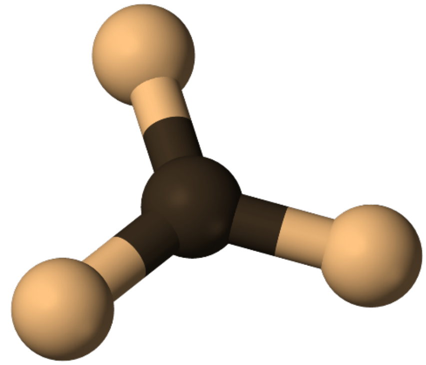
Groundwater Fact Sheet
Nitrate (N or NO_3^-)



Constituent of Concern
Nitrate

Synonym
N, NO_3, nitrooxidane, trioxidonitrate, trioxonitrate

Chemical Formula
N or NO_3^-

CAS Number
14797-55-8

Storet Number
71850

Summary
Nitrate is a regulated drinking water contaminant with an established State Maximum Contaminant Level (MCL) of 10 mg/L (as N, Nitrogen) or 45 mg/L (as NO_3^-). Nitrate and nitrite are two nitrogen compounds that are needed by plants and animals to live and grow. Nitrate is produced in the atmosphere from nitrogen and occurs naturally in groundwater at concentrations typically below 2 mg/L (as N). Their presence in groundwater is generally associated with septic systems, confined animal feeding operations or fertilizer use. Nitrates are also present in treated wastewater, and as such can be present in surface water, or in treated wastewater used in groundwater recharge projects. These sources can pose risks to urban drinking water supplies. Nitrates are also used in industry, for example, in the production of fertilizers and explosives. Nitrate is only a concern for ingestion.

Based on State Water Resources Control Board (SWRCB) data from 2007 to 2017, 854 active and standby public wells (of 11,906 sampled, 9,835 detections) had at least one detection of nitrate (as N) above the MCL. Most nitrate detections above the MCL occurred in Los Angeles (128 wells), Tulare (95 wells), and Kern (88 wells) counties.

REGULATORY WATER QUALITY LEVELS[1] NITRATE		
Type	**Agency**	**Concentration**
Federal MCL	EPA[2]	10 mg/L as Nitrogen (N)
State MCL	SWRCB[3]	10 mg/L as Nitrogen (N)
Detection Limit for Purposes of Reporting (DLR)	SWRCB[3]	0.4 mg/L as Nitrogen (N)
Public Health Goal (PHG)	OEHHA[4]	10 mg/L as Nitrogen (N)

[1]These levels generally relate to drinking water, other water quality levels may exist. For further information, see A Compilation of Water Quality Goals, 17th Edition, (SWRCB, 2016).
[2]EPA – United States Environmental Protection Agency
[3]SWRCB – State Water Resources Control Board
[4]OEHHA – Office of Environmental Health Hazard Assessment

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NITRATE DETECTIONS IN PUBLIC WATER WELL SOURCES[5]	
Number of active and standby public wells with a nitrate concentration[6] > 10 mg/L (N)	854 of 11,906 wells tested with 9,835 detections
Top 3 counties with active and standby public wells with a nitrate concentration > 10 mg/L (N)	Los Angeles (128), Tulare (95), and Kern (88)

[5]Based on 2007-2017 public standby and active well (groundwater sources) data collected by the SWRCB.
[6]Water from active and standby wells is treated to prevent exposure to chemical concentrations above the MCL or other health-based benchmarks. Data from private domestic wells and wells with less than 15 service connections are not available.

ANALYTICAL INFORMATION		
Approved EPA methods	300.0/300.1	353.2
Detection Limit (mg/L)	0.01-0.08	0.05
Notes	Nitrate-Nitrogen by Ion Chromatography	Nitrate-Nitrite by Automated Colorimetry
Public Drinking Water Testing Requirements	Public water systems are required to test for nitrate and must report the results to the SWRCB.	

Nitrate Occurrence

Anthropogenic Sources

The largest source of anthropogenic nitrate is industrial production via the Haber-Bosch process. The Haber-Bosch process catalyzes atmospheric nitrogen gas with hydrogen to produce ammonia – which can then be further oxidized to produce nitrate. Approximately 3 to 5 percent of the world's natural gas production is consumed in this process, producing approximately 450 million tons of nitrogen fertilizer per year.

High concentrations of nitrate are often associated with fertilizer production and application. Fertilizer that is not used by plants can leach into groundwater and ammonia will rapidly convert to nitrate in the presence of oxygen. Other anthropogenic sources of nitrate to groundwater include septic systems, discharges from wastewater and agricultural ponds, leaky sewer lines, manure fertilizer application, and the production of explosives.

Natural Sources

Nitrogen is an important biologic element and is a required component of amino acids and proteins. Although nitrogen is the most abundant gas in the atmosphere (as N_2), it is not easily used by most organisms in this form. N_2 must first be transformed to a more easily utilized compound, such as nitrate, before incorporation into biologic tissue or plant matter. Nitrate is naturally produced from N_2 through biologic fixation and from organic nitrogen through mineralization. Minor amounts may also be produced through oxidation of atmospheric nitrogen by lightning. Some nitrate from these sources may naturally enter groundwater, but these concentrations are generally low. NO_3^- concentrations greater than 10 to 15 mg/L are generally indicative of anthropogenic sources.

History of Occurrence

Nitrate is the most common chemical contaminant in the world's groundwater aquifers (Spalding and Exner, 1993). The USGS has estimated that nitrate exceeded background concentrations in 65 percent of shallow wells (<100 feet) in agricultural and urban areas. According to 2010, US Geological Survey publication, up to 7% of 2,388 domestic wells sampled in agricultural and urban areas have nitrate levels above the MCL. Concentrations exceeding the MCL were less common in public-supply wells (about 3 percent of 384 wells sampled). In California, multiple areas have elevated levels of nitrate contamination in groundwater including the San Joaquin Valley, Santa Ana Valley, and Salinas basins.

Contaminant Transport Characteristics

Nitrate dissolves rapidly in water and once dissolved is difficult to remove. Some natural degradation (denitrification) can occur under low or no-oxygen groundwater conditions. However, evidence suggests that aquifer-scale denitrification does not occur, and that once nitrate enters groundwater it can remain there for decades.

Remediation and Treatment Technologies

There is no simple way to remove nitrate from water. Boiling, softening, and filtration as a means of purifying water do not reduce nitrate concentrations. The following methods can reduce or remove nitrate:

Demineralization

Distillation - Removes nitrate and all other minerals from the water. Distillation is one of the most effective types of demineralization. This process involves boiling the water, then collecting and condensing the steam by using a metal coil.

Reverse osmosis - Water is placed under pressure and forced through a membrane that filters out minerals and nitrate.

Both distillation and reverse osmosis are costly and require time and energy to operate efficiently. They are low-yield systems, and storage space for treated water is required.

Ion-exchange

Water containing nitrate flows through a tank filled with resin beads that are charged with chloride. As the water flows through the tank, the resin takes up the nitrate and exchanges with chloride.

Electro-dialysis

Water containing nitrate flows across anion-exchange and cation exchange membranes in a constant electric field. The use of these mono-anion-selective membranes offers additional possibilities of nitrate removal by enabling preferential flow of mono-valent anions.

Other potential options include phytoremediation and above ground biochemical denitrification.

Health Effect Information

High levels of nitrate in drinking water are associated with adverse health effects. Domestic well users are encouraged to test their well water regularly for nitrate.
Infants under six months of age have a greater risk of nitrate poisoning, called methemoglobinemia ("blue baby" syndrome). Toxic effects occur when bacteria in the infant's stomach convert nitrate to more toxic nitrite. When nitrite enters the bloodstream, it interferes with the body's ability to carry

oxygen to body tissues. Symptoms include shortness of breath and blueness of the skin around the eyes and mouth. Infants with these symptoms need immediate medical care since the condition can lead to coma and eventually death. During pregnancy, it is common for methemoglobin levels of the pregnant woman to increase from normal (where 0.5 to 2.5% of the total hemoglobin is in the form of methemoglobin) to a maximum of 10% in the 30th week of pregnancy. The level of methemoglobin declines to a normal level after delivery. Pregnant women are susceptible to methemoglobinemia and should be sure that the nitrate concentrations in their drinking water are at safe levels. Some scientific studies suggested a linkage between high nitrate levels in drinking water with birth defects and certain types of cancer. However, long-term scientific studies are needed to determine a direct relationship. According to the EPA, long-term exposure to water with high nitrate levels may cause diuresis, increase starchy deposits, and hemorrhaging of the spleen. People with heart or lung diseases are more susceptible to the toxic effects of nitrate than others because of reduced levels of gastric acidity.

Key Resources

1. California State Water Resources Control Board - Division of Drinking Water, Nitrates and Nitrites in Drinking Water. (January 2016) http://www.waterboards.ca.gov/drinking_water/certlic/drinkingwater/Nitrate.shtml
2. California State Water Resources Control Board, A Compilation of Water Quality Goals 17th Edition (SWRCB, 2016). http://www.waterboards.ca.gov/water_issues/programs/water_quality_goals/index.shtml
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5. Nolan, B.T., Hitt, K.L. Vulnerability of Shallow Groundwater and Drinking-Water Wells to Nitrate in the United States. *Environ. Sci. & Technol.*2006, 40,7834-7840. https://pubs.acs.org/doi/10.1021/es060911u
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9. U.S. Environmental Protection Agency. Consumer Fact Sheet. Nitrates/Nitrites. https://archive.epa.gov/water/archive/web/pdf/archived-consumer-fact-sheet-on-nitrates-and-or-nitrites.pdf
10. U.S. Geological Survey. National Water-Quality Assessment (NAWQA) Program. Nutrients in rivers, streams and aquifers in the United States. http://water.usgs.gov/nawqa/nutrients/
11. Ward M.H., deKok, T.M., Levallois, P, Brender, J., Gulis G., Nolan B.T., VanDerslice, J., 2005 . Workgroup report: Drinking-Water Nitrate and Health - Recent Findings and Research Needs. *Environ. Health Persp.* Vol.113:11. https://doi.org/10.1289/ehp.8043

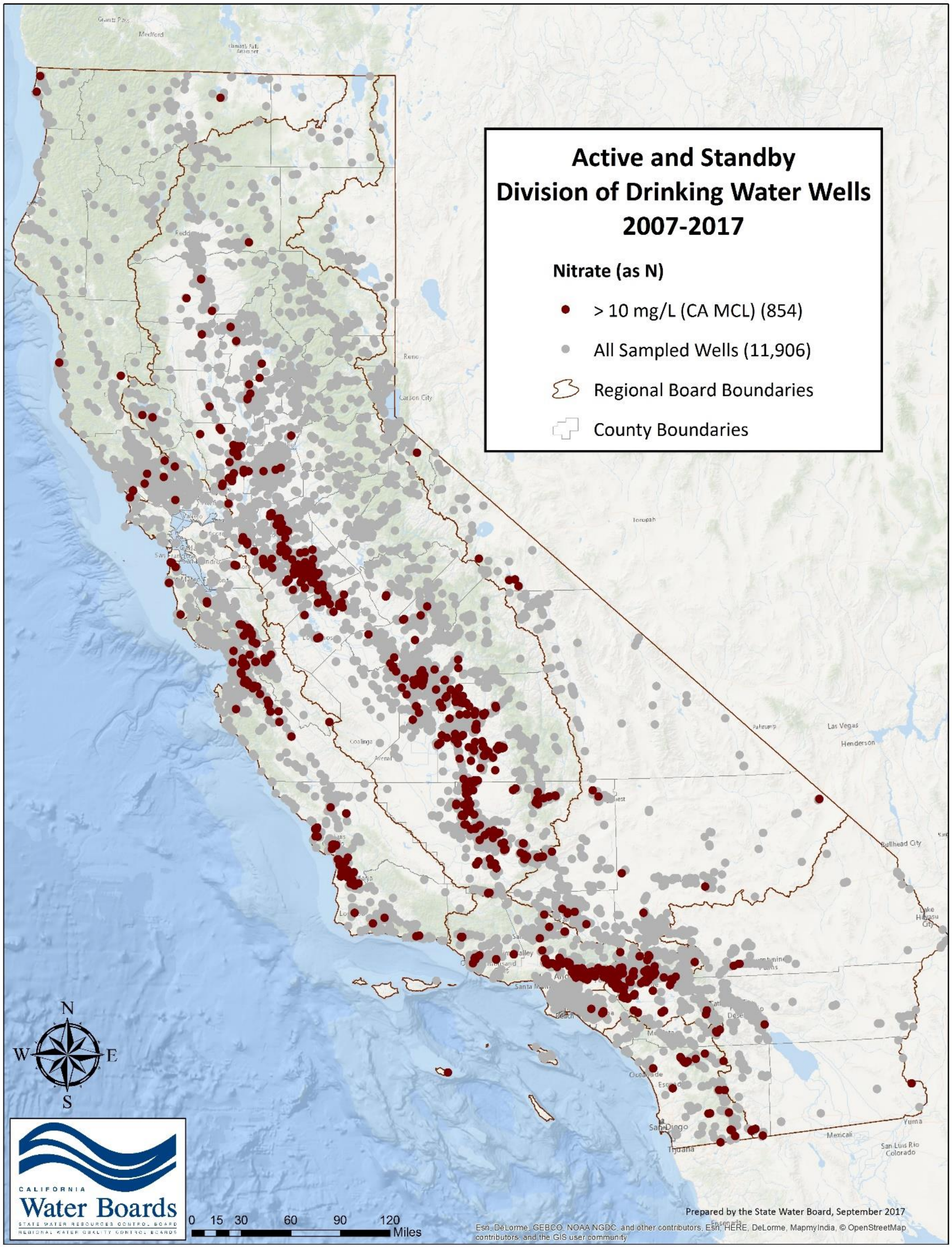

Figure 1. Active and standby public drinking water wells that had at least one detection of nitrogen above the MCL, 2007-2017, 854 wells. (*Source: Public supply well data in [GAMA GIS]*).