopoulou-Stamati, R. Ronchetti, G. Salines, G. Schoeters, G. ten Tusscher, M. Wallis, and M. Zuurbier. (2006). Exposure to multiple environmental agents and their effect. Acta Paediatrica Supplement 95(453):106-13.

[104] Ibid.

[105] National Environmental Justice Advisory Committee Cumulative Risks and Impacts Group. (2004). *Ensuring Risk Reduction in Communities With Multiple Stressors: Environmental Justice and Cumulative Risks/Impacts*. Washington: U.S. Environmental Protection Agency.

[106] Committee on Pesticides in the Diets of Infants and Children, National Research Council. (1993). *Pesticides in the Diets of Infants and Children*. Washington: National Academy Press.

[107] National Environmental Justice Advisory Committee Cumulative Risks and Impacts Group (2004).

[108] Gronberg et al (2004). See also: Ramos (2003); Ferriss, S. (August 18, 2009). Central Valley continues marathon fight for clean drinking water. *Sacremento Bee*; Troiano, J., T. Barry, C. Nordmark, and B. Johnson. (1997). Profiling areas of ground water contamination by pesticides in California: phase II - evaluation and modification of a statistical model. *Environmental Monitoring and Assessment* 45(3):301-318; Environmental Working Group. Drinking Water Quality Report, City of Tulare. Retrieved February 23, 2010, from http://www.ewg.org/tap-water/whatsinyourwater/CA/City-of-Tulare/5410015/. The State Water Resources Control Board's Geotracker database compiles cases of leaking underground storage tanks, leaking landfills, and other sources of potential aquifer contamination. The database on January 7, 2009 listed over 60,000 cases, of which over 24,000 are open. Most of the contaminants listed are gasoline, diesel, heating oil, hydraulic fluid, benzene and solvents.

[109] American Lung Association. (2010). *State of the Air 2010*. Washington: American Lung Association.

[110] Ibid.