Evaluation of Household Water Quality in Essex, King and Queen, King William, and Middlesex Counties, Virginia

2000

Household Water Quality Series 42
Department of Biological Systems Engineering
Virginia Polytechnic Institute and State University
Blacksburg, Virginia 24061-0303

Virginia Cooperative Extension

Virginia Tech
VIRGINIA POLYTECHNIC INSTITUTE AND STATE UNIVERSITY

Publication 442-932
March 2000

VIRGINIA STATE UNIVERSITY

EVALUATION OF HOUSEHOLD WATER QUALITY IN ESSEX, KING AND QUEEN, KING WILLIAM, AND MIDDLESEX COUNTIES, VIRGINIA

B. B. Ross[1]

T. K. Balderson[2]

C. L. Lawrence[3]

D. M. Moore[4]

K. R. Parrott[5]

A. C. Bourne[6]

Virginia Polytechnic Institute and State University
Department of Biological Systems Engineering
Household Water Quality Series 42
March 2000

[1] Professor, Dept. of Biological Systems Engineering, VPI&SU, Blacksburg, Virginia.

[2] Extension Agent, Essex County, Tappahannock, Virginia.

[3] Extension Agent, King and Queen and King William Counties, King and Queen and King William, Virginia.

[4] Extension Agent, Middlesex County, Saluda, Virginia.

[5] Associate Professor, Dept. of Near Environments, VPI&SU, Blacksburg, Virginia.

[6] Undergraduate Student Assistant, Dept. of Biological Systems Engineering, VPI&SU, Blacksburg, Virginia.

Evaluation of Household Water Quality in Essex, King and Queen, King William, and Middlesex Counties, Virginia

ABSTRACT

During Spring 1999 in Essex, King and Queen, King William, and Middlesex Counties, Virginia, programs of household water quality education, which included water sampling, testing, and diagnosis, were conducted. Participation in the water quality programs was made available to any resident of these four counties who utilized a private, individual water supply. During the course of the projects, 342 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. These analyses identified the major household water quality problems in these four counties as iron/manganese, corrosivity, and bacteria, although the occurrence and extent of these problems varied across the four counties. Chloride and total dissolved solids were particular problems only in Middlesex County. Additionally, a number of samples in all four counties were determined to have concentrations of sodium and nitrate high enough to possibly lead to health complications for at-risk segments of the population.

After the completion of the general water testing program, water supplies from 15 households were resampled for the testing of 29 pesticides and other chemical compounds. None of the samples had a concentration of any of these contaminants exceeding EPA Health Advisory or Maximum Contaminant Levels. Furthermore, a total of only five detections were observed in five separate samples.

Following completion of the programs, a survey was mailed to the 342 participants. One hundred and seven participants returned survey forms on which they identified their reason(s) for participating in such a program; the primary reason was concern about safety of their water supply. Returned survey forms also provided insight into measures participants had already taken, or planned to take, to improve the quality of their water supply. Nearly three-fourths of the households who reported having at least one water quality problem had taken, or planned to take, at least one measure to improve the quality of their water supply. Thirteen percent or more of all participants had taken, or planned to take, one or both of the following actions: shock chlorinate the water system and use bottled water for drinking/cooking.

ACKNOWLEDGMENTS

Many thanks are due the residents of Essex, King and Queen, King William, and Middlesex 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, such as Master Gardeners and others, who provided support in terms of publicity, encouragement, and interest, thus contributing to the success of the household water quality educational program. Virginia Department of Health and Virginia Department of Environmental Quality personnel, as well as others, who spoke at the public meetings, are appreciated for their contributions. In particular, Janet Leigh, Extension Agent (FCS), Gloucester County, is acknowledged for her presentations at meetings held in three of the four Counties.

The Southeast Rural Community Assistance Project, Inc. of Roanoke, Virginia provided funding to offset the cost of testing for all participants. CSREES/USDA Water Quality Program Support 3-d funds were also made available for this program.

The Water Quality Laboratory of the Department of Biological Systems Engineering at Virginia Tech was responsible for the majority of the water quality analyses, as well as coordination among the various labs and for much of the data management. Julie Jordan, Laboratory Supervisor, and her staff are especially acknowledged for their efforts. Assisting with the general water chemistry analysis was the Soils Testing Laboratory of the Department of Crop and Soil Environmental Sciences at Virginia Tech. The Pesticide Research Laboratory, of the Biochemistry and Anaerobic Microbiology Department of Virginia Tech, performed the chemical compound analyses.

Additional support from Virginia Tech should also be noted. Judy Poff, of the Virginia Water Resources Research Center, was instrumental in providing educational publications for participants at the public meetings. Joe Gray, of the Virginia Cooperative Extension Distribution Center, is appreciated for his assistance in preparing and mailing the evaluation survey packets to participants. Appreciation is due Diane Mahaffey for her efforts in preparing project forms and in typing this manuscript, and to Liz Epley for her assistance in data management. In addition, Bev Brinlee and Tim FisherPoff are acknowledged for their editorial and design contributions.

TABLE OF CONTENTS

ABSTRACT II

ACKNOWLEDGMENTS III

LIST OF FIGURES AND TABLES V

INTRODUCTION 1

OBJECTIVES 2

METHODS. 2

FINDINGS AND RESULTS 3

- Profile of Participant Households 4
- Profile of Household Water Supplies 4
- Participants' Perceptions of Household Water Quality 6
- Household Water Quality Analysis 7
  - General Water Chemistry Analysis 7
  - Bacteriological Analysis 16
  - Chemical Compound Analysis 19
- Post-Program Survey 20
  - Household Water Testing History 20
  - Reasons for Program Participation 20
  - Follow-up Activities Taken or Planned 20

CONCLUSIONS 21

REFERENCES 22

APPENDIX 23

LIST OF FIGURES AND TABLES

Figure 1. Educational Level Achieved by Participants 5

Figure 2. Family Income of Participants 5

Figure 3. Housing Environs of Participants 6

Figure 4. Household Water Treatment Devices Installed 9

Figure 5. Unpleasant Tastes Reported by Participants 9

Figure 6. Objectionable Odors Reported by Participants 10

Figure 7. Unnatural Appearance Reported by Participants. 10

Figure 8. Particles in Water Reported by Participants. 11

Figure 9. Staining Problems Reported by Participants 11

Table 1. Average and Range of Concentration of Contaminants Comprising General Water Chemistry Analysis 14

Table 2. Percent of Concentrations Exceeding Established Standards for Contaminants Comprising General Water Chemistry and Bacteriological Analysis 15

Table 3. Pesticides and Other Chemical Compounds Analyzed in 15 Household Water Supplies 17

Table 4. Measures Taken or Planned by Participants, Since Water Quality Analysis, to Improve Water Supply 18

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 Essex, King and Queen, King William, and Middlesex Counties, for example, four-fifths of all housing units (80%) are served by individual water systems (Koebel et al., 1993). Virtually all of these homes depend on groundwater sources.

Throughout these four counties, most wells were drilled only for farm or domestic water supply. George and Gray (1988) have estimated that 90% of the drilled wells are inadequately constructed, while 95% of all dug/bored wells are inadequate. One in five households were also estimated to have failing or inadequate waste disposal systems.

Essex, King and Queen, King William, and Middlesex Counties have a combined land area of 980 square miles. All four counties lie within the Coastal Plain physiographic province. The four counties comprise much of Virginia's Middle Peninsula, therefore, are drained entirely by the Rappahannock and York Rivers, which along with the latter's major tributaries, the Mattaponi and Pamunkey Rivers, form much of the borders of the four counties.

The population of the four-county area increased by slightly more than 8% during the period 1980-90. Some new home sites are rural-based without public water and sewage services. As rural home sites encroach on agricultural land, the water supply becomes suspect to residents. Of equal importance is the potential failure of septic systems, since many home sites are on land less than ideal for a properly functioning septic system.

In addressing similar concerns, Ross et al. (1991) initiated a pilot program of household water quality education in Warren County, Virginia, which included water sampling, testing, and diagnosis. Based on requests and support from local interests, subsequent programs have been conducted in 55 additional counties. During the course of these projects, more than 8,150 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 fecal coliform/E. coli bacteria.

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 most 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). It was the need to assess the current state of rural household water supplies in Essex, King and Queen, King William, and Middlesex Counties, in addressing the above water quality issues, that led to the implementation of the Household Water Quality Education Program in the four counties.

OBJECTIVES

The primary goal of this project was to conduct educational programs on household water quality to include water testing/diagnosis in Essex, King and Queen, King William, and Middlesex Counties, Virginia. The general program objectives were to: (1) improve the quality of life of rural homeowners by increasing 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 Essex, King and Queen, King William, and Middlesex Counties during Spring 1999. Any household 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). Local news media and agency newsletters publicized the program in each county, and program fact sheets were prepared (see Appendix).

The programs were launched through local meetings held in Deltaville, Saluda, and Tappahannock in early April, and King and Queen and King William in early May. Attendees of these initial meetings were presented with information on local hydrogeologic characteristics in relation to groundwater pollution, likely sources of, and activities contributing to, groundwater contamination, the nature of household water quality problems (both nuisance and health-related), and specifics of the water testing program to follow. At these meetings, individuals were invited to sign up to participate in the testing program at a basic cost of $20 per household water sample submitted.

Provisions were made to analyze up to 150 household water samples per county. Water sampling kits, for use by the participants themselves, were made available at the meetings and at the county Cooperative Extension offices after the meetings for late registrants. Two types of water sampling kits were distributed: (1) general water chemistry analysis for iron, manganese, hardness, sulfate, chloride, fluoride, total dissolved solids, pH, saturation index (Langlier), copper, sodium, and nitrate; and (2) bacteriological analysis (total coliform and E. coli).

The sampling kits included a 250 ml plastic bottle for general water chemistry samples and a sample identification form (see Appendix). The form included sampling instructions and a questionnaire on which participants were asked to describe the characteristics of their water supply. Also included in the kits was a 125 ml sterilized plastic bottle for bacteriological samples. 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. Persons who already had a water treatment device, such as a water softener, were requested to provide information about the type of equipment so that effective evaluation of their water quality and proper interpretation of results could be obtained, as further explained below.

Water samples were collected on April 14 and 28 at the Extension offices in Essex and Middlesex Counties, and May 12 and 26 in King and Queen and King William Counties. At the close of each collection day, all samples were packed in ice and immediately delivered to Virginia Tech in Blacksburg for analysis.

The general water chemistry and bacteriological analysis was 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, 1979).

After the analysis had been completed for each county, participants were reminded by mail to attend subsequent meetings in either Deltaville, Saluda, Tappahannock, King and Queen, or King William to obtain and discuss the test results and management practices to reduce or prevent water contamination. Complete test results were ultimately mailed to those participants who could not attend any of the meetings. A sample report form and accompanying report interpretation are shown in the Appendix.

At the conclusion of the general water testing program described above, participating households were given the opportunity to have their water further tested, for the presence of pesticides and other chemical compounds, at a cost of $75 per sample. The Pesticide Research Laboratory of the Biochemistry and Anaerobic Microbiology Department at Virginia Tech performed the analysis. Sample jars and forms (see Appendix) were provided, whereby local project personnel collected the samples during August 1999.

At the conclusion of the programs, an evaluation survey was mailed to participants (see Appendix). The objectives of the survey were to determine (1) the reasons for participation in the educational programs and for having household water tested, and (2) the actions to correct water quality problems the participants had taken, or planned to take, as a result of participation in the programs. Limited socio-economic information was also requested to obtain a profile of the total audience reached by the programs.

In addressing overall project objective 2, local government and public officials were kept apprised of water quality test results, during the course of the programs and at their completion. While the project was designed to involve voluntary participation, and quality control in sampling was not assured, the information gathered was nevertheless deemed useful for water quality assessment and planning at county and regional levels.

FINDINGS AND RESULTS

During the course of the projects, 342 individual household water samples were returned for general water chemistry and bacteriological analysis from all areas of the four counties. Two surveys were distributed to all water testing participants: One, the questionnaire with the water sampling kit, to be completed and returned by all participants with the sample submitted for analysis; and the other, an evaluation of the completed programs (see Appendix). For the latter, of the 342 forms mailed, 107 were returned (a 31% response rate). Both surveys provided insight into the characteristics of the households and their water supplies.

Profile of Participant Households

The average length of the respondents' residence in Essex, King and Queen, King William, and Middlesex Counties was 15 years. The length of residence reported ranged from 1 to 77 years. Twenty-eight percent of those responding had lived in their present county for 5 years or less. The size of the respondents' households ranged from one to six members; average household size was 2.49. It can, therefore, be estimated that more than 850 residents of the four counties were directly impacted by the water analysis/diagnosis aspect of the programs.

Three-fifths (60%) of the respondents were college graduates and more than 95% had at least a complete high school education (see Figure 1); facts that are not surprising, since it is likely that such individuals would have a greater awareness and understanding of water quality issues and be more likely to participate in such a program.

Participation in the program was on the high end of income distribution. Figure 2, which shows the family income (before taxes) of the respondents, indicates that a majority of the respondents exceeded the median family income ($33,056 averaged for the four counties and according to the 1990 Census) (Koebel et al., 1993). Thirteen percent of respondents declined to indicate family income.

Profile of Household Water Supplies

The initial survey answers, provided by all 342 participants in the water testing programs, helped to characterize their water supplies (see Appendix). One set of questions dealt with the proximity of the household water supply to potential sources of groundwater contamination. One such question sought to define housing density, which may have an impact primarily from the standpoint 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 a remote, rural lot, (3) in a rural community, and (4) in a housing subdivision. As shown in Figure 3, rural community was the most common at 54%, while subdivision (9%) was the least common.

Participants were also asked to identify potential contamination sources within 100 feet of their water supply. The major sources identified were septic system drainfields and home heating oil storage tanks, noted by 23% and 14%, respectively, of all households. 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; 11% of the participants indicated that their water supply was located within one-half mile of field crop production and 8% within one-half mile of a major farm animal operation.

Information was also obtained regarding characteristics of the participants' water supply systems. Regarding the type of water source supplying the household, all of participants reported that they rely on a well. Participants were furthermore asked to provide an estimate of the well depth, if known. Of those participants indicating well depths, 73% reported depths of more than 50 feet, while 27% reported less than or equal to 50 feet. The maximum well depth reported was 999 feet; the average well depth was 171 feet. Sixteen percent of the wells were constructed in or prior to 1970. The earliest reported well construction date was 1865.

Figure 1. Educational Level Achieved by Participants

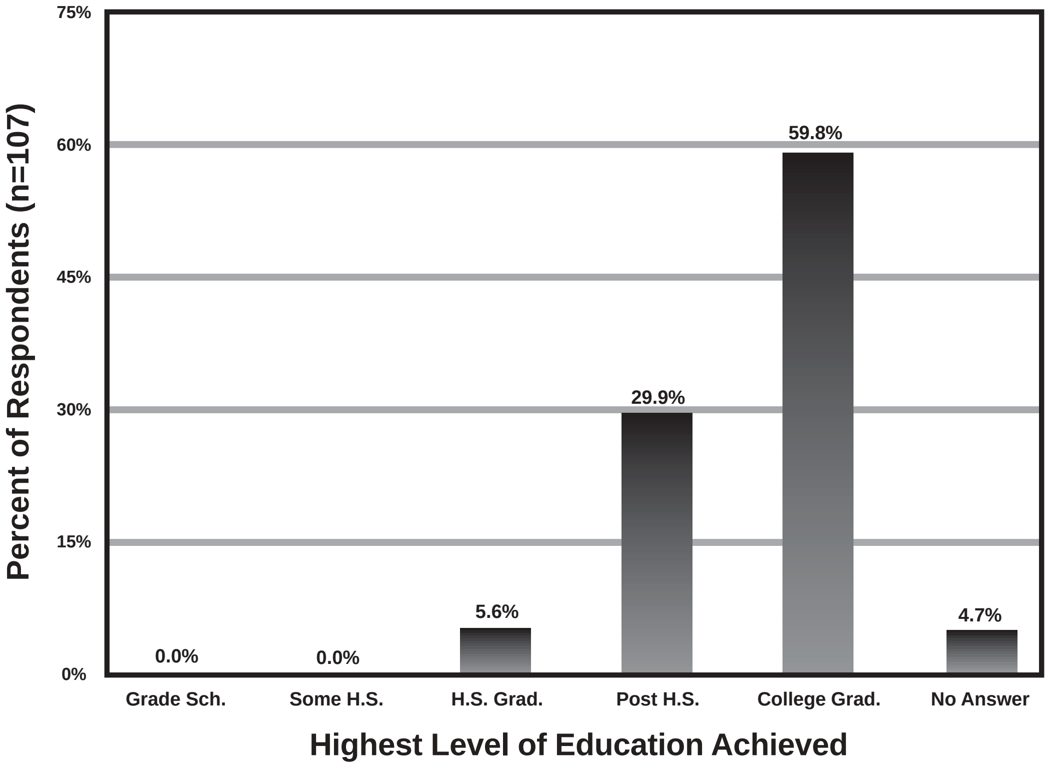


Figure 2. Family Income of Participants

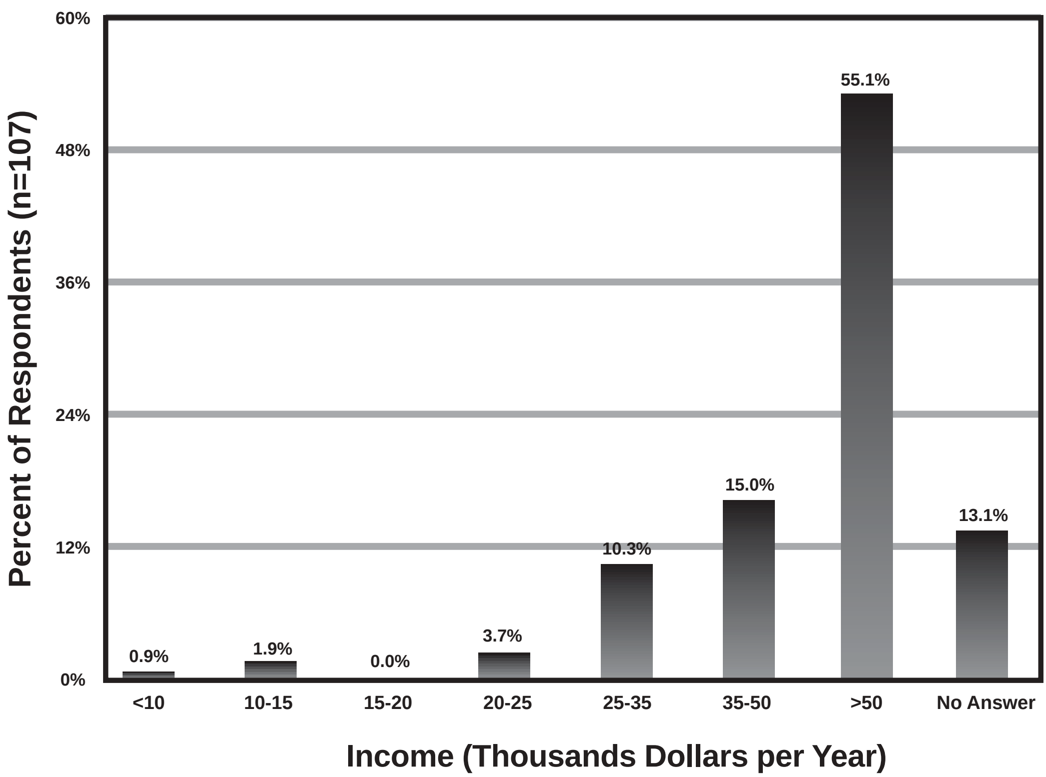
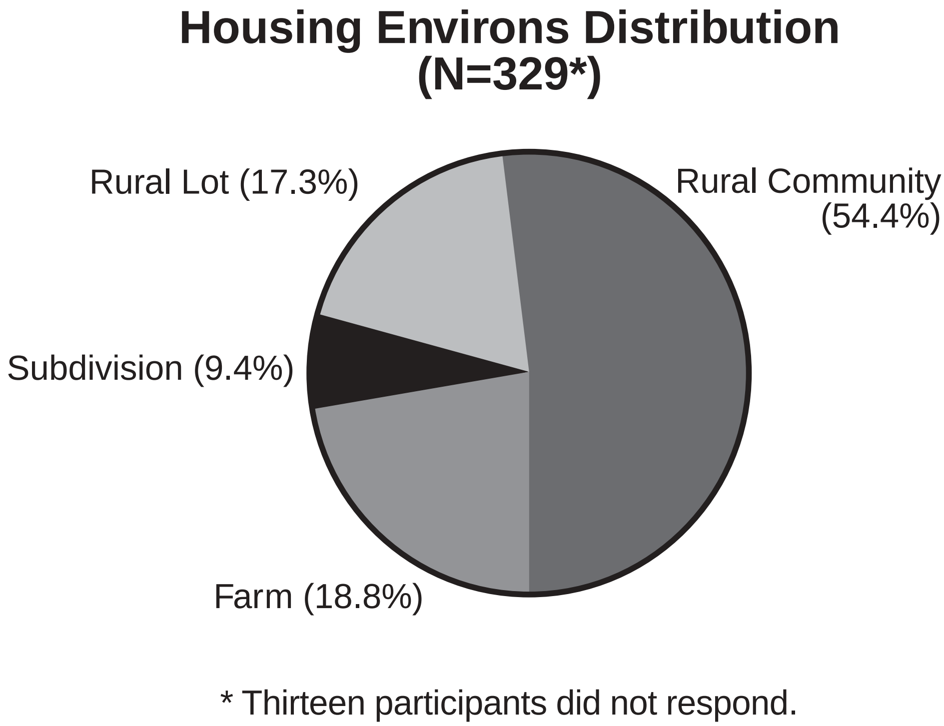


Figure 3. Housing Environs of Participants



Household water systems were further identified with respect to the type of material used in the piping network for water distribution throughout the dwellings. The most widely used material was copper (58%), while plastic was reported by 34% of the participants. Six 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 household water systems had water treatment devices currently installed, and if so, the type of device. The results of the inquiry are presented in Figure 4. Twenty percent of the participants reported at least one treatment device installed, with the most common type of treatment device in use being a water softener (48%), followed closely by sediment filter at 43%. Ten percent of those with treatment device(s) indicated “other”, such as reverse osmosis.

Participants' Perceptions of Household Water Quality

Participants were also asked about problems they were experiencing in their household water systems (see Appendix). They were asked initially 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. With the exception of (1) above, with which 18% of the participants identified, participants were given several more specific descriptions from which to choose if answering positively.

Twenty-six percent of the participants responded that their water had an unpleasant taste. For these participants, the identification of tastes is presented in Figure 5. "Sulfur" taste was the most common problem (31%), followed by "bitter" and "metallic," both identified by 22% of those who reported taste problems. Ten percent of these reported "other" tastes, such as stale.

An objectionable odor was reported by 28% of the participants. Of these, the description of odors selected is shown in Figure 6. The most prevalent odor described, by far, was "rotten egg," or sulfur, identified by 72% of those reporting odor problems.

Twelve percent of the participants affirmed their water had an unnatural color or appearance. "Milky" was identified by 35% of those who reported appearance problems (Figure 7), followed by 28% indicating "yellow." Eighteen percent offered their own descriptions by selecting "other" to include greenish.

A related question sought to identify the presence of solid particles in participants' water supplies. Fourteen percent described such a condition; more than one-third of these (38%) reported that they noticed "white flakes" in their water, followed by "brown sediment" and "black specks" at 27% and 23%, respectively (Figure 8). Seventeen percent indicated "other," such as sand.

Staining problems on plumbing fixtures, cooking appliances/utensils, and/or laundry were reported by 40% of the participants. As presented in Figure 9, the major problem was that of "rusty" identified by 51% of those with staining problems, followed by "blue-green" stains, reported by 36%.

Household Water Quality Analysis

Ultimately, two sample groups resulted: the "tap water" and "raw water" samples. The "tap water" group consisted of the 342 individual household water supplies analyzed to represent the actual water quality at the drinking water tap (including treated water). The "raw water" group consisted of samples from untreated systems only - a total of 275 samples.

The raw water sample results presented below may not be entirely indicative of the status of raw groundwater quality in Essex, King and Queen, King William, and Middlesex Counties. This may be particularly true for many of the nuisance contaminants for which treatment systems have been installed, since many of the already treated supplies likely represented the worst cases for specific contaminants correctable by treatment devices. Therefore, the inclusion of actual raw water (before treatment) analyses, if they had been available from those households with treatment devices installed, would likely have tended to worsen the overall assessment of raw water quality in the four counties.

General Water Chemistry Analysis

The tests included in the general water chemistry analysis are listed in Table 1, along with the detection limits, where appropriate, for each test as determined by laboratory equipment and testing procedure constraints. Also presented are the averages and ranges for each sample group defined for all four counties combined. Table 2 provides, for both sample groups and each county, as well as all four counties combined, the percentage of constituent values exceeding a given water quality standard or guideline. The results and importance of each test for both of the sample groups are individually discussed 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, 5% of samples in the tap water and 4% of samples in the raw water sample groups 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 in view of the generally accepted notion that excessive iron is prevalent in rural water supplies throughout much of Virginia. Only 4% of the participants reported the installation of an iron removal filter, however, water softeners, which can remove small amounts of iron, as well as manganese, had been installed in 9% of the households. Despite the treatment equipment in place, the results of the sample questionnaire (see Appendix) revealed that 51% of the 138 who reported staining problems, or 21% of all participants, 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 than long-term staining tendencies, particularly on plumbing fixtures. It has been suggested that concentrations below 0.1 mg/L are preferred, when stain prevention is of concern. When a value of 0.1 mg/L was used as the threshold concentration, an additional 16% and 15% of samples in the tap water and raw water sample groups, respectively, of all four counties 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.

The results of these analyses indicated that the extent of manganese problems in the four counties was similar to that of iron, and that Middlesex County had more samples with excessive concentrations of both (Table 2). While manganese stains are generally dark and only 2% of all participants indicated "black" stains, 5% of the tap water and 4% of the raw water samples exceeded the SMCL for manganese of 0.05 mg/L. The "particles in water" description of "black specks," reported by 3% of all participants, may also provide evidence of excessive manganese concentrations.

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 this region of Virginia. The exception to this rule is the far eastern portion of the Middle Peninsula where ancient marine deposits have provided a source of calcium. While some use of water softeners is warranted, and 9% of all participants had installed a water softener (Figure 4), 3% of the tap water and 2% of the raw water samples, all but one sample of which were from Middlesex County in both cases, exceeded the maximum recommended hardness level of 180 mg/L. Not surprisingly, five-sixths of all installed water softeners were in Middlesex County.

Figure 4. Household Water Treatment Devices Installed

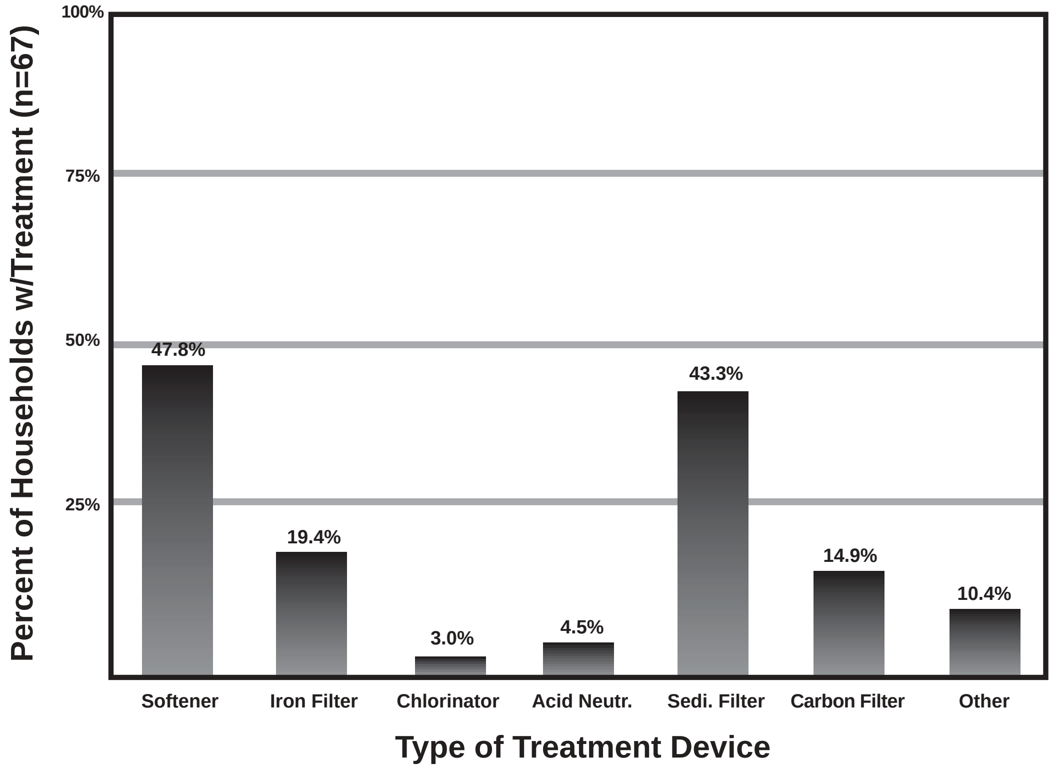


Figure 5. Unpleasant Tastes Reported by Participants

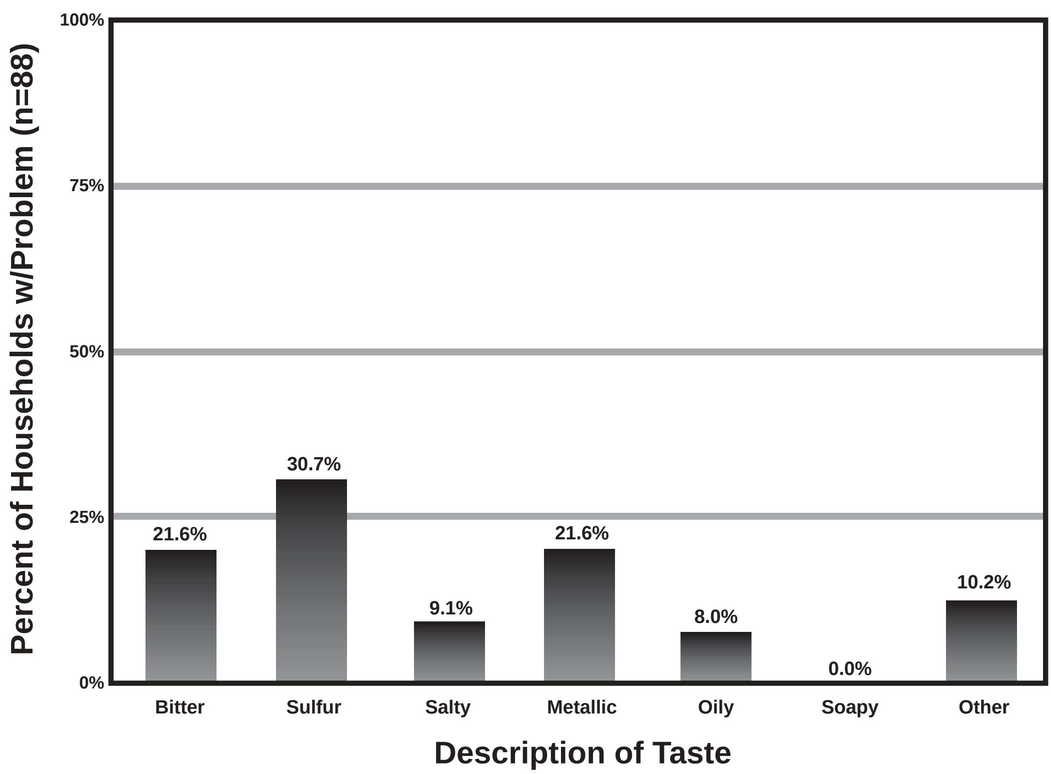


Figure 6. Objectionable Odors Reported by Participants

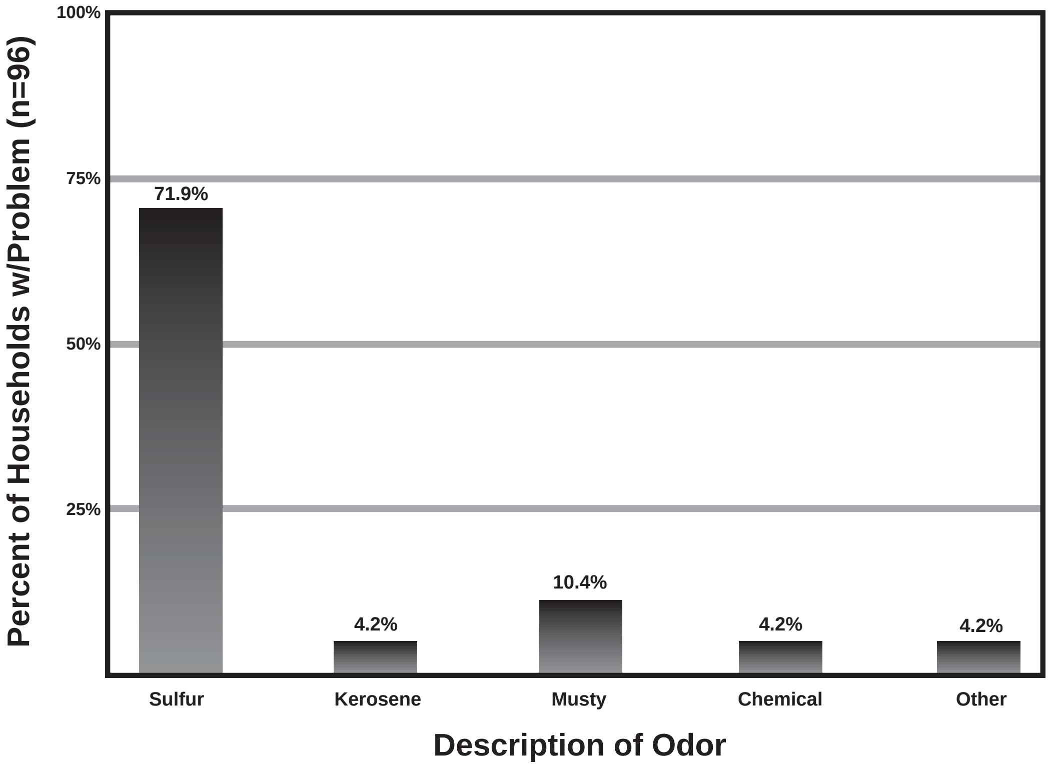


Figure 7. Unnatural Appearance Reported by Participants

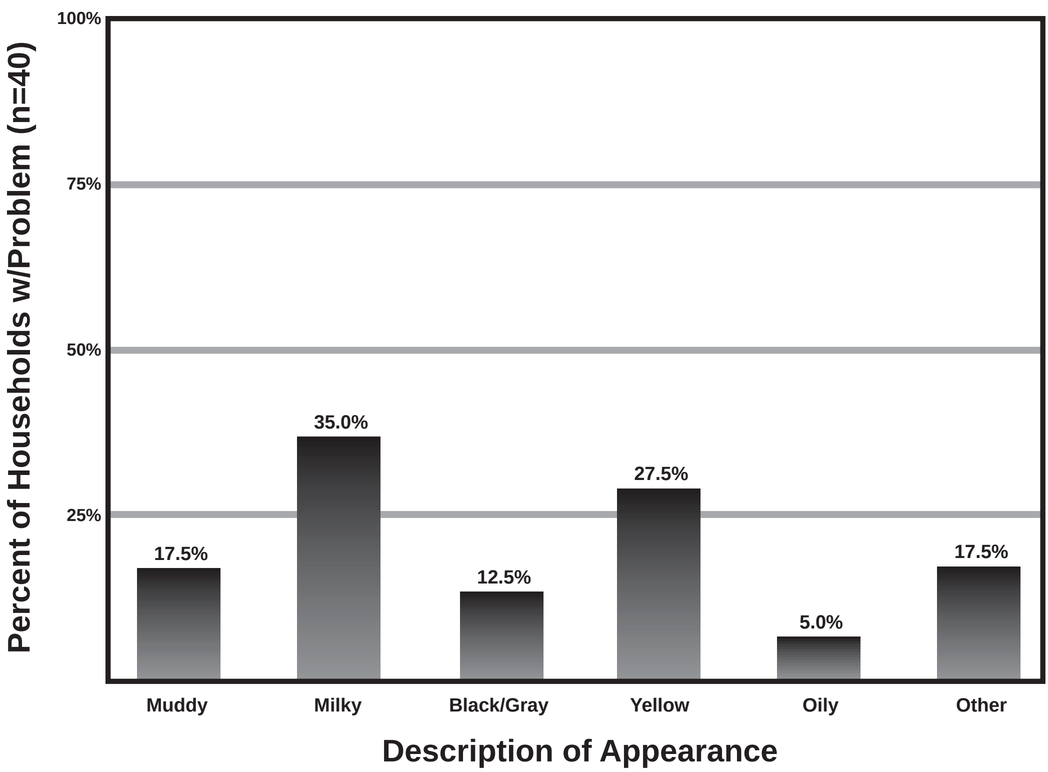


Figure 8. Particles in Water Reported by Participants

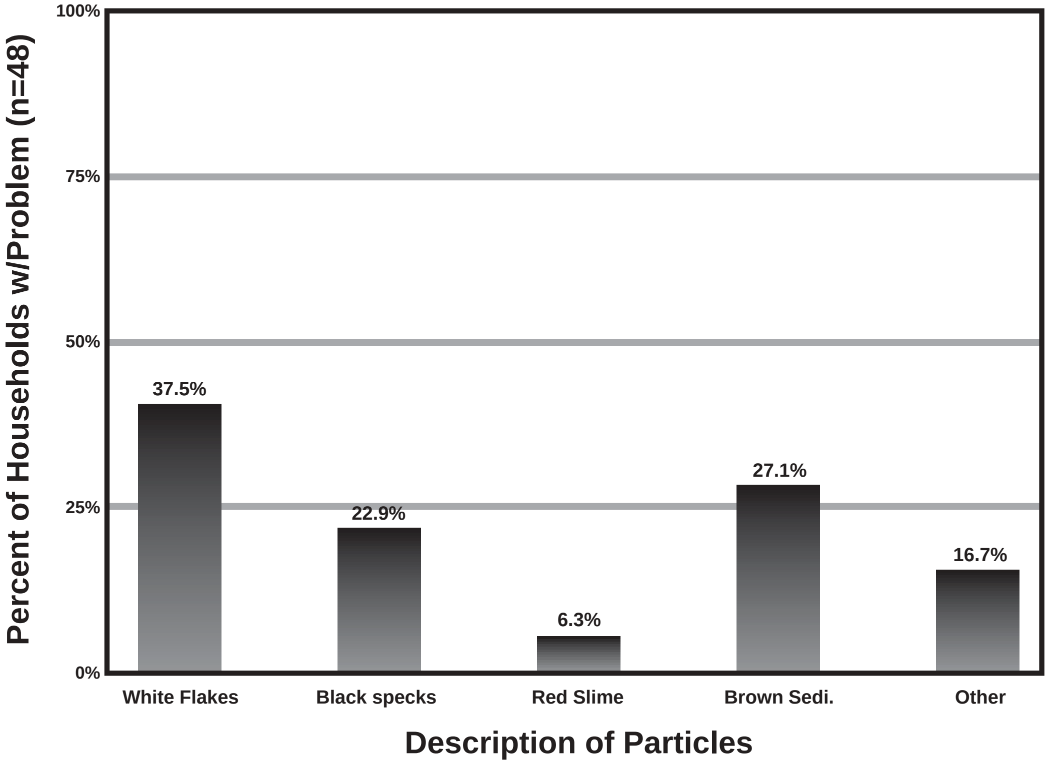
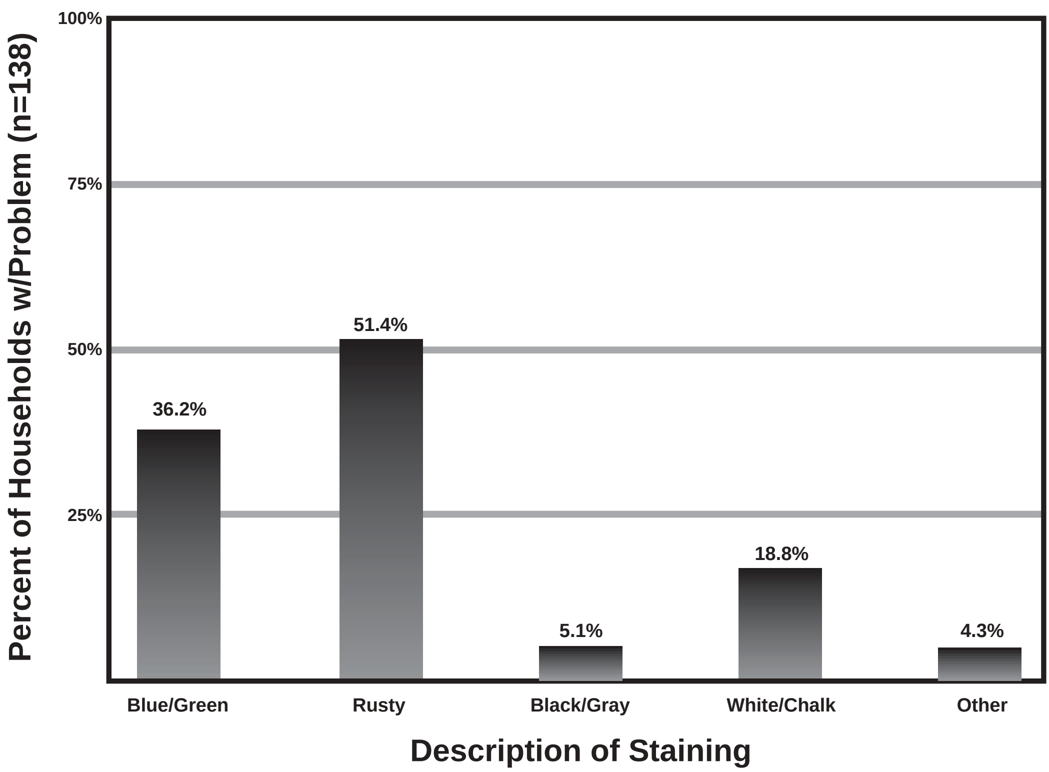


Figure 9. Staining Problems Reported by Participants



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 household water users while others are satisfied with untreated water. Twenty-seven percent of the tap water and 28% of the raw water samples of all four counties were in the range of 60 mg/L to 180 mg/L total hardness, indicating that nearly one-third of all samples could be classified as "moderately hard" or "harder."

Sulfate. High sulfate concentrations may result in adverse taste or may cause a laxative effect. The SMCL for sulfate is 250 mg/L. Sulfates are generally 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 for both the raw water and tap water sample groups. Only one (from Essex County) of the tap water and none of the raw water samples exceeded 250 mg/L. The complaints of a "rotten egg/sulfur" odor by nearly three-fourths of those reporting odor problems indicate that hydrogen sulfide gas may be a somewhat widespread problem in household water systems in the four 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 corrosion rates of metal pipes and cause pitting and darkening of stainless steel. The EPA has set an SMCL for chloride of 250 mg/L. Seven percent of the tap water and 2% of the raw water samples, all but one sample of which were from Middlesex County in both cases, 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. Two percent of the tap water and 3% of the raw water samples exceeded the SMCL, however, none exceeded the MCL. King and Queen County had as many of these samples as the other three counties combined.

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. Average TDS concentrations were 176 mg/L and 208mg/L for the raw water and tap water sample groups, respectively. Six percent of the tap water and 2% of the raw water samples (with the exception of one tap water sample from Essex county, all of these samples were from Middlesex County) exceeded the standard. The maximum TDS concentration among both the raw water and the tap water samples was 2600 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 7.2 for both the tap water and raw water sample groups. None of the samples in either sample group exceeded a pH of 8.5. For the tap water and raw water sample groups, 26% and 30%, respectively were less than 6.5 and incidence of excessive acidity varied somewhat across the four 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 8% of both the tap water and the raw 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. It is a calculated value based on the calcium concentration, total dissolved solids concentration, measured pH, and alkalinity. 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.

No saturation index values were determined to be above +1 in either sample group. Values of less than -1, however, were determined for 63% of the tap water and 62% of the raw water samples. Average saturation index values were -2.01 for the tap water and -2.05 for the raw water sample groups with minimum values of -5.80 in both groups.

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.

Six samples in both the tap and raw water groups exceeded the recommended health level of 1.3 mg/L as well as the SMCL of 1.0 mg/L (all of these samples were from King William County). An additional two samples (one each from Essex and King William Counties) exceeded the SMCL but not the MCL. The maximum copper concentration measured was 14.4 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. Average sodium concentrations were 52 mg/L for the tap water and 41 for the raw water sample groups, while the maximum concentration was 537 mg/L in the former case and 367 mg/L in the latter case. For the tap water and raw water sample groups, 51% and 48%, respectively, exceeded 20 mg/L with the incidence of excessive sodium fairly consistent across the four counties (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

Table 1. Average and range of concentration of contaminants comprising general water chemistry analysis for Essex, King and Queen, King William, and Middlesex Counties.

Test	Detection Limit	Measured Concentrations					
		Raw Water (n=275)			Tap Water (n=342)		
		Avg.[1]	Min.	Max.	Avg.	Min.	Max.
Iron (mg/L)	0.005	0.085	DL[2]	1.962	0.086	DL	1.962
Manganese (mg/L)	0.001	0.020	DL	0.940	0.026	DL	1.783
Hardness (mg/L)	0.3	49.9	DL	980.0	50.4	DL	980.0
Sulfate (mg/L)	0.3	8.4	DL	73.9	9.0	DL	362.8
Chloride (mg/L)	40.0	67.0	DL	2500.0	93.0	DL	2500.0
Fluoride (mg/L)	0.5	0.65	DL	3.04	0.64	DL	3.04
TDS (mg/L)	1.0	176.0	17.0	2600.0	208.0	17.0	2600.0
pH	-	7.15	4.55	8.63	7.19	4.55	8.63
Saturation Index	-	-2.05	-5.80	-0.18	-2.01	-5.80	-0.18
Copper (mg/L)	0.002	0.167	DL	14.370	0.138	DL	14.370
Sodium (mg/L)	0.01	41.37	1.12	367.20	51.68	1.12	536.80
Nitrate (mg/L)	0.005	1.232	DL	14.657	1.063	DL	14.657

[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.*

Table 2. Percent of concentrations exceeding established standards for contaminants comprising general water chemistry and bacteriological analysis for Essex, King and Queen, King William, and Middlesex Counties.

Test	Standard	Percent of Values Exceeding Standard									
		Raw Water					Tap Water				
		Total n=275	Essex n=45	K&Q n=52	K. W. n=118	Midd. n=60	Total n=342	Essex n=48	K&Q n=55	K. W. n=135	Midd. n=104
Iron (mg/L)	0.3	4.0	2.2	3.8	2.5	8.3	4.7	2.1	3.6	3.7	7.7
Manganese (mg/L)	0.05	3.6	0	0	3.4	10.0	4.7	2.1	0	3.0	10.6
Hardness (mg/L)	180.0	1.8	0	0	0.8	6.7	2.9	0	0	0.7	8.7
Sulfate (mg/L)	250.0	0	0	0	0	0	0.3	2.1	0	0	0
Chloride (mg/L)	250.0	2.2	0	0	0.8	8.3	7.0	0	0	0.7	22.1
Fluoride (mg/L)	2/4	2.5/0	2.2/0	7.7/0	0.8/0	1.7/0	2.3/0	2.1/0	7.3/0	0.7/0	1.9/0
TDS (mg/L)	500.0	1.5	0	0	0	6.7	5.8	2.1	0	0	18.3
pH - Low	6.5	29.8	40.0	34.6	27.1	23.3	26.0	39.6	32.7	25.9	16.3
pH - High	8.5	0	0	0	0	3.3	0.6	0	0	0	1.9
Saturation Index - Low	-1.0	61.8	84.4	61.5	63.6	41.7	62.8	85.4	60.0	63.0	52.9
Saturation Index - High	+1.0	0	0	0	0	0	0	0	0	0	0
Copper (mg/L)	1.0/1.3	2.9/2.2	2.2/0	1.9/0	5.1/5.1	0/0	2.3/1.8	2.1/0	1.8/0	4.4/4.4	0/0
Sodium (mg/L)	20.0	48.4	51.1	51.9	50.8	38.3	51.2	52.2	49.0	51.9	51.0
Nitrate (mg/L)	10.0	2.5	2.2	7.7	0	3.3	2.3	4.2	7.3	0	1.9
Total Coliform	ABSENT	40.0	33.3	55.8	37.3	36.7	38.3	31.3	52.7	37.8	34.6
E. coli	ABSENT	2.5	0	5.8	2.5	1.7	2.0	0	5.5	2.2	1.0

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. Sixteen percent of the tap water and 12% of the raw water samples exceeded this 100 mg/L threshold. A quarter of these tap water samples, all but one sample of which were from Middlesex County, actually exceeded 200 mg/L. While much of this excessive sodium can be attributed to natural causes, in Middlesex County, where the vast majority of the water softeners are in use, some sodium is provided by water softeners, as evidenced by the difference in the excessive sodium percentages of Middlesex County tap and raw water samples (Table 2).

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 14.7 mg/L for both the tap water and raw water sample groups. Only 2% of tap water and 3% of raw water 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 excessive nitrate was determined. In this case, 23% of the tap water and 27% of the raw water samples, exceeded the level of potential concern to infant health. Furthermore, 12% of the tap water and 15% of the 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 four counties. In both of the non-standard threshold cases, Essex and King and Queen Counties had substantially more samples exceeding these thresholds.

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-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 342 household water samples from the four counties analyzed for total coliform bacteria, 131 (38%) tested positive (present). Subsequent E. coli analysis for these total coliform positive samples resulted in 7, or 5%, positive results, or 2% of all household water samples undergoing bacteriological analysis. The percentages of positive total coliform and E. coli results for the raw water sample group were 40 and 3, respectively. It is interesting to note that the

Table 3. Pesticides and other chemical compounds analyzed in 15 household water supplies (Essex, King and Queen, King William, and Middlesex Counties).

Common Name	Trade name	Maximum Desired Concentration[1] (ppb)[2]	Maximum Measured Concentration (ppb)	Frequency of Sample Detection
Alachlor	Lasso	2.0	ND	0
Atrazine	Aatrex	3.0	ND	0
Butylate	Sutan	350.0	ND	0
Captan	Orthocide	-	ND	0
Chlordane		2.0	ND	0
Chlorpyrifos	Dursban	20.0	0.003	1
Cyanazine	Bladex	1.0	ND	0
DCPA	Dacthal	400.0	ND	0
DDTs		–	ND	0
Diazinon	Spectracide	0.6	ND	0
Dicamba	Banvel	200.0	0.008	1
Dieldrin		200.0	ND	0
Disulfoton	Disyston	0.3	ND	0
Endosulfan	Thiodan	–	ND	0
Lambda-Cyhalothrin	Karate	–	ND	0
Lindane		0.2	ND	0
Linuron	Lorox	–	ND	0
Malathion	Cythion	200.0	ND	0
Methoxychlor	Marlate	40.0	ND	0
Metolachlor	Dual	70.0	ND	0
Metribuzin	Lexone	100.0	ND	0
PCB's		0.5	ND	0
Pendimethalin	Prowl	-	ND	0
Picloram	Tordon	500.0	0.093	1
Prometon	Pramitol	100.0	ND	0
Simazine	Princep	4.0	ND	0
2, 4-D		70.0	1.060	2
2, 4, 5-T		70.0	ND	0
2, 4, 5-TP	Silvex	50.0	ND	0

[1] *U.S. EPA MCL or HAL, if available*

[2] *ppb - parts per billion, equivalent to micrograms per liter in water*

[3] *ND - Non-detectable (below laboratory detection limit of 0.01 ppb)*

Table 4. Measures taken or planned by respondents, since water quality analysis, to improve water supply (Essex, King and Queen, King William, and Middlesex Counties)

Measure	Percent of All Respondents (n=107)	Percent of Respondents who Reported the Following Problems: Health Only (n=46)	Nuisance Only (n=12)	Health & Nuisance (n=16)	None (n=33)
Contact an Agency, such as the Health Department	8.4	13.0	0	18.8	0
Seek Additional Water Testing from Another Lab	6.5	8.7	0	12.5	3.0
Determine Source of Undesirable Condition	9.3	10.9	8.3	25.0	0
Pump Out Septic System	2.8	4.3	0	6.3	0
Improve Physical Condition of Water Source	7.5	8.7	8.3	12.5	3.0
Shock-Chlorinate Water System	21.5	30.4	8.3	43.8	3.0
Obtain New Water Source	3.7	2.2	8.3	12.5	3.0
Use Bottled Water for Drinking/Cooking	13.1	15.2	16.7	18.8	6.1
Temporary Disinfection, such as Boiling Water	3.7	2.2	0	12.5	3.0
Purchase or Rent Water Treatment Equipment	7.5	8.7	16.7	6.3	3.0
Improve Existing Water Treatment Equipment	6.5	6.5	16.7	6.3	3.0
Take Other Measures to Eliminate/Reduce Contaminant(s)	3.7	2.2	16.7	6.3	0
Have Not Done Anything	45.8	37.0	33.3	0	84.8

incidence of both total coliform and E. coli was substantially greater in King and Queen water samples, than those of the other three counties.

The susceptibility of household water supplies to bacteriological contamination has often been associated with the type of water source. For example, it is generally accepted that the likelihood of bacteriological contamination of springs is greater than that of well water supplies, 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 contention is clearly borne out by the results of this program, which indicated that the incidence of total coliform and E. coli contamination of dug/bored wells was 68% and 5%, respectively, while for drilled wells, positive total coliform and E. coli results were obtained for only 24% and 1% of the samples.

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 1970's and early 1990's. 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) 59, (2) 39, and (3) 26. For E. coli bacteria, the corresponding percentages were: (1) 6, (2) 1, and (3) 0. A reduction in positive bacteria cases overall was noted with time, likely influenced not only by the newness of the wells, but also the substantiality of the most recent legislation, requiring stricter well standards, licensing of well drillers, and post-construction inspections.

Fecal bacteria in household water supplies may have originated from animal waste generation 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 further investigated 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.

Chemical Compound Analysis

As mentioned earlier, several of the original participating households opted to pay for additional testing of pesticides and other chemical compounds. Ultimately, 15 household water supplies, of the original total of 342, were resampled. The 29 constituents analyzed were considered to be the most likely to be found in groundwater partly because they are currently, or were recently, in common use in the four-county area. These pesticides and other compounds are listed in Table 3.

Analysis of these constituents revealed little evidence of excessive contamination in terms of human health implications. Out of a total of 435 test results, 430 or 98.9%, resulted in concentrations below the laboratory detection limit (considered to be approximately 0.01 parts per billion, or ppb). Five separate water samples had a compound present at a detectable concentration. As shown in Table 3, two detections of 2,4-D and one each of chlorpyrifos, dicamba, and picloram resulted, all of which were well below the respective EPA MCL or Health Advisory Level (HAL).

Post-Program Survey

Following the completion of the basic educational program, a survey form (see Appendix) was mailed to the 342 households whose water supply had been tested. The objectives of the survey were to determine: 1) reasons for program participation and for having water tested, and 2) what the respondents had done to correct water quality problems as a result of participation in the educational program. One hundred and seven (31%) had returned the survey forms by the deadline.

Household Water Testing History

Participants were asked to indicate their previous experience with water testing and, specifically, if and when they had last had a laboratory analysis of their present household water supply. Thirty-five percent of the respondents indicated that they had previously obtained water test results. Of those reporting a prior testing date, 39% had done so within the past five years and 28% within the past two years.

Reasons for Program Participation

People participated in the water quality program for one or more reasons. Seventy-seven percent of the respondents were prompted to participate by concern about the safety of their water supply. Forty-one percent of the respondents were prompted by nuisance problems, such as staining, objectionable taste and odor, etc. Ten percent wanted to follow up on previous tests of their household water. Twenty-two percent cited other reasons, such as general curiosity and low-cost opportunity.

Follow-up Activities Taken or Planned

Participants were asked to indicate the measures they planned to take, or had already taken, to improve the quality of their water supply, since receiving the results of their water quality analysis. Table 4 presents the results of this inquiry, with the greatest number of households indicating that they had already, or planned to, shock chlorinate the water system.

Participants were asked if the water analysis showed that their water was unsatisfactory for one or more of the following: bacteria, nitrate, sodium, iron, manganese, hardness, and pH. Responses were grouped in four categories: 1) households with potential health problems (positive bacteria test results and/or unsatisfactory levels of nitrate or sodium in their water samples), 2) households with unsatisfactory levels of nuisance contaminants (one or more of the following: iron, manganese, hardness, and pH), 3) households with potential health problems and unsatisfactory levels of nuisance contaminants, and 4) households with neither potential health problems nor unsatisfactory levels of nuisance contaminants.

The measures planned or already taken to improve household water as follow-up to the water quality analysis were generally in agreement with the water quality problems identified by the testing. Of the households with potential health problems only, and those with health problems in combination with unsatisfactory levels of nuisance contaminants, 73% had taken, or planned to take, at least one measure to improve their water supply. The measures taken by the greatest number of households in these two categories were: shock chlorinate the water system and use bottled water for drinking/cooking.

Respondents were only slightly more likely to address health-related problems than nuisance problems. Of the households with unsatisfactory levels of one or more nuisance contaminants only and those with nuisance problems in combination with potential health problems, 64% had taken, or planned to take, at least one measure to improve their water supply. Only 15% of the households with neither potential health problems nor unsatisfactory levels of nuisance contaminants reported taking follow-up measures.

CONCLUSIONS

The Household Water Quality Educational Programs conducted in Essex, King and Queen, King William, and Middlesex Counties were considered to be successful. The opportunity to participate in the programs was well-received by those residents who chose to do so. Individuals participated in the programs primarily because of concern about the safety of their water supply. Despite being voluntary programs, a geographically distributed sample representing diverse household and water supply characteristics was obtained. While the project was designed for voluntary participation and quality control in sampling was not assured, the type of information gathered and summarized was, nevertheless, deemed useful for water quality assessment at county and regional levels.

Water quality analysis, for many nuisance constituents, generally supported the participants' descriptions of their water supplies regarding such problems as staining, taste and odor, and appearance. The severity of these symptoms is confirmed by the high incidence of water treatment devices installed – 20% of all households participating had one or more water treatment devices installed.

Considering the results for both the raw and tap water sample groups, and the influence of the few water treatment devices in use, the major remaining household water quality problems in Essex, King and Queen, King William, and Middlesex Counties, existing from a nuisance standpoint, were iron/manganese and corrosivity. Chloride and total dissolved solids were particular problems only in Middlesex County. The 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 and sodium concentrations may present a health risk to infants and some adults, respectively, in a number of cases. Thirty-eight percent of the samples tested positive for total coliform and 2% 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.

The limited analysis for pesticides and other chemical compounds revealed few problems with such contamination. In all but five samples, for a total of five detections, all concentrations were nondetectable at levels below 0.01 ppb. None of the 15 tested samples had a concentration of any of the 29 pesticides and other chemical compounds analyzed present in a quantity exceeding the corresponding EPA MCL or HAL.

Seventy-two percent of the households that reported having at least one water quality problem had taken, or planned to take, at least one measure to improve the quality of their water supply. Thirteen percent or more of all respondents had taken, or planned to take, one or both of the following actions: shock chlorinate the water system and use bottled water for drinking/cooking.

REFERENCES

George, C.A. and J.L. Gray. 1988. Water for Tomorrow - A Report on Water and Conservation Needs in Virginia. Roanoke, Virginia: Virginia Water Project, Inc.

Koebel, C.T., M.S. Cavell, and W.L. Morgan. 1993. The Virginia Housing Atlas: Housing Trends and Patterns to 1990. Blacksburg, Virginia: VPI&SU, Virginia Center for Housing Research.

Ross, B. B., J. E. Woodard, T. A. Dillaha, E. B. Orndorff, J. R. Hunnings, and K. M. Hanna. 1991. Evaluating Household Water Quality in Warren County, Virginia. Information Series 91-1 (Household Water Quality Series 1). Blacksburg, Virginia: VPI&SU, College of Agriculture and Life Sciences.

USEPA. 1979. Methods for Chemical Analysis of Water and Wastes. Report No. EPA 600/4-79-020. Washington, D.C.: U.S. Environmental Protection Agency.

APPENDIX*

(1) Program Fact Sheet

(2) Sample Identification and Questionnaire Form

(3) Sample Water Quality Analysis Report

(4) Report Interpretation

(5) Chemical Compound Analysis Form

(6) Post-Program Survey

* *The following examples represent forms, reports, etc. used in the Middlesex County Program only. Paperwork for Essex, King and Queen, and King William Counties only was similar, except for the information that was county-specific.*

(1) Program Fact Sheet

1999 Middlesex County
Groundwater Education and Water Testing Program

Fact Sheet

Purpose: Improve the quality of life of private water system users by increasing awareness and understanding of groundwater quality problems, protection strategies, and treatment alternatives; and to create a groundwater quality data inventory to assist local government decision making for groundwater protection purposes.

WATER TESTING PROGRAM

Who's eligible?

1. Private Household Water Supplies
2. Approximately 200-250 Middlesex County Water Supplies
3. Priority given to persons attending the April 7th Informational Meetings

Costs

$20.00 per sample paid in advance. (Normal test around $150.00)
After first 150, cost is $30.00

Testing for:

Nitrate	Iron	Hardness (Ca & Mg)
Chloride	Sodium	pH (acidity)
Fluoride	Copper	Corrosion Index
Sulfate	Manganese	Total Dissolved Solids

Bacteria

Total Coliform and E. coli Bacteria Tests are available to determine if bacteria is present/absent.

FUNDING FOR THIS PROJECT

USDA Extension Water Quality Initiative
Southeast Rural Community Assistance Project, Inc. – Roanoke, VA
Virginia Cooperative Extension

IMPORTANT DATES and SCHEDULES

INFORMATIONAL MEETINGS & WATER SAMPLE KITS:

Wednesday, April 7, 1999 3:30 P.M. DCA Building – Deltaville
Wednesday, April 7, 1999 7:00 P.M. Middlesex High School – Saluda

****BRING YOUR CHECKBOOK**** Checks payable to: **VCE-Middlesex**
****CASH IS ACCEPTED****
Persons attending these meetings will receive the first opportunity for water testing. Any remaining openings for testing will be made available beginning April 9, by calling the Extension Office At 804-758-4120

Sampling Kits purchased and picked up at the 4-7-99 meeting are returnable on April 14th or April 28th. **Delivery date will be determined when you sign up.**

SAMPLE RETURN DATES, TIMES, PLACES:

April 14, 1999	7:30 A.M. to 12:30 P.M.	Middlesex Extension Office
	9:00 A.M. to 12:00 Noon	Deltaville Library
April 28, 1999	7:30 A.M. to 12:30 P.M.	Middlesex Extension Office
	9:00 A.M. to 12:00 Noon	Urbanna Library

TEST RESULTS and EXPLANATION of ANALYSIS:

May 19, 1999 7:00 P.M. Middlesex High School – Saluda

Your water analysis results will be given to you on this night with specialists available to explain results and any necessary treatment and protection strategies.

CONFIDENTIALITY:

All results will be kept confidential. Survey maps made from the information gathered will bear no names and will not be of sufficient detail to determine a particular water supply.

MIDDLESEX COOPERATIVE EXTENSION
P.O. BOX 96 SALUDA, VA 23149
(Intersection of Route 33 and US 17 business)
804-758-4120

(2) Sample Identification and Questionnaire Form

MIDDLESEX COUNTY HOUSEHOLD WATER QUALITY PROGRAM

Middlesex County Cooperative Extension
Courthouse Complex Woodward Bldg., Second Floor
P.O. Box 96
Saluda, VA 23149-0096
(804) 758-4120

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 758-4120.

1. 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.
2. 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.
3. 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.
4. 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.
5. 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.
6. 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.

Sample Identification and Questionnaire Form (cont.)

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* _____*home heating oil storage tank (above or below ground)*
_____*pit privy or outhouse* _____*pond or freshwater stream*
_____*cemetery* _____*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* _____*marina*
_____*illegal dump* _____*plant production*
_____*active quarry* _____*farm animal operation*
_____*abandoned quarry, industry, etc.* _____*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.

(3) Sample Water Quality Analysis Report

Middlesex County
Household Water Quality Program

Middlesex County Cooperative Extension
P.O. Box 96
Saluda, VA 231490096
(804) 758-4120

Sample No: M

Saluda, VA 23149
(804) 758-

Source: Dug/Bored Well

Treatment: None

Water Quality Results
Date of Sample: 4/28/99

Test	Household Water Sample	Maximum Recommended Level or Range
Iron (mg/l)	0.0064	0.3
Manganese (mg/l)	0.0723**	0.05
Hardness (mg/l)	44	180
Sulfate (mg/l)	1.565	250
Chloride (mg/l)	110	250
Fluoride (mg/l)	< 0.5	2
Total Dissolved Solids (mg/l)	102	500
pH	5.2**	6.5 to 8.5
Saturation Index	-4.6**	-1 to 1
Copper (mg/l)	< 0.002	1.0
Sodium (mg/l)	8.86	20
Nitrate-N (mg/l)	7.758	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. The material is based upon work supported by the U.S. Department of Agriculture, Extension Service.

(4) Report Interpretation

Middlesex 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 objectional 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 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 be 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 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 called 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%) 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 natural sources such as soil or decaying vegetation. Analysis for total coliform bacteria is the EPA standard test for microbiological contamination of a water supply. A positive test result reported as "present" indicates the presence of coliform bacteria and is followed by a test for fecal coliform bacteria.

E COLI

A test for fecal coliform bacteria is necessary to determine whether or not any coliform bacteria present are from human and/or animal waste. A positive E. coli test result reported as "present" indicates that waste from a septic system or nearby animals is likely contaminating the water supply.

Glossary

EPA - U. S. Environmental Protection Agency

mg/l - Concentration unit of milligrams per liter in water, equivalent to one part 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. These standards are not enforced by governments. However, they are useful guidelines for individual water supplies.

Compiled by Blake Ross, Extension Agricultural Engineer, and Kathy Parrott, Extension Specialist, Housing, Virginia Tech, Blacksburg, VA

May 1999

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

(5) Chemical Compound Analysis Form

MIDDLESEX COUNTY
HOUSEHOLD WATER QUALITY PROGRAM
CHEMICAL COMPOUND ANALYSIS

Department of Biological Systems Engineering
Virginia Polytechnic Institute and State University
Blacksburg, Virginia 24061-0303

SAMPLE NUMBER: ____________ DATE COLLECTED: ________________

SAMPLE SUBMITTED BY:

NAME: ____

MAILING ADDRESS: ____

____

TELEPHONE: ____

WAS THE WATER TREATED BEFORE SAMPLING? ____YES ____NO (IF AT ALL POSSIBLE, SAMPLE WATER **BEFORE** TREATMENT)

IF YES, WHAT TREATMENT DEVICE(S) DID THE WATER PASS THROUGH PRIOR TO SAMPLING?

____

COMMENTS REGARDING LIKELIHOOD OF CHEMICAL CONTAMINATION (SPILLS, NEARBY USE, STORAGE, ETC.):

____

____

____

____

SAMPLING INSTRUCTIONS:

1. *Do not remove cap from Sample Jar until you are ready to take sample. Do not touch inside of cap or mouth of the jar.*
2. *Take the sample as close to the water source (well or spring) as possible. If there are no water treatment devices in use, the sample may be taken from a kitchen or bathroom tap. If there is a treatment device in the house, the sample should be taken from a spigot not affected by a treatment device.*
3. *Turn on the Cold Water and allow it to run until it is as cold as it will get. Then allow it to run one minute more.*
4. *Slowly and carefully fill the jar to avoid splashing and overflowing. Pour out this water and refill the jar completely.*
5. *Place the Aluminum Foil Sheet over the mouth of the jar with the Dull Side down. Tighten cap on the jar securely.*
6. *If sample is not to be delivered immediately, store on ice until ready to deliver.*

(6) Post-Program Survey

Middlesex County

HOUSEHOLD WATER QUALITY PROGRAM EVALUATION SURVEY

Please answer each question below as instructed in reference to your **household** water supply only. **Your answers are completely confidential and cannot be identified with any individual participant.**

1. Have you had a laboratory test of your water supply before this Household Water Quality Education Program? Yes _____ No _____

   If Yes, about what year was your last test? __________

2. What prompted you to participate in this program? (Check **all** that apply.)

   _____ Concern about safety of my water supply
   _____ Nuisance problems such as staining, objectionable taste or odor, corrosion, etc.
   _____ Follow-up to previous test of my water supply
   _____ Other (explain) ____

3. Did your household water analysis in this program show that your water was unsatisfactory for **any** of the following tests? (Check **one** response for each test.)

Nitrate	Yes _____	No _____
Sodium	Yes _____	No _____
Iron	Yes _____	No _____
Manganese	Yes _____	No _____
Hardness	Yes _____	No _____
pH	Yes _____	No _____

4. What were the results of the tests for the following? (Check **one** response for each test.)

Total coliform bacteria	Present _____	Absent _____
E. coli bacteria	Present _____	Absent _____

5. Since receiving the results of your water quality analysis, which of the following measures do you plan to take, or have already taken, to improve the quality of your water supply? (Check **all** that apply.)

   _____ Contact a state agency such as the Health Dept., Dept. of Environmental Quality, etc. for assistance or additional information
   _____ Seek additional water testing from a laboratory
   _____ Determine source of undesirable condition
   _____ Pump out septic system
   _____ Improve physical condition of water source (well, spring, or cistern)
   _____ Shock chlorinate water system
   _____ Obtain new water source
   _____ Use bottled water for drinking/cooking
   _____ Temporary disinfection, such as boiling water
   _____ Purchase or rent water treatment equipment
   _____ Improve functioning of existing water treatment equipment
   _____ Take other measures to eliminate or reduce contaminant(s) in your water (explain)

____

____

Haven't done anything because ____

____

Post-Program Survey (cont.)

The following questions are designed to provide us with a profile of the total audience we've reached with this program. **Be assured that answers cannot be identified with individual participants.**

6. How many years have you lived at your present location? _____

7. Number of persons in your household. _____

8. What is the highest grade in school you've completed? (Check **one**.)

_____ Grade school
_____ Some high school
_____ High school graduate
_____ Some education after high school
_____ College graduate

9. What is your **family** income before taxes? (Check **one**.)

_____ Less than $10,000
_____ $10,000 to $14,999
_____ $15,000 to $19,999
_____ $20,000 to $24,999
_____ $25,000 to $34,999
_____ $35,000 to $49,000
_____ $50,000 or more

10. Other comments about the Household Water Quality Education Program:

____

____

____

11. Are there other educational programs that you would like to see offered by the Middlesex County Extension Office?

____

____

12. How did you hear about this Household Water Quality Education Program? (Check **all** that apply.)

_____ Newspaper
_____ Radio
_____ Television
_____ Extension Newsletter
_____ Flyer from child's school
_____ Friend or Neighbor
_____ Other (explain)

____

Thank you for your participation. Please return this survey form by **July 10, 1999.** A postage-paid envelope has been provided for your use in returning this form to:

David Moore, Middlesex County
Virginia Cooperative Extension
Extension Distribution Center
112 Landsdowne Street
Blacksburg, VA 24060-9984

Notes

Notes

Notes

VT/002/1199/200/202002/442929