WELL WATER CONTAMINANTS AND CONSUMER-BASED TREATMENT SYSTEMS: A RESOURCE FOR PRIMARY CARE PROVIDERS

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ABSTRACT

An estimated 95% of rural residents use groundwater as their household water supply for drinking and everyday use. Public policy in Montana and through most of the United States dictates no rules about well water testing, only recommends testing be done on a yearly basis. Well water can contain lead, arsenic, volatile organic compounds (VOCs), synthetic organic compounds (SOCs), nitrates, and copper and many other possible contaminants. The choice of a consumer-based water filtration system should be based on the contaminant profile of the water source. Filter types vary in design and their contaminant removal profile, such as simple pitcher filters, activated carbon, and reverse osmosis, but many filtration systems can remove multiple contaminants and reduce the risk of exposures. The purpose of this project is to provide a list of potential contaminants and their health effects that have commonly been identified as contaminants in water samples in Gallatin County, Montana, as well as provide a comprehensive resource for consumers and health care providers to make decisions about well-water treatment.

CHAPTER 1

INTRODUCTION

In August 2007 a southwest Montana community in Gallatin County had its drinking water supply threatened with possible contamination of bacteria and nitrates (Richardson, 2007). The threat of contamination had residents seeking information about the health effects of these contaminants. There were many questions during visits with primary care providers about how to treat this contamination and if the water was safe to drink. Many of these questions focused on the possible health effects of the contaminants on their families and how to abate this contamination with filtration systems.

Rural residents rely heavily on ground water supplies and groundwater makes up 96% of the world's total freshwater reserves (Sahoo, Ray, & Wade, 2005). There are approximately 15 million wells used for domestic water in the United States (US) and 99% of individual domestic wells use groundwater that is untreated (Squillace, Scott, Moran, Nolan, and Kolpin, 2002). Approximately 95% of rural residents use ground water as their source of drinking water (Sahoo, Ray, & Wade), so healthcare professionals working in rural areas should be aware that drinking water wells frequently contain one or more environmental contaminants (Kross, Hallberg, Bruner, Cherryholmes, and Johnson, 1993). The widespread use and storage of many chemicals has led to an increased release of chemicals into the environment and many of these chemicals are commonly found in groundwater supplies. Many chemical contaminants have also been found to be resistant to degradation once in the ground and can be found in groundwater for decades after use (Chalupka, 2005).

Water constitutes 60-70% of the human body and plays a large role in many functions of the human body. The current recommendation for daily water intake by the Institute of Medicine (2004) for women is approximately 90 ounces of water per day and 125 ounces per day for men, including all food and beverage sources. This amount of fluid intake can cause a potentially harmful level of exposure to many toxins if the water source has been contaminated. The exposure to contaminants in drinking water can have many deleterious effects on the body and can contribute to or cause many diseases as a result of the exposures. Prevention of the exposures to these contaminants by using the proper water treatment can have a profound impact on the health of entire households and save future health problems from occurring, as well as reducing future healthcare visits and expenditures for families.

The National Ground Water Association (NGWA) recommends testing groundwater wells annually for bacteria, nitrates, and any other contaminants of local concern (NGWA, 2007). The NGWA also recommends testing more often for changes in taste, odor, or appearance, recurrent incidence of gastrointestinal symptoms in the family, an infant living in the home, and for monitoring home treatment systems. It is also recommended that testing be done to protect pregnant members of the household (Weir, 2005).

The use of consumer-based water filtration units can remove contaminants from well water. Once a water source has been found to contain contaminants, the profile of the contaminants can be used to find the most appropriate filtration unit. There are numerous types of units that are available that can be easily installed into many homes. The price range of these units varies widely, but there is also a large variation in contaminants they filter. With the proper identification of well water contaminants, healthcare providers can help to guide patient selection of consumer-based water treatments systems.

The purpose of this project is to first outline the many possible contaminants that may occur in groundwater wells in Gallatin County, including lead, copper, arsenic, nitrate, synthetic organic chemicals (SOCs), and volatile organic compounds (VOCs). Second, this project will describe consumer-based water treatment systems that can be used to abate contamination. The identification and implementation of the appropriate consumer-based filtration system can prevent many deleterious short- and long-term health effects from occurring in populations that use ground water wells.

CHAPTER 2

REVIEW OF LITERATURE

It is estimated that the average American drinks three glasses of water per day (Chalupka, 2005) and more than 50 percent of the population relies on groundwater as a source of drinking water (Tabbot & Robson, 2006). Depending on the water source, this can result in the potential exposure to many different contaminants. The US Environmental Protection Agency (EPA) currently regulates 87 known natural and synthetic contaminants for drinking water from regulated sources (US EPA, 2006). However, upwards of 15 million families in the US obtain their drinking water from unregulated well water (Greer & Shannon, 2005), for which the standards of the Safe Drinking Water Act do not apply to private wells or water supplies for fewer than 25 people (Chalupka). Additionally, since private residential wells are not required to systematically check for contamination the number of contaminated well-water supplies is unknown (Aelion & Conte, 2004; Tabbot & Robson).

Contaminants occur in surface, ground, sediment, and drinking water via two primary routes: point-source pollution and non-point source pollution (Ritter et al, 2002). Point source pollution can occur from areas such as steel mills, food processing plants, and municipal sewage treatment plants (Ritter et al). Non point-source pollution, such as agricultural runoff, storm water runoff, and atmospheric deposition, occurs over broad geographical areas. (Ritter et al). Land use also has a significant effect on the detection of groundwater contaminants (Squillace et al, 2002).

The most common sources of groundwater pollution include leaking underground storage tanks, septic tanks, municipal landfills, and farming practices (Tabbot & Robson, 2006). Shallower wells are generally considered more prone to anthropogenic contamination than deeper wells (Squillace et al, 2002). However, public supply wells, which are generally deeper than domestic wells, are more prone to anthropogenic contamination as a result of their location in urban areas (Squillace et al). Though well depth is commonly used to explain the presence of many contaminants, it has commonly been found to vary inversely with pesticide detection (Barbash, Thelin, Kolpin, and Gilliom, 2001).

Contaminants from both point and non-point sources may pose significant risks to human health and effects can vary widely from subclinical manifestations to death. It is important to remember that many cases of waterborne disease are subclinical since an exposure to a contaminant can occur for many years before clinical changes or effects can be seen (Physicians for Social Responsibility, n.d). The repeated exposure to contaminants for many years can pose a danger to future health conditions of people that can far outweigh a single large dose. The chemicals involved in health risks can include nutrients, metals, pesticides, organic pollutants, chlorination by-products, and pharmaceuticals (Ritter et al, 2002). The US EPA currently sets standards for maximum contaminant levels (MCLs) allowable in public drinking water supplies that limit the exposure to contaminants.

The MCLs are set to “protect drinking water quality by limiting the levels of specific contaminants that can adversely affect public health and are known or anticipated to occur in water" (US EPA, 2006). These levels are not enforced for private domestic wells, but it is recommended they be followed when testing is done. The MCLs are included with a review of the contaminants below and are also included in Appendix A.

Contaminants

Nitrates/Nitrites: It is estimated that 2 million families drink water from wells that do not meet the drinking-water standard for nitrate (Greer & Shannon, 2005). Nitrates are possibly the most widespread contaminant of groundwater in the world (Liu, Ming, & Ankumah, 2005) and have become almost ubiquitous in shallow groundwater systems (Kross et al, 1993). Nitrates are commonly found to be in high enough concentrations to pose a hazard in rural areas (Ritter et al, 2002). Nitrate concentration in well water is significantly related to well depth, pH, and cropping activity; increased concentrations occur with decreased well depth and pH, and with increased cropping activity (Liu, Ming, & Ankumah). The current MCL for nitrate is 10 mg/L and for nitrite is 1 mg/L.

Agricultural land use can increase the probability of detecting higher levels of nitrates in groundwater wells (Aelion & Conte, 2004; Kross et al, 1993). The increased level of nitrates in agricultural regions is a result of the widespread use of fertilizers and animal manure, with the use of inorganic fertilizers suspected to be the most important factor for increased levels (Liu, Ming, & Ankumah, 2005; Chalupka, 2005).

Nitrate intake can cause many health problems. The conversion of nitrates to nitrites occurs upon ingestion in the saliva of people of all ages, as well as in the gastrointestinal tract of infants due to flora differences (Boink & Speijers, 2001). Infants are more susceptible to nitrates because they convert around 10 percent of nitrates to nitrite, whereas older children and adults only convert 5 percent (Boink & Speijers). Nitrites are then able to change the normal form of hemoglobin into the altered methemoglobin form, which disrupts the oxygen carrying capacity of erythrocytes (Boink & Speijers). The risk to infants is of concern when preparing formula with well water high in nitrates, placing them at a high risk for nitrate contamination. The most common clinical manifestation of methemoglobinemia is cyanosis. There is little to no risk of nitrate poisoning of infants on commercially prepared foods in the United States (Greer & Shannon, 2005). Nitrate intake by water is proportionately more important for children and is often the largest contributor of intake compared to adults (Kross et al., 1993).

Nitrate can also cause symptoms in older children and adults. These symptoms include irritability, tachypnea, altered mental status, and headache. It has also been found to be associated with increased risks of non-Hodgkin's lymphoma, spontaneous abortions, and bladder and ovarian cancers (Squillace et al, 2002). The increased risk of cancer is thought to be due to the effects of nitrites in the body that react with amine-containing substances found in food to form nitrosamines, which are known to be potent cancer causing chemicals (New Hampshire Department of Environmental Services, 2006).

Arsenic: Arsenic contamination is a problem that occurs on a global scale (Bhattacharya et al, 2007), appearing naturally in groundwater throughout the US in higher concentrations in groundwater wells than in surface systems (Afzal, 2006). Arsenic enters well water sources from natural deposits, industrial releases, agricultural runoff from pesticides, mining processes, and petroleum refining (Bhattacharya et al; Lubin, Freeman, & Cantor, 2007; Afzal). Chemicals that contain arsenic are commonly used in wood preservatives, manufacturing of agricultural chemicals, glass, metals, electronics, and industrial discharge (Chalupka, 2005). These products often contribute to the contamination of the soil and the groundwater from runoff.

Arsenic exposures can vary widely in the US based on dietary intake and concentration in the water supply (Tsuji, Yost, Barraj, Scrafford, and Mink, 2007). In 2006, the US EPA began a new standard for arsenic levels, lowering the maximum contaminant level from 50 mcg/L to 10 mcg/L to further prevent harmful effects of exposure. Levels of arsenic are considered to be highest in the western states compared to the rest of the US due to differences in climate and geology (Bhattacharya et al, 2007; Davey, Bodwell, Gosse, & Hamilton, 2007; Lubin, Freeman, & Cantor, 2007; Afzal, 2006).

The International Agency for Research on Cancer has identified sufficient evidence linking arsenic exposure to basal cell cancer of the skin, tumors of the bladder, kidney, liver, and lung; it has also been associated with blood vessel damage, peripheral vascular disease, and cardiovascular disease (such as hypertension and cardiac bypass surgery), numbness of the hands and feet, and diabetes mellitus (Lubin, Freeman, & Cantor, 2007; Zierold, Knobeloch, & Anderson, 2004). Arsenic may be the only human carcinogen for which there is evidence of increased risk from both inhalation and ingestion (Bhattacharya et al, 2007). It can also act as a potent endocrine disruptor at very low concentrations, disrupting gene regulation of endocrine receptors (Davey, Bodwell, Gosse, & Hamilton, 2007). Arsenic can also cross the placental barrier, increasing stillbirths, low-birth weight deliveries, spontaneous abortions, and post-natal mortality (Lubin, Freeman, & Cantor, 2007).

Copper: Copper is an essential nutrient for the human body in small concentrations to maintain normal metabolic processes, maintain hair and skin health, and repair and maintain connective tissue in the cardiovascular system (US EPA, 2006). Copper occurs naturally in ore deposits on the earth, but the greatest risk for exposure to copper contamination for water supplies lies in the corrosion of household pipes (US EPA). Copper concentrations also increase from water erosion of natural deposits when an acidic pH of the water occurs (Pitt, Clark, Parmer, and Field, 1996). Elevated levels of copper are often found below storm water drainage systems that have been used in paved areas of streets and highways (Pitt et al). The current MCL for copper is 1.3 mg/L.

Copper ingested by drinking water in the short term can cause gastrointestinal disturbance, including nausea and vomiting while long-term exposure above recommended levels can lead to liver and kidney damage (US EPA, 2006). Copper often accumulates in the liver and is released by the bile in normal conditions (National Digestive Diseases Information Clearinghouse, 2003). When copper levels rise to toxic levels the liver is unable to retain the excess copper and releases it directly into the blood stream causing systemic effects to occur. The systemic effects can include anemia, a low platelet and white blood cell count, kidney damage, and softening of the bones (National Digestive Diseases Information Clearinghouse). Some diseases, such as Wilson's disease, can cause people to retain copper and result in accumulation of toxic levels of copper.

Lead: Lead contamination in drinking water accounts for as high as 20% of an adult's total lead exposure and up to 85% for infants (Chalupka, 2005; Ternus, 1995). Lead in water-based exposures can occur as a result of leaching from old pipes in houses and from the soldering of copper pipes, old faucets, and water meters (Guidotti et al, 2007; Ternus). The current MCL for lead is 0.015 mg/L (US EPA, 2006)

There are no demonstrated functions of lead in the human body and lead exposure can result in a vast array of health problems (Ahamed & Siddiqui, 2007). It can act as a neurotoxin and/or can also result in kidney problems and hypertension (Ahamed & Siddiqui; Chalupka, 2005). Low level exposures to lead have a graded association with several disease outcomes and lead is also capable of inducing oxidative damage to many organs of the body, including the brain, heart, kidneys, and reproductive organs (Ahamed & Siddiqui). Lead exposure on the nervous system has been linked to lower IQ, memory reduction, limited attention span, and learning disabilities (Physicians for Social Responsibility, n.d; Ternus, 1995).

Lead levels in blood samples have an association with the amino acid homocysteine levels in the elderly, which signifies an increased risk of heart disease, stroke, peripheral vascular disease, and decreased cognitive function (Ahamed & Siddiqui, 2007; Physicians for Social Responsibility, n.d). Lead also affects membrane structure and function of all cells, with erythrocytes particularly affected since over 99% of lead in the body accumulates in erythrocytes (Ahamed & Siddiqui). The cell membrane is affected by lipid peroxidation caused by lead in the membrane and results in altered membrane integrity, permeability, and function (Ahamed & Siddiqui).

It also may be of particular concern in infants affected by methemoglobinemia from nitrate exposure since lead facilitates conversion of hemoglobin to methemoglobin (Ahamed & Siddiqui, 2007). Young children are also at increased risk for health problems related to lead exposures since their nervous systems are still developing. Additionally, the current EPA MCL for lead is not completely protective for children and health care providers should advise that children's exposure be reduced as much as possible (Guidotti et al, 2007).

Fluoride: Fluoride is often added to public water supplies to enhance teeth strength, but often occurs in ground water as a result of erosion of natural deposits or as a result of fertilizer use (US EPA, 2006). However, excess fluoride can cause pain and tenderness in bones as a result of bone disease (US EPA). Increased fluoride intake can also lead to severe dental fluorosis or disruption of tooth enamel causing staining or yellowing of the teeth, pitting, or mottling (Physicians for Social Responsibility, n.d), as well as nausea, vomiting, diarrhea, sialorrhea, abdominal pain, seizures, cardiac arrhythmias, and coma (American Academy of Family Physicians, 2007). The current recommendation for fluoride intake for children to maintain optimal oral health is 1 mg/day of consumed fluoride (American Academy of Family Physicians) and the current MCL for fluoride is 4 mg/L.

Volatile Organic Compounds (VOCs): VOCs are commonly found in groundwater and can be released in the air, water, and/or land to cause contamination of groundwater; they are also naturally formed in groundwater (Squillace, Moran, and Price, 2004). VOCs are also often used in solvents, fumigants, refrigerants, organic synthesis compounds, gasoline components, and the use of chlorine as a disinfectant produces large amounts of VOC byproducts, such as chloroform and bromoform, which are forms of trihalomethanes (THMs) (Williams, Benton, Warmerdam, and Sheehan, 2002) The presence of VOCs has been found to be increased in densely populated areas, but increased populations do not directly cause an increase in industrially derived VOCs (Aelion & Conte, 2004). According to a study conducted by the US Geologic Survey (2007), groundwater wells found in new residential areas used for drinking water had at least one VOC present in 88% of samples taken, with at least two VOCs found in 69% of samples (Squillace, Moran, and Price). VOCs are also more frequently detected than pesticides or nitrates (Squillace et al, 2002), with the most commonly found VOCs in water supplies across the US being chloroform, toluene, and perchloroethane (Squillace, Moran, and Price). The EPA has currently set MCLs for the individual VOCs of each contaminant and values vary dependent on the VOC. A complete list of the MCLs for the VOCs can be found in Appendix A.

Many VOCs are commonly found in water supplies and are considered to be potentially carcinogenic to humans, but there has been little study done on the relative risks of VOCs on human health in drinking water on a regional or national basis (Williams et al, 2002). There is potential for a large variation of effects on human health including cancer, eye irritation, nasal irritation, throat irritation, headaches, nausea, vomiting, dizziness, asthma exacerbation, cancer, liver damage, kidney damage, and central nervous system damage (Minnesota Department of Health, 2005; Cohn, Klotz, Bove, Berkowitz, and Fagliano, 1994).

Trihalomethanes, which are a type of VOCs, are by-products of drinking water disinfection and are less likely to be found in untreated water systems (Gibbons & Laha, 1999). However, recent research has shown that people who regularly drink tap water with elevated levels of disinfection by-products have a greater risk for bladder and rectal cancers than those who drink untreated water (Gibbons & Laha). Exposure to THMs may also result in adverse pregnancy outcomes, including low birth weight and spontaneous abortions (Gibbons & Laha). These contaminants can become vapors and the exposure to volatilized vapors through inhalation in the home accounts for the greatest total risk for most VOCs, but exposure to VOCs from routes other than inhalation may account for larger exposures than inhalation alone (Williams et al, 2002; Physicians for Social Responsibility, n.d).

Synthetic Organic Chemicals (SOCs): SOCs are commonly known as pesticides and include insecticides, pesticides, fungicides, and herbicides, but are commonly referred to by their functional class for the organisms that they are designed to control. SOCs have been detected in groundwater across the nation and have been found to reach shallow ground water within detectable concentrations within only 1 year after their initial application; a majority of those SOCs detected are herbicides (Sahoo, Ray, & Wade, 2005).

Currently, the EPA does not have an approval process for herbicides and has limited testing requirements for health effects of these chemicals, including hormone and immune system damage (Chalupka, 2005). The EPA has acknowledged that over 140 pesticides are neurotoxic, yet has only received neurotoxicity testing results for nine pesticides (Lanphear, Vorhees, and Bellinger, 2005). The EPA has established MCLs for the individual SOCs and these can be found in Appendix A.

Exposure to pesticides can result in many health issues, including genetic mutations, cancer (Non-Hodgkin's Lymphoma, Leukemia, Myeloma, sarcoma, prostate, pancreas, ovary, testis, kidney, brain, and stomach), and birth defects (US EPA, 2006; Alavanja, Hoppins, and Kamel, 2004; Ternus, 1995). The effects of herbicides in the water can also damage the reproductive system beginning in the uterus and continuing through the adult years (Ternus). Effects of pesticides can also be found in the liver and exposure can lead to liver damage, jaundice, and liver cancer (US EPA; Alavanja, Hoppins, and Kamel, 2004). Exposure to pesticides can also result in lung and throat irritation, leading to an exacerbation of lung problems, including asthma and lung cancer (Lee et al, 2006; US EPA; Alavanja, Hoppins, and Kamel). In addition, exposure of a fetus in-utero to pesticides may make a person more prone to obesity later in life (vom Saal, Newbold, Blumberg, Corcoran, O'Callaghan, 2007)

Neurotoxicity can also result from pesticide exposure. High levels of pesticide exposure can lead to coma or death, mild exposures can result in headache, dizziness, nausea, vomiting, pupillary constriction, and excessive sweating, tearing, and salivation (Alavanja, Hoppins, and Kamel, 2004). Long-term effects can also occur, resulting in deficits in cognitive and psychomotor function, decreased vibration sensitivity, and impaired nerve conduction (Alavanja, Hoppins, and Kamel). Pesticide exposure may have greater effects on the central nervous system than the peripheral nervous system, but more studies need to be done to support this since there is limited evidence for this conclusion (Alavanja, Hoppins, and Kamel).

Mixtures of Contaminants: The persistent use of compounds in agricultural use areas has a large affect on the presence of mixtures, resulting in frequent detection of some mixtures (Squillace et al, 2002). Frequently occurring mixtures in many ground water wells have now been identified, which makes it possible to predict what compounds to test for when others are found in the same areas (Squillace et al). The most commonly found mixtures were multiple VOCs in one sample or multiple SOCs in one sample, and metals and chlorinated hydrocarbons (US Geological Survey, 2007). A commonly found mixture is nitrates with the SOC atrazine, which has been found to have effects on thyroid levels, to decrease the ability of the immune system to make antibodies, and to alter aggressive behavior (Squillace et al). A mixture of chemicals, even with the mixture containing levels below that of the MCL, may produce effects that cannot be predicted from exposure to each chemical alone and may have a synergistic effect.

Microbial Contaminants: Common pathogens associated with well water contaminants include *Campylobacter*, *E. coli*, *Salmonella*, *Shigella*, enterovirus, norovirus, rotavirus, *Cryptosporidium*, and *Giardia*. These commonly occur with sewage contamination and agricultural runoff (Chalupka, 2005). *Cryptosporidium* can be especially dangerous to individuals that are immunocompromised and are also commonly resistant to many standard methods of disinfection and filtration (Chalupka). *E. coli* can cause an acute illness with diarrhea, or can result in uremic syndrome. Viral contaminants are common as well, are difficult to identify, and often result in a wide spectrum of illness.

Many of the above contaminants can be simply removed from water supplies by the addition of a consumer-based water filtration unit. The use of these units can decrease or eliminate many of the contaminants from the water supply when the correct unit is chosen based on the contaminant(s) present. Filters can be chosen based on the needs of the water system and, depending on the model, can be modified to be most effective to prevent the negative health consequences of the contaminants of concern. These units are also readily available and can be easily installed in the home.

Water Filters

Water filters can be an effective method to remove contaminants from water. Not every filter removes every contaminant so consumers and patients should be instructed as to which filter may be the most appropriate for their situation. More than one filter may be needed depending on the contaminants present in the drinking water supply. Maintenance and upkeep should be done on a regular basis for best protection when using a water filter. A complete listing of sample filters, their contaminant removal profile, price, general maintenance such as filter changes recommended by the manufacturer, and approximate filter change interval are included in appendix C.

Selection of the proper filter should be made based on multiple variables, the most important of which is the contaminant profile. Appendix B provides a list of each filtration type and the broad category of contaminants that it removes, which may provide a starting point for initial filter selection. Secondly, filters come in many different designs or styles and not all may be practical in every case. While many filters can simply be used on the counter-top or faucet, others require a larger storage area, such as under-sink types, which can be large and bulky. The third consideration is cost. Many filters may be available for certain contaminants, but there can be a large range of price when purchasing these filters. An under-sink reverse osmosis system can be 10 times more expensive than a pitcher type filter, but may not offer additional benefits compared to the pitcher filter depending on contaminants present. Long-term costs should also be taken into account, as frequent filter replacements can quickly make up the gap between an initially more expensive option and a cheaper type due to upkeep and maintenance.

There are currently two certification agencies used for setting standards and regulating water filters which are the National Sanitation Foundation International (NSF) and the American National Standards Institute (ANSI). The NSF currently operates using standards based upon those set by ANSI. These two agencies regulate the filters to ensure they remove particles to the levels advertised based upon EPA standards.

The following sections describe specific filter types reviewed for this paper. A prototype approach is used to review aspects of each type of consumer-based filtration system. While specific commercial products are discussed, no endorsements are implied.

Pitcher Type Filters: The pitcher type filters are very convenient and inexpensive. They are widely available in a variety of designs and are designed to filter out a limited number of contaminants, but can be of great value despite their need to be maintained more often than other filter types (see Appendix C). They are designed to be easy to transport, easy to maintain, but filters need to be replaced more often to maintain maximal efficacy than many other types.

The Brita Pitcher Filter cost around $25 and requires only the occasional filter change approximately every 40 gal. This system requires little maintenance and filter replacement is approximately $10. This system has a high long-term cost and price per gallon, but is very useful for short- to moderate-length use removing chlorine, cryptosporidium, and lead. Pitcher filters can vary greatly with each specific pitcher type and can also remove copper, some SOCs, and some VOCs. The full contaminant removal profile can be seen in Appendix C.

Faucet Mount Water Filters: Faucet mount filters are slightly more expensive than pitcher type filters, but have the potential to filter out many more additional contaminants. They mount quickly to the faucet, with some brands having bypass capabilities if filtration is not needed. They can be purchased with a large variety of contaminant filtration capabilities. They are also available with 2 or 3 stage filtration, with additional inserts potentially available to increase their filtration activity, such as activated carbon filters, which are discussed below.

A typical filter of this type is the PUR 2-Stage Faucet Mount Filter, with a cost around $30. This system is very easy to install and maintain, with costs approximately $15 for a filter change every 100 gallons. The cost per gallon is slightly less than the typical pitcher filter, but is still relatively expensive. This filtration unit can also be modified to include a larger contaminant removal profile by replacing the 2-stage filter with a slightly more expensive ($20) 3-stage filter (see Appendix C).

Point-of-Use/Under-the-Sink Filters: Point-of-use filters are further capable of expanded filtration of contaminants and can use simple filters or can be installed as reverse osmosis type of filters (discussed below). These systems are limited to one faucet and are often bulky and can take up a majority of space on the counter or under the sink. These devices are not portable, owing to their increased size. Installation can be complex and a plumber is often recommended for this purpose. However, multiple filter types are available for these units and can often be customized dependent on contaminant type by purchasing filters.

The typical filtration unit for this system varies. There are simple filtration units, activated carbon filters, and reverse osmosis that fall under this category. The Crystal Quest Countertop 6-stage Nitrate Filter (Model CQE-CT-00160) costs around $200 and is an activated carbon system with a special additional filter for removing nitrates and nitrites. This system recommends a plumber installation. It removes all metals listed in Appendix C, but does not remove bacteria. It also removes almost all SOCs and VOCs since it contains an activated carbon filter, which is discussed below. The per gallon cost is dependent on nitrate concentrations, but replacement cartridges are listed at $57 dollars, so long term costs are less than pitcher-type filters. A complete list of these filtration units is seen in Appendix C.

Whole House/Point-of-Entry Filters: Whole house filters are often attached to water mains or the main line entering the house. Whole house filters are able to filter water used in every faucet in the house and are also capable of filtering many chemicals. They are often very large in size and require professional installation. Flow rate is much faster with this system than all others and these systems can also be switched to use a bypass when not needed. These filters are not intended to reduce many of the contaminants since they must allow water flow to continue. It is often recommended that use of a whole-house filter be used in conjunction with point-of-use filters for drinking water.

An example of this filtration type is the Aquasana EQ-300. This system costs approximately $1000 and must be installed by a plumber for warranty coverage. It is designed to allow a high flow rate to be maintained, but does filter out chlorine. Replacement filters are expensive and cost around $700, but they only need replaced every 300,000 gallons, which keeps the per gallon cost minimal compared to many filter types. This system also has a prefilter that must be replaced every 3-4 months, but this filter only costs about $25. See appendix C for a list of the contaminants filtered.

Reverse Osmosis Filters: Reverse osmosis is a filtration process that uses pressure to force a solvent (e.g. water) through a membrane that retains the solute on one side and allows the pure solvent to pass to the other side. Also known as hyperfiltration, these filters are effective in eliminating or substantially reducing a vast array of contaminants compared to most filter types by forcing water molecules through a 0.0001 micron semi-permeable membrane. The result is that contaminants are removed and only uncontaminated, clean water is available on the other side of the filter. For the removal of arsenic from water supplies, the Montana Department of Health and Environmental Sciences recommends reverse osmosis and distillation (Vogel, n.d.).

Reverse osmosis is a very effective method for removing contaminants, but is very slow compared to other filter types. This process may also require from 3 to 10 gallons of untreated water to make a single gallon of purified water and would not be a good choice for homes that have limited water supplies or use large amounts of water over short periods of time. This filter type can require a periodic backwash to maintain the efficacy for the life of the filtration unit and membrane.

The Everpure ROM II is a typical reverse osmosis system that initially costs approximately $600. The filtration needs to be changed every 1,000 gallons and the filter replacement is approximately $75. This system is designed as an under-sink unit and has a slightly more complicated filter-change process compared to the other filters. The ROM II filters only 14.4 gallons per day, with a maximum filtration rate of 0.5 gallons per minute. This system can be upgraded to filter out many VOCs and SOCs by addition of another filter with the reverse osmosis filter, or by using the more expensive ROM III. Appendix C contains a complete list of all contaminants filtered for this filter type.

Activated Carbon Filters: Activated carbon filters are effective in removing contaminants by using molecules of carbon that have a small positive charge added to them which allows the carbon to be more attractive to chemicals and impurities. The two most important factors that determine the efficacy and efficiency of activated carbon filtration are the amount of carbon in the unit and the amount of time the contaminant spends in contact with it. This means that the flow rate has a large effect on efficacy of this filter type. This type of filtration is most effective against chlorine and VOCs, and is considered the best filter for organic contaminants. Activated carbon filters are most effective when used at filtration levels of 0.5 microns.

The Culligan SY-2650 undersink unit is a good example of this type of unit and costs approximately $140, with 500 gallons between filter replacements that cost $45. Filter replacement is easily accomplished and yearly costs are reduced compared to pitcher filters due to the less frequent filter change requirements. This unit is very effective against all the SOCs and VOCs and a complete list of filtered contaminants is available in Appendix C.

Electrodialysis: Electrodialysis uses electric current and special membranes that are permeable to ions, based on their charge, to remove contaminants from the water (Goh, 2004). This technique uses electric potential to cause movement of positive and negative ions of dissolved salts through special membrane filters leaving clean water behind (Goh). This method of filtration does not remove organics, pyrogens and elemental metals due to their weak or nonexistent surface charges (APS Water, 2002). This system requires a skilled operator, routine maintenance, and more than the normal amount of electricity to produce clean water (APS Water). These units are often very large and can consume large amounts of space for use in homes, making them impractical.

Cooking/Boiling: Cooking and boiling water is useful for killing organisms, such as G*iardia*, *Cryptosporidium,* and bacteria in contaminated water. However, this technique can also concentrate other contaminants as a result of lost water vapor from boiling, so it is only appropriate for killing organisms, not for removing chemicals. The current recommendation from the Centers for Disease Control (CDC) is that water be boiled for one minute, with three minutes needed for altitudes above 6562 feet (2000 meters) (CDC, 2007).

Ion Exchange: This type of filtration is used most often for softening water by ion exchange. The most common ion exchange is sodium ions exchanged for calcium or magnesium ions. Water softening can reduce the build-up of precipitates that are caused by calcium or magnesium ions on surfaces. Small beds of synthetic resin are treated to selectively absorb certain ions and replace them by counter-ions. The process of ion exchange lasts, until all available spaces are filled up with ions, then the ion-exchanging device has to be regenerated by suitable chemicals. Ion exchange is an on-demand process, with water available at rapid rates.

Ion exchange resins can be used to remove poisonous and heavy metals, such as lead from solution. They are replaced with more innocuous ions, such as sodium and potassium. Ion exchange is not recommended for removing chlorine or organic contaminants from water (Elga Lab, 2007). Organic compound removal is more effectively achieved by using an activated charcoal or reverse osmosis filter after ion exchange is complete. There are currently no known harmful health effects due to drinking water containing calcium or magnesium in a healthy individual.

An example of an ion exchange system is the GE Logix On Demand 32,000 Grain Water Softener that sells for approximately $540. This unit requires periodic maintenance, as adjustments must be made and brine solutions need to be used to maintain the proper softening characteristics. This unit is recommended for a family of 4 persons, but can be purchased for more or less people, depending on the household size. Salt-free softeners are available, but are much more expensive (see Appendix C).

CHAPTER 3

METHODS

The list for all possible water contaminants is very lengthy, with hundreds of potential contaminants listed in any one region of the United States. The US EPA (2006) currently sets standards for 90 contaminants and their allowable levels in drinking water. For focus and clarity, the list of contaminants described for this project was delimited by those of interest in the Montana State University Environmental Risk Reduction through Nursing Interventions and Education (ERRNIE) project. These contaminants (See Appendix A) were selected by the ERRNIE project based on prevalence estimates in Gallatin County, Montana. Additionally, the consumer-based water treatment systems described in this project must be easily obtained through local or internet stores and be easily used and maintained in a single family household.

The information was gathered using multiple search terms on the databases provided by the Montana State University Library Systems and under general web searches. The MSU Library Systems search was done using the Medline Search Engine and Article First, accessed from the MSU Libraries web site. Search terms included all the contaminants listed in Chapter 2. For a complete list see Appendix D. Whenever possible the information used was most pertinent to Montana water supplies. Information for consumer-based water systems was used to include at least one prototype filter in the category for each type of filtration system in this report. Multiple filtration systems were compared when there was variance in the types of filtration design for each process, such as faucet mount filters that contained single or multiple filters, to include options that can be considered during use.

The setting for this project was determined by the Montana State University ERRNIE program, which is rural well water users located in southwest Montana in Gallatin County. The purpose of the ERRNIE project is "to test environmental health risk reduction education intervention provided by nurses to determine whether interactive, personalized intervention materials are more effective education tools than traditional sources of environmental health information" (Hill, n.d).

CHAPTER 4

APPLICATION TO PRACTICE

Importance for Practice

A child dies from a water-related disease every eight seconds in the world (Goh, 2004). Many of these deaths could be prevented with proper testing and treatment of the water supply. Household well water testing as recommended, along with the use of water filtration systems, could prevent exposure and complications from these contaminants. Preventative measures can have both immediate and long term effects on the overall health of individuals exposed to contaminated water. For example, if a childbearing family has SOCs in their water and has not taken steps to test or reduce exposure, family members can experience liver damage, dizziness, nausea and vomiting, and potentially birth defects. New infants in the home could also have an increased risk for developing asthma and a possibility of death.

Human exposure to well water contaminants can manifest themselves in physically-evident clinical symptoms. However, human exposure to well water contaminants can often lead to sub-clinical effects on patients and these exposures can have detrimental effects on an individual's health. The repeated sub-clinical exposures that lack physical symptoms can be worse for patients compared to a single, clinically evident, high-dose exposure. The mutation of genetic material, cells, and tissues can lead to many of the changes that can cause long-term health changes. The repeated sub-clinical exposure to VOCs or arsenic can place a well water user at an increased risk for developing Cancer (Minnesota Department of Health, 2005; Cohn, Klotz, Bove, Berkowitz, and Fagliano, 1994). Providers should be aware of any past exposures to identify those conditions associated with the contaminant that may appear in the future so proper primary education and secondary screenings can be done. However, it should also be noted that exposure to contaminated well water does not always lead to future health consequences.

Professional Guidance

Water can have large effects on the health of a population and detection of contaminants can prevent many of these problems. Without detection of the contaminants outbreaks can occur, most likely on a small scale, which involves only a few individuals, especially those isolated on well water. However, since leaching of contaminants can occur through soil and groundwater to multiple wells it is important to identify those contaminants that may affect neighboring wells. This can prevent large outbreaks, such as an outbreak of 403,000 that occurred in a community during a single episode of water-borne cryptosporidiosis (CDC, 1995).

To prevent future water-borne illnesses, Healthy People 2010 (2001) identifies a target of 95% of the population that receive a supply of drinking water that meets the regulations of the Safe Drinking Water Act. The reduction of disease outbreaks through water-borne causes is also an objective listed for Healthy People 2010, along with the reduction of blood levels of lead in children, the reduction of pesticide exposures that cause visits to health care facilities, and reduction of exposures to environmental pollutants, such as pesticides, lead, arsenic, and asbestos.

Recommendations for routine testing of well water also exist from many individual healthcare organizations. The guidance to accomplish these objectives can be found from various professional healthcare organizations. The American Academy of Nurse Practitioners refers the provider to the EPA website and uses their recommendations for well water testing; these include testing annually for bacteria, nitrates, and any other contaminants of local concern, as well as testing more often for changes in taste, odor, or appearance, recurrent incidence of gastrointestinal symptoms in the family, an infant living in the home, and for monitoring home treatment systems (NGWA, 2007). The American Academy of Pediatrics (AAP) further recommends that pediatricians and health care professionals ask parents about well water use during prenatal and well-child visits (AAP, 2005). The AAP also states that if the family drinks well water, the well should be tested for nitrates for prevention of methemoglobinemia. The American Academy of Family Physicians (2005) also states the same information as the AAP for families and directs you to the AAP website, as well as following EPA standards. The American Academy of Gastroenterology recommends using the EPA guidelines for well water testing (Butler & Martin, 2006).

Distribution and Discussion of Information During Healthcare Visits

Clinicians should be aware that water-borne illness can be a major concern for well water users. A discussion with well water users should be offered to help guide them in their well water health for maintaining, testing, and referral to sources for accomplishing this need. Recommendations of professional organizations can be used by the provider to guide these discussions while opening a continuous dialogue between patients and clinicians about concerns with well water use. The discussion or distribution of information on this topic to patients can also help in prevention of future health problems or complications.

Providers should strive for a continuous dialogue with patients about well water health, occurring over as many clinical visits as needed. The distribution of information to well water users could help to foster this dialogue by empowering the patient to seek information about well water health while leading to better communication between patients and provider; it could also lead to earlier detection of clinical signs and symptoms of well water users. The use of educational material could also help to guide patients in selection of a filtration methods by showing them each system has a unique contaminant removal profile, leading to selection of proper filtration systems and is a vital step in future health. A guided discussion by a clinician can also help well water users to choose the right filter for the contaminants that are present, ensuring removal and better health for the family.

If clinicians are aware of the health issues surrounding well water they can also be aware of changes that can be concerning to their patients and families. Though many of these contaminants are not present in high concentrations, a reduction could improve health by reducing sub-clinical effects. Since groundwater contaminants have the potential to disperse over large areas, the identification in one well could lead to the increased awareness and communication with other well users about detected contaminants. The interest in well water health and overall family health could develop an increased trust with their provider.

Follow-up and Referral

Once the identification of a well contaminant has been found treatment should be aimed at returning the patient to optimal health levels and correcting the contamination. Nurse Practitioners (NP) can guide treatment of the affected patient by referring patients to the proper treatment facilities. Illness or damage to specific organs or systems that occurred as a result of exposure could be referred to the proper specialist as needed. A patient suffering from neurological damage or defects as a result of lead exposure could be referred to a neurologist, as well as occupational, speech, or physical therapy if needed. The guidance offered by the NP could lead the patient back to pre-exposure health levels, which should be the goal.

The discussion about well treatment systems can also begin with the NP, but could continue with the public health office, which might offer further guidance. In addition, Public Health Nurses could be used to make home visits to follow-up on treatments and plans, as well as initiate implementation of filtration systems. The follow-up home visits could be an invaluable experience for patients and help them to a healthier future.

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APPENDICES

APPENDIX A

MAXIMUM CONTAMINANT LEVEL (MCL) AND PUBLIC HEALTH GOALS OF SELECT GROUNDWATER CONTAMINANTS OCCURRING IN GALLATIN COUNTY, MONTANA AS DESIGNATED BY THE US EPA IN 2007

Contaminant	MCL (mg/L)	Public Health Goal (mg/L)
Arsenic	0.01	0
Chlorine	4	4
Chlorine dioxide	0.8	0.8
Coliforms (Total)	Present in < 5% samples per month	0
E. coli	Present in < 5% samples per month	0
Copper	1.3	1.3
Cryptosporidium	99% Removal	0
Fluoride	4	4
Giardia	99.9% Removal/Inactivation	0
Lead	0.015	0
Nitrate	10	10
Nitrite	1	1
Synthetic Organic Compounds (SOCs)		
alachor	0.002	0
atrazine	0.003	0.003
dalapon	0.2	0.2
dinoseb	0.007	0.007
diquat	0.02	0.02
endothall	0.1	0.1
endrin	0.002	0.002

APPENDIX A - CONTINUED

glyphosate	0.7	0.7
lindane	0.0002	0.0002
methoxychlor	0.04	0.04
picloram	0.5	0.5
simazine	0.004	0.004
2,4-D	0.07	0.07
Volatile Organic Compounds		
benzene	0.005	0
benzopyrene	0.0002	0
bromate	0.01	0
bromodichloromethane	0	0
chloroform (trichloromethane)	0.057	0
chloromethane	0	0
ethylbenzene	0.7	0
methyl tert-butyl ether (MTBE)	not established	0
perchloroethane (PCE)	5	0
1,2,4-trimethylbenzene (TMB)	not established	0
trichloroethane (TCE)	5	0
1,1-dichloroethane (DCA)	5	0
1,1,1-trichloroethane (TCA)	0.2	0.2
toluene	1	1

APPENDIX A – CONTINUED

toxaphene	0.003	0
xylenes (total)	10	10
Disinfection by-products		
Trihalomethanes (THMs)		
Total THMs	0.08	0
bromodichloromethane	0	0
bromoform	0	0
chloroform (trichloromethane)	0.057	0
dibromochloromethane	0.06	0

APPENDIX B

GENERAL CONTAMINANTS AND TYPES OF FILTERS DESIGNED TO REMOVE CONTAMINANTS (NOT EVERY FILTER IN EACH CATEGORY WILL REMOVE CONTAMINANTS LISTED – CHECK WITH MANUFACTURER SPECIFICATIONS)

Contaminants Removed	Filter Types
Arsenic	Reverse Osmosis
Copper	Reverse Osmosis
	Pitcher Type
	Faucet Mount
Bacteria	None – no filters alone will remove
	Boiling water
Cryptosporidium	Pitcher Type
	Faucet Mount
	Reverse Osmosis
	Absolute 1 micrometer filters or less
	Boiling water
Cyanotoxins	Activated Carbon
Fecal coliforms	Same as bacteria – no filters alone remove
Hardness	Ion Exchange
Lead	Pitcher Type
	Faucet Mount
	Ion Exchange
	Activated Carbon
	Reverse Osmosis

APPENDIX B – CONTINUED

Nitrate/Nitrite	Reverse Osmosis
	Electrodialysis
Volatile organic Compounds (VOCs)	Pitcher Type (Select contaminants only)
	Faucet Mount
	Activated Carbon
	Reverse Osmosis (reduces only)
Synthetic Organic Compounds (SOCs)	Pitcher Type (Select contaminants only)
	Faucet Mount
	Activated Carbon
	Reverse Osmosis (reduces only)
Trihalomethanes (THMs)	Faucet Filter
	Activated Carbon
	Let water sit for 6 hours at room temp
	Cooking/Boiling

APPENDIX C

COMPARISON OF FILTERS AND THE CONTAMINANT REMOVAL PROFILE

Filter Type	Brita Pitcher Filter	PUR Pitcher – 2 stage
Price	$ ($25)	$ ($25)
Water per Filter Change	40 gal	40 gal
Replacement Indicator	Yes	Yes
Replacement Cartridge Price	$ ($15)	$ ($10)
Cost per Gallon	$$	$$
Total 1 yr cost (1000 gal use)	$$$	$$$
Source	www.brita.com	www.purwater.com
Filter Type	Pitcher	Pitcher

Contaminant		
Arsenic		
Bacteria/Coliforms (Total)		
Chlorine	X – 75%	X
Chlorine dioxide	X – 75%	X
Copper		X
Cryptosporidium	X – 99%	X
Fluoride		
Giardia		X
Lead	X – 93%	X
Nitrate		
Nitrite		

SOCs		X
alachor		
atrazine		X
carbofuran		X
chlordane		
dalapon		
dinoseb		
diquat		
endothall		
endrin		
glyphosate		
heptachlor epoxide		
lindane		X
methoxychlor		
picloram		
simazine		X
2,4-D		
2,4,5 TP (Silvex)		

APPENDIX C - CONTINUED

Filter Type **(Continued)**	Brita Pitcher Filter	PUR Pitcher – 2 stage
Trihalomethanes		
VOCs		X
asbestos		X
benzene		
benzopyrate		
bromate		
bromodichloromethane		
carbon tetrachloride		X
chloroform		
chloromethane		
0-dichlorobenzene		X
1,1-dichloroethane (DCA)		
ethylbenzene		X
methyl tert-butyl ether (MTBE)		X
monochlorobenzene		X
perchlorane (PCE)		
styrene		
tetrachlorethane		X
1,2,4-trimethylbenzene (TMB)		
trichloroethane (TCE)		
1,1,1-trichloroethane (TCA)		
toluene		X
toxaphene		X
xylenes (total)		

APPENDIX C - CONTINUED

Filter Type	Culligan Pitcher Filter OP-1	Brita Faucet Filter
Price	$ ($20)	$ ($30)
Water per Filter Change	40 gal	100 gal
Replacement Indicator	Yes	Yes
Replacement Cartridge Price	$ ($15)	$ ($20)
Cost per Gallon	$$	$$
Total 1 yr cost (1000 gal use)	$$$	$$
Source	www.culligan.com	www.brita.com
Filter Type	Pitcher	Faucet Mount Point of Use
Contaminant		
Arsenic		
Bacteria/Coliforms (Total)	Bacteriostatic	
Chlorine	X	X – 99%
Chlorine dioxide	X	X – 99%
Copper	X	
Cryptosporidium		X – 99%
Fluoride		
Giardia		
Lead	X	X – 99%
Nitrate		
Nitrite		
SOCs	X	X
alachor		X – 99%
atrazine		X – 92%
carbofuran		
chlordane		
dalapon		
dinoseb		
diquat		
endothall		
endrin		
glyphosate		
heptachlor epoxide		
lindane		X
methoxychlor		
picloram		
simazine		
2,4-D		
2,4,5 TP (Silvex)		

APPENDIX C - CONTINUED

Filter Type **(Continued)**	Culligan Pitcher Filter OP-1	Brita Faucet Filter
Trihalomethanes		
VOCs		X
asbestos		
benzene		X – 96%
benzopyrate		
bromate		
bromodichloromethane		
carbon tetrachloride		
chloroform		
chloromethane		
0-dichlorobenzene		
1,1-dichloroethane (DCA)		
ethylbenzene		
methyl tert-butyl ether (MTBE)		
monochlorobenzene		
perchlorane (PCE)		
styrene		
tetrachlorethane		
1,2,4-trimethylbenzene (TMB)		
trichloroethane (TCE)		X – 99%
1,1,1-trichloroethane (TCA)		
toluene		
toxaphene		
xylenes (total)		

APPENDIX C - CONTINUED

Filter Type	Brita On Tap Faucet Filter	Culligan Faucet Mount (FM-5 or 15)
Price	$ ($30)	$ ($50)
Water per Filter Change	100 gal	120 gal FM-5/ 200 gal FM-15
Replacement Indicator	Yes	Yes (FM-5 only)
Replacement Cartridge Price	$ ($15)	$ ($20)
Cost per Gallon	$$$	$$$
Total 1 yr cost (1000 gal use)	$$$	$$$
Source	www.brita.com	www.culligan.com
Filter Type	Faucet Mount/Point-of-Use FF-100 with FR-200 filter	Faucet Mount/Point-of-use
Contaminant		
Arsenic		
Bacteria/Coliforms (Total)		
Chlorine	X	
Chlorine dioxide	X	
Copper		
Cryptosporidium	X	X
Fluoride		
Giardia	X	X
Lead	X	X
Nitrate		
Nitrite		
SOCs	X	X
alachor	X	
atrazine	X	X
carbofuran	X	
chlordane	X	
dalapon	X	
dinoseb		
diquat		
endothall		
endrin	X	
glyphosate		
heptachlor epoxide	X	
lindane	X	X
methoxychlor	X	
picloram		
simazine	X	
2,4-D	X	
2,4,5 TP (Silvex)		

APPENDIX C – CONTINUED

Filter Type **(Continued)**	Brita On Tap	Culligan Faucet Mount (FM-5 or 15)
Trihalomethanes	X	
VOCs	X – 99.8%	
asbestos	X	
benzene	X	
benzopyrate	X	
bromate		
bromodichloromethane		
carbon tetrachloride	X	
chloroform		
chloromethane		
0-dichlorobenzene	X	
1,1-dichloroethane (DCA)		
ethylbenzene	X	
methyl tert-butyl ether (MTBE)		
monochlorobenzene		
perchlorane (PCE)		
styrene	X	
tetrachlorethane	X	
1,2,4-trimethylbenzene (TMB)		
trichloroethane (TCE)	X	
1,1,1-trichloroethane (TCA)	X	
toluene	X	
toxaphene	X	
xylenes (total)		

APPENDIX C - CONTINUED

Filter Type	PUR Faucet Mount 2 stage	PUR Faucet Mount 3 stage
Price	$ ($35)	$ ($40)
Water per Filter Change	100 gal	100 gal
Replacement Indicator	Yes	Yes
Replacement Cartridge Price	$ ($20)	$ ($20)
Cost per Gallon	$$$	$$$
Total 1 yr cost (1000 gal use)	$$$	$$$
Source	www.purwater.com	www.purwater.com
Filter Type	Faucet Mount/Point-of-Use	Faucet Mount/Point-of-Use

Contaminant		
Arsenic		
Bacteria/Coliforms (Total)		
Chlorine	X	X – 98%
Chlorine dioxide	X	X – 98%
Copper		
Cryptosporidium	X	X – 99.9%
Fluoride		
Giardia	X	X
Lead	X	X – 96%
Nitrate		
Nitrite		

SOCs	X	X
alachor	X	X
atrazine	X	X – 96%
carbofuran		X
chlordane		X
dalapon		
dinoseb		
diquat		
endothall		
endrin		X
glyphosate		
heptachlor epoxide		X
lindane	X	X – 97%
methoxychlor	X	X
picloram		
simazine		X
2,4-D		X
2,4,5 TP (Silvex)	X	X

APPENDIX C – CONTINUED

Filter Type **(Continued)**	PUR Faucet Mount 2 Stage	PUR Faucet Mount 3 Stage
Trihalomethanes		X
VOCs	X	X
asbestos	X	X
benzene	X	X
benzopyrate		
bromate		
bromodichloromethane		
carbon tetrachloride		X
chloroform		
chloromethane		
0-dichlorobenzene		X
1,1-dichloroethane (DCA)		
ethylbenzene		X
methyl tert-butyl ether (MTBE)		X
monochlorobenzene		X
perchlorane (PCE)		
styrene		X
tetrachlorethane		X
1,2,4-trimethylbenzene (TMB)		
trichloroethane (TCE)		X
1,1,1-trichloroethane (TCA)		
toluene		X
toxaphene	X	X
xylenes (total)		

APPENDIX C – CONTINUED

Filter Type	Culligan SY-2650	Multipure Arsenic Filtration System
Price	$$$ ($140)	$$$$ ($440)
Water per Filter Change	500 gal	600 gal
Replacement Indicator	Yes	No
Replacement Cartridge Price	$$ ($45)	$$$ ($110)
Cost per Gallon	$	$$
Total 1 yr cost (1000 gal use)	$$	$$$
Source	www.culligan.com	www.bestfilters.com/CBASSB.html
Filter Type	Point of Use/Under-sink Activated Carbon	Point of Use/Under-sink Activated Carbon with Arsenic filter Model CB-AS-SB
Contaminant		
Arsenic		X
Bacteria/Coliforms (Total)		X
Chlorine	X	X
Chlorine dioxide	X	X
Copper		
Cryptosporidium	X	X
Fluoride		
Giardia	X	X
Lead	X	X
Nitrate		
Nitrite		
SOCs	X	X
alachor	X	X
atrazine	X	X
carbofuran	X	X
chlordane	X	X
dalapon	X	X
dinoseb	X	X
diquat	X	X
endothall	X	X
endrin	X	X
glyphosate	X	X
heptachlor epoxide	X	X
lindane	X	X
methoxychlor	X	X
picloram	X	X
simazine	X	X
2,4-D	X	X
2,4,5 TP (Silvex)	X	X

APPENDIX C – CONTINUED

Filter Type **(Continued)**	Culligan SY-2650	Multipure Arsenic Filtration System
Trihalomethanes	X	X
VOCs	X	X
asbestos	X	X
benzene	X	X
benzopyrate	X	X
bromate	X	X
bromodichloromethane	X	X
carbon tetrachloride	X	X
chloroform	X	X
chloromethane	X	X
0-dichlorobenzene	X	X
1,1-dichloroethane (DCA)	X	X
ethylbenzene	X	X
methyl tert-butyl ether (MTBE)	X	X
monochlorobenzene	X	X
perchlorane (PCE)	X	X
styrene	X	X
tetrachlorethane	X	X
1,2,4-trimethylbenzene (TMB)	X	X
trichloroethane (TCE)	X	X
1,1,1-trichloroethane (TCA)	X	X
toluene	X	X
toxaphene	X	X
xylenes (total)	X	X

APPENDIX C – CONTINUED

Filter Type	Crystal Quest Countertop Nitrate Filter	Crystal Quest Countertop 6-stage Nitrate Filter
Price	$$ ($190)	$$ ($200)
Water per Filter Change	Dependent on Nitrate Concentration	
Replacement Indicator	No	No
Replacement Cartridge Price	$ ($57)	$ ($57)
Cost per Gallon	$$	$$
Total 1 yr cost (1000 gal use)	Dependent on Nitrate Concentration	
Source	www.crystalquest.com	www.crystalquest.com
Filter Type	Point of Use/Nitrate Model CQE-CT-00153	Point of Use/Nitrate Model CQE-CT-00160
Contaminant		
Arsenic		X
Bacteria/Coliforms (Total)		
Chlorine		X
Chlorine dioxide		X
Copper		X
Cryptosporidium		X
Fluoride		X
Giardia		X
Lead		X
Nitrate	X – 90-95%	X – 90-95%
Nitrite	X – 90-95%	X – 90-95%
SOCs		X
alachor		X
atrazine		X
carbofuran		
chlordane		X
dalapon		X
dinoseb		X
diquat		X
endothall		X
endrin		X
glyphosate		X
heptachlor epoxide		X
lindane		X
methoxychlor		X
picloram		X
simazine		X
2,4-D		X
2,4,5 TP (Silvex)		X

APPENDIX C - CONTINUED

Filter Type **(Continued)**	Crystal Quest Countertop Nitrate Filter	Crystal Quest Countertop 6-stage Nitrate Filter
Trihalomethanes		X
VOCs		X
asbestos		
benzene		X
benzopyrate		X
bromate		X
bromodichloromethane		X
carbon tetrachloride		X
chloroform		X
chloromethane		X
0-dichlorobenzene		X
1,1-dichloroethane (DCA)		X
ethylbenzene		X
methyl tert-butyl ether (MTBE)		
monochlorobenzene		X
perchlorane (PCE)		X
styrene		X
tetrachlorethane		X
1,2,4-trimethylbenzene (TMB)		X
trichloroethane (TCE)		X
1,1,1-trichloroethane (TCA)		X
toluene		X
toxaphene		X
xylenes (total)		X

APPENDIX C - CONTINUED

Filter Type	Everpure ROM II	Everpure ROM III
Price	$$$$ ($600)	$$$$ ($750)
Water per Filter Change	1,000 gal	1,000 gal/ every 6 months
Replacement Indicator	Yes	Yes
Replacement Cartridge Price	$$ ($300)	$$$$ ($675)
Cost per Gallon	$$$	$$$
Total 1 yr cost (1000 gal use)	$$	$$
Source	residential.everpure.com	residential.everpure.com
Filter Type	Under-sink/Point of Use Reverse Osmosis	Under-sink/Point of Use Reverse Osmosis
	ROM II and ROM III with 14.4 gal/day max filtration at ½ gal/min	
Contaminant		
Arsenic	X	X
Bacteria/Coliforms (Total)	X	X
Chlorine	X	X
Chlorine dioxide	X	X
Copper	X	X
Cryptosporidium	X	X
Fluoride	X	X
Giardia	X	X
Lead	X	X
Nitrate	X	X
Nitrite	X	X
SOCs		X
alachor		X
atrazine		X
carbofuran		X
chlordane		
dalapon		
dinoseb		X
diquat		
endothall		
endrin		X
glyphosate		
heptachlor epoxide		X
lindane		X
methoxychlor		X
picloram		
simazine		X
2,4-D		X
2,4,5 TP (Silvex)		X

APPENDIX C – CONTINUED

Filter Type **(Continued)**	Everpure ROM II	Everpure ROM III
Trihalomethanes		X
VOCs		X
asbestos		X
benzene		X
benzopyrate		X
bromate		X
bromodichloromethane		X
carbon tetrachloride		X
chloroform		X
chloromethane		X
0-dichlorobenzene		X
1,1-dichloroethane (DCA)		X
ethylbenzene		X
methyl tert-butyl ether (MTBE)		X
monochlorobenzene		X
perchlorane (PCE)		X
styrene		X
tetrachlorethane		X
1,2,4-trimethylbenzene (TMB)		X
trichloroethane (TCE)		X
1,1,1-trichloroethane (TCA)		X
toluene		X
toxaphene		X
xylenes (total)		X

APPENDIX C – CONTINUED

Filter Type	GE Logix On Demand 32,000 Grain Water Softener	SoftSorb Water Softener
Price	$$$ ($540)	$$$$ ($1450)
Water per Filter Change	NA	at least 5 yrs
Replacement Indicator	Regeneration indicator	NA
Replacement Cartridge Price	NA	NA
Cost per Gallon	$	$
Total 1 yr cost (1000 gal use)	$	$$
Source	www.discountwatersofteners.com	www.discountwatersofteners.com
Filter Type	Ion Exchange Flow rate 9 gal/min Hardness up to 20 grains/gal For up to 4 person Home	Ion Exchange/Salt Free System Flow rate 6 gal/min Hardness up to 25 grains
Contaminant		
Arsenic		
Bacteria/Coliforms (Total)		
Chlorine		
Chlorine dioxide		
Copper		
Cryptosporidium		
Fluoride		
Giardia		
Lead		
Nitrate		
Nitrite		
SOCs		
alachor		
atrazine		
carbofuran		
chlordane		
dalapon		
dinoseb		
diquat		
endothall		
endrin		
glyphosate		
heptachlor epoxide		
lindane		
methoxychlor		
picloram		
simazine		

APPENDIX C – CONTINUED

Filter Type **(Continued)**	GE Logix On Demand 32,000 Grain Water Softener	SoftSorb Water Softener
2,4-D		
2,4,5 TP (Silvex)		
Trihalomethanes		
VOCs		
asbestos		
benzene		
benzopyrate		
bromate		
bromodichloromethane		
carbon tetrachloride		
chloroform		
chloromethane		
0-dichlorobenzene		
1,1-dichloroethane (DCA)		
ethylbenzene		
methyl tert-butyl ether (MTBE)		
monochlorobenzene		
perchlorane (PCE)		
styrene		
tetrachlorethane		
1,2,4-trimethylbenzene (TMB)		
trichloroethane (TCE)		
1,1,1-trichloroethane (TCA)		
toluene		
toxaphene		
xylenes (total)		

APPENDIX C – CONTINUED

Filter Type	CarbonSorb Water Softener	Aquasana Whole House Water Filter EQ-300
Price	$$$$$ ($1950)	$$$$ ($1000)
Water per Filter Change	at least 5 yrs	300,000 gal/prefilter every 3-4 mos.
Replacement Indicator	NA	Yes
Replacement Cartridge Price	NA	$$$ ($700)/prefilter $25
Cost per Gallon	$$	$
Total 1 yr cost (1000 gal use)	$$	$
Source	www.discountwatersofteners.com	www.aquasanastore.com
Filter Type	Ion Exchange/ Salt free system Flow rate of 6 gal/min Hardness up to 25 grains/gal	Whole House Sediment Pre-filter
Contaminant		
Arsenic		
Bacteria/Coliforms (Total)		
Chlorine	X	X
Chlorine dioxide	X	X
Copper		
Cryptosporidium		
Fluoride		
Giardia		
Lead		
Nitrate		
Nitrite		
SOCs	X	
alachor	X	
atrazine	X	
carbofuran	X	
chlordane	X	
dalapon	X	
dinoseb	X	
diquat	X	
endothall	X	
endrin	X	
glyphosate	X	
heptachlor epoxide	X	
lindane	X	
methoxychlor	X	
picloram	X	
simazine	X	
2,4-D	X	
2,4,5 TP (Silvex)	X	

APPENDIX C - CONTINUED

Filter Type **(Continued)**	CarbonSorb Water Softener	Aquasana Whole House Water Filter EQ-300
Trihalomethanes	X	
VOCs	X	
asbestos	X	
benzene	X	
benzopyrate	X	
bromate	X	
bromodichloromethane	X	
carbon tetrachloride	X	
chloroform	X	
chloromethane	X	
0-dichlorobenzene	X	
1,1-dichloroethane (DCA)	X	
ethylbenzene	X	
methyl tert-butyl ether (MTBE)	X	
monochlorobenzene	X	
perchlorane (PCE)	X	
styrene	X	
tetrachlorethane	X	
1,2,4-trimethylbenzene (TMB)	X	
trichloroethane (TCE)	X	
1,1,1-trichloroethane (TCA)	X	
toluene	X	
toxaphene	X	
xylenes (total)	X	

APPENDIX D

SEARCH TERMS USED FOR COLLECTION OF DATA

Arsenic

Arsenic and Water

and Montana

and Montana Well Water

and Montana Groundwater

and Groundwater Contamination

and Health Effects

and Cancer

Bacteria and Groundwater

and Groundwater Contamination

and Well Water

and Well Water Treatment

Coliforms and Well Water Contamination

Common Well Water Contaminants

Consumer Based Well Water Treatment Systems

Copper

Copper and Groundwater

and Health Effects

and Treatment Methods

and Well Water Contamination

APPENDIX D - CONTINUED

E. coli and Well Water Contamination

and Well Water Treatment

Ground Water Contaminants

and Environmental Protection Agency

Herbicides and Agriculture

and Cancer

and Common Used

and Common Well Water Contaminants

and Health Effects

and Montana

and Well Water

and Well Water Contamination

and Well Water Occurrence

Lead and Health Effects

and Well Water Contamination

and Well Water Treatment

Nitrates

Nitrates and Groundwater

and Health Effects

and Water

and Water Contamination

APPENDIX D - CONTINUED

and Well Water Contamination

Pesticides and Cancer

and Health Effects

and Montana

and Well Water Contamination

Synthetic Organic Chemicals and Montana

Synthetic Organic Compounds

Synthetic Organic Compound and Agriculture

and Montana

and Well Water

Volatile Organic Compounds

Volatile Organic Compounds and Agriculture

and Health Effects

and Montana

and Well Water Treatment

Water Contamination

Water Contaminants

Well Water

Well Water and Agriculture

Well Water Treatment Systems