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Excessive nitrates in drinking water pose a human health threat, especially to infants. Methemoglobinemia, or blue-baby syndrome, is a potentially fatal condition that inhibits the ability of red blood cells to bind and transport oxygen. Nitrates/nitrites have also been linked to such conditions as cancer, birth defects, and behavioral and developmental abnormalities.

Nitrates are frequently found in wells in rural farming areas because synthetic fertilizers (containing nitrates) leach from the soil into the groundwater. The Lower Umatilla Basin (LUB) in Morrow and Umatilla counties of Oregon represents an intensively farmed and irrigated area in which relatively high amounts of nitrates are present in the groundwater and domestic well water.

This study investigated population demographics for the rural Lower Umatilla Basin, comparing these data to

identified well-water nitrate levels for the purpose of estimating nitrate exposures and potential risk of adverse health effects in the survey area. Results of the investigation revealed that 25 percent of the domestic-use wells in the survey area had nitrate levels that were in excess of the 10 ppm nN MCL for drinking water, as established by the U.S. Environmental Protection Agency. From access to these wells, 23 percent of the surveyed population was exposed to nitrate concentrations in excess of the MCL standard. However, resident infants were neither exposed to well-water nitrates in excess of the standard, nor were they exposed to illness that could have increased the risk of methemoglobinemia.

The LUB survey population was generally older than the populations from cities in the LUB or the combined populations of rural areas of Morrow and Umatilla counties. The population included few women of childbearing age, and it was not subject to an appreciable increase in the proportion of younger to older families. These factors reduced the likelihood of a significant increase in the infant population, which also minimized the risk of methemoglobinemia to this population. Even though the risk of methemoglobinemia to infants was low in the LUB area, it is recommended that exposures to well-water nitrates be prevented, if possible even for adults, to reduce the potential for chronic, adverse health effects from excess nitrate ingestion.

Continued monitoring of private wells by state agencies is recommended, with attention directed at domestic-use wells with nitrate levels in excess of 10 ppm nN. This information should be shared with local health departments for follow-up, investigation, and educational efforts as needed. Future studies by the Oregon DEQ, or other agencies which seek to document the sources of well-water nitrate contamination in the LUB, should include an investigation of the influence of local sources of nitrate contamination.

An Evaluation of Well-Water Nitrate Exposure and Related Health Risks in the Lower Umatilla Basin of Oregon

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CHAPTER 1

INTRODUCTION

It is estimated that 18 percent of the U.S. population obtains water for domestic use from private systems, 98 percent of which are wells (Solley, Merk, & Pierce, 1988). Similar patterns appear for Oregon residents. In 1985, 18 percent of Oregon residents derived their drinking water from their own private systems, and groundwater accounted for 88 percent of that supply (U.S. Geological Survey [USGS], 1990). As the population continues to increase and expand into rural areas, it is anticipated that more people will use private well water.

Because private water systems are not routinely monitored by any governmental agency, little is known about the quality of private water supplies in Oregon. Individual well owners may have their well water sampled only after the well is initially installed, or only after concern arises about a possible water-borne health problem. Because groundwater contamination problems are becoming more pervasive and serious, and because the use of groundwater is expected to expand in proportion to the rate of Oregon population growth, there is concern that growing numbers of Oregon residents will be exposed to nitrates in their drinking water (Oregon Department of Environmental Quality [Oregon DEQ], 1990).

Due to the extensive use of synthetic fertilizers on crops, wells in rural farming areas are especially prone to nitrate contamination. This problem may be exacerbated when excess moisture, either as rain or irrigation water, infiltrates the soil. The Oregon DEQ ranks agricultural activities as its principal concerns among the major sources of groundwater contamination, and nitrate contamination as the issue of greatest concern with regard to groundwater resources (Oregon DEQ, 1990).

The groundwater in the Lower Umatilla Basin (LUB) area of Umatilla and Morrow counties of northeastern Oregon is contaminated with nitrates. Documentation of the degree of nitrate pollution has been established by the results of intermittent sampling of LUB wells from the mid-to-late 1980s, and has been confirmed by more recent sampling (Oregon DEQ, 1991). Several factors are responsible for current levels of contamination. First, the area has a history of intensive farming practices which employ synthetic fertilizers and field irrigation methods; second, a food processing industry operates within the same region; and third, other potential sources of nitrogen pollution, such as septic systems, are in common use. Both the food processing and agricultural industries are primary sources for the application of nitrogen-containing compounds to the land.

The LUB is primarily a rural region with a high concentration of private domestic water wells, none of which are routinely and regularly monitored for water quality. (Of 21 Oregon counties empowered to monitor private well-water quality in their jurisdictions, only five counties currently observe this practice.) As a result of Oregon groundwater legislation, properties which are sold or exchanged must be tested for nitrates and total coliform bacteria. The results are reported to the Oregon Health Division (Oregon, Legislative Assembly, 1991).

Even though high nitrate levels have been documented, no studies have been conducted that evaluate the extent of population exposure to these well-water nitrates. Excessive nitrates in drinking water pose a threat to human health, especially to infant health. Methemoglobinemia, or "blue-baby" syndrome, is the most documented of these adverse health effects. In relation to rural well contamination, this condition was first investigated in the U.S. by Comly in 1945. Following this investigation, numerous other cases of methemoglobinemia related to rural well-water contamination in the U.S. have been regularly documented (Walton, 1951), the most current of which was a study conducted in 1986 (Johnson & Kross, 1987). In addition to methemoglobinemia, nitrates, or compounds derived from nitrates, have been linked to cancer and mutagenic effects (National Research Council [NRC], 1981), birth defects (Dorsch, Scragg, McMichael, Baghurst, & Dyer, 1984), and behavioral and developmental abnormalities (Gottlieb, 1988).

Insofar as the majority of private wells sampled in the LUB have been found to reflect varying nitrate concentrations, the populations which rely upon private wells for domestic use in this area are potentially at risk from the adverse health effects of nitrate exposure. Therefore, the purpose of the present study was to document demographic factors of domestic well users in the LUB, and to evaluate and discuss potential health risks to this population from exposure to well-water nitrates. A background review of the degree to which nitrates/nitrites constitute potential health hazards, their origin in the environment, the sources of human exposure, and an evaluation of the health risks from exposure to these chemicals were also considered.

Research Questions

The principal research questions posed were as follows:

1) What segments of the LUB population are exposed to well-water nitrates, and what are the levels of exposure?

2) What are the potential health risks to those exposed to water-borne nitrates in the LUB?
3) Have measures been undertaken that would serve to mitigate nitrate exposure from well water? If so, what are they, and how have they served to alter the effect of exposure to nitrates?
4) Are factors present that may have altered the degree of risk among those exposed to well-water nitrates? If true, what are these factors and how do they influence the degree of health hazard risk?
5) What are the local sources of potential well nitrate pollution, and to what degree do these sources influence well-water nitrate levels?

Definitions

Amides/Amines: Classes of organic compounds that may react with nitrates/nitrites or nitrogen-oxide precursors in the bodies of animals to form potentially carcinogenic compounds.

Aquifer: An underground layer of porous rock, sand, or gravel that is saturated with water and capable of yielding water to a well or spring.

Community Water System (CWS): A public water system which provides piped water to 15 or more year-round service connections, or which serves at least 25 year-round residents.

Contaminant: Any substance, such as a chemical or microorganism, that does not occur naturally in groundwater, or that occurs naturally but at a relatively lower concentration.

Cyanosis: Bluish or purplish discoloration of the skin or mucous membranes due to a lack of oxygen in the blood.

Endogenous: Occurring as a result of conditions within the body.

Groundwater: Water that occurs in an underground layer of porous rock, sand, or gravel.

Hemoglobin (Hb): Oxygen-carrying portion of red blood cells.

Leaching: Process through which excess waters move through soils, carrying soluble nutrients with them.

Methemoglobin (metHb): Type of hemoglobin that contains an oxidized form of iron incapable of combining with and transporting oxygen.

Maximum Contaminant Level (MCL): Maximum allowable concentration of a contaminant in water, as determined by the U.S. Environmental Protection Agency, which may be supplied to people who use water from a public system.

N-nitroso Compounds: Category of chemical compounds formed by the reaction of nitrates, nitrites, or nitrogen-oxide precursors with amides or amines to produce nitrosamines and nitrosamides; compounds that are found in the environment and which have been shown to be formed in animal bodies, including humans. N-nitroso compounds are known to cause cancers in many animal species and are suspected of causing cancers in humans.

Point Source: Reference to the origin of a pollutant or contaminant; a source that originates from a discrete place (as opposed to a nonpoint source, which originates over a diffuse area).

Public Water System (PWS): In Oregon, a water system that provides piped water for human consumption to more than three service connections; or that supplies water to a public or commercial establishment which operates a total of at least 60 days per year and is used by 10 or more individuals per day; or that is a facility licensed by the Oregon Health Division.

Unconfined Aquifer: An aquifer that is not protected above or below by relatively impervious materials, such as clay.

CHAPTER 2

LITERATURE REVIEW

Nitrates in the Environment: Nitrogen Cycles

Nitrogen (N) compounds, including nitrates, are ubiquitous in the environment. Air, water, vegetation, and soil all contain N-compounds, either naturally or as a result of human activity. For example, nitrates occur in foods as a result of absorption from soil. They may be present in drinking water as a result of natural leaching from geologic deposits or from such human sources as septic systems. Nitrates/nitrites are found in foods because these compounds are used as preservatives.

Nitrate leaching in undisturbed soils is minimal because there exists a balance between the influx and the release of soil nitrates. However, when soils are cultivated, or when N-fertilizers are applied, nitrate formation and buildup in soils increases (Hegert, 1986). If crops are not able to absorb all the soil-N that is available, then the excess may be incorporated in runoff to surface water, or it may be leached with water into deeper soil layers or the groundwater.

Nitrates/Nitrites and Human Exposure

Humans are exposed to nitrates and nitrites principally in foods, water, and from endogenous (i.e., within the body) synthesis. The amounts of nitrate/nitrite available for ingestion from foods varies, depending upon plant species, growing conditions, and crop management practices. Vegetables which are relatively high in natural nitrate content include spinach, beets, broccoli, leaf-lettuce, celery, kale, radishes, mustard greens, and collards (World Health Organization [WHO], 1978). Meats are a common food source of nitrites. Processed and packaged forms, including lunchmeats and sausages, which require a longer shelf-life than freshly prepared meats, are routinely treated with this compound. The addition of nitrites to meats helps to maintain esthetic coloration and retards bacterial growth, primarily that of *Clostridium botulinum* (NRC, 1972).

Nitrates have also been found to be a source of contamination in drinking water. The 1990 *National Pesticide Survey* revealed that nitrates were one of the two most frequently detected undesirable chemicals in drinking water from either public or private systems (U. S. Environmental Protection Agency [USEPA], 1990, 1992). Johnson and Kross (1990) ranked nitrate contamination among the top water quality issues in the U.S. because of the potential widespread exposure.

Nitrate levels in water are variable, depending on the source. Rural well water tends to have higher concentrations than do urban municipal water supplies (Mirvish, 1983; NRC, 1981). Increased concentrations of nitrates in rural water supplies appear to be related to both the greater number of potential point sources of pollution in rural areas and to the widespread use of fertilizers on rural arable lands (NRC, 1972). Over the past 30 years, the American Midwest has experienced steadily increasing amounts of nitrates in water supplies, with the greater part of this increase associated with rural private wells. Many of these wells have been found to exceed the 10 parts-per-million (ppm) nitrate-nitrogen (nN) standard (Bednar, 1989; Exner & Spalding, 1985). Nitrate ingestion has also been studied in other countries. A study of well-water users in England estimated the contribution of well-water nitrates to total nitrates ingested in the diet, finding that when nN in ingested water was 10-20 ppm, water contributed an average of 70% to the total N-intake (Chilvers et al., 1984).

It has also been demonstrated that nitrates are synthesized in the human body. Tannenbaum, Fett, Young, Land, and Bruce (1978) found that humans excreted nitrates in amounts which exceeded ingested amounts. In addition, the amounts synthesized may be greatly enhanced in infants with gastrointestinal (GI) tract infections with resultant diarrhea (Hegesh & Shiloah, 1982). A portion of the ingested nitrates is absorbed and transported to the salivary glands and then secreted in saliva. Some salivary nitrates are reduced by oral bacteria to nitrites, and are then swallowed. It is estimated that of the total daily nitrite intake conveyed to the stomach, 20 percent is ingested in foods, whereas 80 percent originates from swallowing nitrites produced in saliva (Mirvish, 1983).

According to the National Pesticide Survey (USEPA, 1992), approximately 4.5 million people in the U.S., including 66,000 infants under one-year of age, are exposed to nN which exceeds the 10 ppm standard for drinking water. Fan, Willhite, and Book (1987) have estimated the average U.S. adult population exposure to nN in foods at between 8.8 mg to 22.6 mg per day, with a maximum daily intake from food and water combined of approximately 43 mg.

Nitrates in Groundwater

Records of nitrate contamination of U.S. well water have been maintained since 1895. The earliest records indicate typical ranges of from 10 to 100 ppm nN in the central American states, largely due to wells which were dug or were poorly constructed (NRC, 1972). The *National Pesticide Survey* (USEPA, 1990, 1992) was conducted between 1988 and 1990 for the purpose of documenting the frequency and concentration of pesticides and/or nitrates in the nation's well water, in addition to investigating the relationship between the use of pesticides and possible groundwater contamination. This survey estimated that there were 94,600 community water system (CWS) wells, in addition to 10,500,000 rural private wells, in use in the U.S. Of the private wells sampled, 57 percent, serving six million people, had nitrate levels which exceeded 0.15 ppm nN, including 2.4 percent with water nitrate concentrations in excess of 10 ppm nN. The median concentration for private wells was approximately 1.6 ppm nN, with the highest concentration in a single well at 120 ppm nN. The survey concluded that substantial numbers of wells contained nitrate concentrations which exceeded levels which posed a public health concern, and further study was recommended.

Rajagopal and Tobin (1989) conducted a limited study for a Midwestern state (Iowa) with a long history of nitrate-contaminated rural wells. Between 1978 and 1986, it was determined that 128 public water systems (PWS) using groundwater as a primary source of supply had exceeded the acceptable standard of 10 ppm nN at some time during the period surveyed. An estimated 50,000 residents were using these PWS. Of the more than 725,000 people using private well sources, it was estimated that 110,000 were exposed to nitrate levels in excess of the same standard during the same time period.

Although nitrate contamination of groundwater has been widely documented, the health effects of excessive nitrate consumption and sources of contamination continue to be discussed (Keeney, 1986). For example, although point sources may be less difficult to identify as the polluters of nearby wells, their contribution to aquifer contamination is more difficult to quantify when non-point sources of pollution also contribute to overall contamination problems (Hallberg, 1987).

Given the complex nature of the sources of groundwater, aquifer contamination may persist undetected for years, and even after it is detected, contamination may be impossible to reverse due to the lack of appropriate technology or prohibitive costs (Hergert, 1986). Among diverse groundwater contaminants, nitrates are unique since they tend to emanate from diffuse sources over large areas. However, it is beyond question that groundwater in the U.S. has become more vulnerable to nitrates and other pollutants largely as a result of human activities. To further complicate the issue, this increasing threat has occurred at a time when there is growing reliance upon groundwater as sources of drinking water (Keeney, 1986).

In certain localities, a large portion of the soil nitrates capable of being leached into aquifers may be derived from naturally occurring sources, such as geologic deposits, grazed grasslands, and forest lands (Keeney, 1986). Specific human sources of nitrates in the environment include the following major contributors: (a) industrial waste, (b) municipal waste, (c) landfills/dumps, (d) septic tanks and leach fields, (e) feedlots and organic animal waste, and (f) inorganic fertilizers (NRC, 1972). As Keeney pointedly observed, the usual cause of ground-water nitrate contamination is the intensive use of lands, especially for agricultural purposes.

The NRC (1972) attributed the growth in the use of inorganic fertilizers in U.S. agricultural production, from the early years of the 19th century, to population growth and parallel growth in diets rich in animal proteins. Large amounts of nitrogen are required to grow crops for animal feeds, and as natural nitrogen stores in the soils have been depleted, the use of inorganic N-fertilizers has become a virtual necessity. This process has led to higher levels of agricultural productivity, but also to the accompanying increased potential of nitrate-leaching, especially when soils are coarse and well drained. The NRC (1972) concluded that if the upward trends in the use of N-fertilizers was continued, without a commensurate increase in the nitrogen efficiency of plant and animal production, the future would surely promise increased nitrate-related drinking water problems.

Potential Toxic Effects of Nitrates/Nitrites

Methemoglobinemia is a medical condition related to nitrate/nitrite toxicity. This condition affects the blood when an oxidized form of hemoglobin (Hb), methemoglobin (metHb), is unable to combine with oxygen, and results in oxygen deprivation (anoxia) in tissues. At metHb levels of approximately 10 percent of total Hb, clinical signs may appear in the form of blue-gray discoloration of the skin in light-skinned persons. Among infants, this discoloration has led to the use of the term, "blue-baby syndrome." When metHb reaches approximately 20 percent or greater of total Hb, then such symptoms of brain cell anoxia as headache, confusion, and seizures may result. Comas and deaths occur at levels of 60 percent or greater of total Hb (NRC, 1981).

Acute Effects

The metHb blood levels in adults normally average one percent of total Hb and are generally less than two percent in children (NRC, 1981). Mild secondary cases of methemoglobinemia can be treated with doses of ascorbic acid or the removal of the oxidizing source. More severe cases respond to the injection of methylene blue, which results in the conversion of metHb to Hb by the enhancement of metHb reductase activity (Olson, 1991). Nitrates are per se relatively non-toxic in humans since they are readily absorbed and/or excreted. Before methemoglobinemia can result, conversion to nitrites must first occur, a process completed by bacterial enzymatic reduction. This reduction process may take place either environmentally or in vivo. Thus, the primary health hazard in food and water is from nitrite compounds, a fact which is not consistently understood by the public (European Chemical Industry Ecology and Toxicology Center [ECETOC], 1988).

Methemoglobinemia, Historical Experience

Historically, exposure to nitrates from well water used in the preparation of infant formulas has been believed to be the most frequent cause of infant methemoglobinemia in the U.S. Accounts of infant methemoglobinemia related to water ingestion were initiated with the Comly (1945) report. Infants were being fed formulas made with well water with high nitrate and bacterial contents. The children evidenced high blood metHb levels and developed diarrhea, but responded to methylene blue therapy. There was no recurrence or sequelae after they had stopped ingesting the water in question.

Cornblath and Hartman (1948) monitored ingestion of water, to which controlled amounts of nitrates had been added, among young infants. The metHb levels increased, but not to the extent that they exceeded 10 percent of total Hb, and no symptoms were observed. It was determined that bacteria from the infants' stomachs did not grow in a highly acid medium (i.e., below pH 4.0), and that the bacteria in the upper GI tract, in combination with a stomach acid of pH 4.0 or above, was necessary before the nitrate/nitrite reduction process could occur. Thus, as an isolated cause, the quantity of ingested nitrates was not sufficient to cause the syndrome.

A U.S. survey conducted by Walton (1951) from 1945 to 1950 yielded 278 cases of methemoglobinemia associated with water ingestion, 39 of which had resulted in death. Most of these cases were among residents of Minnesota and Iowa. Walton found that none of the cases were associated with a water-nitrate content of 10 ppm nN or below; less than three percent of the cases were related to nitrate concentrations less than 20 ppm nN; and most of the cases reflected water-nitrate content in excess of 40 ppm nN. The results of Walton's survey, in conjunction with the recommendations provided previously by Comly (1945), formed the basis for the present regulatory limit of 10 ppm nN in drinking water.

The only U.S. case of infant methemoglobinemia related to a PWS occurred in Colorado in 1962. In this case, the infant reportedly had experienced diarrhea, but it was determined that the origin of the condition was probably not bacteria because this municipally-supplied water had been boiled prior to use in the infant's formula. The demonstrated nitrate level in the water was 14-16 ppm nN. However, the case did not prove to be fatal (Vigil, Warburton, Haynes, & Kaiser, 1965).

Between 1952 and 1969, a total of 50 cases of non-fatal blue-baby syndrome were reported in the U.S. (NRC, 1972). In Europe, 1,000 infant cases, with 80 related deaths, were reported between 1948 and 1964. Almost all of these cases involved the ingestion of rural well water (Knotek & Schmidt, 1964). However, similar to the experience in the U.S., western Europe has witnessed a gradual decline in reported cases of the blue-baby syndrome. Nonetheless, it has been assumed that milder cases have continued to occur in the American Midwest that have not been reported (ECETOC, 1988).

Two relatively recent series cases of methemoglobinemia have been reported in the U.S. In 1981, a South Dakota infant ingested well water with a nitrate concentration of 121 ppm nN. After becoming cyanotic, the infant was taken off the water and the cyanosis disappeared within several days (Busch & Meyer, 1982). Johnson et al. (1987) also reported a fatal case of infant methemoglobinemia in South Dakota in 1986, where a nN concentration of 150 ppm was present in the well water. The study stated that 16 cases of the blue-baby syndrome had occurred between the years 1972 and 1982 in South Dakota. In the mid-80s, 27 percent of the private wells tested in this state were found to exceed 10 ppm nN, with four percent of the wells exceeding 100 ppm nN. Johnson and Kross (1990) have stated that the public remains unaware of the continuing incidence of infant methemoglobinemia, which they believe remains a contributor to infant mortality statistics in the U.S. They attribute most cases of rural well-water nitrate contamination to local point sources.

Infant Susceptibility

Young infants are more vulnerable than adults to nitrate poisoning and methemoglobinemia. One reason is that infants, compared to adults, ingest relatively large amounts of water per unit of body weight, which leads to an increased dosage per unit of body weight. Comly (1945) suggested that the immature Hb of infants was oxidized to form metHb more readily than Hb in adults. This position was challenged subsequently by Lukens (1987), who explained that young infants, who are subject to immature enzyme systems, lack the full ability to quickly reduce metHb to Hb as occurs in adults. Lukens estimated that only 60 percent of adult metHb reductase activity is present in infants three months of age or younger.

Because the stomach acid of infants is generally believed to be higher in pH relative to adults, infants experience greater risk of bacterial colonization in the stomach. If these colonies are capable of reducing nitrates, then nitrites may be produced and absorbed (NRC, 1972). It should be noted this theory has been disputed. A dissenting view by the ECETOC (1988) concluded that the gastric acid pH of the infant stomach is sufficiently low to prevent bacterial colonization, but that other areas of the GI tract in addition to the stomach may reduce nitrates, resulting in metHb formation.

Infant susceptibility is also influenced by nutrition. For example, ascorbic acid inhibits the oxidation of Hb to metHb (Gruener & Shuval, 1970). Knotek and Schmidt (1964) found that certain types of infant milk preparations could reduce bacterial growth in the GI tract and, in turn, help to prevent nitrate reduction. No buildup of nitrates or nitrites in human milk appears to occur after food consumption (Green, Tannenbaum, & Fox, 1982), or after ingesting water below the 10 ppm nN level (Fan et al., 1987). Therefore, for nursing infants, the likelihood of this route of exposure is likely to be low.

The most controversial factor of infant susceptibility to methemoglobinemia is the role played by GI disturbance, which has the potential to alter the metabolic state of the infant. This controversy can be traced at least as far back as Comly (1945), who stated that infants with stomach upsets experienced relatively high levels of gastric pH, which thus supported the growth of nitrate-reducing microorganisms. Since this time, a number of investigations have examined this concept, suggesting that nitrates/nitrites may not be the sole or even the primary cause of methemoglobinemia in infants. For example, Shearer, Goldsmith, Young, Kearns, and Tamplin (1972) followed a total of 256 infants from birth to six months of age in two areas of California. The results of the investigation indicated that infants two months of age or younger tended to have higher metHb levels than older infants, independent of the water-nitrate concentration. Also, diarrhea and respiratory illness among infants, compared to non-ill babies from the same age group, were associated with increased metHb levels. It was concluded that age and general state of health appeared to exercise the strongest influence upon infant metHb levels among infants ingesting 5 mg or more of nN per day from water.

A descriptive study of 468 Southwest African/Namibian infants, ranging in age from 1 to 12 months, investigated subclinical methemoglobinemia and related adverse health effects (Super et al., 1981). The results showed a strong correlation between nitrate ingestion and blood metHb levels. In contrast, there was no correlation between infant history of diarrhea or respiratory infections and either nitrate ingestion or blood metHb levels. Also absent from these results were any findings similar to those of Shearer et al. (1972), in which only infants two months of age or younger had the highest metHb levels. The investigators stated their belief that there was no discernible effect for vitamin C.

An Israeli study by Hegesh and Shiloah (1982) investigated 58 infants hospitalized for acute diarrhea, comparing them to 130 control infants without GI conditions. Exposure to excessive nitrate levels in drinking water was not a factor for either group. The control group was fed a diet low in nitrates, and had no previous history of high nitrate exposure or other possible causes of methemoglobinemia. Blood nitrate and metHb levels were found to be higher among the acute diarrhea group. The urinary nitrate excretion rate of the diarrhea cases was higher than for the controls. No correlation was established between nitrate ingestion in foods or water and metHb levels. From these findings, Hegesh and Shiloah hypothesized that nitrates were endogenously produced in the GI tract of infants with acute diarrhea and were the primary cause of infant methemoglobinemia. These results were clearly in opposition to the long-held assumption that ingested nitrates were responsible for methemoglobinemia.

An earlier study by Goldsmith (1986) paralleled the results subsequently obtained by Hegesh and Shiloah (1982). Goldsmith followed 256 infants from birth to one year of age, regularly checking their metHb levels. Results revealed that illness (either GI or respiratory) was associated with more than one-half of the highest metHb level infants. It was concluded that other factors in addition to high water-nitrate levels exercised an effect upon the production of elevated blood metHb levels among infants. Other case studies completed by Yano, Danish, and Hsia (1982) and Avner, Henretig, and McAneney (1990) tend to support previous descriptive and controlled investigations which had linked methemoglobinemia to causes other than nitrates alone.

An exhaustive review of the world literature on the effects of nitrates in drinking water established some salient points (ECETOC, 1988). First, 85 percent of the studies reviewed on drinking-water induced methemoglobinemia were associated with bacterial contamination, diarrhetic/GI disturbances, and water nitrate levels of 20 ppm nN or less. The remainder of the studies reviewed either did not report or did not investigate bacterial contamination and accompanying illness. It was concluded that aside from what was produced by only the ingestion of nitrates, other causes of methemoglobinemia apparently existed, or at least they did for water-nitrate content below 20 ppm nN. The cause of methemoglobinemia induced by water-nitrate content below this level was ascribed to water-borne bacteria, as well as to the resulting GI infections and diarrhea produced. The ECETOC observed that some public water supplies in the U.S. had for many years exceeded the nitrate standard, but that only a few resulting cases of methemoglobinemia were reported.

The sporadic occurrence of methemoglobinemia in the U.S. is another possible indication of its association with bacterially contaminated water. Better well construction and siting, public education, increased reliance on community water systems (CWS), and changes in infant feeding habits, may all play a role in its decreasing incidence (Craun 1981).

Adult Susceptibility

Adults may become susceptible to increased metHb levels. Such GI diseases as pernicious anemia, chronic gastritis, and peptic ulcer are often treated by lowering gastric acidity with drugs. Nitrate-reducing microorganisms may proliferate in this environment (Fan et al., 1987). Metcalf (1961) examined the blood of pregnant women and found increased susceptibility to metHb formation from the sixth week of pregnancy and beyond. An U.S. EPA (1987) report stated that during the 30th week of pregnancy, the metHb level may be elevated to as much as 10.5 percent of total Hb. With normal adult metHb concentration at less than one percent, excessive intake of nitrates/nitrites could increase susceptibility to methemoglobinemia during the later stages of pregnancy (NRC, 1981).

Chronic Effects

There is no evidence that nitrates or nitrites are per se carcinogenic in animals. In some microbial systems, nitrites are mutagenic and can become carcinogenic in many animal species when combined with precursors to form N-nitroso compounds. However, nitrates do not appear to be mutagenic (NRC, 1981). Tissue pathologies in some vital organs have accompanied high nitrite ingestion in experimental animals, and nitrites can lower blood pressure through smooth-muscle relaxation (ECETOC, 1988). In an unusual case described by Henderson and Raskin (1972), sodium-nitrite-cured meats were found to produce headaches. It has also been found that nitrates and nitrites provide no known health benefits (Hartman, 1982).

Animal studies have shown neither toxic effects upon the unborn from nitrates ingested by their mothers, nor demonstrable instances of birth defects. However, while nitrites can pass the placental barrier in mammals and do increase metHb levels in the fetus, nitrites do not appear to exercise a fetotoxic effect in mammals (Fan et al., 1987). Among humans, Dorsch et al. (1984) investigated possible relationships between birth defects and the ingestion of nitrates from water during pregnancy, based upon a retrospective case-control study of congenital birth defects in 218 pairs of infants in Australia. Results showed almost three times the risk of birth defects when pregnant mothers ingested moderate amounts of water nitrates, with approximately four times the same risk factor when the water-nitrate levels were 25 ppm nN or greater. The analysis found an increasing risk of birth defects corresponding to increasing dosage of water nitrates, and greater risk of birth defects associated with residence in a rural area versus residence in an urban area.

Bednar (1989) studied Nebraska community water systems and found that five percent of the 453 communities investigated had water-nitrate levels above 10 ppm nN. This investigation examined possible relationships between water-nitrate concentrations and various disease mortality rates, as well as possible relationships between birth defects and water nitrate levels, revealing no significant relationships between these factors for either hypotheses.

The relationships of animal activity/behavior to nitrate exposure were examined by Gruener and Shuval (1970), who exposed one group of mice to nitrate and noted differences in behavior and lowered activity levels in comparison to the activity/behavior of mice in a non-exposed control groups. Follow-up studies revealed more "aggressive" behavior and reduced motor activity among mice exposed to nitrates, leading to the observation that there was a possible direct toxic effect from nitrate ingestion (Shuval & Gruener, 1977, p. 3).

A 1970 Russian study by Petrov and Ivanov (cited in NRC, 1972) investigated groups of children from ages 12 to 14 years who were exposed to either high or low water-nitrate supplies, comparing groups on the basis of reactions to light and sound stimuli. The children exposed to the high nitrate levels had slower reaction times to both stimuli. Super et al. (1981) found no association between birth weight, prematurity, or delayed physical development in human infants and the amount of well-water nitrates ingested by the mothers. Gottlieb (1988) studied possible associations between nitrate exposure in foods and water and human development in infants to one year of age. A five-year cohort of infants living in an area of relatively high groundwater nitrates were examined. Unlike the findings obtained by Super and colleagues, a significant association was determined to exist between nitrate intake of 10 ppm nN or more and the infants who weighed the most in relationship to their heights.

N-Nitroso Compounds

N-nitroso compounds are formed by the reaction (nitrosation) of nitrite, nitrate, or nitrogen-oxide precursors with amides or amines to form nitrosamides and nitrosamines. Nitrosamines are readily absorbed in the human GI tract and have a half-life of less than 24 hours. Following metabolic transformation, they are quickly excreted in the urine (WHO, 1978).

N-nitroso compounds may form in foods, tobacco and tobacco smoke, air, and water. These compounds may also form at various sites within the body, including the stomach, bladder, colon, and saliva of the mouth (NRC, 1972, 1981). The stomach has been the most frequently studied area (Fraser, Chilvers, Beral, & Hill, 1980). The acid environment of the stomach, especially at a pH of 3.5 or lower, creates the ideal area for the reaction of nitrites with amines and amides (NRC, 1977, 1981).

Acute Effects

Some N-nitroso compounds are known to be acutely toxic. Dimethylnitrosamine has a historical record of involvement in liver toxicity among industrial workers (Newberne & Nauss, 1980). Liver and lung damage and convulsions have been induced by N-nitroso compounds in rats (NRC, 1972). The fetal tissue of certain test animals is quite susceptible to these compounds, and toxicity or death may follow exposure (Swann, 1975).

Chronic Effects

In most testing systems, the mutagenicity of nitrosamides is very high, whereas nitrosamines are less mutagenic. The products formed from the disintegration of N-nitroso compounds act as alkylating agents, producing genetic damages which have led to mutations (NRC, 1972). Considerable efforts in the study of N-nitroso compounds have centered upon speculations of their carcinogenic effect in humans. Animal experiments have established the highly carcinogenic nature of a number of nitrosamines and nitrosamides in rodents, and it has been determined that nitrosamines will cause cancer in many different species of animals (NRC, 1972). Factors of cancer causation in humans due to direct exposures have not been isolated. However, it is generally assumed that endogenous formation of N-nitroso compounds may lead to certain types of cancer

(WHO, 1978). A National Research Council (1981) report states: "Tests for carcinogenicity in animals provide evidence that N-nitroso compounds are likely to be carcinogenic in humans" (p. 1-9).

Nitrosamides have been at the center of theories of the origin of gastric cancer. Mirvish (1983) stated that the evidence for the link between stomach cancer and N-nitroso compounds remains "circumstantial" (p. 642). Epidemiologic investigations in widespread locations throughout the world have led to the theory of the environmental causation of gastric cancers, but the link has not been firmly established for reason of the problems inherent in the estimation of exposure to nitrates, nitrites, and N-nitroso compounds (Fraser et al., 1980).

Forman (1987) noted there was a strong association between gastric cancer and exposure to nitrates/nitrites or N-nitroso compounds even in areas of low exposure to these compounds. The inhibitors of the N-nitroso compound formation may be at work in these instances, offering protection in high-exposure areas, whereas promoters, such as chronic gastritis, may increase incidence in relatively low-exposure areas. Forman also supported the theory that nitrate levels of 10 ppm nN of more in water may increase the risk of gastric cancer.

The National Research Council (1981) faulted the epidemiologic studies of stomach cancer in relation to N-compounds because no direct measurements were performed for any of the suspected compounds. In addition, it was stated that other agents are equally likely to be causes of stomach cancers. Nonetheless, Fraser et al. (1980) have concluded as follows: "On the epidemiological evidence to date, the hypothesis that high nitrate ingestion is involved in the aetiology of gastric cancer, should not be lightly discarded" (p. 9).

Evaluation of Health Risks

Nitrates/Nitrites and Disease

A report issued by the National Research Council (1972) stated that those most at risk of death from methemoglobinemia due to nitrate exposure were infants less than six months of age who were fed formulas prepared with nitrate-contaminated water. Thus, water may be the major source of exposure, especially if wells are proximate to the point sources of pollution. The report identified 20 ppm nN in water as the threshold level above which the greatest potential for the inducement of clinical methemoglobinemia in infants exists.

At the same time, the NRC (1972) acknowledged that accurate determinations of the lowest levels of fatal human dosage were not currently available. There were apparently no acute harmful effects to adults or children six months of age or older which had been linked to the current levels of nitrate/nitrite generally found in foods or water. However, a potential for "subclinical" effects from additive nitrites on "susceptible" individuals did exist (p. 82). It should be noted that the NRC report did not, at the time the report was issued, define either of these terms.

A subsequent NRC (1981) report predicted increasing future concern about nitrate exposure in drinking water. Johnson and Kross (1990) warned that methemoglobinemia was a significant contributory factor to worldwide rates of infant mortality. In 1987, Lukens would warn: "Despite public health surveillance and physician education, . . . toxic methemoglobinemia remains a potentially lethal problem for infants in rural America" (p. 2794).

From a review of the literature, Gottlieb (1988) found that there was sufficient evidence to implicate nitrates as a potential contributing cause of birth defects in humans (Fan et al., 1987; Dorsch et al., 1984; Shuval & Gruener, 1972, 1977; Super et al., 1981). Focusing upon human development with respect to nitrate exposure, Gottlieb concluded that there was "cause for concern" (p. 240) in the U.S., adding that the

> more subtle aspects of development may be adversely impacted by nitrate exposure at lower levels than those currently recognized as safe to protect against the development of acute (clinical) methemoglobinemia in young infants. (p. 52)

N-Nitroso Compounds and Disease

Based on extensive animal studies demonstrating extreme sensitivity to many N-nitroso compounds, a potential for the production of human cancers has been suggested (ECETOC, 1988; NRC, 1972). At the same time it was acknowledged that a strong drop had occurred in the incidence of stomach cancers in the U.S. and throughout Europe, indicating the possible absence of a link between cancers and nitrate ingestion (ECETOC, 1988). It was also observed that dietary protective factors may render N-nitroso compounds unimportant as far as concerned risks of cancer (Newberne & Nauss, 1980).

Reducing the risks of potential adverse health effects from nitrates/nitrites and N-nitroso compounds, with any degree of certainty, would require the reduction or elimination of human exposure. However, the complete elimination of exposure to these hazards may not be possible due to the widespread distribution of N-compounds and the resultant potential for the endogenous formation of nitrates/nitrites and N-nitroso compounds. Nonetheless, the reduction of exposures from water-borne sources of nitrates is possible through: (1) prevention of contamination, (2) protection of water supplies (i.e., groundwater wells), and/or (3) treatment to remove the contaminant, including avoidance measures or neutralization of adverse effects once the contaminant is ingested.

At present, there is a general consensus that the best long-term solution to the reduction of nitrate exposures is the prevention of groundwater contamination (Gottlieb, 1988; NRC, 1972; Winton, Tardiff, & McCabe, 1971). Protection of well-heads would serve to significantly reduce chances of local-source contamination from either nitrates or bacteria. Wells with proper grouting around the casing and the exposed well-head are less likely to be polluted. The use of concrete skirting and/or diversion trenches could also prevent contamination from surface water runoff (Vomocil & Hart, 1991).

In the area of treatment and/or removal, nitrate removal by reverse osmosis and ion exchange methodology are techniques presently used by municipal water suppliers (USEPA, 1987). Nitrates, however, cannot be removed by boiling, by ordinary filtration methods (i.e., sand, activated carbon), or by the addition of water softeners (Vomocil & Hart, 1991). Home water treatments for nitrate treatment/removal are used only on a limited basis since such systems are both expensive to purchase and to maintain (Rajagopal & Tobin, 1989). At present, the most useful alternatives to the use of contaminated water sources include the use of water from non-contaminated wells or connection to a CWS, when such means are available. Infant formulas that do not require water dilution have also come into common use. These various methods of avoidance are probably the most expedient and the least costly means of reducing infant exposures to nitrates.

Naturally occurring protective factors which serve to reduce exposure to nitrates/nitrites or N-nitroso compounds are also present in the diet. These factors include vitamins C, E, and polyphenols, which reduce nitrites to more benign substances and lessen the possibility of the formation of N-nitroso compounds and metHb (Mirvish, 1983). Bednar (1989) tested males and females for the effect of ingested vitamin C from fruit juices on the urinary excretion of nitrates/nitrites. Though the amounts of urinary excretion of these compounds varied widely among the subjects, it was also apparent that lowered nitrate/nitrite levels could be observed from the urine of those subjects whose diets included fruit juices.

Johnson and Kross (1990) have urged continuing education for both the public and health care providers in rural areas. Since methemoglobinemia reporting is not a federal requirement, it was recommended mandatory reporting to health authorities and regular monitoring of well-water quality be instituted. This position was based upon the argument that the true incidence of methemoglobinemia-related mortality may be underreported because of physician misdiagnosis.

Standards for the Presence of Nitrates in Drinking Water

In 1962, the U.S. Public Health Service recommended that nitrates should not exceed 10 ppm nN in drinking water. This recommendation was based on several factors, as follows:

a) Findings from a comprehensive survey in which no cases of methemoglobinemia were found when nitrates in ingested water were less than 10 ppm nN (Walton, 1951);

b) No cases of methemoglobinemia had been reported in relation to public water systems in the U.S.; and

c) International Drinking Water Standards had determined that nitrate exposures in excess of 10 ppm nN were a potential cause of methemoglobinemia.

The World Health Organization (1978) has recommended a nitrate exposure standard of 10 ppm nN in drinking water. In some countries, levels between 10-20 ppm nN are considered to be acceptable, but levels in excess of 20 ppm nN are uniformly considered to constitute a public health risk. In recent years in the U.S., the EPA has set, and most states have adopted, 10 ppm nN as the maximum contaminant level (MCL) and standard for drinking water supplies (Gottlieb, 1988).

However, the 10 ppm nN standard has not met with universal agreement. Rajagopal and Tobin (1989) have stated their belief that the processes for the establishment of a nitrate standard for drinking waters have not been based upon all pertinent scientific findings. Karmin (1987) explained that cancers were not considered when the interim nitrate standard for drinking water was set by the U.S. EPA in 1976. At that time, epidemiological evidence which linked nitrates to cancers had not been presented, and the potential for the transformation of nitrates into N-nitroso compounds was a continuing subject of discussion within the scientific community. Thus, two principal schools of thought have emerged, supporting differing standards for nitrates in drinking water. One group favors the current U.S. EPA-enforced MCL of 10 ppm nN, and the other seeks to raise the acceptable level of exposure to 20 ppm nN.

Arguments Favoring the Standard of 10 ppm nN

Fan et al. (1987) have stated that the 10 ppm nN standard for drinking water is appropriate to protect infants from methemoglobinemia, also providing sufficient protection against embryotoxic and reproductive effects. Even earlier, Winton et al. (1971) stated that the 10 ppm nN standard provided the safety "to cover all reasonable situations" (p. 98). While in agreement with this standard, Shuval and Gruener (1977) noted that their Israeli study had resulted in infants with elevated metHb levels when exposure to nitrate water concentrations were only slightly in excess of the standard. Thus, they issued this cautionary judgment with respect to the 10 ppm nN standard: "Little, if any, safety factor is provided by it" (p. 58).

Craun (1981) also questioned confidence in the adequacy of the 10 ppm standard because he felt that some subpopulations of infants were more susceptible to methemoglobinemia that others. The National Research Council (1977) had agreed earlier that for some susceptible infants, the 10 ppm standard bordered on the level of no-observable-health-effects. The NRC further indicated that merely insuring reasonable protection against infant methemoglobinemia at the 10 ppm standard did not thereby diminish the reality of other potential adverse effects from the same types of exposures: "There is . . . little scientific basis to support conclusions on the safety of any concentration of nitrate in water with regard to carcinogenic potential" (p. V-246).

Finally, as a result of a study conducted by Goldsmith (1986), which demonstrated adverse physiological changes among infants ingesting high-nitrate water, the State of California reaffirmed the 10 ppm nN standard. This report had stated that "the absence of clinical illness due to elevated metHb (methemoglobinemia [sic]) was not a sufficient basis for accepting the safety of high-nitrate water supplies" (pp. 153-54).

Arguments Favoring Standards Higher Than 10 ppm nN

Though most investigations have supported the 10 ppm nN MCL standard for drinking water, persuasive arguments have been presented for raising this standard to 20 ppm nN. The basis for these arguments is that none of the published studies have demonstrated that clinical methemoglobinemia will result from the ingestion of water to approximate levels of 20 ppm nN, unless the water has been bacterially contaminated or unless the infants in question have experienced GI disturbances (ECETOC, 1988). Thus, it has been hypothesized that the microorganisms in ingested water produce GI disturbances which, in some as yet unidentified process, lead to the endogenous synthesis of high amounts of nitrates. In this view, nitrates are dismissed as the cause of methemoglobinemia when their concentrations are below 20 ppm nN, a position which brings into question the long-held belief that microorganisms harbored in the stomach are responsible for the processes of nitrate reduction that lead to methemoglobinemia. Therefore, it has been suggested that two separate standards be instituted: a 20 ppm nN standard applicable to most situations, and the present 10 ppm nN standard applicable in the presence of the bacterial contamination of water.

Various studies have questioned whether nitrate ingestion, in itself, among infants could be the ultimate causal factor in the development of methemoglobinemia (Cornblath & Hartman, 1948; Goldsmith, 1986; Shearer et al., 1972; Shuval & Gruener, 1972; Winton et al., 1971). In addition, only a few cases of methemoglobinemia have been documented in relation to municipal water supplies, though it has been recognized that some of the CWS in use in the U.S. distribute drinking water which exceed the 10 ppm nN standard and have been doing so for many years (ECETOC, 1988; Parsons, 1978).

In 1951, Walton's findings supported a standard of 20 ppm nN MCL. Of the more than 200 cases of methemoglobinemia investigated, only a few cases were associated with nitrate concentrations between 10 and 20 ppm nN, and each of these cases was accompanied by GI disturbances and diarrhea. Most cases were linked to nitrate concentrations in excess of 40 ppm nN. To the proponents of a higher nitrate standard, too much attention has been focused on well-water nitrates as the direct cause of infant methemoglobinemia. It is argued that, at best, nitrates levels under 20 ppm nN in drinking water are probably just a single incidental factor in the onset of methemoglobinemia and, considered in isolation, are of "minor importance" (ECETOC, 1988, p. 101).

Water Standards in the Lower Umatilla Basin

As a follow-up to preliminary sampling completed in the mid-to-late 1980s, the Oregon DEQ (1991) conducted more thorough well-sampling in the LUB from July, 1990 through October, 1991. The latter surveys included sampling well water to determine if there was contamination from land-applied agricultural chemicals. None of the well-water surveys for the LUB collected data for the evaluation of population demographics or for the estimation of the extent of human exposure to detected contaminants.

The 1990-1991 survey samples were analyzed for about 30 inorganic constituents (including nitrates and nitrites), volatile organic compounds (VOCs), pesticides, herbicides, bacteria, a number of other parameters (Oregon DEQ, 1991). Of the total of 198 LUB wells included in the survey, 49 percent had water-nitrate contents equal to or greater than 5 ppm nN; 15 percent were between the levels 5 ppm and 10 ppm nN; 27 percent reflected 10 ppm nN or greater; and 9 percent of the wells either had no detectable nitrates or were not sampled. Almost twice the percentage of samples drawn from relatively shallow alluvial aquifers, when compared to samples drawn from deeper basalt aquifers, were in excess of the 10 ppm nN drinking-water standard. Pesticides and VOCs were found in nine wells, but only in low concentrations. Only one well of these nine was considered to pose an issue of health concern (Grondin, 1992).

With respect to physical characteristics, the LUB includes a 780-square kilometer area located between northern Morrow and Umatilla counties (Figure 1). The approximate boundaries of the LUB are as follows: (a) The southern boundary is an east-west line between Township 2N and 3N; (b) the northern boundary is the Columbia River; (c) the eastern boundary is a north-south line between Ranges 29E and 30E; and (d) the western boundary is a north-south line between Ranges 22E and 23E (Gerald Grondin, personal communication, April 2, 1992). In geographical terms, the Oregon DEQ (1986) describes LUB terrain as level to rolling in nature. The land has an average elevation of 183 m and it is sloped toward the Columbia River to the north. The main centers of population include the cities and townships of Umatilla, Boardman, Irrigon, Hermiston, and Stanfield.

In climate, the LUB has the hottest summer temperatures and is the driest area in Oregon. It receives annual precipitation of less than 25 cm. Crops lack roughly 50 cm of required water during the annual 190-day growing season. The soils are generally sandy (Oregon DEQ, 1986). Geologically, a number of layers of basalt rock underlie the LUB area . Atop these basalt layers, there is a sedimentary layer deposited by old rivers and lakes. It is in the relatively shallow sedimentary layer and the upper basalt layer that easily accessed and unconfined aquifers are

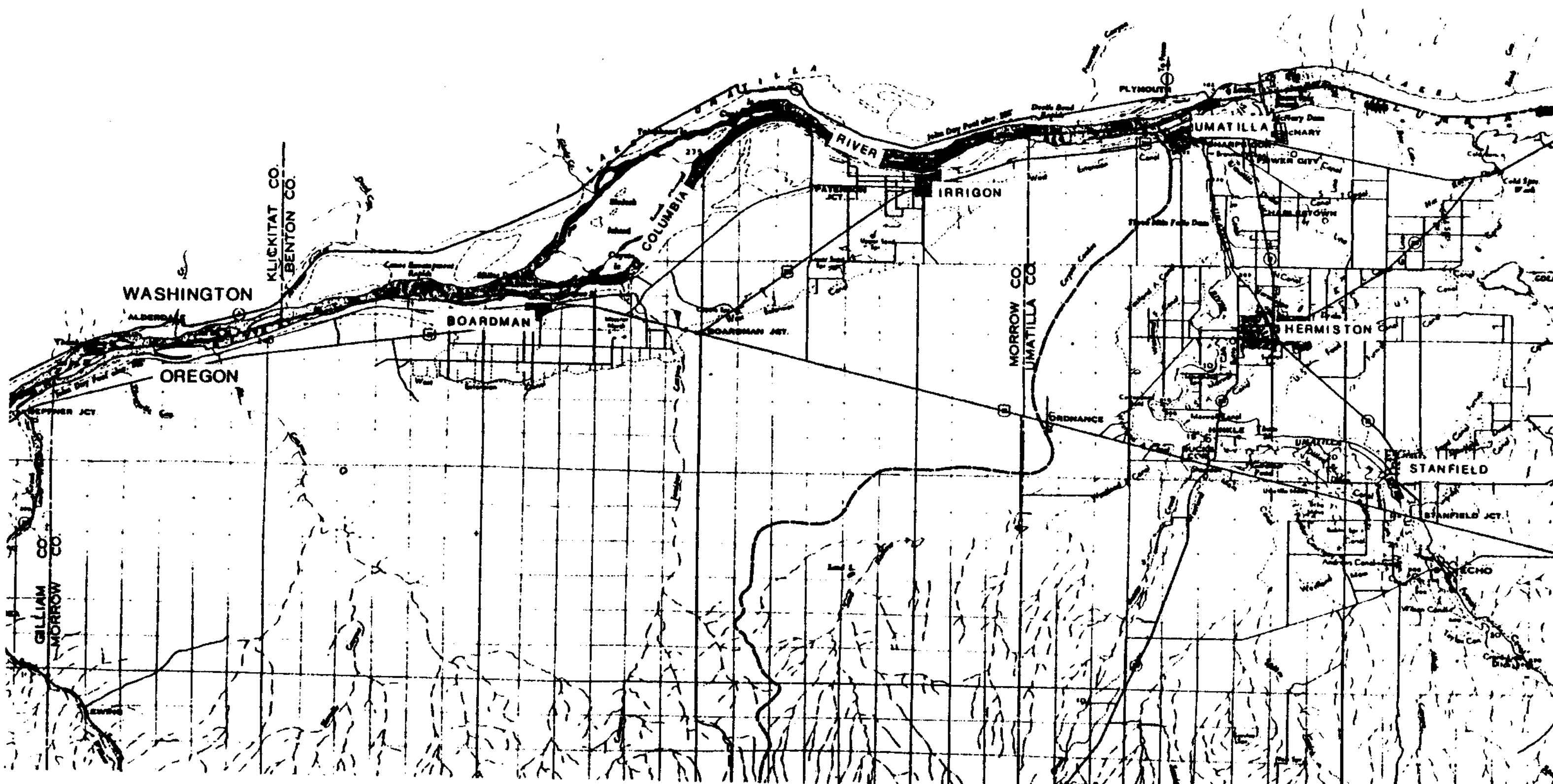

Figure 1. Lower Umatilla Basin Survey Area, scale: 1" = 3.5 mi (5.6 km) (Oregon, State Water Resources Board, 1963).

found. Typically, these aquifers are positioned beneath coastal plains and river valleys throughout Oregon (USGS, 1986).

According to Sweet, Wells, and Maxwell (1980), these shallow, unconfined aquifers usually underlie fertile, intensively farmed areas with accompanying dense populations. Because of the relative ease and low costs associated with tapping these aquifers, within the state they are the predominant source of water used for domestic, agricultural, and industrial purposes. They are also the sources of water which are the most vulnerable to pollution and to the buildup of contaminants over time.

CHAPTER 3

METHODS

Data Collection

Three data sets were used in this study. First, individuals/families living in rural residences who used private water wells were surveyed by telephone regarding their ingestion of well water and factors relating to water-nitrate exposure. Additional data from the Oregon DEQ (1991) provided information on well-water nitrate concentrations derived from samples collected and analyzed between July, 1990 and October, 1991. A third data set included demographic information about Oregon residents taken from the 1990 U.S. census (U.S. Department of Commerce, 1991).

Surveys were administered to 83 residences in the LUB area. Although the Oregon DEQ (1991) study sampled 198 wells in this area, 80 wells (serving these 83 residences) were selected because they were the only private wells used for drinking water. Wells used exclusively for irrigation, stock watering, purposes of commercial or industrial supply, or as public water supplies were not included.

The telephone survey (Appendix A) collected information regarding population demographics and socioeconomic data, dietary practices, experience of illness, the existence of alternative sources of water, water treatment devices in use, well-siting practices, and other factors that could potentially affect well-water nitrate exposure. Information was also gathered on local sources of potential well-water nitrate pollution. This questionnaire was developed with the assistance of the Oregon State University (OSU) Survey Research Center, following completion of a literature review to determine pertinent survey questions. The survey was approved by the Oregon State University Committee for the Protection of Human Subjects.

The telephone survey was pilot tested to improve instrument validity and reliability. This included administering the survey to six Corvallis-area rural residents who owned private wells. The participants provided recommendations that were incorporated into the final survey questionnaire.

The final questionnaire was administered by the researcher as follows:

1) Well-owners' names, phone numbers, and addresses were obtained from DEQ records as generated from well-sampling results (Oregon DEQ, 1991).
2) The possible outcomes of each phone number dialed included: a) a completed questionnaire, b) a partially completed questionnaire, c) refusal to be interviewed, d) qualified respondent not home, or e) busy signal/recorded message.

3) Survey phoning took place generally between 1:00 p.m. and 4:00 p.m. or between 7:00 p.m. to 8:30 p.m. weekdays, with some calls required between 1:00 p.m. and 4:00 p.m. on weekends.

4) The researcher asked to speak to the individual most knowledgeable about food preparation within the home. If this person was unavailable, the spouse or other adult living in the home answered the survey questions.

5) Households without an adult present, or those in which a busy signal or recorded message was encountered, were recalled that same day or the following day.

A letter of introduction (Appendix B) was mailed to all households included on the telephone survey list approximately one week before the phone calls were made. The letter informed residents of the nature of the study, indicated how their households were selected, and advised them that participation in the survey was voluntary.

Data Analysis

Data collected from the telephone survey, DEQ sampling data (Oregon DEQ, 1991), and U.S. Census data for Oregon (U.S. Department of Commerce, 1991) were described using median values, proportions, and frequency distributions. Comparisons were made to well sampling data from both a national survey (USEPA, 1990, 1992) and an earlier well-water nitrate survey in Malheur County, Oregon (Stahl, 1991). Because the data were not normally distributed, medians rather than means were used as measures of central tendencies.

CHAPTER 4

RESULTS AND DISCUSSION

Survey Population Demographics

Respondents from 85 households were surveyed by telephone. Two refused to be questioned and one did not complete the survey. In all but a few cases, the respondent answering the telephone was able to answer all of the survey questions without difficulty.

The 83 households contacted comprised a total survey population of 221 people. Of the total population in the survey area, these residents represented approximately 0.8 percent of the LUB population, approximately 0.3 percent of the population residing in Morrow and Umatilla counties, and approximately 0.7 percent of the rural residents of the two counties. All residents of the households included in the survey, except for the residents of three households who drank bottled water or city water, consumed water from private wells. They also prepared food with well water.

Age Distribution and Gender

The age distribution of the survey population is shown in Figure 2. Three infants, ages 3 months, 8 months, and 11 months, were included in the survey population. The percentage of the population in each of the five age groups increased with age, with those aged 40 years or more comprising the largest group (62.1%). Twenty-eight percent were 65 years of age or older.

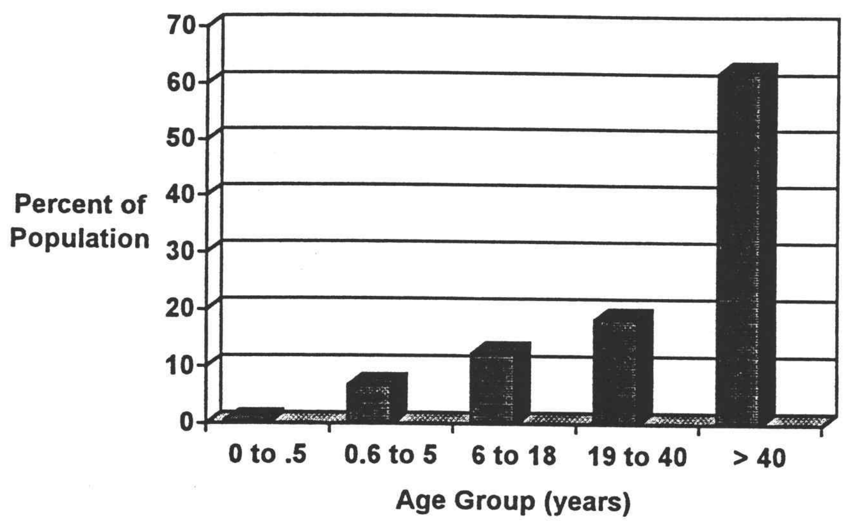

Figure 2. Age Distribution of Study Population.

Approximately equal numbers of males and females were included in each age, except for the group younger than five years of age (Figure 3). The median age for males and females was 52 and 51 years of age, respectively. Males and females comprised 51.6% and 48.4%, respectively, of the survey population. The percentage of individuals in each of four age groups in the survey area was compared to the same age groups comprising the rural areas of the two counties and the five major population centers in the LUB (Table 1).

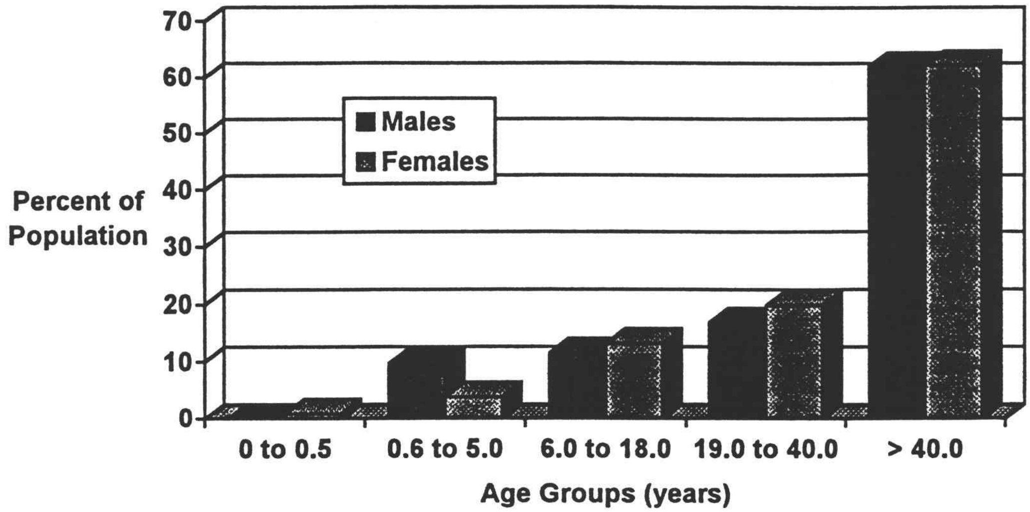

Figure 3. Age Distribution of Study Population by Gender.

Table 1. Comparison of Population Age Distributions, LUB vs. Rural Areas of Morrow and Umatilla Counties.

	Population		
Age Group (years)	LUB Survey Area (%)	LUB Cities (%)	Counties, Rural (%)
≤ 5	16 (7)	1,614 (9)	1,551 (5)
6 to 18	27 (12)	3,952 (23)	8,479 (27)
19 to 40	40 (18)	6,993 (41)	7,985 (26)
> 40	136 (62)	4,718 (27)	13,298 (42)
Total	219	17,277	31,313

Source: U.S. Department of Commence, Bureau of the Census (1991).

The age distribution in the LUB survey population differed from the age distribution in the rural areas and population centers for three of the four age groups. Compared to the rural areas of Morrow and Umatilla counties, the LUB survey population was older, and a smaller percentage of residents were in the age range 6 through 40 years. Also, a higher percentage of the over-40 age group resided in the survey area than in rural areas of both counties.

Twice the percentage of residents ages 6 through 40 years lived in cities (64%) than in the survey area (30%). In contrast, compared to city residents (27%), over twice the percentage of residents in the survey area (62%) were in the over-40 age group.

Health

The general health condition of the survey population was assessed by asking respondents to report household illness or currently existing medical conditions. None were reported for those 19 years of age or younger, whereas 7.4 percent of the residents between the ages of 20 to 50 years reported a current medical problem. Approximately 93 percent of the medical conditions reported were indicated for those 50 years of age or older.

Digestive conditions affected 8.9 percent of the population, but no one under the age of 10 years reported such a condition; 70 percent of these conditions were reported by the 50 years of age or older group. Three (2.8%) of a total of 107 females were reported to be pregnant. All three were young adults under the age of 40 years, none of whom indicated plans to relocate residences during the following year.

Home Ownership and Permanency in Area

Ninety-four percent of the respondents stated they owned their own residence, whereas the remaining six percent rented their homes. Residences were reported to be mostly framed dwellings (62.7%); the remainder were mobile/manufactured (33.7%) or other construction (3.6%). The majority of respondents (62.7%) had lived elsewhere in the LUB area prior to moving to their current location. Approximately 75 percent of the respondents had lived in their present location for more than 10 years, and only 7.3 percent reported that they had lived in their present location for two years or less. Six of the respondents (7.2%) stated that they planned to move within the following year (Figure 4).

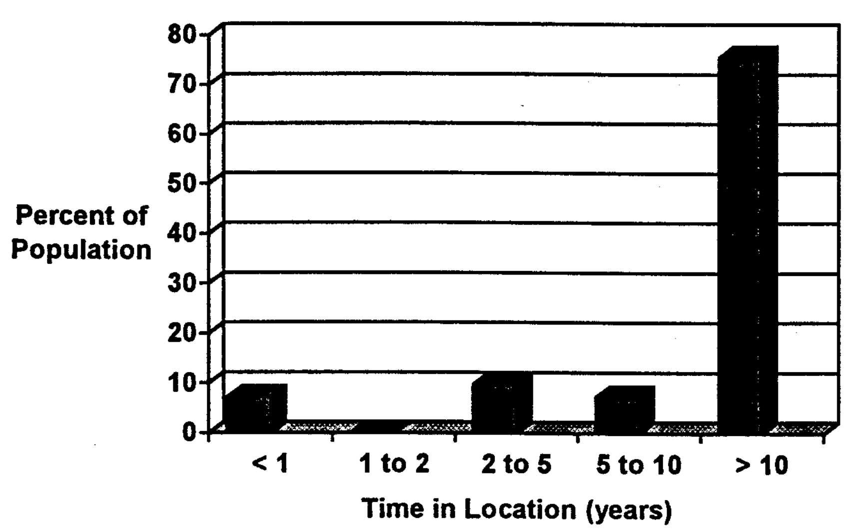

Figure 4. Duration of Residency at Current Location.

Income Distribution

Household income distribution, representing 71 of 83 reporting households, is shown in Figure 5 . Sixteen (22.5%) had yearly incomes less than $15,000 and 43 (60%) reported incomes less than $35,000 per year. Slightly more than one-quarter (27%) reported annual incomes from $35,000 to $55,000, whereas 6 households (8.5%) reported incomes in excess of $95,000 per year.

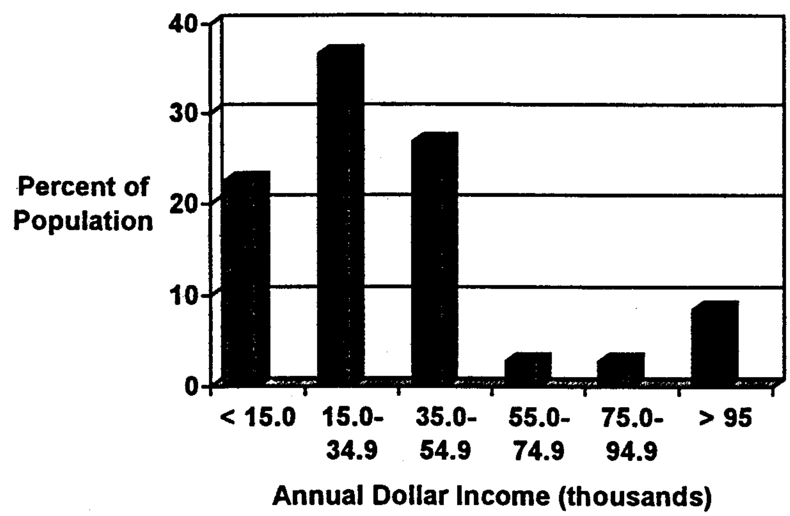

Figure 5. Income Distribution of Survey Population, by Household.

Water Quality Issues

Respondents were asked for opinions about the general quality of well water in Oregon and about the need for mandatory nitrate testing for private wells. Responses are shown in Figures 6 and 7. Approximately 73 percent of the respondents rated Oregon well water as either excellent or

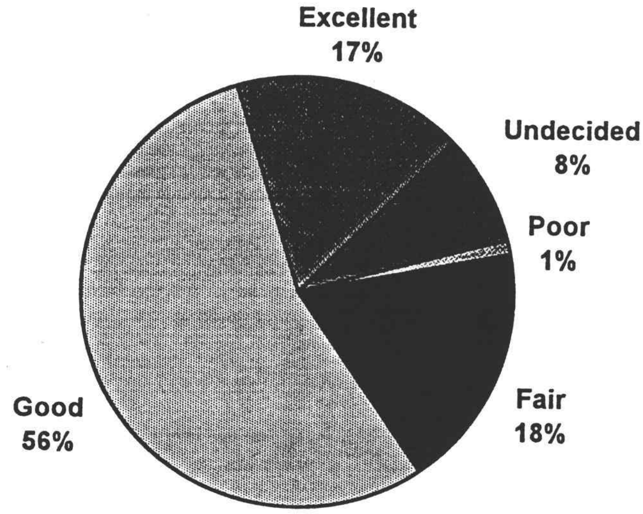

Figure 6. Opinions About Well-Water Quality in Oregon.

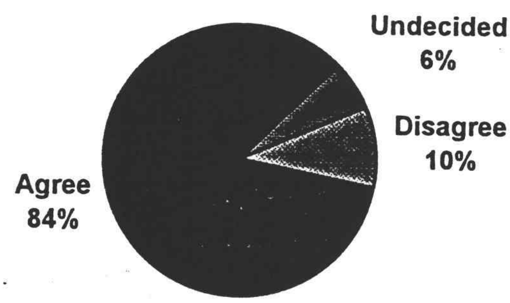

Figure 7. Opinions Toward Mandatory Well Testing in Oregon.

good, whereas less than two percent felt that the quality of well water was poor. However, 84 percent of the respondents agreed that mandatory testing of private wells should be conducted prior to use for drinking purposes.

Ten percent of the respondents disagreed with this statement.

The 80 wells within the survey area constituted approximately six percent of all private wells in the LUB. In this area, sampled nitrate concentrations ranged from a high of 40.0 ppm nN to a low of 0.0 ppm nN. The median nitrate concentration for all wells was 4.5 ppm nN. Thirty-seven (46.3%) wells had water nitrate levels which were equal to or greater than 5ppm nN, whereas six (7.5%) wells had nitrate levels which were below detectable limits.

Potential Sources of Well Pollution

Respondents were asked to identify local sources of potential water-well nitrate contamination, such as the presence of agricultural crops, barnyards, feedlots, or septic systems within 30 m (100 ft) of well locations. Three of 83 households reported the location of barnyards within 30 meters of their wells, and 32 households reported the presence of either septic systems, agricultural crops, vegetable gardens, or pastures within 30 meters of their wells.

Because shallow wells are generally more at risk of nitrate contamination than deeper wells (Hallberg, 1987; Keeney, 1986), well depth and nitrate concentrations were compared for 78 wells in the LUB survey area. The results are shown in Figure 8. In general, shallow wells (less than 50 m in depth) were more apt than deeper wells to have nitrate levels of 10 ppm nN or more. However, the majority of the 78 wells (i.e., 46 wells) had water-nitrate content of less than 10 ppm nN and were less than 50 meters in depth, with 36 of these 46 wells containing water with nitrates of 5 ppm nN or less.

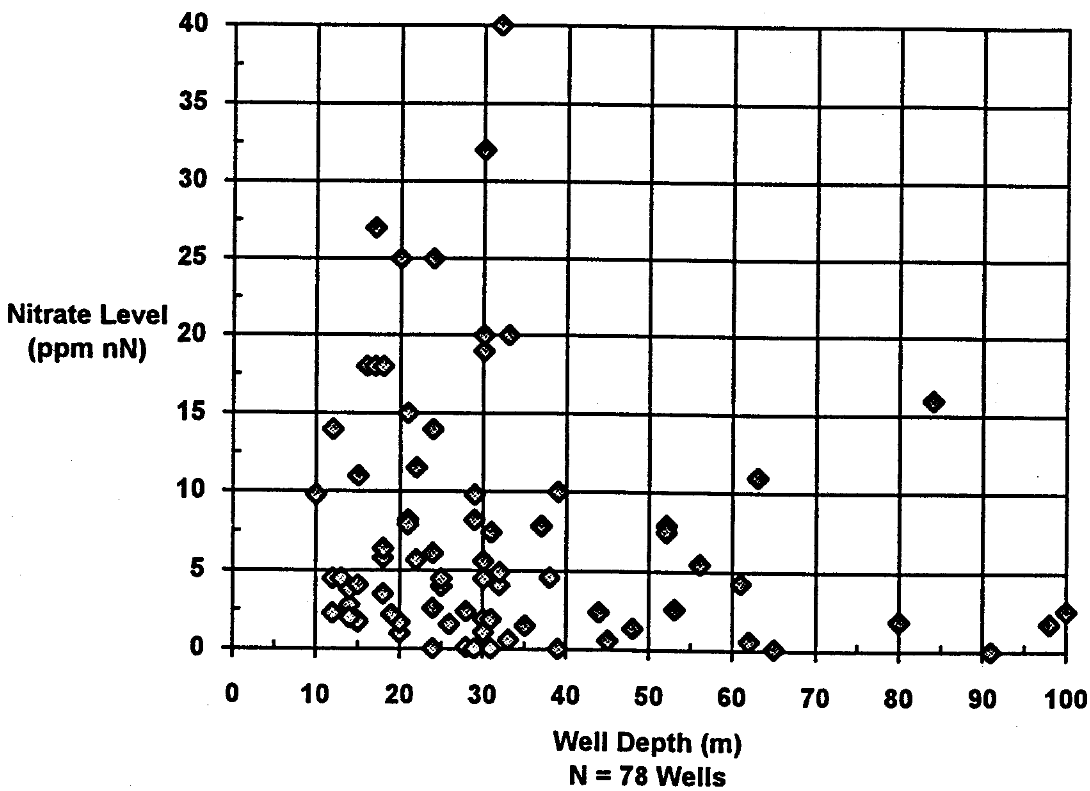

Figure 8. Nitrate Level vs. Well Depth for Private Wells in LUB Survey Area.

Use of Water Purification Systems

Several of the surveyed households had installed water purification devices. Eight households (9.6%) used reverse osmosis purifying systems, 75 percent of which had been in place three years or more. Seven households (8.4%) employed charcoal filter devices and 10 households (12%) used alternative water-treatment methods which were not capable of removing nitrates, such as sand filters or water softeners (Vomocil & Hart, 1991). In addition, two households used bottled and/or city water because Oregon DEQ sampling had revealed nitrates in excess of the maximum contaminant level (MCL) in their well water.

Nitrate Exposure

In this study, exposure to well-water nitrates is defined as any ingestion (without regard to quantity) of well water containing nitrates. Table 2 summarizes nitrate exposure levels by gender for the total survey population in the range 0 to 40 ppm nN.

Table 2. Population Exposure to Well-Water Nitrates by Gender.

	Total Number	Males	Females
Number Exposed	221	114	107
Median Concentration (ppm)	4.5	4.5	4.1

Of the total population surveyed, 127 (57.5%) individuals had been exposed to nitrate concentrations between 0.0 and 4.9 ppm nN; 44 (19.9%) had been exposed to concentrations between 5.0 and 9.9 ppm nN; and 50 (22.6%) had been exposed to concentrations from 10.0 to 40.0 ppm nN

(Figure 9). Similar percentages of males and females were exposed to the three ranges of nitrate concentrations considered (Figures 10 and 11).

Almost 61 percent of the population exposed to 4.9 ppm nN or less in their well water were 40 years of age or older; approximately 55 percent of those exposed to levels from 5.0 to 9.9 ppm were 40 years of age or older; and 72 percent of those exposed to 10 ppm nN or greater were 40 years of age or older. One child under six months of age was exposed to a water-nitrate concentration of 4.9 ppm nN or less, and no children less than six months of age were exposed to higher nitrate concentrations. The actual number of individuals from each age group for each range of exposure is shown in Table 3.

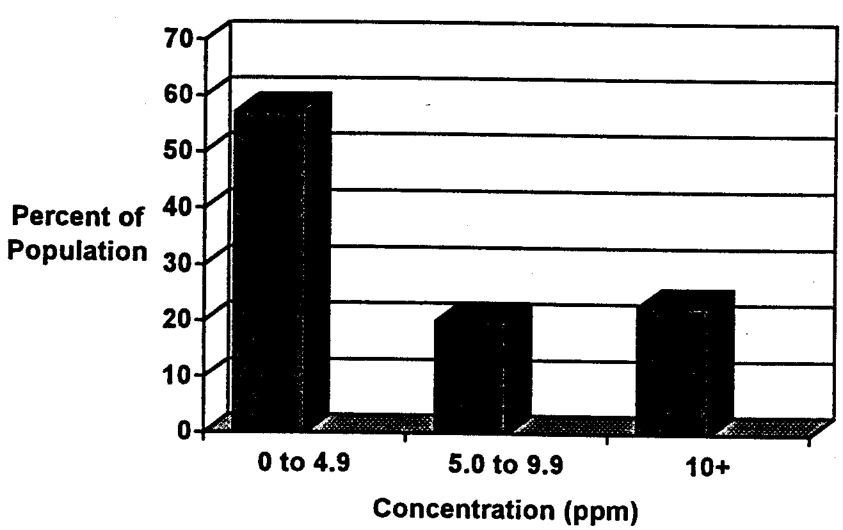

Figure 9. Well-Water Nitrate Exposure for Total Survey Population.

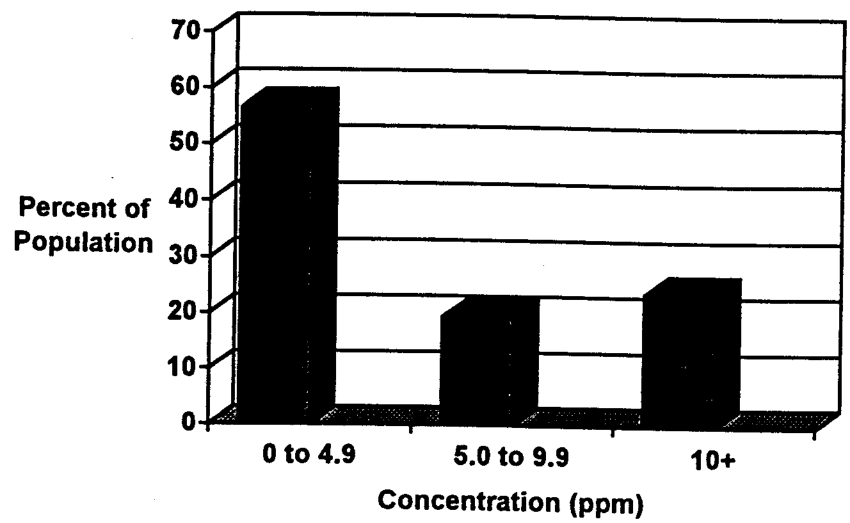

Figure 10. Well-Water Nitrate Exposure for Males in Survey Population.

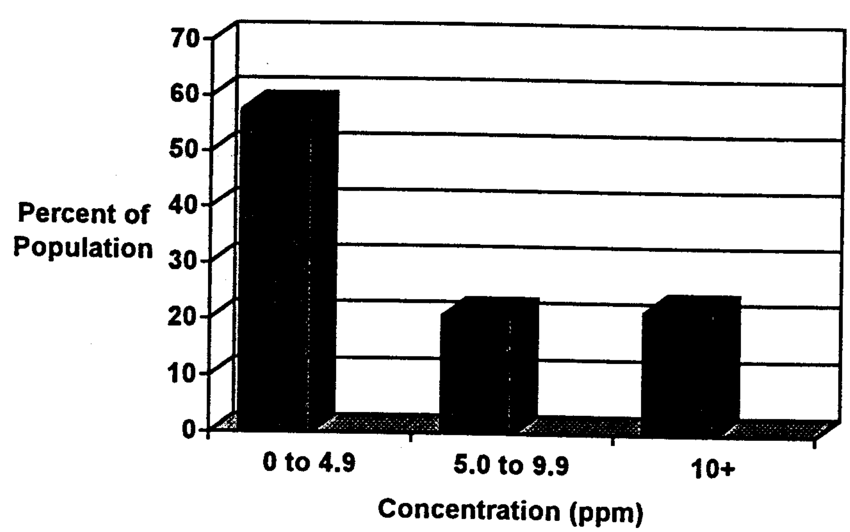

Figure 11. Well-Water Nitrate Exposure for Females in Survey Population.

Table 3. Population Exposure to Well-Water Nitrates by Level and Age.

	Level of Exposure		
Age Group (years)	0-4.9 ppm nN Number (%)	5-9.9 ppm nN Number (%)	≦ 10 ppm nN Number (%)
0 to 0.5	1 (0.8)	0 (0.0)	0 (0.0)
0.6 to 5	11 (8.8)	3 (6.8)	1 (2.0)
6 to 18	9 (7.2)	11 (13.6)	7 (14.0)
19 to 40	28 (22.4)	6 (13.6)	6 (12.0)
> 40	76 (60.8)	24 (54.5)	36 (72.0)
Total	125	44	50

Figures 12, 13, and 14 report age distributions for the three exposure ranges. The three infants included in the population were among households whose well water had less than 4.9 ppm nN. The youngest individual, an infant of three months of age, resided in a household where well-water nitrates had been sampled at 4.5 ppm nN. At the time of the survey, the infant was fed formula prepared with well water and also received daily supplemental feedings of several ounces of plain well water or drinks mixed with well water. Two other infants, ages 8 and 11 months, were exposured to 4.1 and 1.8 ppm nN, respectively. None of these infants was reported to have experienced GI disturbances or diarrhetic conditions.

In addition, from the total population surveyed, three women were pregnant at the time of the survey. Reported well-water nitrate concentrations at their residences were 0.6 ppm, 4.5 ppm, and 4.9 ppm nN.

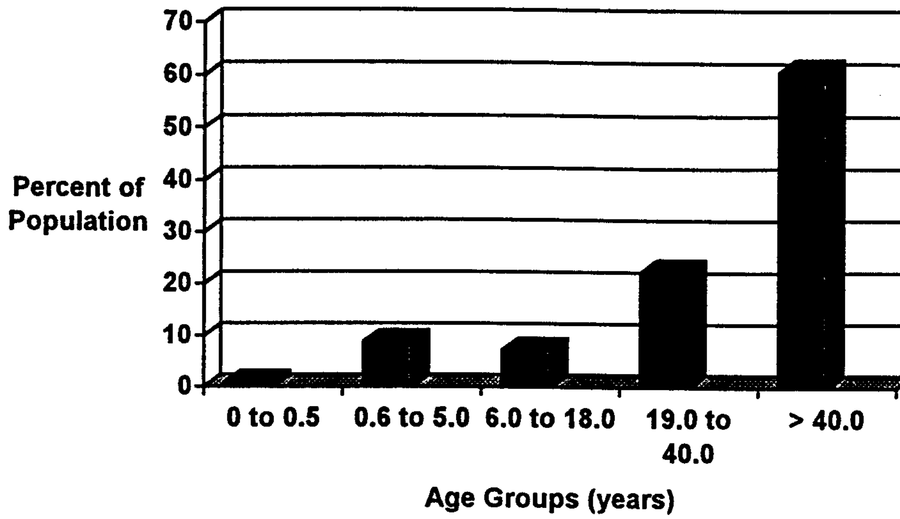

Figure 12. Total Survey Population Exposed to Well-Water Nitrates, 4.9 ppm nN or Less.

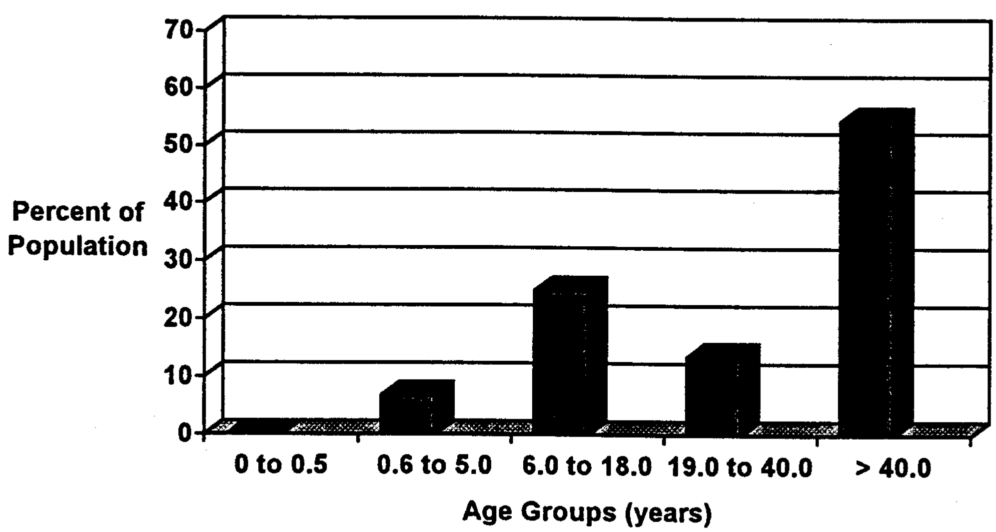

Figure 13. Total Survey Population Exposed to Well-Water Nitrates, 5.0 to 9.9 ppm nN.

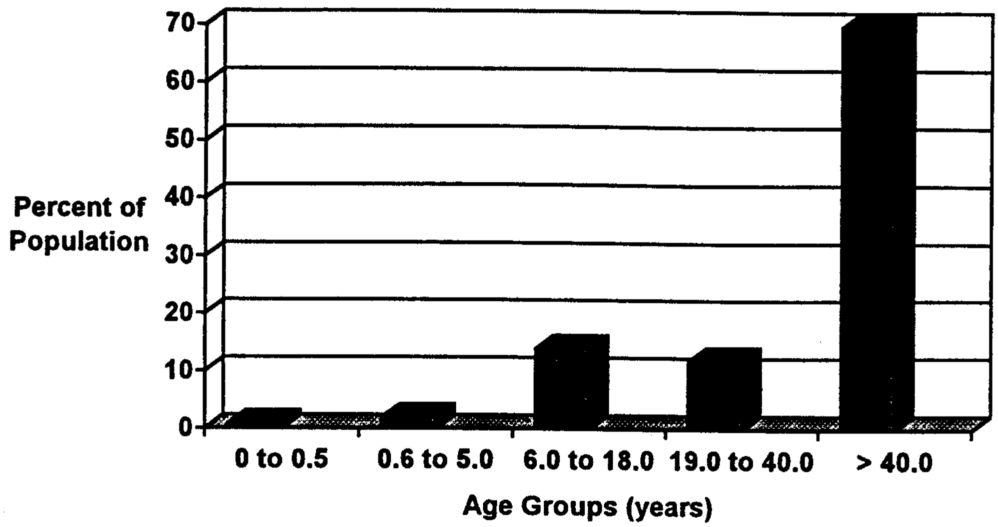

Figure 14. Total Survey Population Exposed to Well-Water Nitrates, 10 ppm nN or Greater.

Discussion of the Results

Well-Water Nitrate Levels

The median nitrate levels for wells serving the households surveyed in the Lower Umatilla Basin area were three times greater than national median levels for well nitrates. National median concentrations for community water systems and private wells combined was recently reported at 1.6 ppm nN (USEPA, 1990), whereas the median concentration for the survey area was 4.5 ppm nN (Oregon DEQ, 1991). Nationally, 2.4 percent of all rural private wells exceeded the 10 ppm nN maximum contaminant level, whereas 25 percent of the LUB survey wells exceeded this level.

LUB survey findings were similar to those reported in an earlier study of well-water nitrates in northern Malheur

County (Oregon), where approximately 30 percent of the sites exceeded 10 ppm nN MCL (Oregon DEQ, 1990). The LUB, like the northern Malheur County area, was chosen by the Oregon DEQ for more intensive study because of the known existence of relatively high groundwater nitrate levels.

Local Sources of Potential Pollution/Well Depth and Nitrate Concentration

Of the 80 wells surveyed, 33 were located within 30 meters of potential sources of nitrate contamination, and 17 (51.5%)of this number had reported nitrate levels of 5 ppm nN or greater. Of the remaining 47 wells with no apparent sources of potential local nitrate pollution reported, only 15 (31.9%) had nitrate concentrations of 5 ppm nN or greater.

These results suggest a possible relationship between nearby potential sources of nitrate pollution and nitrate concentrations in the LUB wells. If confirmed by further investigation, these findings would not be unusual in light of previous studies conducted in other states, demonstrating relationships parallel to the findings of the present study (Exner & Spaulding, 1985; Hallberg, 1987).

Among the private wells included in this study, there was an apparent if nonlinear relationship between well depth and well-water nitrate concentration, with nitrate concentrations generally decreasing with increasing well depth. This finding is in agreement with those of Hallberg (1987) and Keeney (1986) with respect to the increased risk of nitrate contamination in shallow wells.

Exposure and Risk

Although a high percentage of the residents in the survey area (22.6%) were exposed to nitrates at or above the 10 ppm nN MCL, 72 percent were over age 40 years. Because no infants were exposed to well-water nitrates above the MCL level, the risk of infant methemoglobinemia was considered to be low among the population considered at the time of the survey. Although the youngest infant in the survey population (three months of age) was fed formula prepared with well water and was receiving supplemental feedings based upon well water, she was exposed to waterborne nitrates which were well below the concentration levels considered to predispose infants to methemoglobinemia. Two older infants were also exposed to well-water nitrate levels that were not considered to constitute a health risk for their age groups. All of these infants' susceptibility to methemoglobinemia was further reduced because they were reported to have experienced no GI disturbances or diarrhea.

Of the eight women exposed to well-water nitrates exceeding 10 ppm nN, only four were of childbearing age and an additional four were between the ages of 11 to 18 years.

All of the childbearing-age women were married, but three were near the end of the childbearing years.

Three women were pregnant at the time of the survey, but were exposed to well-water nitrates below levels considered to be a health hazard. Although metHb levels rise during pregnancy (USEPA, 1987), no cases of maternal methemoglobinemia in humans during pregnancy have been documented. The literature also suggests that nursing infants who may ingest nitrates through mother's milk are at only low risk (Green et al., 1982).

Therefore, should demographic patterns remain the same, and there is no sudden increase in the number of young families moving into the area, the risk of methemoglobinemia will remain low in the rural areas of the Lower Umatilla Basin.

Exposure Mediating Factors

Two factors, the use of reverse osmosis purifying devices and alternative water sources, lowered exposures to well-water nitrates among the survey population. Six of the eight reverse osmosis devices in use had been in service for three years or longer. This means that they were installed prior to the commencement of water quality sampling of private wells in the LUB by the Oregon DEQ in 1990 (1991). Two other units had been in use less than one year. One respondent, who used one of the recently installed devices, stated that "poor taste" rather than high nitrate levels was the primary reason for this procedure. However, it should be noted that the nitrate level in that particular sample was 19 ppm nN. The other household with a recently installed device did not share this high range of nitrate concentration (i.e., 1.7 ppm nN).

Reverse osmosis units provided protection for 12 individuals in five households, with well-water nitrate levels from 19 to 40 ppm nN. The youngest person protected in this category was 11 years of age, and eight others exposed to this level were over 40 years of age. Six other individuals with these devices were exposed to nitrate levels of 1.8 ppm nN or less. The Oregon Health Division discourages the ingestion of water with nitrate content of 20 ppm nN or above by both adults and children, and suggests the use of alternative sources of water at these levels (Stahl, 1991).

Two households with a total of five residents used bottled water and/or city water to avoid excessive well-water nitrates of 31 ppm and 14 ppm nN. One three-year-old child resided in the home with the lower concentration. Both households had begun to use alternative water sources during the previous year, following notification by the Oregon DEQ of well-water nitrates which exceeded the standard.

A total of 37 individuals (16.7%) were exposed to no nitrates in their well water, assuming: a) the reverse osmosis devices in use were functioning properly and able to completely remove nitrates, b) the bottled and/or city water were free of nitrates, and c) water samples from six wells (serving six individuals) with no detectable nitrates were accurately ~~analyzed~~ and nitrate levels were not subject to fluctuation. This group included only nine individuals under the age of 40 years, with the youngest age three years. Reverse osmosis users and those using an alternative water source (23 individuals), represented approximately 10 percent of the population surveyed. These avoidance measures were generally used when nitrates exceeded the 10 ppm nN MCL, and those individuals who employed these measures were primarily adults.

An important finding is that 14 of 20 households (70%) with well-water nitrate contents at or exceeding the 10 ppm nN level did not use purification devices, nor were they using alternative water sources to avoid exposure. Members of these households represented 15.8 percent of the surveyed population. Eleven of these 14 households, with a total of 27 residents, were supplied by wells with nitrate contents from 10.0 to 19.9 ppm nN. Of these 27 individuals, 20 were over the age of 40 years, three were between ages 11 to 14, one was a woman of childbearing age (38 years), two were male (mature adults less than 40 years of age), and the youngest was age six years. Although this group was exposed to nitrates which exceeded the water standard, the risk of methemoglobinemia was not high because of the absence of infant exposure. The remaining three of the 14 households, with a total of eight individuals, were supplied by well water with a nitrate content of 20 ppm nN or greater. All of these individuals, with the exception of two childbearing-age women (18 and 22 years) exposed to nitrate concentrations of 20 ppm nN, were over the age of 40 years. While there were no infants within this group, these individuals were exposed to water nitrate levels that exceeded Oregon Health Division recommendations (Stahl, 1991).

Individuals over 40 years of age composed the largest age group exposed to well-water nitrates of 10 ppm nN or more without the use of protective measures. These individuals may have opted to avoid protective measures because they believed they were not at risk of nitrate-related disease because of their age. Or, those who had installed one of several devices in common use (charcoal filters, paper filters, or water softeners) may have erroneously believed that these devices would remove nitrates.

Health

Though no currently existing medical conditions or illness were reported by respondents for anyone under the age of 20 years, it is unlikely this report was accurate. Respondents may have considered that the interviewer was not asking about routine illnesses for this age group, and reported only those conditions perceived as more serious or life-threatening. Because no GI illness was reported among any of the infants at the time of the survey, this health condition posed no increased risk of methemoglobinemia.

It is possible that some individuals considered may have been predisposed to complications of an existing illness if diseased or malfunctioning tissues or organs had become oxygen-starved, such as occurs in conjunction with elevated blood metHb levels. This may be part of the underlying rationale when Hartman (1986) stated that relatively high endogenous nitrite formation among the very old increases the risk of death. Based upon this reasoning, there was no apparent increase in the risk of medical complications due to high metHb levels among very old individuals in the survey population. Only four of the seven people over 80 years of age were reported by respondents to have relatively serious medical conditions. Two of these four individuals were exposed to low nitrate levels in their well water (0.0 and 1.8 ppm nN), and the remaining two individuals were subject to reduced nitrate levels from the use of a reverse osmosis unit.

Permanency of Population

The population in the survey area was relatively permanent and stable. The majority of families owned their homes and lived in permanent-type dwellings. Few families were planning to relocate. No significant movements of families to or from the survey area was occurring, and no major movements were anticipated in the future. Any growth in the rural population was expected to occur only at a slow rate (Tom Gillese, personnel communication, Dec. 30, 1992). Because few women of childbearing age resided in the survey area, and because no significant increase in younger families could be anticipated, the infant population was not expected to grow appreciably. This finding suggests there will be a continuing low risk of methemoglobinemia among the survey population.

Limitations of Study

The findings of this study are limited to the LUB area for several reasons. First, wells were not randomly selected for water sampling by the Oregon DEQ. The primary purpose of the sampling process was to profile the general nature and degree of groundwater contamination occurring in shallow aquifers, the type used by most rural residents for supplying their well water, and was not to investigate population exposure. Second, sampling was completed in an area already known to have relatively high concentrations of groundwater nitrates, and the research purpose of this study was to employ existing data to investigate exposure to nitrates in an area where this had not previously been done. Finally, information determining exposure to water-borne nitrates was based on responses by household members to a telephone survey, and no attempt was made to quantify the amount of nitrates ingested in well water.

CHAPTER 5

CONCLUSIONS/RECOMMENDATIONS

Conclusions

This study investigated population demographics for the rural Lower Umatilla Basin, comparing these data to identified well-water nitrate levels for the purpose of estimating nitrate exposures and potential risk of adverse health effects in the survey area. Results of the investigation revealed that 25 percent of the domestic-use wells in the survey area had nitrate levels that were in excess of the 10 ppm nN MCL for drinking water, as established by the U.S. Environmental Protection Agency. From access to these wells, 23 percent of the surveyed population was exposed to nitrate concentrations in excess of the MCL standard.

Although exposure to well-water nitrates of a relatively high level was widespread, and almost all the residents were using nitrate-contaminated wells for their only source of drinking water, the risk of methemoglobinemia among the surveyed population remained low because few infants resided within the area. The degree of risk was probably not elevated for those women who were pregnant at the time of the survey, nor would it have been a concern for their newborn infants because these individuals were not exposed to high levels of nitrates in their drinking water.

The data did not reveal that medical conditions among either infants or the very old (80 years of age or older) predisposed these age groups to any appreciable increase in the risk of adverse health effects. Gastrointestinal disorders were not reported for the infants, and the nitrate levels reported would be unlikely to complicate any existing health disorders among the older residents. The sample over 40 years of age was either exposed to low water-nitrate levels or used reverse osmosis devices to reduce the nitrate levels in their well water.

Recommendations

Concerns in addition to the risk of methemoglobinemia should dictate the retention of the 10 ppm nN MCL for drinking water. An increasing number of scientific reports have indicated the existence of potentially chronic, adverse health effects in conjunction with the consumption of high levels of water-borne nitrate contamination. In humans, N-nitrosamines may form in vivo, predisposing exposed individuals to the risk of cancers (NRC, 1972). Moreover, nitrates may exert direct effects and produce birth defects (Dorsch et al., 1984) and behavioral or developmental aberrations (Gottlieb, 1988). Until the role of nitrates/nitrites in the etiology of these chronic conditions is elucidated, prudence dictates the maintenance of low exposure levels to drinking-water nitrates.

As part of the effort to reduce the total body burden of nitrites, and at the same time reduce the potential for both acute and chronic adverse health effects, the use of foods believed to protect against nitrites should be encouraged by health authorities. Public education efforts have been conducted in the LUB aimed at the reduction of the risk of methemoglobinemia. These efforts should be continued on a periodic basis, with the addition of information about those foods which may afford protection.

Continued monitoring of private wells by state agencies is recommended, with attention directed at domestic-use wells with nitrate levels in excess of 10 ppm nN. This information should be shared with local health departments for follow-up, investigation, and educational efforts as needed.

Avoidance measures should be taken by individuals exposed to well-water nitrate levels in excess of the U.S. EPA standard. When feasible, private-well users should seek connections to community water systems by means of annexation to communities with existing systems. Bottled water used as an alternative source must be of known (low) nitrate content to be regarded as a safe substitute. Reverse osmosis and other point-of-use water treatment devices are not universally recognized as offering adequate water treatment for nitrates, and are not recommended by the Oregon Health Division (Stahl, 1991). Individuals relying on these devices need to be informed of their limitations, and ongoing maintenance of these units and testing of the treated water should be encouraged.

Finally, studies by the Oregon DEQ or other agencies which seek to document the sources of well-water nitrate contamination in the LUB should include an investigation of the influence of local sources of nitrate contamination.

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APPENDICES

Appendix A

Telephone Survey Questionnaire

WELL SURVEY INTRODUCTION

NAME ______________________

PHONE______________________

LUB WELL SURVEY

Hello, is this the ____________________residence? **(IF NO, READ NUMBER. IF INCORRECT, TERMINATE WITH:** I'm sorry I have the wrong number.) **REDIAL CORRECT NUMBER.**

My name is Tom Mitchell. I'm calling from Oregon State University in Corvallis. Did you receive my letter? **(IF NO, STATE:** I'm sorry yours didn't reach you. It was a brief letter explaining a little about this study, and letting people know know I'd be calling them.)

Am I speaking to the person who knows the most about food preparation in your home? **(IF NO, STATE:** May I speak with that person?)

I'm doing a research survey on the residents of the Lower Umatilla Basin and their use of well water. Your name was selected from DEQ records because they indicate that you have a private well that was sampled in the past two years. This survey will only take about 8 to 10 minutes. It's voluntary, and you may withdraw at any time. Also, if you don't wish to answer a question, just let me know and we can skip to the next one. I want you to know that the information you give me will be treated in strict confidence. I'd be happy to hear any comments you might have, but I would appreciate it if you could hold them until the end. Okay?

Date	Time	Results (code)	Time to Recall Day/Time

Codes for results:

NH - Not Home
CB - Call Back
REF - Refused
PC- Part Completed
COMP - Completed

DK=Don't Know
NA=No Ans.(Refused)

1. Do you believe the quality of well water in Oregon is generally Excellent, Good, Fair, or Poor?

DK/NA 1
EXCELLENT 2
GOOD 3
FAIR 4
POOR 5

2. Would you agree or disagree with this statement: All new private water wells in Oregon should be required to pass a test for adequate water quality prior to use for drinking purposes.

DK/NA 1
AGREE 2
DISAGREE 3

3. Now, in order to find out what other information I need, I first need to know how many of the members of your household are using the water from your well for drinking? Is it . . .

DK/NA 1
ALL(**SKIP TO Q 3b**) 2
NONE(**SKIP TO Q 13**) 3
SOME 4

3a. For family members who ARE drinking your well water, do they live there 12 months out of the year?

DK/NA(**SKIP TO 3d**). 1
NO(**SKIP TO 3c**) . . 2
YES(**SKIP TO 3d**) . 3
SOME(**SKIP TO 3d**) . 4

3b. Do they live there 12 months out of the year?

DK/NA(**SKIP TO 3d**) . 1
SOME(**SKIP TO Q 3d**). 2
YES(**SKIP TO Q 4**) 3
NO 4

3c. What % of the time is spent there? _________%

3d. ALL of my remaining questions will be about household members who ARE drinking your well water and who are at least part-time residents there. Later, I'll ask you to identify them by age and ralationship. When I refer to "you" in the following questions, I'll really be referring to those household members who ARE drinking your well water and who ARE either full-time or part-time residents there.

4. Are you using your well water for cooking foods?

DK/NA 1
NO 2
YES 3

5. When you prepare foods that require water to be mixed with them, do you use well water?

DK/NA 1
NO 2
YES 3

6. Now, I'm going to ask if there are any children in your home, and if there are, I'll ask some questions about their eating habits. Do you have any children in your home who are under 6 mos. old?

DK/NA(SKIP TO Q 10) 1
NO (SKIP TO Q 10) 2
YES 3

6a. Is the child (Are the children) being fed formula, solid food, or other liquid drink?

DK/NA(SKIP TO Q 8) 1
NO (SKIP TO Q 8) . 2
YES 3

6b. Which type of food? Is it . .

FORMULA 1
SOLID FOOD . . 2
BOTH 3
OTHER LIQUID . . 4

6c. Type: ______________

6c. Is your well water used for preparing it?

DK/NA(SKIP TO Q 9) 1
YES(SKIP TO Q 7) 2
NO 3

6d. What is used to prepare it?

(SKIP TO Q 9)

7. Is the water being boiled before preparing the formula/food?

DK/NA 1
NO 2
YES 3
(SKIP TO Q 9)

8. If formula or solid foods are not being used, is the child (Are the children) being breast fed?

DK/NA . . . 1
YES 2
NO 3

8a. What feeding method is used?______________________

9. Is the child (Are the children) also being supplemented with well water or drinks prepared with well water?

DK/NA(**SKIP TO Q 10**) 1
NO(**SKIP TO Q 10**) . 2
YES 3

9a. About how much water per day is supplemented? Is it . . . .

1 to 5 ounces 1
5 to 10 oz. 2
10 to 15 oz. 3
Over 15 oz. 4

9b. Of the well water that's supplemented, is it being boiled first?

DK/NA 1
NO 2
YES 3

10. Is there anyone in your household who is pregnant at this time?

DK/NA(**SKIP TO Q 11**). 1
NO(**SKIP TO Q 11**) . . 2
YES 3

10a. How many weeks pregnant are they? Is it . . . .

DK/NA 1
1 TO 12 WKS . . 2
12 TO 24 WKS . . 3
24 TO 36 WKS . . 4

11. Is there anyone in your household who <u>presently</u> has an illness or medical condition that has been diagnosed by a doctor? (HD, organ dis.,diabetes, Ca, circulatory dis., etc.)

DK/NA(**SKIP TO Q 12**) 1
NO(**SKIP TO Q 12**) . 2
YES 3

11a. What is the person's age and the illness or medical condition?

AGE	DIAGNOSIS
____	______________
____	______________
____	______________
____	______________

12. Along this same line, does anyone in your home have a problem digesting food?

DK/NA(**SKIP TO Q 13**) 1
NO(**SKIP TO Q. 13**) 2
YES 3

12a. Has the problem been diagnosed by a doctor?

DK/NA 1
NO 2
YES 3

12b. What is the person's age, and what is the problem or diagnosis?

AGE	PROBLEM/DIAGNOSIS
____	______________
____	______________
____	______________

13. Sometimes, people will use a different source of water, like bottled water, for drinking and cooking. Are you using a different source of water for drinking and cooking?

DK/NA **(SKIP TO Q 14)** 1
NO**(SKIP TO Q 14)** 2
YES 3

13a. How long ago did you change your water source?

LESS THAN 1 YR . . 1
1 TO 2 YRS AGO . . 2
2 TO 5 YRS. AGO . 3
Over 5 YRS. AGO . 4

13b. Why did you choose to use a different source?

13c. What source are you using?

BOTTLED**(SKIP TO Q 16)** 1
OTHER 2
OTHER WELL 3

13d. Type ______________
(SKIP TO Q 16)

13e. Location ______________________
(IF IN LUB, SKIP TO Q 4, OTHERWISE, SKIP TO Q 16)

14. Some people choose to filter or purify their water before use. Are you using any water filter or purifying devices in your home?

DK/NA **(SKIP TO Q 16)** 1
NO **(SKIP TO Q 16). .** 2
YES 3

14a. Which fixtures have filters or purifying devices on them?

	NO	YES	DK/NA
A. KITCHEN	1	2	3
B. BATHROOM(S) .	1	2	3
C. OTHER	1	2	3

14b. Where? ______________________________

15. What type of filter or purifying devices are you using? Is it..

	NO	YES	DK/NA
A. CHARCOAL . .	1	2	3
B. DISTILLATION .	1	2	3
C. ION EXCH. . .	1	2	3
D. REV. OSMOSIS .	1	2	3
E. Other	1	2	3

15a. Type ________________

16. In order to get some idea of how settled you are in your present location, I'd like to ask a few related questions. How long have you lived in your present location? Is it . . . .

LESS THAN 1 YR. . .	1
1 TO 2 YRS.	2
2 TO 5 YRS.	3
5 TO 10 YRS. . . .	4
Over 10 YRS	5

16a. Was your last home in the LUB area?

DK/NA(**SKIP TO Q 17**).	1
NO(**SKIP TO Q 17**) . .	2
YES	3

→16b. What city or area? ______________________

17. Are you planning to move from your present location within the next year?

DK/NA(**SKIP TO Q 18**).	1
NO(**SKIP TO Q 18**) . .	2
YES	3

→17a. About how many miles from your present location will you be moving? ______________ Miles

18. What type of home are you living in? Is it a . . .

A. FRAMED HOME	1
B. MANUFACTURED HOME . . .	2
C. MOBILE HOME	3
D. OTHER	4

→18a. Type ______________

19. Do you own your home or do you rent?

DK/NA	1
OWN	2
RENT	3

20. Is the well you get drinking water from located at least 50 ft. from the septic tank and at least 100 ft. from the drain field?

DK/NA 1
YES. 2
NO 3

20a. Describe location of septic tank and drain field:

21. As far as you know, is your septic system working properly?

DK/NA 1
YES 2
NO 3

21a. What is the problem? ______________________

22. Is there a barnyard or feedlot within 100 ft. of your well?

	NO	YES	DK/NA
A. BARNYARD	1	2	3
B. FEEDLOT	1	2	3
C. OTHER	1	2	3

22a. Describe:

23. Are any agricultural crops being grown within 100 ft. of your well?

DK/NA 1
NO 2
YES 3

23a. Type crop/How close?

WE'RE JUST ABOUT DONE NOW. JUST TWO MORE QUESTIONS.

24. Your answer to the following question will help in figuring out the number of people in the various age groups that live in the LUB. Could you please give me the following information on each person in your household:

1) their relationship to you; 2) their age; 3) whether or not they're drinking the water; and 4) whether or not they live in your home 12 months out of the year. I'll also need your age.

RELATIONSHIP	AGE	SEX M	SEX F	DK. WATER	YR.-ROUND yes	YR.-ROUND no
Respondent	____	1	2	____	1	2
____________	____	1	2	____	1	2
____________	____	1	2	____	1	2
____________	____	1	2	____	1	2
____________	____	1	2	____	1	2
____________	____	1	2	____	1	2
____________	____	1	2	____	1	2
____________	____	1	2	____	1	2

25. I'm now going to read a series of income levels representing total, combined household income before taxes for 1991. Would you please let me know when I reach the range that best represents your level by saying "stop"?

UNDER 15,000 1
15-34,999 2
35-54,999 3
55-74,999 4
75-94,999 5
OVER 95,000 6

26. **By observation:**

MALE 1
FEMALE . . . 2

That's the end of the interview. You've been very helpful, and I thank you. Do you have any comments you would like to make?

You have a good evening/day. Good-by.

Appendix B

Letter of Introduction

DEPARTMENT OF
PUBLIC HEALTH

OREGON
STATE
UNIVERSITY

Waldo Hall 256
Corvallis, Oregon
97331-6406

Telephone
503-737-2686
Fax
503-737-4001

June 26, 1992

1~
2~
3~

Dear 4~:

Within the next three to ten days, I will be calling you from Corvallis as part of a research study I am doing at Oregon State University. My name is Tom Mitchell, and I am a graduate student working on a masters degree in Environmental Health. My thesis investigates nitrates in well water and the uses of well water by the residents of the Lower Umatilla Basin. This is an independent study and is not being directed by the State or other governmental agency. Your name was selected from Oregon Department of Environmental Quality records which indicate your home has a domestic well that was sampled within the past two years for water quality.

When you are contacted, I will be asking to speak to the member of your household who does most of the food preparation and knows the most about eating habits of the people in your home. The survey will only take eight to ten minutes. Your participation is voluntary, and you may withdraw at any time. The information you give me will be treated with strict confidence. Also, if I should reach you at an inconvenient time, please tell me and I will be happy to call back later.

If you have any questions about this study before you are called, you may contact me by phone at 752-1408 or by mail. Questions you may have about your well water quality or past survey results may be directed to Dennis Nelson at the Oregon Health Division. His phone number is 731-4889, and his address is 1400 S.W. 5th, Portland, OR 97201.

Sincerely yours,

Thomas J. Mitchell
Masters Candidate

Anna K. Harding, Ph.D.
Major Professor

cc: Henry Lorenzen, Citizens Groundwater Committee Chairperson 276-3331

Emil Holeman, Umatilla County Commissioner 276-7111

Ray French, Morrow County Commissioner 676-9061

Luther Fitch, Senior O.S.U. Extension Agent 276-8321

Gerald Grondin, Hydrogeologist 229-6743

Gary Burnett, Regional Engineer 276-8006

Mike Ladd, Regional Watermaster 276-7111

Dennis Nelson, Geologist 731-4889