Guidance Document
Nitrate Treatment
Alternatives for Small Water Systems

June 2005

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Guidance Document

Nitrate Treatment Alternatives for Small Water Systems

June 2005

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Foreword

This guidance document is for small water system owners and board members of water systems that have elevated nitrate concentrations in one or more of their sources. It may also serve as guidance for engineers who work with small water systems. This document is very general – more specific information on source protection and nitrate treatment can be obtained from the cited references and contacts provided.

Executive Summary

Nitrate contamination of drinking water supplies is an acute public health concern for people throughout the country, including many in Washington State. Both nitrate and nitrite are significant public health concerns since they can cause methemoglobinemia or “blue-baby syndrome.” Nitrite interferes with the ability of infant hemoglobin to carry oxygen. Left untreated, this condition may lead to brain damage and death.

Based on samples taken between 1999 and 2003, there have been 129 public water systems in Washington State that have had a sample that exceeded 10 milligrams per liter (mg/L) and 400 water systems with a sample that exceeded 5 mg/L. As of 2004, nationwide there are more public water systems that exceed the nitrate maximum contaminant level (MCL) than any other health-related chemical contaminant.

The purpose of this document is to summarize the options available for water systems to take action if a source exceeds the MCL for nitrate. In the short-term, water systems must provide public notification for all their customers when nitrate exceeds the MCL. Long-term solutions include source water protection activities, drilling a new well, and installing treatment.
Chapter 1: Introduction

Nitrate and nitrite contamination of drinking water supplies are a concern for people throughout the country, including many in Washington State. The maximum contaminant level (MCL) for nitrate in drinking water is 10 milligrams per liter (mg/L) and the MCL for nitrite is 1 mg/L. Both nitrate and nitrite are significant public health concerns since they can cause methemoglobinemia or “blue-baby syndrome.” Nitrite interferes with the ability of infant hemoglobin to carry oxygen. Left untreated, this condition may lead to brain damage and death. Nitrate and nitrite are primarily a health concern for infants, pregnant women and their developing fetuses, adults with reduced stomach acidity, and those with certain enzyme deficiencies. Since nitrate and nitrite can cause short-term health effects, their presence in drinking water is a high priority public health issue. In the remainder of this document, the term nitrate implies both nitrate and nitrite, since nitrite usually occurs at concentrations above the MCL only when nitrate concentrations are also elevated.

Nitrate is also a health concern for livestock and other animals. Similar to humans, domesticated animals can experience methemoglobinemia that, when left untreated, can be deadly. Cows are also subject to chronic nitrate poisoning, leading to lower milk production, weight loss, and miscarriages.

The purpose of this document is to summarize the options available for water systems to take action if a source exceeds the MCL for nitrate. In the short-term, water systems must provide public notification for all their customers when nitrate exceeds the MCL. More information on public notification requirements is provided in Appendix A. Possible long-term solutions include source water protection activities, drilling a new well, and providing treatment. These options are developed in more detail in this guidance manual.

Nitrate Checklist

1. **Sample**
   Sample at least annually for nitrate. Nitrate concentrations in groundwater can change over months and years due to changes in land use such as increased agricultural activities, deforestation, and installation of septic systems.

2. **Confirm**
   Although rare, sampling mistakes are possible. A repeat sample must be collected within 24 hours if an initial sample exceeds the MCL. If a repeat sample is not taken, follow-up action must be taken based upon the initial sample.
3. **Public Notification**
   Conduct public notification as outlined in Appendix A. Since nitrate is an acute contaminant, public notification is required within 24 hours of a MCL violation.

4. **Evaluate Alternatives**
   Usually, the first step in evaluating long-term alternatives is to develop a compliance schedule with the Department of Health (DOH). Possible long-term solutions include developing a new well, source water protection activities, and providing treatment. Ultimately, an engineer will be required to submit a project report prior to further development of the selected alternative. These alternatives include:

   - **Non-Treatment Alternatives**
     The feasibility of non-treatment alternatives should always be considered. Possible non-treatment alternatives include drilling a new well, connecting to an adjacent system, removing sources of nitrate contamination, and blending with a low nitrate source.

   - **Treatment**
     Prior to evaluating treatment options, some basic information should be collected about the source(s) to be treated. This basic information includes:

     - Well Capacity (gpm).
     - Average Daily Well Production (gpd)
     - Water Quality Data (nitrate concentration and other water quality parameters)

     With this information, it will be possible to evaluate treatment options reviewed in this manual.

5. **Cost Estimates**
   Once feasible alternatives are identified, preliminary capital, operations and maintenance costs can be developed.

6. **Secure Funding**
   Evaluate funding options, such as a Drinking Water State Revolving Fund (DWSRF) loan. Other potential sources of funding can be investigated at the Infrastructure Assistance Coordinating Council website: [http://www.infrafunding.wa.gov](http://www.infrafunding.wa.gov)

7. **Implement the Project**
   Implementation includes preparing a pre-design report, designing the project, submitting it for approval, project construction, certification of construction completion, and start-up activities. A professional engineer will be required to implement the project.
Nitrate Occurrence

Nitrate contamination of drinking water occurs throughout the United States and is most frequently associated with shallow wells in agricultural areas with well drained (gravelly) soils (Nolan, 2002). In Washington State, the two areas most vulnerable to nitrate contamination of groundwater include agricultural areas in Eastern Washington and in Whatcom County (Erwin, 1997; Frans, 2000). The main factors that affect the potential for nitrate contamination of groundwater include land use practices, well depth, and soil type. Nitrate occurrence is addressed in more detail in Chapter 2.

Nitrate Compliance Approaches

This guidance document addresses general approaches to remedy nitrate contamination of drinking water. With any water treatment process, there are variables that are unique to a specific system. Water systems with more complex or unusual situations are encouraged to seek the advice of water professionals early in the planning process. With any selected alternative, a project report must be prepared in accordance with Washington Administrative Code (WAC) 246-290-110. The project report, as well as the design, must be prepared by a professional engineer licensed in Washington State.

A brief summary of compliance approaches is provided below. Each alternative is described in more detail in Chapters 3 and 4. Additional source protection resources and contact information are found in Appendix C.

Non-Treatment Alternatives and Long-Term Source Protection

Water systems should first consider non-treatment alternatives before considering treatment for nitrate removal. Non-treatment alternatives include:

- Developing a new well
- Redrilling or modifying an existing well
- Improving source protection
- Connecting to a nearby system
- Blending with a low nitrate source

When feasible, non-treatment alternatives are typically less burdensome, less costly, and more reliable than treatment. Non-treatment alternatives are described in more detail in Chapter 3.

Nitrate contamination of drinking water sources is the result of land use activities that allow nitrate and other nitrogen-based compounds to enter water supplies. These land use activities include the use of synthetic fertilizers, land application of manure, and septic systems. Good management of fertilizers and manure can minimize nitrate leaching into the groundwater. Long-term source protection activities are recommended regardless of other actions taken by the purveyor, since improved source protection may eliminate the need for treatment in the future. Source protection activities are described in more detail in Chapter 3.
**Treatment Alternatives**

In some cases, it will not be feasible to implement a non-treatment alternative. Reasons include the impracticality of connecting to another water system, widespread nitrate contamination that eliminates the possibility of blending, and inability to identify, control or remove the source(s) of nitrate contamination. In these cases, treatment alternatives must be considered.

Nitrate is a stable and highly soluble ion with a low potential for precipitation or adsorption. These properties make it difficult to remove from water using conventional processes such as filtration or activated carbon adsorption. As a result, more complex treatment processes must be considered. These treatment processes—ion exchange, reverse osmosis, electrodialysis, and biological denitrification—are summarized in this section. More information on these treatment processes is provided in Chapter 4.

- **Ion Exchange**—involves the exchange of chloride ions for nitrate ions with periodic regeneration of the ion exchange resin with a salt solution. The difficulty of brine disposal and health concerns associated with inadequate operation of this treatment process should be considered in the evaluation process.

- **Reverse Osmosis**—uses high pressure to force water through a membrane. Most of the nitrate is removed, along with other dissolved ions.

- **Electrodialysis**—is an electrochemical process in which ions migrate through ion-selective membranes due to their attraction to oppositely charged electrodes.

**Experimental Treatment**

The following types of treatment should be considered highly experimental since there are currently no full-scale applications in the United States.

- **Biological Treatment**—involves using microorganisms to convert the nitrate to nitrogen gas. The microorganisms are then removed by filtration followed by disinfection. This type of treatment has been used in Europe, but the operational experience in the United States is limited.

- **Subsurface Biological Treatment**—enhances naturally occurring biological processes in groundwater to stimulate the conversion of nitrate to nitrogen gas (a process called denitrification). Since naturally occurring denitrification is limited by the amount of organic carbon in the soil, sources of carbon such as wood chips, straw, or ethanol are provided to enhance the biological process.

- **Phytoremediation**—uses plants to remove the nitrate from groundwater. Phytoremediation has been used to clean-up nitrate from soils contaminated by fertilizer spills and other accidental chemical releases. The applicability of phytoremediation to clean-up drinking water supplies may be limited, since even deeper rooting plants such as poplar trees have roots that extend less than 30 feet deep.
Summary
Ion exchange, reverse osmosis, electrodialysis, and biological denitrification have all been applied at full-scale for the removal of nitrate from drinking water. Each treatment process has its advantages, disadvantages and limitations, as summarized in Table 1-1.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Ion Exchange</th>
<th>Reverse Osmosis</th>
<th>Electrodialysis</th>
<th>Engineered Biological Treatment</th>
<th>Subsurface Biological Treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td>U.S. Installations</td>
<td>Many</td>
<td>Few</td>
<td>None is U.S. Several in Europe</td>
<td>None in U.S. Some in Europe</td>
<td>None</td>
</tr>
<tr>
<td>Pretreatment Required</td>
<td>Sometimes</td>
<td>Significant</td>
<td>Sometimes</td>
<td>None</td>
<td>None</td>
</tr>
<tr>
<td>Cost</td>
<td>Moderate</td>
<td>High</td>
<td>High</td>
<td>Moderate</td>
<td>Uncertain, but likely low</td>
</tr>
<tr>
<td>Raw Water Issues</td>
<td>Resin sensitive to iron, manganese, sulfate, organic matter, and TDS</td>
<td>Process sensitive to iron, manganese, organic matter, TDS and turbidity</td>
<td>Membrane sensitive to iron, manganese, organic matter, and turbidity</td>
<td>Optimum pH 7-8.5. Temperature: 5-30ºC</td>
<td>Optimum pH 7-8.5. Temperature: 5-30ºC</td>
</tr>
<tr>
<td>Post Treatment</td>
<td>pH adjustment may be required</td>
<td>Low TDS may require water quality adjustments</td>
<td>None</td>
<td>Filtration, disinfection, and taste and odor control</td>
<td>None</td>
</tr>
<tr>
<td>Waste Disposal</td>
<td>Salt brine and rinse water</td>
<td>Concentrate</td>
<td>Concentrate</td>
<td>Biological solids</td>
<td>None</td>
</tr>
<tr>
<td>Feasibility of Automation</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
<td>Partial</td>
<td>Not required</td>
</tr>
<tr>
<td>Process Start-up</td>
<td>Minutes</td>
<td>Minutes</td>
<td>Minutes</td>
<td>Weeks (if new)</td>
<td>Undetermined</td>
</tr>
</tbody>
</table>

Non-treatment alternatives such as wellhead protection activities, land use management, connection to an adjacent system, blending, and developing a new source should always be investigated prior to focusing on treatment alternatives.

Other Compliance Options
Other compliance options are mentioned here because they may be evaluated by the water system, but have limited applicability.

- **Point-of-Use/Point-of-Entry (POU/POE)** – also referred to as under-the-sink and whole-house treatment units have limited applicability. The 1996 amendments to the Safe Drinking Water Act outline the conditions under which POU/POE devices may be used as a compliance option. The sampling, access and management issues associated with POU/POE treatment are expected to limit its applicability.
• **Bottled Water** – Bottled water can be used as an interim solution while a permanent remedial option is implemented, in accordance with a compliance agreement signed by the purveyor and DOH. Federal law prohibits public water systems from using bottled water to achieve permanent compliance following an MCL violation. Finally, the water system owner is responsible for providing water to all customers who request it.

### Conclusions

Concentrations of nitrate above the MCL are an immediate public health concern. As such, water purveyors must take immediate action to notify their customers within 24 hours and begin planning for a long-term solution to the nitrate contamination. Although there are treatment processes that can remove nitrate from water, a low nitrate source will more reliably provide water with nitrate below the MCL than a treated source. There are also ongoing operation and maintenance costs with treatment that should be considered.

### Chapter 1 References


Chapter 2: 
Nitrate Occurrence

Nitrate contamination of drinking water occurs throughout the United States and is most frequently associated with shallow wells in agricultural areas with well drained (gravelly) soils (Nolan, 2002). In Washington State, the two areas most vulnerable to nitrate contamination include agricultural areas in Eastern Washington and in Whatcom County (Erwin and Tesoriero, 1997; Frans, 2000). These aquifer vulnerability assessments by the United States Geological Survey (USGS) reflect the occurrence of nitrate contamination of drinking water sources in the state which is illustrated in Figure 2-1.

Based on samples taken between 1999 and 2003, there have been 129 public water systems in Washington State that have had a sample that exceeded 10 mg/L and 400 water systems with a sample that exceeded 5 mg/L. As of 2004, nationwide there are more public water systems that exceed the nitrate MCL than any other health related chemical contaminant (Roberson, 2004).

Reasons for Nitrate in Groundwater

The main factors that affect the potential for nitrate contamination of groundwater include land use practices, well depth, and soil type.

Land Use Activities
Agricultural activities are the main sources of nitrate in groundwater (Ryker and Jones, 1995). Nitrogen fertilizers are frequently used in large quantities, especially for some crops such as corn and potatoes. In Eastern Washington, the high annual rate of fertilizer application coincides with high nitrate concentration in groundwater. Other sources of nitrogen, such as livestock operations, food processing wastes, and septic discharge are not as substantial an influence at the regional scale (Ryker and Jones, 1995). In Whatcom County, agricultural activities are estimated to contribute 85 to 88 percent of the total nitrate load to groundwater (Cox 1998). However, septic systems, lawn fertilizers, and other non-agricultural activities have been associated with localized nitrate contamination of groundwater (Anderson, 2003; Risinit, 2003; Tesoriero and Voss, 1997).

Well Depth
Shallow wells, especially wells in unconfined aquifers, are more likely to have nitrate contamination than deeper wells. For high risk sources evaluated throughout the United States, the risk of exceeding the nitrate MCL dropped from 24% for wells less than 100 feet deep to almost 0% for well greater than 200 feet deep (Nolan, 2002). Similar analyses have been conducted for groundwaters in Eastern Washington and Puget Sound.
Figure 2-1: Nitrate Sampling Results for Public Water Systems (1993-2003).

Source: Washington State Department of Health
Soil Type
USGS reports indicate fractured bedrock and coarse grained glacial deposits have been associated with higher concentrations of nitrate in groundwater (Tesoriero and Voss, 1997; Frans, 2000). These same reports indicate high concentrations of nitrate are less likely to occur where fine grained silts and clays are present.

Temporal Changes in Nitrate Concentrations
The concentration of nitrate in groundwater can change over time. These changes can be seasonal swings in nitrate concentrations as well as long-term trends (Figure 2-2 and Figure 2-3). Seasonal swings can be indicative of changes in fertilizer application, nitrate uptake by plants, and changes in natural denitrification rates. Plants consume nitrogen from the soil during spring and summer when they are growing. During the winter, little plant uptake of nitrogen occurs. As a result, nitrogen applied during this time of year will tend to leach into the groundwater. Leaching can be enhanced by rain or excessive irrigation. In addition, during cooler weather, the rate of natural denitrification slows down, which may also increase nitrate leaching and mobility.

![Figure 2-2: Seasonal Changes in Nitrate Concentration for a Well in Douglas County.](image-url)
Nitrate Occurrence in Washington

There have been a number of studies evaluating nitrate contamination in Washington State. These studies focused on parts of Eastern and Western Washington with the greatest frequency of nitrate contamination including Whatcom County and the Columbia Basin. These studies are summarized here along with discussions of on-going efforts to monitor and control nitrate contamination in these parts of the state.

Whatcom County
Whatcom County is an area west of the Cascade Mountains where high concentrations of nitrate have frequently been detected in the groundwater. High nitrate concentrations are mainly found in the northern part of the county underlain by the Blaine-Sumas and Abbotsford-Sumas aquifers. The Abbotsford-Sumas aquifer is a shallow, mostly unconfined aquifer that occupies approximately 200 square kilometers and serves as the principal water supply for more than 100,000 people in the United States and Canada. Intensive agricultural practices in both Canada and the United States have been reported to contribute to high concentrations of nitrate in the groundwater (Cox, 1997; Cox and Kahle, 1998; Erickson, 1998; Erickson, 2002; Mitchell et al, 2003).

![Figure 2-3: Long-term Trend in Nitrate Concentration for a Well in Franklin County.](image-url)
Generally, groundwater in the aquifer flows from the north to the south. Since the aquifer spans the U.S./Canada border, communities in both countries are involved in efforts to decrease nitrate contamination through local activities and involvement in the Abbotsford-Sumas Aquifer International Task Force. One recent study (Mitchell et al, 2003) evaluated a 10 km² area just south of the international border. Results indicated the highest concentrations of nitrate (>20 mg/L) were detected in shallow regions of the aquifer and linked to agricultural practices in Whatcom County. Nitrate concentrations deeper in the aquifer were not quite as high and were related to agricultural sources in Canada. Isotope data indicate the main sources of nitrate were mainly manure and manure mixed with synthetic fertilizers.

Based on this and other water quality data, communities on both sides of the border have taken action to reduce nitrate leaching into the groundwater. In Canada, one focus has been on raspberry farms combined with poultry production. It is estimated that the risk of nitrate contamination of aquifer waters doubled between 1971 and 1991 (Coote and Gregorich, 2000). Part of the reason for this increase in nitrate is the shift to raspberry farming. Raspberries have lower nitrogen needs than pasture for forage crop production, which was historically practiced in the area. The shift to raspberry farming occurred along with a shift from cattle rearing to poultry production. Most of the poultry feed, which is higher in nitrogen than forage crops, is brought into the Abbotsford area from outside the watershed. In this way, nitrogen is imported into the watershed in the form of poultry feed.
The high nitrogen poultry manure is then applied to the raspberry fields, which are the main crop in the area. Since raspberries require little nitrogen, a significant amount of nitrogen leaches into the groundwater.

The following actions have been taken to reduce nitrogen leaching.

- **Truck poultry manure out of the watershed.** By 1997, about 15 percent of the manure produced was trucked to areas with low livestock densities. The goal is to truck at least 50 percent of the manure off the aquifer.

- **Improve nitrogen management and uptake in raspberry farms.** Some of the improved management practices evaluated include growing cover crops between raspberry rows, and adjusting the timing, amount and methods of poultry manure application to decrease nitrogen leaching.

- **Education about and enforcement of regulations.** To increase awareness, periodic inspections are conducted to encourage good management activities such as covering manure piles during the rainy season to minimize leaching.

In Whatcom County, groundwater quality improvements focused on diary and other farming operations. In 1998, the Washington State Legislature passed the Dairy Nutrient Management Act, which required dairies to develop manure management plans by July 1, 2002. Dairy farms were required to implement their plans by December 31, 2003. In Whatcom County, approximately 99% of dairy farms had approved plans by June 30, 2002 (Whatcom Conservation District, 2002).

Statewide, 80% met the deadline to implement their plans (Washington State Department of Agriculture, 2004; Dodge, 2004). Farmers in Whatcom County have also taken advantage of state and federal programs encouraging responsible farming practices to improve water quality. These programs include the Conservation Reserve Enhancement Program (CREP) and the Environmental Quality Incentive Program (EQIP), which are administered locally by the Whatcom Conservation District. Participation in these programs has increased in recent years with over $1 million in EQIP contracts awarded to farmers in 2004 (Whatcom Conservation District, 2004).

**Columbia Basin**

The Columbia Basin includes a large portion of Eastern Washington bounded by the Snake River on the south and the Columbia River on the west. Nitrate occurrence in this area has been studied extensively in the past 10 years (Ryker and Jones, 1995; Frans, 2000). Many wells in this region currently have or have had nitrate concentration above the MCL, a significant public health issues since more than 80 percent of drinking water in this area comes from groundwater. In some parts of the basin, the groundwater nitrate concentration has increased 100 times from the early 1950’s to the mid-1990’s (Ebbert et al, 1995).

A study by the USGS (Frans, 2000) summarizes the factors most closely associated with the occurrence of nitrate above 10 mg/L. These factors are:
• Amount of fertilizer applied annually within a 3 km radius of the well
• Depth of the well casing
• Soil type

The sources at greatest risk are shallow wells in gravelly or rocky soil near heavily fertilized fields.

Figure 2-5: Nitrate Groundwater Concentration in the Columbia Basin
(Source: Ryker, 1995)

In February 1998, the Washington State Department of Ecology identified the Columbia Basin Groundwater Management Area (GWMA), which includes all of Adams, Franklin, and Grant Counties. In 2001, the Boards of County Commissioners for these three counties adopted the GWMA Plan, which identifies activities to be taken to reduce nitrate contamination of the groundwater. The County Commissioners have joined with more than 100 local volunteers to form and direct the GWMA efforts. To decrease groundwater nitrate concentrations, the GWMA will focus on:
  • Irrigation water management
  • Fertilizer management and application guidelines
  • Public education about drinking water safety and groundwater protection

Monitoring will be conducted to gauge the success of these activities. Contact information for the Columbia Basin GWMA is provided in Appendix C.
Conclusions

Nitrate occurrence information in this chapter can be used to minimize the risk of nitrate contamination of drinking water, as well as take appropriate action when elevated nitrate is detected. Changes in land use activities near a well may decrease nitrate concentrations in groundwater, eliminating the need for treatment in the future. Several local agencies have agricultural technicians available to assist farmers and others reduce nitrate contamination of groundwater supplies. The following chapter provides more information on short and long-term activities to reduce groundwater nitrate levels or otherwise avoid the need to install treatment at the wellhead.

Chapter 2 References


Whatcom Conservation District, “EQIP Contracts – Over $1,000,000 in Environmental Quality Incentive Program Contracts Will Be Awarded to Whatcom County Producers this Year,” *Whatcom Conservation News*, 2004, Vol. 13 (2).
Chapter 3: Non-Treatment Alternatives and Source Protection

When feasible, non-treatment alternatives are typically less burdensome, less costly, and more reliable than treatment. Non-treatment alternatives include wellhead protection activities, land use management, connection to an adjacent system, blending, and developing an alternate source of supply. These non-treatment alternatives, which are described in more detail in this chapter, should be investigated along with treatment alternatives.

Alternate Source

Alternate sources of supply include developing a new well, redeveloping the existing well, and connecting to an adjacent system. Developing a new well will require sufficient information to determine the location and depth needed in order to increase the likelihood of having nitrate below 10 mg/L. In general, the deeper the well, the less likely nitrate will be greater than the MCL. Nitrate is also less likely to occur in confined aquifers than unconfined aquifers.

In some cases, redeveloping the existing well to tap into a low nitrate source of water may be possible. This approach will require similar knowledge to developing a new well to estimate the feasibility of obtaining groundwater from an aquifer low in nitrate. In North Carolina, one well in fractured bedrock was reconstructed after it was determined that shallow rock fractures produced water with high nitrate concentrations (Mitchell and Campbell, 2003). In Washington State, the USGS has developed maps showing the lower risk of nitrate from deeper groundwater. (Frans, 2000, Tesoriero and Voss, 1997)

An intertie with a nearby water system is another way for a water system to obtain drinking water low in nitrate. To implement this approach, the water systems must be close enough to economically construct the intertie. Both DOH and the Department of Ecology regulate interties. These regulations include specific intertie requirements to ensure that the neighboring system has the capacity to provide service to the water system in need.

Case Study: Town of Rosalia

The Town of Rosalia, located in Whitman County south of Spokane, has two wells. One of the wells had a nitrate sample that exceeded 10 mg/L in September 2002. The well was quickly taken off line and inspected. A video of the well revealed the casing extended down only 31 feet and there was a seam of water entering the well approximately 10 feet below the bottom of the casing. This seam of water had a nitrate concentration of 18 mg/L. Based upon this information, the well was reconstructed with a 105 foot deep casing and a cement seal to a depth of 100 feet. Since April 2003, when the well was reconstructed, all nitrate samples have been below the detection limit.
Blending

Some water systems use blending to combine wells with high concentrations of nitrate with wells with low nitrate to meet the MCL. Blending needs to be done before the water enters the distribution system. This option requires an adequate source of low nitrate water. Since nitrate is an acute contaminant, it will be important to make sure the low nitrate source is the primary source of drinking water. Rising or significantly fluctuating source water nitrate concentrations could decrease the reliability of this option. In March 2004, DOH sent a letter to all water systems that blend, outlining the monitoring and reporting requirements for these water systems. A sample of this letter is included in Appendix A.

Maintenance and Monitoring

No maintenance beyond routine well pump maintenance will typically be required for blending. However, there will still need to be daily field monitoring of the blended water along with laboratory samples collected monthly to ensure all consumers are receiving water below the nitrate MCL.

Advantages

- Easier to implement than treatment if low nitrate water is readily available
- Additional certification as a treatment plant operator is not required
- No waste disposal issues

Disadvantages

- Capital costs can be significant to connect to a low nitrate source
- Fluctuating nitrate concentrations in either source may require adjustments to blending operations
- Periodic monitoring of the blended water is required

Case Study: City of Grandview

In Washington State there are several water systems blending water from high nitrate wells with low nitrate wells to produce water that is less than 10 mg/L. The City of Grandview, a municipality of more than 8,000 people in Yakima County, is one such water system. Two of the wells serving the city, Well #13 and Well #14, are located on the outskirts of the city and within a couple hundred feet of each other (Table 3-1). Well #14 has water much lower in nitrate than Well #13, which is not surprising given the difference in well construction. The blended water has consistently been below the MCL for nitrate (Figure 3-1). The City of Grandview also has an active source water protection program to protect their groundwater quality, which should help ensure the future viability of their blending approach.
Table 3-1: City of Grandview Wells

<table>
<thead>
<tr>
<th>Source Number</th>
<th>Well #13</th>
<th>Well #14</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source Number</td>
<td>10</td>
<td>13</td>
</tr>
<tr>
<td>Surface Seal Depth</td>
<td>35 ft</td>
<td>683 ft</td>
</tr>
<tr>
<td>Depth to First Open Interval</td>
<td>222 ft</td>
<td>683 ft</td>
</tr>
<tr>
<td>Total Depth</td>
<td>620 ft</td>
<td>954 ft</td>
</tr>
<tr>
<td>Capacity</td>
<td>450 gpm</td>
<td>1800 gpm</td>
</tr>
<tr>
<td>Nitrate (mg/L) *</td>
<td>5.5-12.0</td>
<td>ND-1.3</td>
</tr>
</tbody>
</table>

Note: *For the period July 2000-October 2004

Source Protection

It some cases, it may be possible to eliminate or otherwise control the source of nitrate contamination, thereby decreasing the concentration of nitrate in the groundwater. Depending upon the aquifer, it may take several months to years for any changes in land use activity to have an appreciable affect on groundwater nitrate concentrations. Source protection activities are important towards protecting the source from contamination regardless of whether or not they can reduce the concentration of nitrate to less than the MCL. The USGS has also found high concentrations of nitrate are frequently associated with the detection of pesticides in groundwater (Ryker, 1995).

Source protection includes land management activities to decrease nitrate concentrations over the long-term. Agricultural fertilizers, septic systems, and dairy facilities are all potential sources of significant nitrate contamination. The wellhead protection area should be delineated as part of this process to best identify potential sources of nitrate contamination.
Removal of the source(s) of nitrate contamination will typically result in decreased nitrate contamination over a period ranging from months to several years.

High nitrate levels are common in agricultural regions where the use of inorganic nitrogen based fertilizers is widespread. There are several programs developed by the United States Department of Agriculture (USDA) that can be used to protect drinking water sources. These programs include the Conservation Reserve Program, Environmental Quality Initiative Program, and Conservation Security Program, which are described in more detail in Appendix B.

Non-agricultural sources of nitrate contamination include septic systems and lawn fertilizers. These sources of nitrate may cause a localized increase in nitrate. Appropriate actions include relocating the source of contamination and changes in landscaping practices. Regardless of the source of contamination, it is important to support activities leading to a decrease in nitrate contamination of groundwater. If source protection activities are not taken, nitrate contamination may increase eliminating some compliance options such as blending and making treatment more expensive.

Case Study: City of Olympia

The City of Olympia, located in southwestern Washington, provides water service to approximately 52,000 people. The main source of supply for the city is McAllister Springs, located on the outskirts of the city southeast of downtown. In 1988, the Thurston County Board of Health adopted a resolution (H-5-88) which established the McAllister Springs Geologically Sensitive Area (GSA). This action was taken in response to concerns the rapid growth and development occurring within the watershed would affect the water quality of McAllister Springs and the associated aquifer system. The GSA established new standards for the design, review and approval of onsite sewage systems, and placed a moratorium on the further subdivision of land.

In August 1990, the Thurston County Board of Health adopted a follow-up resolution (H-3-90) similar to the 1988 version, but with more permanent watershed protection requirements. In addition, Olympia provided educational information to property owners in the watershed for ways they could minimize nitrate leaching into the groundwater. Nitrate concentrations in McAllister Springs began to decrease by the late 1990’s as a result of these and other source protection activities (Figure 3-2).
Conclusions

When feasible, non-treatment alternatives are typically less burdensome, less costly, and more reliable than treatment. However, they may not be applicable in all cases. Some, such as changes in land use and better fertilizer management practices, may be beyond the direct control on the water purveyor. When not the sole solution, non-treatment activities are still recommended as they may decrease or eliminate the need for treatment in the long-term.

Chapter 3 References


Chapter 4:
Source Treatment Alternatives

Nitrate is a stable and highly soluble ion with a low potential for precipitation or adsorption. These properties make it difficult to remove from water using treatment processes such as filtration or activated carbon adsorption. As a result, more complex treatment processes must be considered. Many of these treatment processes have been evaluated for their applicability (Clifford and Liu, 1995; Kapoor and Viraraghavan, 1997; U.S. Bureau of Reclamation, 2001).

Both conventional and experimental treatment processes are reviewed in this chapter. Conventional processes such as ion exchange, reverse osmosis, and electrodialysis have been widely used for drinking water treatment. These processes physically or chemically remove nitrate from drinking water. The experimental treatment techniques reviewed rely upon biological processes to convert nitrate to nitrogen gas, which is then released to the atmosphere. While experimental, these biological processes offer some advantages over conventional treatment techniques, especially in terms of waste disposal.

Ion Exchange

In the ion exchange process, nitrate ions bind to an ion exchange resin and, in the process, displace chloride ions (Figure 4-1). The resin is contained within a pressure vessel (Figure 4-2) and is periodically regenerated with a concentrated salt solution. Water softeners function similarly, removing calcium and magnesium from water in exchange for sodium.

The frequency of regeneration will depend upon the raw water quality. Ions, such as sulfate, can compete with nitrate for binding sites on the ion exchange resin. The performance of the ion exchange process will also be sensitive to the type of resin used to treat the water. Any resin used to treat water must be approved under the American National Standards Institute/National Sanitation Foundation (ANSI/NSF) standards for contact with potable water. Since the frequency of regeneration will vary depending upon the raw water quality and type of resin used, pilot testing will most likely be required with one or more resins prior to design of a full scale system. If an ion exchange column is not regenerated frequently enough, the concentration of nitrate could spike to levels well above 10 mg/L, which is a public health concern.

![Figure 4-1: Ion Exchange Process Schematic](image-url)
Water Quality Issues
The effectiveness of the ion exchange process will depend upon the raw water quality. In some cases, such as with water containing high concentrations of iron and manganese, turbidity, or other contaminants, pretreatment may be required to avoid fouling the column and a decrease in treatment performance. If the combination of iron, manganese, and other metals exceeds 0.1 mg/L, pretreatment will likely be required (Health Education Services, 1997). Other ions such as sulfate and chloride will compete with nitrate for binding sites on the resin. In addition, the ion exchange resin will initially remove some bicarbonate or carbonate ions following regeneration. As a result, the pH of the finished water will fluctuate unless controlled. The magnitude of this pH fluctuation will depend upon the raw water quality and the resin selected.

Maintenance and Monitoring
The ion exchange column regeneration frequency will vary depending upon the raw water quality and resin used. Regeneration requires the preparation and disposal of significant quantities of salt brine. Degradation in resin performance over time may require replacement of the resin every few years.

The treated water should be monitored for nitrate using continuous monitoring and recording equipment equipped with a high level alarm. If continuous monitoring and recording equipment is not provided, the finished water nitrate levels should be determined no less than daily, and just prior to regeneration of the column (Health Education Services, 1997). A field test kit can be used.

Waste Disposal
The ion exchange process generates a salt brine waste following column regeneration. In most cases, the Washington State Department of Ecology will require a State Wastewater Discharge Permit for public water systems employing ion exchange for nitrate removal.
Some research has been done into biological treatment of the brine to remove nitrate so that it can be reused. Biological treatment of brine is not currently documented for drinking water applications. More information on waste disposal is provided on page 35.

**Advantages**

- Ease of operation; relatively reliable
- Lower initial cost
- Effective; More widely used than other forms of treatment
- Suitable for small and large installations

**Disadvantages**

- Requires frequent monitoring for nitrate removal
- Requires storing large volumes of salt
- Resins are susceptible to organic fouling
- Potential for “dumping” of the nitrate from the column resulting in periodic high concentrations of nitrate in the finished water
- Changes in finished water pH
- Salt brine disposal can be difficult

**Reverse Osmosis**

Reverse osmosis (RO) is a physical process in which contaminants are removed by applying pressure to direct raw water through a semi-permeable membrane allowing water to pass through while retaining most of the dissolved minerals (Figure 4-3). In low pressure (<100 psi) applications, only 10 to 25% of the raw water is produced as finished water. High pressure systems can achieve water efficiencies of greater than 85%, but require specialized pumps and significant energy to achieve this level of efficiency. Reverse osmosis is one of the most expensive forms of centralized treatment and will likely not be cost effective unless there are multiple contaminants needing removal.

![Figure 4-3: Reverse Osmosis System Schematic](image-url)
Water Quality
Reverse osmosis requires a careful review of raw water characteristics and pretreatment needs to prevent membranes from fouling, scaling, or degrading. Removal of suspended solids is necessary to prevent membrane fouling, while the removal of dissolved solids is necessary to prevent scaling and chemical degradation of the membrane. Pretreatment is usually achieved by passing the water through a series of progressively finer filters prior to the reverse osmosis membrane. Water passing through a reverse osmosis system will usually require pH and other water quality adjustments to make the finished water less corrosive to distribution system piping. A reverse osmosis membrane is depicted in Figure 4-4.

![Reverse Osmosis Membrane Skid](image)

Figure 4-4: Reverse Osmosis Membrane Skid

Maintenance and Monitoring
The frequency of membrane and prefilter replacement is dependent upon the raw water characteristics, pretreatment provided, and membrane maintenance. Chemical cleaning of the membranes with acid or caustic solutions should be performed periodically to remove deposits and scales. After a sequential cleaning of the membranes, they are typically flushed with finished water and returned to service.

Periodic monitoring of the finished water nitrate is required to ensure the treatment is working properly. The production rate and differential pressure should be monitored across both the membrane and prefilters to track membrane performance, fouling, and the need for cleaning or membrane replacement.

Waste Disposal
Pretreatment waste streams, membrane concentrate flows, and spent filter and membrane elements all require approved disposal.

Advantages
- Produces high quality water
- Low pressure (<100 psi), compact units are available for small installations
Disadvantages

- Expensive to install and maintain
- Disposal of concentrate and pretreatment waste streams may be difficult
- Membranes are prone to fouling
- Pretreatment can make the process complex
- Frequent membrane monitoring and maintenance is required
- Low water efficiency (10-25%) for low pressure applications

Electrodialysis

In the electrodialysis (ED) process, ions migrate through ion-selective semipermeable membranes as a result of electrically charged membrane surfaces (Figure 4-5). A positive electrode (cathode) and a negative electrode (anode) are used to charge the membrane surfaces and attract oppositely charged ions. As a result of this process, ions such as nitrate are removed from the raw water. In electrodialysis reversal (EDR), the charge on the membranes is periodically reversed to minimize scale development. The American Water Works Association has written a manual on both ED and EDR (AWWA, 1995). An electrodialysis reversal package plant is depicted in Figure 4-6.

![Figure 4-5: EDR Process Schematic](image)

![Figure 4-6: Electrodialysis Reversal Package Plant](image)
**Water Quality**

EDR normally requires less pretreatment than other membrane processes. The only pretreatment normally used with groundwater systems is prefiltration with a 10-μm cartridge filter to remove solids. Pretreatment to remove iron and manganese should be provided if iron is greater than 0.3 mg/L or manganese is more than 0.1 mg/L. Hydrogen sulfide can be tolerated up to 0.3 mg/L and turbidity up to 2 NTU. For most groundwaters, turbidity is due to the presence of iron and manganese, so removing these minerals will remove the turbidity.

Precipitation of solids on the membrane surfaces can be an operational concern. As water passes through the equipment, minerals are removed and concentrated in the brine stream, which can lead to the build-up of scales on process equipment. The potential for scale formation increases with water high in total dissolved solids and when the process is operated at high water recovery rates. ED process membranes can be cleaned in place using a dilute acid solution to restore system performance.

**Maintenance**

The process tends to be highly automated, but daily monitoring of differential pressure and other operational parameters should be performed. Chemical cleaning of the accumulated solids from the stack should be performed on at least a weekly basis. Byproducts from the process include small quantities of hydrogen gas formed at the cathode and oxygen and chlorine gas from the anode spacer. These gases should be vented above the building to avoid potential safety concerns associated with the build-up of these gases.

**Advantages**

- Can operate without fouling, scaling, or chemical addition
- Low pressure requirements
- Typically quieter than RO
- Long membrane life expectancy

**Disadvantages**

- Pretreatment required for high levels of Fe, Mn, H₂S, chlorine, or hardness
- Concentrate may require special disposal

**Biological Treatment (Engineered)**

Biological denitrification is a process through which bacteria convert nitrate to nitrogen gas under anoxic (oxygen free) conditions. The nitrogen gas and bacteria are then removed from the water before entering the distribution system (Figure 4-7). Ethanol, methanol, acetate and other chemicals are used to facilitate the biological denitrification process. Although this process has been used in Europe for nitrate removal from drinking water, it is not currently used on any water system in the United States.
Figure 4-7: Engineered Biological Denitrification Schematic

Water Quality
Since denitrification takes place under anoxic conditions, it is important to ensure there is no oxygen in the reactor. As little as 0.1 mg/L of oxygen has an inhibitory effect of the denitrification process (Rittman and Huck, 1989). The optimal process pH is between 7 and 8, and the alkalinity produced by the denitrification process will cause a slight increase in pH (Metcalf and Eddy, 1991). Temperature also has a strong effect on the treatment process with an approximate doubling of the denitrification rate with a 10°C (18°F) increase in temperature. Temperatures less than 5°C (41°F) make the process impractical.

Maintenance and Monitoring
Biological denitrification requires daily, or more frequent, monitoring to ensure the process operates reliably. In addition to monitoring for nitrate, the pH, temperature, oxidation reduction potential, and concentration of organic carbon in the finished water should be checked daily.

Advantages
- No concentrated salt brine or nitrate for disposal

Disadvantages
- No systems currently operating in the United States
- Extensive piloting required. (A minimum of 1 year of continuous operation.)
- Several weeks required from start-up to stable operation for new systems
- Post treatment filtration and disinfection required
- Process is temperature sensitive
- Taste and odor problems may require additional treatment

Subsurface Biological Treatment
Subsurface biological denitrification is a natural process in which nitrate is converted to nitrogen gas. Inert nitrogen gas is then gradually released from the soil to the air, which is itself mostly nitrogen gas. Denitrification occurs at a reasonable rate when the proper conditions are present. These conditions include temperatures above 5°C (41°F), a source of organic carbon, a pH of 7.0 or slightly higher, and a lack of dissolved oxygen.
Subsurface biological denitrification for groundwater water treatment has been evaluated in the United States, Europe, and other parts of the world (Hiscock et al, 1991; Trudell, 1986; Well et al., 2001; Legault et al, 2002). Previous studies have evaluated both naturally occurring denitrification as well as enhancing natural processes through the injection of carbon sources and other materials into the soil.

One type of subsurface biological treatment is the use of permeable reactive barriers to treat groundwater contaminants (U.S. EPA 1998; U.S. EPA 2002, Interstate Technology Regulatory Cooperation, 1999). A permeable reactive barrier is an underground wall of reactive material through which groundwater flows. For nitrate treatment, the reactive material is usually woodchips, straw, or sawdust, mixed with sand or gravel. The woodchips or other organic carbon source serves as a food source for the soil bacteria converting nitrate to nitrogen gas. The sand and gravel provide permeability. The permeability of the permeable reactive barrier should be similar to or greater than the surrounding soil; otherwise groundwater may flow around the barrier rather than through it.

Permeable reactive barriers have been used to effectively convert nitrate to nitrogen gas (Boussiad et al, 1988; Robertson and Cherry, 1995; Robertson et al, 2000; Pons 2002). These studies document nitrate reduction of 60-100 percent. The Department of Defense used permeable reactive barriers to treat groundwater contaminated with perchlorate, a chemical that degrades in a manner similar to nitrate, at 25 percent of the cost of more conventional treatment (Department of Defense, 2002).

![Permeable Reactive Barrier](image)

**Figure 4-8: Permeable Reactive Barrier**

There are several parameters that can affect the denitrification process including dissolved oxygen, organic carbon, and pH.

**Water Quality**

**Dissolved Oxygen:** If oxygen is present, the bacteria that are responsible for denitrification will use it instead of nitrate. In groundwater, denitrification can be promoted by adding carbonaceous materials to the soil, which will create a low oxygen environment to support the growth of denitrifying bacteria.
**Temperature:** Denitrification can occur between 5 to 30°C (41°F to 86°F), with the rate approximately doubling for every 10°C increase in temperature. Groundwater temperatures are fairly constant and show no measurable seasonal changes at depths greater than 30 feet underground. The groundwater temperature averages around the mean annual air temperature. For areas east of the Cascade Mountains, this results in an average temperature of around 10°C (50°F), with slightly higher average temperatures for the Puget Sound region.

**Organic Carbon:** Most denitrifying bacteria are heterotrophic. This means they need a source of organic carbon. Sources of organic carbon used in the past include methanol, ethanol, acetate, sucrose, molasses, straw, and wood chips. Overall, about 3 to 5 mg of organic carbon/mg N\(^1\) is consumed in the process (Carerra, 2003). Methanol, ethanol, and acetate are used in wastewater denitrification processes, and are typically more expensive than other carbon sources. One way of reviewing the applicability of agricultural products for denitrification is their ratio of carbon to nitrogen (C:N ratio) (Table 4-1). At C:N ratios of less than 20:1, the materials may leach nitrogen in the soil, while high carbon materials will pull nitrogen from the soil or groundwater and degrade more slowly.

<table>
<thead>
<tr>
<th>Material</th>
<th>C:N Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chicken Manure</td>
<td>11:1</td>
</tr>
<tr>
<td>Cow Manure</td>
<td>14:1</td>
</tr>
<tr>
<td><em>Nitrogen Leaching Threshold</em></td>
<td>20:1</td>
</tr>
<tr>
<td>Leaves</td>
<td>40-80:1</td>
</tr>
<tr>
<td>Corn Stalks</td>
<td>50-100:1</td>
</tr>
<tr>
<td>Straw</td>
<td>50-150:1</td>
</tr>
<tr>
<td>Paper</td>
<td>150-200:1</td>
</tr>
<tr>
<td>Wood Chips and Sawdust</td>
<td>100-750:1</td>
</tr>
</tbody>
</table>

Sources:
- On-Farm Composting Handbook (NRAES, 1992)
- A Manure Resource Guide (Miles et al, 1999)
- Conservation Tillage Fact Sheet (Rosales et al, 2004)

**Groundwater pH:** The optimum pH value for denitrification is between 7.0 and 8.5. Most groundwater is in this pH range. No significant change in groundwater pH was observed upstream and downstream of permeable reactive barriers used for nitrate treatment (Robertson and Cherry, 1995).

**Maintenance**
Minimal maintenance is expected with permeable reactive barriers. The only expected maintenance is periodic replacement of the carbon source, which will depend on the solid carbon source used and subsurface conditions. Long-term studies of permeable reactive

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\(^1\) The ratio of organic carbon to nitrogen was simplified from using the terms of mg of chemical oxygen demand (COD) per mg of N produced.
barriers made of sawdust and sand demonstrated barriers last for several years and are expected to last for decades with little or no maintenance (Robertson et al, 2000). One potential secondary impact of permeable reactive barriers is the release of total organic carbon (TOC) and mobilization of iron into the groundwater. TOC may be consumed by soil bacteria or otherwise immobilized downstream of the barrier (Robertson and Cherry, 1995). Immobilization of iron was also observed. As a result, the permeable reactive barrier must be separated from the well to minimize the potential for elevated levels of TOC and iron in the well water.

**Advantages**

- Simplicity
- No waste disposal issues
- Very little operator attention required
- Little monitoring required
- Capital costs should be lower than other forms of treatment
- Operation and maintenance costs should be much lower than other types of treatment

**Disadvantages**

- Experimental. No current experience in drinking water applications
- Only suitable for shallow aquifers where it is possible to add an organic carbon source
- Could increase total organic carbon (TOC) and iron in the groundwater

While subsurface biological denitrification has been used for nitrate removal, it has yet to be proven for drinking water applications. Costs for this approach are also uncertain at this time and could be significant if a high carbon material such as wood chips, straw, or cornstalks are not locally available.

**Phytoremediation**

Despite the complex name, phytoremediation is simply the use of plants to remove contaminants from the soil or groundwater. One example is the use of poplar tress to remove nitrate from groundwater (Pivetz, 2001; Licht and Schoor, 1993). These trees lowered the concentration of nitrate from 150 mg/L at the edge of a cornfield to 8 mg/L down gradient of a poplar buffer strip (Licht, 1990). Poplar trees are also grown commercially for wood and wood fiber, so they may serve both as a nitrate barrier and a revenue source.

Poplars grow best in moist soils with low salinity and near neutral pH. Soil, landscape, and climate conditions for growing poplars are summarized here.

- **Precipitation** – Supplemental irrigation will be required where precipitation is less than 16 inches per year. Availability of groundwater within 4 to 16 feet can reduce the reliance on precipitation.
- **Soil** – Poplars grow best in silt or clay loams with a moderate to high water holding capacity.
• **Rooting Conditions** – Poplar roots can extend to more than 20 feet. Therefore, it is important poplar roots be able to extend at least 4 feet without encountering bedrock or other material that may impede their rooting.

• **Salinity** – Poplars do not tolerate saline soils. Conductivity greater than 2.0 microSiemens per cm (mS/cm) will likely limit growth. If the salinity is greater than 4.0 mS/cm, dieback may be severe (Prairie Farm Rehabilitation Administration, 2003).

While poplars are used to remove nitrate from groundwater, there is no information indicating they have been specifically used for drinking water applications. Phytoremediation is not a quick fix. Although poplar tree can grow more than 10 feet per year, it may take a couple years before the roots penetrate deep enough into groundwater for significant nitrate reduction to occur. Although there are deep rooting techniques for poplar trees, phytoremediation is limited to the depth to which plant roots can extend. For these reasons, phytoremediation may work best as part of a long-term strategy to control nitrate in groundwater rather than a total solution.

### Pilot Testing of Source Treatment Alternatives

The best overall alternative must be pilot tested in accordance with WAC 246-290-250(3). Pilot testing consists of setting up and operating a small-scale system to determine its performance using the actual field conditions and raw water that will be treated at full-scale.

In some cases, where the cost of pilot testing would approach the cost of installing the full-scale equipment, the pilot-testing phase could be included in the start-up process for the technology. The water from the full-scale pilot cannot be used for potable water supply.

Due to the complexity and importance of treatment, pilot testing must involve an engineer. Properly conducted pilot testing can provide valuable information to avoid significant mistakes in the final design. For a pilot study to be useful, the pilot study should be conducted for long enough to obtain meaningful data. The length of time required will vary depending upon the process selected and the raw water quality.

DOH must review and approve the pilot study protocol prepared by a licensed engineer. Upon completion of the pilot study fieldwork, a report summarizing the data and results must be submitted for approval.

### Waste Residuals Disposal

Consideration of waste disposal is part of the treatment selection process. The Department of Ecology publication “Fact Sheet for NPDES General Permit: Wastewater Treatment Plants - Wastewater Discharge” explains how permit conditions were developed, presents the legal basis for permit conditions, and provides background information on water treatment facilities. This permit and associated fact sheet are available on the Ecology website at [http://www.ecy.wa.gov/programs/wq/wtp/index.html](http://www.ecy.wa.gov/programs/wq/wtp/index.html). Contact Ecology for additional information or if discharge permit requirements are unclear.
One of the primary concerns with ion exchange, reverse osmosis, and electrodialysis treatment processes is the disposal of the liquid waste streams. These liquid waste streams contain high concentrations of salts, especially ion exchange where salt brine is used to regenerate the ion exchange resin. The disposal options for liquid wastes include sewer discharge, land application, and surface water discharge. Practical disposal options for ion exchange brines are limited. In most cases, both land and surface water disposal of brines will require a permit from Ecology. Sewer disposal is possible, but only if the waste is accepted by the local sewer agency. It may be possible to have a holding tank for brine and periodically truck it to a disposal facility. Waste disposal options will need to be considered with whatever treatment process is selected.

Conclusions

There are a number of treatment processes to consider. These range from conventional processes widely used for drinking water treatment to more experimental technologies relying on biological processes to remove nitrate from groundwater. It is possible that the best approach may combine land use management practices with some treatment process. Land use management practices can decrease the concentration of nitrate in groundwater over the long-term. Some treatment process will be necessary until the nitrate in the groundwater is reliably and consistently below 10 mg/L.

Chapter 4 References


Legault, T., B. Stewart, and J. Lebedin, “In-Situ Remediation of Nitrate in Groundwater - Phase 1: Site Characterization,” Agriculture and Agri-Food Canada, Prairie Farm Rehabilitation Administration, Regina, SK, 2002.


Prairie Farm Rehabilitation Administration, “Consideration for Hybrid Poplar Production,” Prairie Farm Rehabilitation Administration, Saskatchewan, Canada, 2003.


Appendix A:
Department of Health Nitrate Materials

Public Notification Materials (English and Spanish)
Fact Sheet (English and Spanish)
Sample News Release
Sample Letter to Water Systems that Blend

The complete Nitrate Public Health Advisory Packet
is available on our Web site at:
http://www.doh.wa.gov/ehp/dw/Nitrate/nitrate.htm
Sample Letter to Water Systems that Blend

March 25, 2004

Mr. Robert J. Smith
Water System Superintendent
Anytown Water System
123 Main Street
Anytown, WA  98902

Dear Mr. Smith:

The Department of Health (DOH) is committed to helping systems that have nitrate contamination in their source water to comply with State and Federal regulations and protect their customers. A legitimate and cost effective way to treat nitrate contamination is the blending of sources.

You are receiving this letter because your water system has previously been approved to apply a source-blending strategy to treat for exceedence of the nitrate standard in drinking water (10.0 parts per million or milligrams per litter). Blending drinking water to treat for nitrate requires a means of bringing together flow from two or more wells to a common point, prior to water service reaching any customer. If these criteria no longer apply to your water system, please notify DOH immediately.

Due to varying water demand and the possibility of variable nitrate concentration in each of the contributing wells, nitrate levels in the blended water can fluctuate and possibly exceed drinking water standards. Routine analysis of the blended water is the only way to ensure that drinking water standards are being met on a continuous basis.

The Office of Drinking Water has developed a monitoring schedule that must be followed when blending sources for the treatment of nitrates, per WAC 246-290-300 (1) and WAC 246-290-455. This monitoring schedule includes:

- **Collect one blended nitrate sample daily, at least five days per week, taken at a place representative of water being served to the public. Record the results using a hand held test kit.** This requirement is essential since nitrate levels can and do change over time, relative to flow and nitrate concentration. Handheld nitrate test kits can be purchased by vendors such as; HACH (1-800-227-4224 or http://www.hach.com) and Lamotte (1-800-344-3100 or http://www.lamotte.com).

- **Collect one blended nitrate sample each month, to be analyzed by a lab certified for nitrate analysis.** These samples will confirm the accuracy of your daily readings. Please mark these samples as source number “96.” Also, please indicate which sources are being blended in the appropriate box on the sample form.
• Collect one raw nitrate sample annually from the sources being used for blending. These samples will provide a baseline from which to plan blending. Please be sure to indicate the appropriate source number on these samples.

Please use the attached “Daily Nitrate Report” form or the “Daily Nitrate/Chlorine Report” form (if you also treat your water with chlorine) to document your compliance with the previously mentioned monitoring requirements. A copy of this report must be submitted to this office by the 10th of each month. For example, your October report will be due on the 10th of November.

Nitrate is classified as an acute contaminant because it can interfere with the ability of red blood cells to carry oxygen in the bodies of infants. This can result in a potentially fatal disease known as methemoglobinemia or “blue-baby syndrome.” Other adverse health effects are also possible and are explained in the attachment entitled “Nitrate in Drinking Water.” Since even short-term exposure can have adverse human health effects, the Office of Drinking Water has made nitrate compliance a very high priority.

Failure to comply with these requirements could result in the discontinuation of this option for treatment of nitrate at your system.

Thank you for your cooperation on this issue. If you have any questions or concerns regarding these requirements, please feel free to contact me at your convenience.

Sincerely,

Mark Jones
Environmental Specialist

Enclosures: Daily Nitrate Report

cc: Dan Smith, Regional Engineer
    Anita Jones, Source Water Quality Program Manager
    Local County Health Department
Appendix B:  
USDA Watershed Protection Programs
The following programs can be used to decrease nitrate contamination of groundwater and implement other source water quality protection activities.

- Conservation Reserve Program (CRP)
- Conservation Reserve Enhancement Program (CREP)
- Environmental Quality Incentive Program (EQIP)
- Conservation Security Program (CSP)
- Conservation Technical Assistance (CTA)

A few of these programs are summarized here. More information on these programs can be obtained by contacting the Farm Services Agency or Natural Resource Conservation Service in Spokane, or from local conservation district offices. Contact information for these agencies and the Washington State Conservation Commission is provided in Appendix D. Contact information for local conservation districts can be obtained through the Washington State Conservation Commission website.

**Conservation Reserve Program**
The Conservation Reserve Program (CRP) is a voluntary program that retires environmentally sensitive cropland under protective vegetative cover for a 10- to 15-year contract period in exchange for an annual per acre rental payment. Producers can offer land for enrollment under a competitive process during periodic signups or automatically enroll more limited acreages in conservation buffer practices. Land within 2,000 feet of a public water system well can be enrolled in a continuous CRP sign-up. The boundaries of these circular shaped areas can be adjusted to simplify farming practices.

**Environmental Quality Incentive Program**
The Environmental Quality Incentive Program (EQIP) is a voluntary conservation program that promotes agricultural production and environmental quality as compatible goals. Through EQIP, farmers and ranchers receive financial and technical help to install or implement structural and management conservation practices on eligible agricultural land. Reduction of groundwater contamination is one of the national priorities of the program. Incentive payments encourage producers to implement nutrient management and manure management activities designed to decrease groundwater nitrate concentrations. The EQIP cost share rate may be up to 90 percent of the conservation practices for new farmers and those with limited resources, and 75 percent for most others that employ accepted groundwater protection practices.

**Conservation Technical Assistance**
Conservation Technical Assistance (CTA) is a program that provides assistance to land-users, communities, and others to plan and implement conservation systems. The purpose of the conservation systems includes efforts to, improve soil and water quality, enhance fish and wildlife habitat, improve air quality, improve pasture and range condition, reduce upstream flooding and improve woodlands.
Appendix C:  
Other Useful Contacts and Resources

**Interagency and Local Government**
Abbotsford-Sumas Aquifer International Task Force  
Columbia Basin Groundwater Management Agency  
Conservation Districts (Local)  
Whatcom County Health Department

**Washington State**
Conservation Commission  
Department of Agriculture  
Department of Ecology  
Department of Health

**Federal**
United State Department of Agriculture  
United States Environmental Protection Agency  
United States Geological Service

**Interagency and Local Government Organizations**
**Abbotsford-Sumas Aquifer International Task Force**
British Columbia  
Marc Zubel  
Fraser Health Authority  
2776 Bourquin Crescent W, Suite 207  
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**Columbia Basin Groundwater Management Agency**
Project Office  
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Othello, WA 99344  
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E-mail: cbgwna@televar.com  
Website: [http://www.gwma.org/](http://www.gwma.org/)

**Conservation Districts**
Contact information for local conservation districts are listed on the Washington State Conservation Commission website at: [http://www.scc.wa.gov/districts/](http://www.scc.wa.gov/districts/)
Department of Health
Denise Garrett-Berry, Nitrate Program Coordinator
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Federal
United State Department of Agriculture
Washington State Farm Service Agency
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Spokane, WA 99201-2350
Phone:  (509) 323-3000
Fax:  (509) 323-3074
Website:  http://www.fsa.usda.gov/wa/conservation.htm
The website includes local county contacts.
Roylene Rides at the Door, State Conservationist
USDA - Natural Resources Conservation Service
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**Agricultural Research Service**
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**United States Environmental Protection Agency**
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