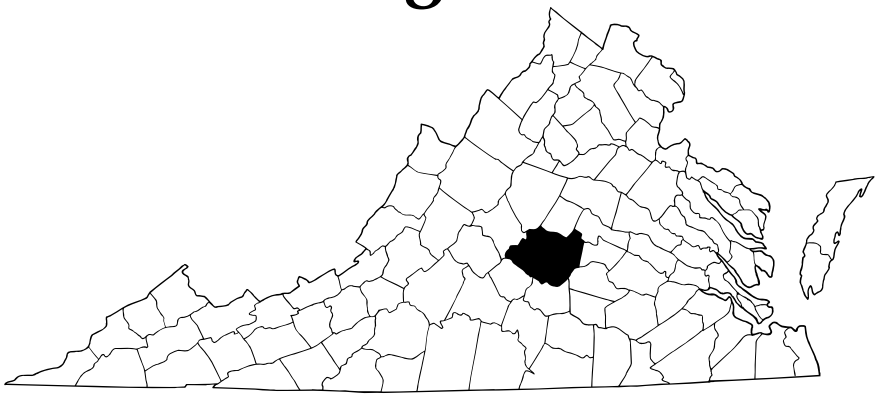
Evaluation of Household Water Quality in Buckingham and Cumberland Counties, Virginia



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Evaluation of Household Water Quality in Buckingham and Cumberland Counties, Virginia

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Abstract

During the fall of 2005, household water-quality education programs, including water sampling, testing, and diagnosis, were conducted in Buckingham and Cumberland counties, Virginia. Participation in the programs was made available to any resident of these two counties who utilized a private, individual water supply. During the course of the projects, 99 households submitted water samples which were analyzed for iron, manganese, hardness, sulfate, chloride, fluoride, total dissolved solids, pH, saturation index, copper, sodium, nitrate, and total coliform and *E. coli* bacteria. Laboratory analyses identified the major household water quality problems in these two counties as iron/manganese, corrosivity, and bacteria. Additionally, a number of samples were determined to have concentrations of nitrate high enough to possibly lead to health complications for at-risk segments of the population.

Acknowledgments

Many thanks are due to the residents of Buckingham and Cumberland counties who participated in the educational program. Without their enthusiasm and cooperation, the program could not have succeeded. Special thanks are extended to local media, agency personnel, volunteers, and others who provided support in terms of publicity, encouragement, and interest, thus contributing to the success of the household water-quality educational program.

The Water Quality Laboratory of the Department of Biological Systems Engineering at Virginia Tech was responsible for the water-quality analyses, as well as data management. Julie Jordan, laboratory manager, and her staff are especially acknowledged for their efforts. Athena Tilley, ICP spectroscopist, of the Soils Testing Laboratory in the Department of Crop and Soil Environmental Sciences at Virginia Tech assisted with the general water chemistry analysis.

Introduction

The water supply and wastewater disposal requirements of the vast majority of rural homes and farms throughout Virginia are met by individual water supply and wastewater disposal systems. In Buckingham and Cumberland counties, virtually all of these homes depend on groundwater sources.

Throughout these counties, most wells were drilled only for farm or domestic water supply. George and Gray (1988) have estimated that more than three-fourths of the drilled wells are inadequately constructed, while more than four-fifths of all dug/bored wells are inadequate. Nearly one in five households was also estimated to have failing or inadequate waste disposal systems.

Buckingham and Cumberland counties have a combined land area of 879 square miles. Both counties lie within the Piedmont physiographic province. This region is part of a largely rural area bounded by the city triad of Charlottesville, Lynchburg, and Richmond. Buckingham and Cumberland counties drain into the James River, which along with one of its major tributaries, the Appomattox River, forms much of the county borders.

The population of Buckingham County increased 21.4 percent from 1990 to 2000 (the last available U.S. census). The population of Cumberland County increased 15.2 percent during the same period. Many of the new home sites in these counties are historically agricultural land and are without public water supply and sewage services. The Virginia Department of Health (VDH) estimates that more than 193,000 new homes were built in the commonwealth between 1991 and 2000 without connections to public water utilities (D. Alexander, personal communication, 27 February 2006). Homeowners without public water utilities are responsible for maintaining their own potable water supply and proper sewage disposal.

To help homeowners deal with these issues, Ross et al. (1991) initiated a pilot program in Warren County, Virginia, of household water-quality education that included water sampling, testing, and diagnosis. Based on requests and support from local interests, subsequent programs have been conducted in 81 counties. During the course of these county projects and additional testing areas, more than 12,000 households submitted water samples through local Virginia Cooperative Extension offices to be analyzed for the following: iron, manganese, hardness, sulfate, chloride, fluoride, total dissolved solids, pH, saturation index, copper, sodium, nitrate, and total coliform and *E. coli* bacteria.

The major household water-quality problems identified as a result of these previous analyses were determined to be iron/manganese, hardness, fluoride, and total dissolved solids, and because of their potential health significance, corrosivity, bacteria, and to a lesser extent, sodium and nitrate although the occurrence and extent of these problems varied across counties. In some county programs, a limited number of additional samples from "high-risk" households were tested for over two dozen pesticides and other chemical compounds. Most of these compounds have been detected in measurable quantities in one or more samples, with several values exceeding a corresponding U.S. Environmental Protection Agency Health Advisory Level (HAL) or Maximum Contaminant Level (MCL). Rural-household water supplies in Buckingham and Cumberland counties were reassessed in fall 2005 as a continuation of the Virginia Household Water Quality Education Program.

Objectives

The goal of this project was to conduct educational programs on household water quality to include water testing/diagnosis in Buckingham and Cumberland counties, Virginia. The general program objectives were to: (1) improve the quality of life of rural homeowners by increasing their awareness and understanding of water-quality problems, protection strategies, and treatment alternatives; and (2) create a groundwater-quality data inventory to assist local governments in land-use and groundwater management planning.

Methods

Household water-quality educational programs were offered through the local Virginia Cooperative Extension offices in Buckingham and Cumberland counties during fall 2005. Any resident of these counties who utilized a private, individual water supply was eligible to participate. The programs were patterned after the model developed under the pilot educational program completed in 1989 in Warren County (Ross *et al.*, 1991). Newsletters publicized the program in each county, and program fact sheets were prepared (see Appendix).

The programs were launched through local meetings held in Buckingham and Cumberland in mid October. Attendees of these initial meetings were presented with information on local hydrogeologic characteristics in relation to groundwater pollution, the nature of household water-quality problems, and specifics of the

water-testing program to follow. Sampling kits were distributed at this meeting.

The sampling kits included a 250 ml Nalgene bottle for general water chemistry samples (iron, manganese, hardness, sulfate, chloride, fluoride, total dissolved solids, pH, saturation index (Langlier), copper, sodium, and nitrate). Also included in the kits was a 125 ml sterilized Nalgene bottle for bacteriological samples (total coliform and *E. coli)*. The sample identification form (see Appendix) included sampling instructions and a questionnaire on which participants were asked to describe the characteristics of their water supply. Instructions called for sampling from a drinking water tap and for flushing water systems prior to sampling to minimize contaminants contributed by the plumbing system. This form also inquired about water treatment devices, such as a water softener to ensure proper evaluation and interpretation.

Water samples were collected on October 12 at the Extension offices in Buckingham and Cumberland counties. At the close of the collection, all samples were packed in ice and immediately delivered to Virginia Tech in Blacksburg for analysis.

The general water chemistry and bacteriological analysis was conducted and coordinated by the Department of Biological Systems Engineering Water Quality Laboratory at Virginia Tech. The Soils Testing Laboratory of the Department of Crop and Soil Environmental Sciences at Virginia Tech was subcontracted to analyze samples for several of the constituents. Water-quality analyses were performed using standard analytical procedures (USEPA, 1983; APHA 1998).

After the analyses were completed, participants were reminded by mail to attend subsequent meetings in either Buckingham or Cumberland to obtain and discuss the test results and management practices to reduce or prevent water contamination. A sample report form and accompanying report interpretation are shown in the Appendix.

Findings and Results

During the course of the projects, 99 individual household water samples were returned for general water chemistry and bacteriological analysis from the two counties. A questionnaire form was distributed to all water-testing participants to be completed and returned with the sample submitted for analysis. The questionnaire provided insight into the characteristics of the households and their water supplies.

Profile of Household Water Supplies

The questionnaire responses, provided by all 99 participants, helped to characterize their water supplies (see Appendix). One set of questions dealt with the proximity of the household water supply to a potential source of groundwater contamination. One question sought to define housing density, which can be an indicator of contamination from septic systems and related water-quality problems. Participants were asked to classify their household environs as one of the following four categories, ranging from low to high density: (1) on a farm, (2) on remote, rural lot, (3) in a rural community, and (4) in a housing subdivision. In Cumberland County, Figure 1, rural community and farm were the most common at 40 percent. In Buckingham County, Figure 2, farm was the most common at 37 percent. Five participants from Buckingham County did not respond.

Figure 1. Housing Environs Distribution in Cumberland County

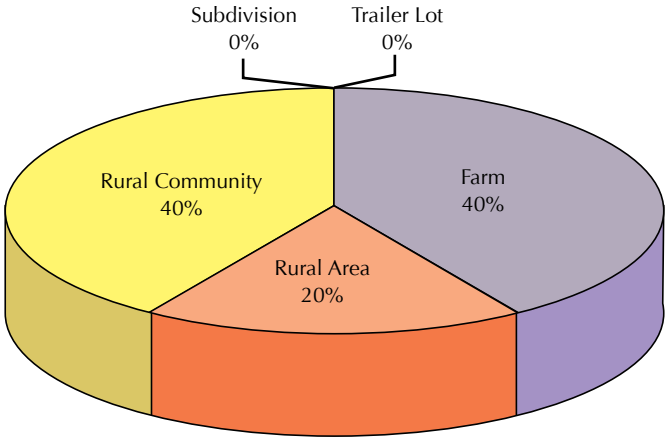
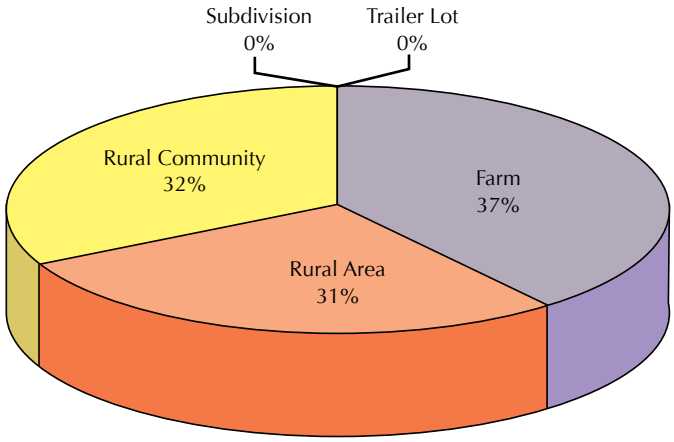


Figure 2. Housing Environs Distribution in Buckingham County



Participants were also asked to identify potential contamination sources within 100 feet of their water supply. The major sources identified were home heating-oil storage tanks and septic system drain fields, noted by 36 percent and 32 percent, respectively (Figure 3). Indications of proximity (within one-half mile) to larger activities which could potentially contribute to groundwater pollution were also sought. Agricultural activities were the most commonly identified; 57 percent of the participants indicated that their water supply was located within one-half mile of a major farm animal operation and 25 percent within one-half mile of field crop production (Figure 4).

Figure 3. Potential Contamination Sources within 100 Feet of Water Supplies

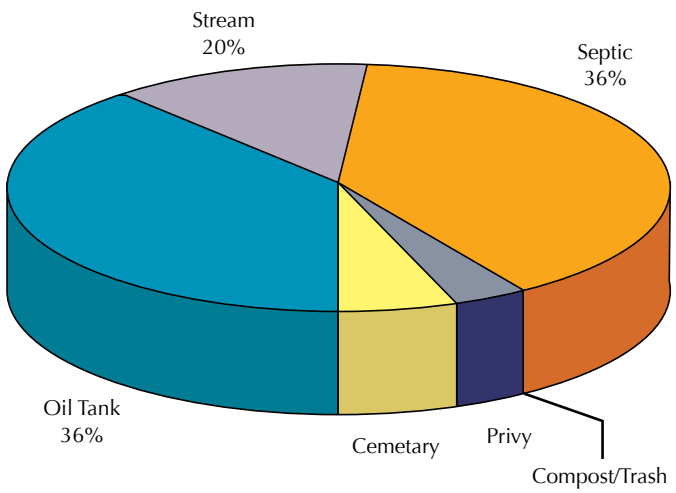
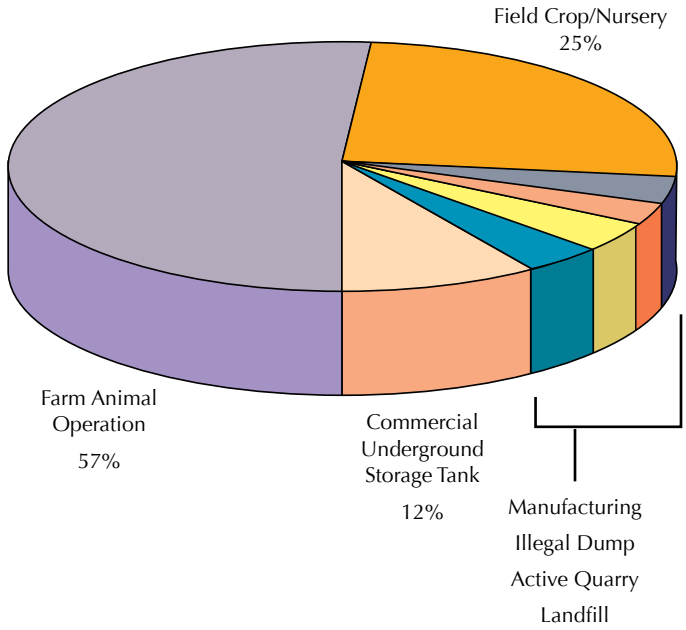


Figure 4. Pollution Sources within One-half Mile of Water Supplies

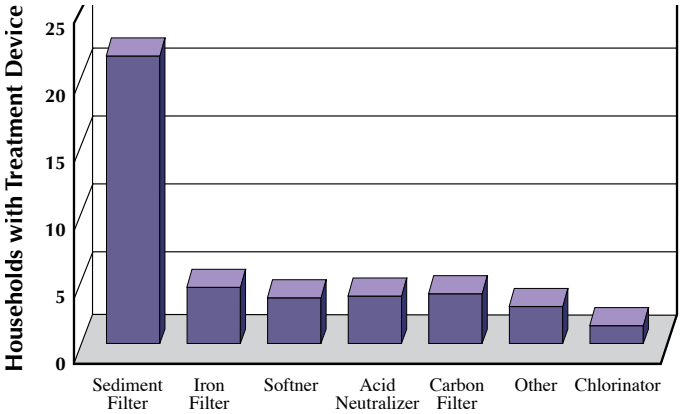


Information was also obtained regarding characteristics of the participants' water-supply systems. The majority (96 percent) of participants reported that they rely on a well with the remaining 4 percent using springs, which were located in Buckingham County. Participants using a well were asked to provide an estimate of the well depth, if known. Of those participants indicating well depths, 94 percent reported depths of more than 50 feet, while 6 percent reported less than or equal to 50 feet. The maximum well depth reported was 420 feet; the average well depth was 174 feet. Eighteen percent of the wells were constructed in or prior to 1970. The earliest reported well construction date was 1900.

Water systems were further identified with respect to the type of material used for water distribution throughout the dwelling. The most widely used pipe material was plastic (63 percent), while copper was reported by 22 percent of the participants. Eleven percent of participants reported, "Don't know."

To properly evaluate the quality of water supplies in relation to the point of sampling, participants were asked if their water systems had water treatment devices currently installed and if so, the type of device (Figure 5). Thirty percent of the participants reported at least one treatment device installed, with the most common type of treatment device in use being a sediment filter (73 percent). Seven percent of those with treatment device(s) indicated "other."

Figure 5. Number of Households with Treatment Devices

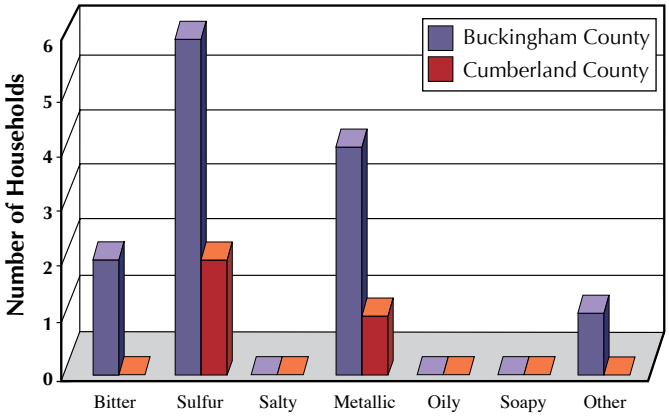


Participants' Perceptions of Household Water Quality

Participants were asked whether or not they experienced one or more of the following conditions: (1) corrosion of pipes or plumbing fixtures; (2) unpleasant taste; (3) objectionable odor; (4) unnatural color or appearance; (5) floating, suspended, or settled particles in the water; and (6) staining of plumbing fixtures, cooking appliances/utensils, or laundry (see Appendix).

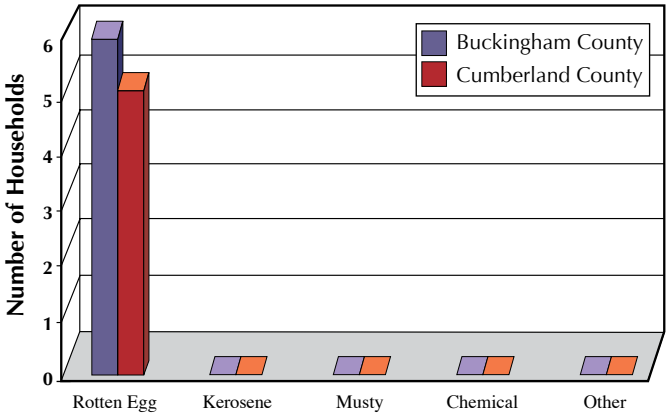
Seventeen percent of the participants from Buckingham County and 9 percent of participants from Cumberland County responded that their water had an unpleasant taste (Figure 6). "Sulfur" taste was the most common (57 percent) followed by "metallic" (36 percent).

Figure 6. Unpleasant Tastes Reported by Participants



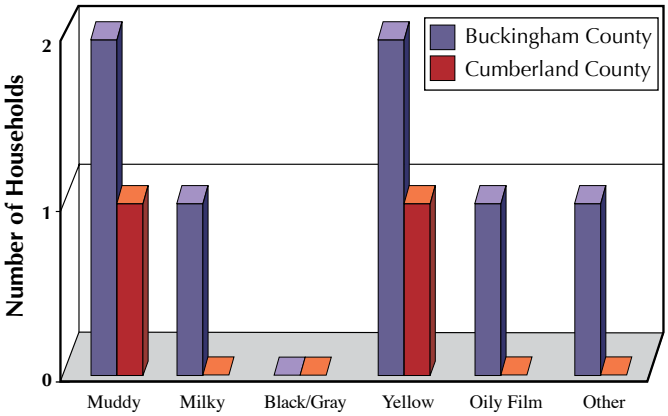
An objectionable odor was reported by 11 percent of the participants (Figure 7). The only odor described was "rotten egg," or sulfur, identified by 100 percent of those reporting odor problems.

Figure 7. Objectionable Odors Reported by Participants



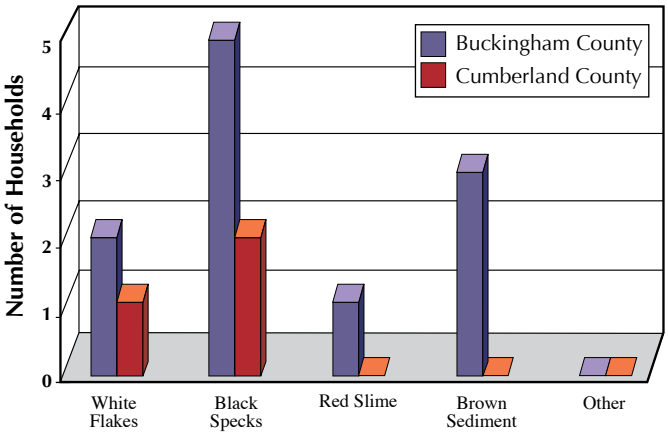
Seven percent of the participants affirmed their water had an unnatural color or appearance. "Yellow" and "muddy" were identified most often by those who reported appearance problems (Figure 8).

Figure 8. Unnatural Appearance Reported by Participants



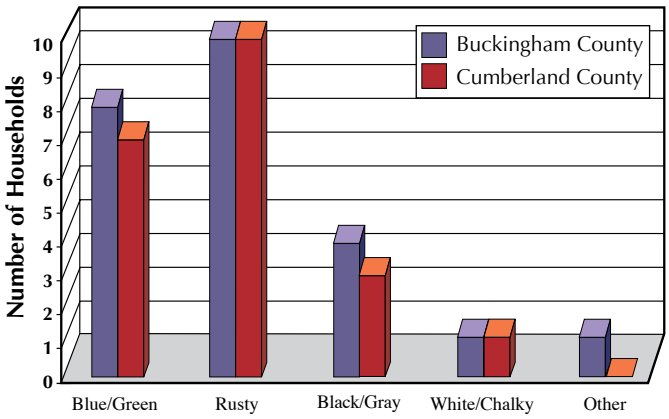
Eleven percent of participants reported particles in their water. Sixty-four percent described the particles as "black specks." Twenty-seven percent selected "brown sediment."

Figure 9. Particles in Water Reported by Participants



Staining problems on plumbing fixtures, cooking appliances/utensils, and/or laundry were reported by 40 percent of the participants (Figure 10). The major problem was "rusty" stains (50 percent) followed by "blue/green" stains (38 percent).

Figure 10. Staining Problems Reported by Participants



Household Water Quality Analysis

General Water Chemistry Analysis

Tests included in the general water chemistry analysis are listed in Table 1 along with detection limits, where appropriate. Also presented are the averages and ranges for both counties. Table 2 provides the percentage of constituent values exceeding a given water-quality standard or guideline. The results and importance of each test are discussed individually below.

Iron

Iron in water does not usually present a health risk. It can, however, be very objectionable if present in amounts greater than 0.3 mg/L. Excessive iron can leave brown-orange stains on plumbing fixtures and laundry. It may give water and/or beverages a bitter metallic taste and may also discolor beverages.

Overall, 3 percent of samples had iron concentrations exceeding the U.S. Environmental Protection Agency (EPA) Secondary Maximum Contaminant Level (SMCL) of 0.3 mg/L. The presence of iron was not surprising given that excessive iron is prevalent in rural water supplies throughout much of Virginia. While only 13 percent of the responding participants reported the installation of an iron removal filter, the results of the sample questionnaire revealed that 50 percent of the 40 who reported staining problems, or 20 percent of all samples, classified the color of those stains as "rusty" (red/orange/brown). Stains of this color on plumbing fixtures, cooking appliances/utensils, and/or laundry are usually attributed to excessive iron concentrations.

It should be noted that the SMCL for iron is likely based more on taste considerations rather than long-term staining tendencies, particularly on plumbing fixtures. It has been suggested that concentrations below 0.1 mg/L are preferred, when staining is an issue. When a value of 0.1 mg/L was used as the threshold concentration, an additional 8 percent of samples exceeded this limit.

Manganese

Manganese does not present a health risk. However, if present in amounts greater than 0.05 mg/L, it may give water a bitter taste and produce black stains on laundry, cooking utensils, and plumbing fixtures.

While manganese stains are generally dark and 17.5 percent of all participant responses indicated "black" stains only, 6 percent of the samples exceeded the SMCL for manganese of 0.05 mg/L. The "particles in water" description of "black specks," reported by 64 percent of responding participants, may provide additional evidence of excessive manganese concentration.

Hardness

Hardness is a measure of calcium and magnesium in water. Hard water does not present a health risk. However, it keeps soap from lathering, decreases the cleaning action of soaps and detergents, and leaves soap "scum" on plumbing fixtures, and scale deposits in water pipes and hot water heaters. Softening treatment is highly recommended for very hard water (above 180 mg/L). Water with a hardness of about 60 mg/L or less does not need softening.

Hardness is an additional "natural" parameter usually linked to karst terrain and limestone formations that are not prevalent in Buckingham and Cumberland counties. Extensive use of water softeners is not warranted, and only three participants had installed a water softener (Figure 4), however, 2 percent of the water samples, all of which were from Cumberland County, exceeded the maximum recommended hardness level of 180 mg/L.

Hardness tolerance, like that of many nuisance contaminants, is somewhat relative to individual preferences. For example, water with total hardness between 60 mg/L and 180 mg/L may warrant the installation of a commercial water softener in the view of some, while others are satisfied with untreated water. Thirty-three percent of the samples from both counties

were in the range of 60 mg/L to 180 mg/L total hardness, indicating that approximately one-third of all samples could be classified as "moderately hard" or "hard."

Sulfate

High sulfate concentrations may result in adverse taste or may cause a laxative effect. The SMCL for sulfate is 250 mg/L. Generally, sulfates are naturally present in groundwater and may be associated with other sulfur-related problems, such as hydrogen sulfide gas. This gas may be caused by the action of sulfate-reducing bacteria, as well as by other types of bacteria (possibly disease-causing bacteria) on decaying organic matter. While it is difficult to test for the presence of this gas in water, it can be easily detected by its characteristic "rotten egg" odor, which may be more noticeable in hot water. Water containing this gas may also corrode iron and other metals in the water system and may stain plumbing fixtures and cooking utensils.

Sulfate concentrations were relatively low in the samples. None of the raw water samples exceeded 250 mg/L. The complaints of a "rotten egg/sulfur" odor by 100 percent of those reporting odor problems indicate that hydrogen sulfide gas may be a somewhat widespread problem in the two counties; a conclusion that can not be confirmed by the presence of sulfate.

Chloride

Chloride in drinking water is not a health risk. Natural levels of chloride are generally low and high levels in drinking water usually indicate contamination from a septic system, road salts, fertilizers, industry, or animal wastes. High levels of chloride may speed the corrosion of metal pipes and cause pitting and darkening of stainless steel. The EPA has set an SMCL for chloride of 250 mg/L. None of the samples from Buckingham or Cumberland County exceeded the SMCL for chloride.

Fluoride

Fluoride is of concern primarily from the standpoint of its effect on teeth and gums. Small concentrations of fluoride are considered to be beneficial in preventing tooth decay, whereas moderate amounts can cause brownish discoloration of teeth and high fluoride concentrations can lead to tooth and bone damage. For these reasons, the EPA has set both a SMCL of 2 mg/L and a Maximum Contaminant Level (MCL) of 4 mg/L. None of the samples exceeded the SMCL.

Total Dissolved Solids (TDS)

High concentrations of dissolved solids may cause adverse taste effects and may also deteriorate household plumbing and appliances. The EPA SMCL is 500 mg/L total dissolved solids. The average TDS concentration for both counties was 101mg/L. One of the samples (from Buckingham County) exceeded the standard. The maximum TDS concentration among the water samples was 522 mg/L.

pH

The pH indicates whether water is acidic or alkaline. Acidic water can cause corrosion in pipes and may cause toxic metals from the plumbing system to be dissolved in drinking water. The life of plumbing systems may be shortened due to corrosion, requiring expensive repair and replacement of water pipes and plumbing fixtures. Treatment is generally recommended for water with a pH below 6.5. Alkaline water with a pH above 8.5 is seldom found naturally and may indicate contamination by alkaline industrial wastes. The EPA has set a suggested range of between 6.5 and 8.5 on the pH scale for drinking water.

The average pH reading was 6.76. None of the samples exceeded a pH of 8.5. Twenty-one percent of the samples were less than 6.5 and incidence of excessive acidity varied somewhat across the two counties (Table 2). While the remaining samples had a pH above 6.5, slightly acidic water with a pH between 6.5 and 7.0 can lead to less immediate staining and corrosion problems. An additional 47 percent of water samples fell into this category.

Saturation Index

The saturation index (Langlier) is used, in addition to pH, to evaluate the extent of potential corrosion of metal pipes, plumbing fixtures, etc. Saturation index is based on the calcium concentration, total dissolved solids concentration, pH, and alkalinity. A saturation index greater than zero indicates that calcium carbonate deposits may readily form on pipe walls. A saturation index less than zero indicates that the water does not have scale-forming properties and pipes may be subject to corrosion. Saturation index values between -1 and +1 are considered acceptable for household water supplies.

No saturation index values were determined to be above +1 in either sample group. Values of less than -1, however, were determined for 90 percent of the samples. The average saturation index values were -2.35 with a minimum value of -4.97.

Copper

The EPA health standard for copper in public drinking water supplies is 1.3 mg/L, the maximum level recommended to protect people from acute gastrointestinal illness. Even lower levels of dissolved

copper may give water a bitter or metallic taste and produce blue-green stains on plumbing fixtures. Consequently, EPA has established an SMCL for copper of 1.0 mg/L in household water.

Two samples exceeded the recommended health level of 1.3 mg/L as well as the SMCL of 1.0 mg/L. The maximum copper concentration measured was 1.64 mg/L. Since natural levels of copper in groundwater are low, and the primary contributor of copper in drinking water is corrosion of copper water pipes and fittings, low copper levels were expected, even in the case of tap water samples, assuming that water lines were flushed properly prior to sampling.

Sodium

Sodium may be a health hazard to people suffering from high blood pressure or cardiovascular or kidney diseases. For those on low-sodium diets, 20 mg/L is suggested as a maximum level for sodium in drinking water, although a physician should be consulted in individual cases. The average sodium concentration was 7.8 mg/L, while the maximum concentration was 52 mg/L. Five percent of the samples exceeded 20 mg/L with three of these samples coming from Cumberland and two coming from Buckingham (Table 2).

It should be reemphasized, however, that the suggested threshold of 20 mg/L for sodium is relatively low and applicable only to individuals suffering from health problems, such as heart disease or high blood pressure. To evaluate the presence of high sodium levels in the context of an otherwise healthy individual, a threshold value of 100 mg/L sodium has been suggested. Considering the maximum sodium concentration presented above, none of the samples exceeded this 100 mg/L threshold.

Nitrate

High levels of nitrate may cause methemoglobinemia or "blue-baby" disease in infants. Though the EPA has set a MCL for nitrate (as N) of 10 mg/L, it suggests that water with greater than 1 mg/L not be used for feeding infants. Levels of 3 mg/L or higher may indicate excessive contamination of the water supply by commercial fertilizers and/or organic wastes from septic systems or farm animal operations, which may be subject to seasonal and climatic influences.

The maximum concentration of nitrate obtained was 6.9 mg/L for the water sample. None of the samples exceeded the MCL of 10 mg/L. Thus, serious nitrate contamination does not appear to be a widespread problem in either county. When a 1 mg/L threshold value was selected, however, a much higher occurrence of nitrate was determined. In this case, 38 percent of the samples exceeded the level of potential concern to infant health. Furthermore, 12 percent of both the tap water and raw water samples had nitrate concentrations exceeding 3 mg/L, indicating that health-impacting levels would likely be approached in a number of cases in the two counties. In the former non-standard threshold case, similar occurrences of excessive nitrate were noted for both counties.

Table 1. General water chemistry analysis contaminant concentrations for Buckingham and Cumberland counties.

		Measured Concentrations Tap Water (n=99)		
Constituent	**Detection Limit**	**Avg.[1]**	**Min.**	**Max.**
Iron (mg/L)	0.005	0.049	DL[2]	0.772
Manganese (mg/L)	0.001	0.027	DL	1.657
Hardness (mg/L)	0.3	54.5	DL	305.0
Sulfate (mg/L)	0.3	6.1	DL	113.3
Chloride (mg/L)	1	19	6	68
Fluoride (mg/L)	0.1	DL	DL	DL
TDS (mg/L)	1.0	101	3	522
pH	–	6.76	6.00	7.80
Saturation Index	–	–2.35	–4.97	–0.23
Copper (mg/L)	0.002	0.080	DL	1.640
Sodium (mg/L)	0.01	7.80	0.07	52.08
Nitrate (mg/L)	0.005	1.224	0.01	6.900

[1] *Averages calculated on the basis of below detection limit (DL) values set equal to the DL.*

[2] *Sample concentration non-detectable, i.e., below the detection limit for the given contaminant.*

Bacteriological Analysis

A common hazard of private household water supplies is contamination by potentially harmful bacteria and other microorganisms. Microbiological contamination of drinking water can cause short-term gastrointestinal disorders, such as cramps and diarrhea that may be mild to very severe. Of the non-gastrointestinal disorders, one particularly important disease transmissible through drinking water is Viral Hepatitis A. Other diseases include salmonella infections, dysentery, typhoid fever, and cholera.

Coliform bacterial detection is simply an indication of the possible presence of pathogenic, or disease-

Table 2. General water chemistry and bacteriological analysis contaminant concentrations exceeding established standards for Buckingham and Cumberland counties.

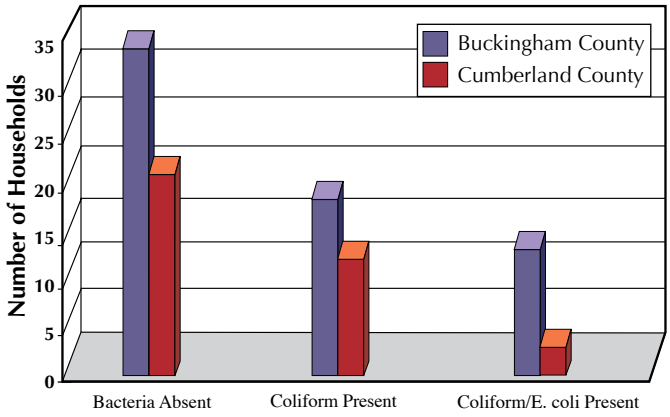
		Percent of Values Exceeding Standard Tap Water		
Constituent	**Standard**	**Total n=99**	**Buck. n=64**	**Cumb. n=35**
Iron (mg/L)	0.30	3	3.1	2.9
Manganese (mg/L)	0.05	6.1	4.7	8.6
Hardness (mg/L)	180.00	2	0	5.7
Sulfate (mg/L)	250.00	0	0	0
Chloride (mg/L)	250.00	0	0	0
Fluoride (mg/L)	2/4[1]	0	0	0
TDS (mg/L)	500.00	1	0	2.9
pH - Low	6.50	21.2	21.9	20
pH - High	8.50	0	0	0
Saturation Index - Low	–1.00	90	95.3	80
Saturation Index - High	1.00	0	0	0
Copper (mg/L)	1/1.3	2	1.6	2.9
Sodium (mg/L)	20.00	5	3.1	8.6
Nitrate (mg/L)	10.00	0	0	0
Total Coliform	ABSENT	44.5	48.4	37.1
E. coli	ABSENT	15.2	20.3	5.7

[1] *Two values separated by "/" reflect the secondary maximum contaminant level (SCML)/maximum contaminant level (MCL) set by EPA.*

causing organisms. Detection of coliform bacteria is confirmed by a total coliform analysis result above zero. Coliforms are always present in the digestive systems of all warm-blooded animals and can be found in their wastes. Coliforms are also present in the soil and in plant material. While a water sample with total coliform bacteria present may have been inadvertently contaminated during sampling, other possibilities include surface water contamination due to poor well construction, contamination of the household plumbing system, or water-table contamination. To determine whether or not the bacteria were from human and/or animal waste, positive total coliform tests were followed up by an analysis for *E. coli* bacteria.

Of the 99 samples collected from the two counties, 29 percent tested positive (present) for total coliform bacteria. Subsequent *E. coli* analysis for these total coliform positive samples showed 15, or 52 percent, positive for *E. coli*.

Figure 11. Bacteriological Analysis Results



The susceptibility of household water supplies to bacteriological contamination has often been associated with the type of water source. For example, bacteriological contamination of springs is greater than that of wells, which usually offer better protection from surface, or near surface, contaminants. Similarly, deep-drilled wells are better protected than shallow-dug and bored wells. This is clearly borne out by the results of this program. The incidence of total coliform and *E. coli* contamination of dug/bored wells was 31 percent and drilled wells was 23 percent. For springs, 50 percent tested positive for total coliform and *E. coli* bacteria.

The age of a water source/system is an additional factor which may have an influence on contamination susceptibility. With respect to wells in particular, deterioration of the well structure over time, cumulative damage caused by equipment traffic, etc., and prolonged exposure of the wellhead area to potentially harmful pollutants may all contribute to the eventual contamination of the well. A major age-related impact could relate to the development of, and conformance with, well construction standards through the years. Major legislation in Virginia to address such issues has been enacted in recent years, most notably in the early 1970s and early 1990s. Therefore, for the purpose of examining the occurrence of bacteriological contamination with well age, the sample results were evaluated for the following three construction date categories: (1) pre-1970, (2) 1970-1989, and (3) 1990 to date. With respect to total coliform bacteria, for each of the above categories, the percentages of well-water samples determined to be positive were as follows: (1) 58, (2) 56, and (3) 14. For *E. coli* bacteria, the corresponding percentages were: (1) 25, (2) 16, and (3) 3. Perhaps not surprisingly, a substantial reduction in positive bacteria cases overall was not noted until the latter time period, likely influenced not only by the newness of the wells, but also the most recent, stricter well standards, licensing of well drillers, and post-construction inspections.

Fecal bacteria in household water supplies may have originated from animal waste and/or human waste from septic systems. Although, positive results should be viewed with concern, they are not a cause for panic. Individuals have probably been drinking this water for some time with no ill effects and could possibly continue to do so. Nevertheless, such problems should be investigated further and remedied, if possible. Program participants whose water tested positive were given information regarding emergency disinfection, well improvements, septic system maintenance and other steps to correct the source of contamination. After taking initial corrective measures, they were advised to have the water retested for total coliform, followed by *E. coli* tests, if warranted.

Conclusions

The Household Water Quality Educational Programs conducted in Buckingham and Cumberland counties were successful. Individuals participated in the programs primarily because of concern about the safety of their water supply. Despite being a voluntary program, a geographically distributed sample that represents diverse households and water-supply characteristics is obtained. While the project is designed for voluntary participation and quality control in sampling is not assured, the type of information gathered and summarized is useful for water-quality assessment at county and regional levels.

Water-quality analyses, for many nuisance constituents, generally supported the participants' descriptions of their water supplies regarding such problems as staining, unpleasant taste, odor, and appearance. The severity of these symptoms is confirmed by the high incidence of water treatment devices installed – 30 percent of all households participating had one or more water treatment devices installed.

From a nuisance standpoint, iron/manganese and corrosivity were the main issues. Major health-related concerns were corrosivity (because of the potential to raise dissolved copper and lead levels in household water) and bacteria. Furthermore, elevated nitrate concentrations may present a health risk to infants in a number of cases. Forty-four percent of the samples tested positive for total coliform and 15 percent were positive for *E. coli* bacteria. In these positive cases, participants were advised of ways to improve water supply conditions and were encouraged to pursue retesting for coliform bacteria.

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Glossary

EPA - U. S. Environmental Protection Agency

mg/L (mg/l in appendix documents) - Concentration unit of milligrams per liter in water, equivalent to one pa rt per million (ppm).

Maximum Contaminant Level (MCL) - Legally enforceable national standard set by the EPA to protect the public from exposure to water hazards. Standards only apply to public drinking water systems, but they also serve as a guide for individual water supplies.

Secondary Maximum Contaminant Level (SMCL) - Concentration limits for nuisance contaminants and physical problems. Governments do not enforce these standards. However, they are useful guidelines for individual water supplies.

Appendix

(1) Program Fact Sheet

(2) Sample Identification and Questionnaire Form

(3) Sample Water Quality Analysis Report

(4) Report Interpretation

* The following examples represent forms, reports, etc. used in the Cumberland County Program only. Paperwork for Buckingham County was similar, except for county-specific details.

(1) Program Fact Sheet

Virginia Cooperative Extension offers Water Quality Testing Program

Cumberland County Extension Office will be conducting household water quality testing programs during the month of October with results to follow in November. Testing is available for water from wells, springs, or cisterns. The programs will be made up of a three part series. The first meeting, which will be held on October 6th at 7:00 PM in the Cumberland Elementary School Cafeteria, will include information on water quality, why you should test your drinking water, and what type of information your tests will include. Participants will receive the test kits and detailed information on how to collect the water samples. The second part of the series involves participants collecting their water samples and dropping them off at the Cumberland County Extension Office on October 12th from 7:00 – 11:00 AM. A final meeting will be held in mid November at the Cumberland Elementary School Cafeteria where test results will be distributed and information will be presented on how to take care of problems with your drinking water.

The cost of the program will be $21 for the first 300 households and $26 for any additional participants. This fee is due when picking up the Test Kit on October 6 and is non-refundable. Cumberland County and Virginia Tech have contributed to significantly reduce the cost of the test from the usual $45 fee. For additional information or to sign up, please contact the Cumberland County Extension Office at 804-492-4390, Monday – Friday from 8:00 to 4:30 PM. This program, like all Virginia Cooperative Extension programs, is open to all people on a non-discriminatory basis.

(2) Sample Identification and Questionnaire Form

CUMBERLAND COUNTY HOUSEHOLD WATER QUALITY PROGRAM

Cumberland County Cooperative Extension
P.O. Box 80
Cumberland, VA 23040-0080
(804) 492-4390

SAMPLE IDENTIFICATION (Please **print** clearly and provide complete information on both sides of form.)

Sample No.:_____ Date collected: _____

Sample submitted by:

Name: _____

Mailing address: _____

_____

Telephone:_____

FOR OFFICE USE ONLY

Map Grid No._____

Lab Sample No._____

Household water supply source **drawn for sample** (check **one**):

___*well* ___*spring* ___*cistern* ___*other (Specify:* _____)

If *well* is checked above: (*a*) is it a ____ *dug or bored well,* ____ *drilled well,* ____ *don't know;*
(*b*) what is its approximate depth, if known? _____*feet*
(*c*) what year was well constructed, if known? _____

Do other households share the same water supply? ___ *yes* ___ *no* **If** *yes*, approximately how many? _____

Water treatment devices currently installed and affecting **cold water only** drawn at faucet for sample (check **all** that apply):

_____*none*
_____*water softener (conditioner)*
_____*iron removal filter*
_____*automatic chlorinator*
_____*acid water neutralizer*
_____*sediment filter (screen or sand type)*
_____*activated carbon (charcoal) filter*
_____*other (specify:*
_____)

SAMPLING INSTRUCTIONS: You must take your water samples only on the collection day you have been assigned. For the general water analysis sample, use the larger plastic bottle as described below. A separate, smaller bottle is provided for bacteriological samples which should be taken last. If you have any questions about sampling procedures, call the Extension Office at (804) 492-4390.

Do not remove caps from sample bottles until you are ready to take each sample. Do not touch inside of cap or mouth of either bottle.

Turn on the cold water faucet in the kitchen or bathroom (select a stationary, non-swivel faucet, if possible) and allow the water to run until it becomes as cold as it will get; then let it run for one more minute.

Slowly and carefully fill the larger bottle to avoid splashing or overflowing. Pour out this rinse water and then refill bottle completely. Tighten cap on bottle securely.

Let the water run for an additional two or three minutes. Reduce flow to prevent splashing and carefully fill the smaller bottle only once to the shoulder (just below the threaded top). DO NOT RINSE BOTTLE. Replace cap tightly.

Do not write anything on the bottle labels. If samples are not to be delivered immediately, store in refrigerator or on ice until ready to deliver later that day.

(2) Sample Identification and Questionnaire Form cont.

Fill out this Sample Identification Form and Questionnaire (on reverse side) completely and bring it, along with both water sample bottles, to the designated collection site on your assigned collection day.

QUESTIONNAIRE (Please answer the following questions as completely as possible, considering how you view the **present** condition of the water sampled, including improvements due to any treatment devices identified on other side of form.)

1. Describe the location of your home. (Check **one**)
   _____*on a farm* _____*on a remote, rural lot* _____*in a rural community* _____*in a housing subdivision*

2. What pipe material is primarily used throughout your house for water distribution? (Check one)
   ___*copper* __*lead* __*galvanized steel* __*plastic (PVC, PE, etc.)* __*other (specify:* _____*)* __ *don't know*

3. Do you have problems with corrosion or pitting of pipes or plumbing fixtures? _____*yes* _____*no*

4. Does your water have an unpleasant taste? _____*yes* _____*no*

5. If *yes*, how would you describe the taste? (Check **all** that apply)
   ___*bitter* ___*sulfur* ___*salty* ___*metallic* ___*oily* ___ *soapy* ___*other (specify:* _____*)*

6. Does your water have an objectionable odor? _____*yes* _____*no*

7. If *yes*, how would you describe the odor? (Check **all** that apply)
   ___*"rotten egg" or sulfur* ___*kerosene* ___*musty* ___*chemical* ___*other (specify:* _____*)*

8. Does your water have an unnatural color or appearance? _____*yes* _____*no*

9. If *yes*, how would you describe the color or appearance? (Check **all** that apply)
   ___*muddy* ___*milky* ___*black/gray tint* ___*yellow tint* ___ *oily film* ___ *other (specify:* _____*)*

10. Do you have problems with staining of plumbing fixtures, cooking appliances/utensils, or laundry? ___*yes* ___*no*

11. If *yes*, how would you describe the color of stains? (Check **all** that apply)
    ___*blue-green* ___*rusty (red/orange/brown)* ___*black or gray* ___*white or chalk* ___*other (specify:* _____*)*

12. In a standing glass of water, do you notice floating, suspended, or settled particles? _____*yes* _____*no*

13. If *yes*, how would you describe this material? (Check **all** that apply)
    ___*white flakes* ___*black specks* ___*reddish-orange slime* ___*brown sediment* ___*other (specify:* _____*)*

14. If your water supply is located **100 feet or less** from any of the following, please indicate. (Check **all** that apply)
    _____*septic system drain field*
    _____*pit privy or outhouse*
    _____*cemetery*
    _____*home heating oil storage tank (above or below ground)*
    _____*pond or freshwater stream*
    _____*tidal shoreline or marsh*

15. If your water supply is located **½ mile or closer** to any of the following, please indicate. (Check **all** that apply)
    _____*landfill*
    _____*illegal dump*
    _____*active quarry*
    _____*abandoned quarry, industry, etc.*
    _____*golf course*
    _____*field crops/nursery*
    _____*farm animal operation*
    _____*manufacturing/processing operation (specify:* _____*)*
    _____*commercial underground storage tank or supply lines (gasoline service station, heating oil supplier, etc.)*

This material is based upon work supported by the U.S. Department of Agriculture, Extension Service.

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(3) Sample Water Quality Analysis Report

Cumberland County
Household Water Quality Program

Cumberland County Cooperative Extension
P.O. Box 80
Cumberland, VA 23040
(804) 492-4390

Sample No: C

Cartersville, VA 23027
(804)

Source: Dug/Bored Well

Treatment: Sediment Filter

Water Quality Results
Date of Sample: 10/12/05

Test	Household Water Sample	Maximum Recommended Level or Range
Iron (mg/l)	0.02	0.3
Manganese (mg/l)	< 0.001	0.05
Hardness (mg/l)	44.5	180
Sulfate (mg/l)	2.066	250
Chloride (mg/l)	30	250
Fluoride (mg/l)	< 0.1	2
Total Dissolved Solids (mg/l)	102	500
pH	6.2**	6.5 to 8.5
Saturation Index	-2.98**	-1 to 1
Copper (mg/l)	0.04	1.0
Sodium (mg/l)	7.8	20
Nitrate-N (mg/l)	4	10
Total Coliform Bacteria	PRESENT**	ABSENT
E. Coli Bacteria	ABSENT	ABSENT

** Measured Value exceeds recommendation for household water.

Analysis coordinated by Water Quality Laboratory, Dept. of Biological Systems Engineering, Virginia Tech, Blacksburg, VA. The information provided is for the exclusive use of the homeowner and should not be used as official documentation of water quality. This material is based upon work supported by the U.S. Department of Agriculture, Extension Service.

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Cumberland County Household Water Quality Program

INTERPRETING YOUR HOUSEHOLD WATER QUALITY ANALYSIS REPORT

IRON

Iron in water does not usually present a health risk. It can, however, be very objectionable if present in amounts greater than 0.3 mg/l. Excessive iron can leave red-orange-brown stains on plumbing fixtures and laundry. It may give water and/or beverages a bitter, metallic taste and discolor beverages.

MANGANESE

Manganese does not present a health risk. However, if present in amounts greater than 0.05 mg/l it may give water a bitter taste and produce black stains on laundry, cooking utensils, and plumbing fixtures.

HARDNESS

Hardness is a measure of calcium and magnesium in water. Hard water does not present a health risk. However, it keeps soap from lathering, decreases cleaning action of soaps and detergents, leaves soap "scum" on plumbing fixtures, and leaves scale deposits on water pipes and hot water heaters. Softening treatment is highly recommended for very hard water (above 180 mg/l). Water with a hardness concentration of about 50 mg/l or less does not need softening. Water hardness may also be reported in units of grains per gallon, or gpg (1 gpg = 17.1 mg/l hardness). In all but extremely hard water situations, it may be desirable to soften only the hot water.

SULFATE

High sulfate concentrations may result in adverse taste as well as cause a laxative effect. The Secondary Maximum Contaminant Level for sulfate is 250 mg/l. Sulfates are generally naturally present in groundwater and are linked to other sulfur-related problems, such as hydrogen sulfide gas. This gas may be caused by the action of sulfate reducing bacteria as well as other types of bacteria on decaying organic matter. While it is difficult to test for the presence of hydrogen sulfide gas in water, it can be easily detected by its characteristic "rotten egg" odor, which may be more noticeable in hot water. Water containing this gas may also corrode iron and other metals in the water system as well as stain plumbing fixtures and cooking utensils.

CHLORIDE

Chloride in drinking water is not a health risk. Natural levels of chlorides are low; high levels in drinking water usually indicate contamination from a septic system, road salts, fertilizers, industry, or animal wastes. High levels of chloride may speed corrosion rates of metal pipes, and causing pitting and darkening of stainless steel. The EPA has set a Secondary Maximum Contaminant Level for chloride of 250 mg/l.

FLUORIDE

Fluoride is of concern primarily from the standpoint of its effect on teeth and gums. Small concentrations of fluoride are considered to be beneficial in preventing tooth decay while moderate amounts can cause brownish discoloration of teeth and high fluoride concentrations can lead to tooth and bone damage. For these reasons, the EPA has set both a Secondary Maximum Contaminant Level and a Maximum Contaminant Level of 2 and 4 mg/l, respectively.

TOTAL DISSOLVED SOLIDS (TDS)

High concentrations of dissolved solids may cause adverse taste effects and may also lead to increased deterioration of household plumbing and appliances. The EPA Secondary Maximum Contaminant Level is 500 mg/l for total dissolved solids.

pH

The pH of water indicates whether it is acidic (below 7.0) or alkaline (above 7.0). Acidic water can cause corrosion in pipes, and may cause toxic metals from plumbing systems, such as copper and lead, to be dissolved in drinking water. Dissolved copper may give water a bitter or metallic taste, and produce blue-green stains on

plumbing fixtures. The life of plumbing systems may be shortened due to corrosion requiring expensive repair and replacement of water pipes and plumbing fixtures. The use of plastic pipes throughout the water distribution system should lessen these concerns. Water with a pH below 6.5 is considered to be acidic enough to require treatment. Alkaline water with a pH above 8.5 is seldom found naturally, and may indicate contamination by alkaline industrial wastes. The EPA has set a suggested range of between 6.5 and 8.5 on the pH scale for drinking water.

SATURATION INDEX

The saturation (Langlier) index, in addition to pH, is used to evaluate the extent of potential corrosion of metal pipes, plumbing fixtures, etc. It is a calculated value based on the calcium concentration, total dissolved solids concentration, measured pH, and alkalinity, and is a measure of the scale formation potential of the water. A saturation index greater than zero indicates that protective calcium carbonate deposits may readily form on pipe walls. A saturation index less than zero indicates that the water does not have scale-forming properties and pipes may be subject to corrosion. Saturation index values between -1 and +1 are considered acceptable for household water supplies. NOTE: **Values of less than -1 need not be of concern if the water is not acidic (indicated by a pH of 7.0 or above)**. Water softener owners may note a saturation index reading lower than desired. While these treatment devices correct hardness, they may enhance the corrosion potential of the water. Concerns about resulting drinking water quality may be lessened by softening only the hot water or bypassing drinking water lines.

COPPER

The EPA drinking water standard for copper is 1.3 mg/l, based on concerns about acute gastrointestinal illness. Since dissolved copper also leaves blue-green stains on plumbing fixtures, a Secondary Maximum Contaminant Level of 1.0 mg/l is also provided for copper. While copper in household water most often comes from the corrosion of brass and copper plumbing materials, this type of contamination is not likely to be detected under the sampling procedure followed in this program, which calls for flushing the water lines. Therefore, any excessive amounts of copper from the water source itself may indicate contamination from industrial wastes or dumps/landfills.

SODIUM

Excessive sodium has been linked to problems with high blood pressure, and heart and kidney diseases. Moderate quantities of sodium in drinking water are not considered harmful since an individual normally receives most (over 90 percent) of his/her sodium intake from food. For those on low-sodium diets, both the American Heart Association and EPA suggest 20 mg/l as a maximum level for sodium in drinking water; a physician should be consulted in individual cases. Water softening by ion exchange will increase sodium levels in water. To reduce sodium in drinking water requiring such treatment, soften only the hot water or bypass drinking water lines.

NITRATE

High levels of nitrate may cause methemoglobinemia or “blue-baby” disease in infants. Though the EPA has set a Maximum Contaminant Level for nitrate-nitrogen of 10 mg/l, they suggest that water with greater than 1 mg/l be used with caution for feeding infants. Levels of higher than 3 mg/l may indicate excessive contamination of water supply by commercial fertilizers as well as organic wastes from septic systems or farm animal operations.

TOTAL COLIFORM BACTERIA

Microbiological contamination of drinking water can cause short-term gastrointestinal disorders, resulting in cramps and diarrhea that may be mild to very severe. Other diseases of concern are Viral Hepatitis A, salmonella infections, dysentery, typhoid fever, and cholera. While coliform bacteria do not cause disease, they serve as indicators of the possible presence of disease bacteria. Coliform bacteria are always present in the digestive systems of humans and animals and could also come from other sources such as soil or decaying vegetation. Analysis for total coliform bacteria is the EPA standard test for microbiological contamination of a water supply, for which none should be present.

E. coli

In the event that there are coliform bacteria present, a test for fecal bacteria, such as E. coli, is necessary to determine whether or not any bacteria are from human and/or animal waste. E. coli bacteria, this species of which is harmless, always originate within the intestinal tract of warm blooded animals and humans and do not survive very long outside of the digestive system. The presence of E. coli bacteria indicates that waste from a septic system or nearby animals is likely contaminating the water supply.