

## Drinking water assessment at underserved farms in Virginia's coastal plain

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### ABSTRACT

Homeowners in rural communities, especially those classified as "underserved" by federal and state education and extension efforts, face a great risk of drinking water contamination from various sources. This study assessed the chemical and microbiological qualities of drinking water samples collected from 185 locations covering 22 counties along the Coastal Plain of Virginia. All samples were taken from rural wells or springs where underserved farms and families in the region obtain their drinking water. Separate samples were collected for biological and chemical analyses and screened for selected water quality indicators. Total coliform, fecal coliform, and *Escherichia coli* were detected in 34, 11, and 6% of the samples, respectively. The levels of microbial contamination would be high during summer months when recharge is at minimum. Chemical analysis showed that 25% of the total wells surveyed were near the Atlantic Ocean and the Chesapeake Bay. Among them approximately 10% had salt-water intrusion, as indicated by sodium content exceeding USEPA limits for drinking water. Shallow wells in close proximity to agricultural fields would be expected to be high in nitrate and phosphorus, but most of the values obtained in this study were not considered detrimental to human health based on USEPA's drinking water standards. The pH of well waters ranged from 4.5 to 8.5 depending on location. Survey results indicated that color, taste, and turbidity were the most common complaints reported by homeowners.

*Keywords: drinking water, source assessment, underserved, rural*

### INTRODUCTION

Underserved (limited resource) farmers and ranchers are defined by the United States Department of Agriculture (USDA) as follows: (1) a person with direct or indirect gross farm sales not more than \$100,000 in each of the previous two years, and (2) a person with a total household income at or below the national poverty level of a family of four; or less than 50% of the country median household income

in each of the previous two years (USDA-NRCS, 2006). Perhaps a reasonable definition of the underserved was given by an earlier, 2003 edition, as follows: "underserved are those farmers and ranchers who, when compared with other farmers, ranchers, and farm operations in a given geographic area, such as a state, county or project area, have distinct disadvantages in obtaining U.S. Department of Agriculture program assistance" (USDA-NRCS, 2003). Recognizing the above to be the fundamental

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definitions for the underserved, this study identified communities and farms in the Coastal Plain of rural Virginia that best fit those definitions while collecting well water samples from homes and farmsteads.

In general, drinking water quality protection is a concern for all rural areas, farms, and communities, where the socio-economic status (poverty level), demographic distribution (primarily consisting of elderly black residents) and education levels (usually not beyond the elementary school) are vastly different from more affluent communities. The EPA standards and regulations for drinking water do not apply to private wells; in fact, well owners are not required to get their water tested. They may volunteer to get their water tested and correct their water quality problems. Most of the current homeowners have also lived on the same farms all their lives, as did other generations before them. Since they do not fully comprehend technical water quality jargon distributed in their mailboxes, they tend to discard them. They consider the long lives they lived drinking the same water as proof that there is nothing wrong with their hand-dug wells. Some are apprehensive about getting their well water tested for fear of being reported to state or federal regulators. In most cases, there is total lack of awareness about the dangers of pesticide and fertilizer use and storage, wellhead protection, and contamination of drinking water from animal domestic manure. Thus, the potential exists for contamination of their water supplies from these and other pollution sources. The majority of homeowners at underserved farms obtain their drinking water from shallow, hand

dug wells or springs, most of which are prone to contamination due to their poor maintenance (IEN, 1992). Such contaminations might be rampant that usually go unnoticed by the homeowner until serious sickness occurs.

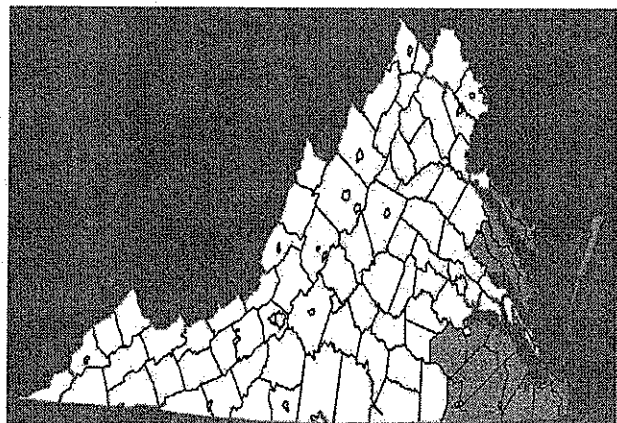
Drinking water sources may be exposed to runoff and other types of pollution from local farming operations. It is not uncommon to find underserved farmers who do not know the threats that fertilizers, pesticides, and herbicides pose when not stored or disposed of properly. Another major dilemma is the location of septic tanks and outdoor toilet facilities near drinking water wells. Uninformed farmers usually don't realize that such proximity could lead to fecal coliform and *Escherichia coli* contamination. A report by Poff and Blake (2000) indicated that Virginia's ground water is heavily contaminated from various sources including agricultural chemicals, septic systems, and mining activities. Consequently, rural households may be at risk, if the only source of drinking water comes from shallow and hand-dug wells, as it is the case in most underserved farm communities. A separate research done by Reichenberger (1990) and Ross et al., (2000), had confirmed this concern to be true for most rural drinking water resources in Virginia. However, both studies did not target the underserved communities in their drinking water assessment. The main objective of this study was to assess drinking water quality of underserved rural households from 22 counties in the Coastal Plain of Virginia using sample analysis and survey data.

## MATERIALS AND METHODS

### Water Sampling

A total of 185 samples from 22 counties in the Coastal Plain physiographic region of Virginia (Figure 1) were collected with collaborations from Natural Resources Conservation Service (NRCS) Research Conservation and Development (RC&D) Coordinators, volunteers, and extension personnel. The USEPA standard procedures for well water sampling (USEPA, 1981) were followed. Two sets of samples were collected: one set for chemical and the other for biological analyses. Samples for chemical analysis were collected in washed and acid rinsed, clean, amber glass bottles containing 10 mL 1N HNO<sub>3</sub> as preservative. For biological analysis, samples were collected in USEPA approved water sample collection vials (Biotrace, Bothell, WA), each containing one 10 mg sodium thiosulfate tablet that served as preservative. All samples were immediately sealed and transported on ice. Microbial testing was done within 24 h of sampling while samples for chemical analysis were kept frozen until analysis.

**Figure 1. Map of Virginia showing counties (shaded areas) where well water samples were collected from underserved households.**



### Chemical Analysis

Water samples (100 mL) were placed in 250 mL beakers and evaporated to dryness on hot plates. They were then digested with periodic additions of nitric acid and hydrogen peroxide until the digestion was complete (USEPA, 1981). Samples were then quantitatively transferred to 50 mL volumetric flasks and made to volume with deionized water. Digested samples were assayed for metals using Inductively Coupled Plasma (ICP). Five-milliliter aliquots of non-acidified samples were assayed for anionic content using Ion Chromatograph (Dionex Corporation, Sunnyvale, CA).

### Microbial Testing

The levels of total coliform, fecal coliform, and *E. coli* bacteria were analyzed using either a 5- or 3-tube most probable number (MPN) evaluation according to standard water testing methods (Greenberg et al., 1992). After incubation and transfer, cell growth with air production in both lauryl tryptose broth (LST) and brilliant green bile broth (BGB) indicates the presence of coliform organisms. Further growth with air production in EC-mug broth indicates the presence of fecal coliform organisms. Under long-wave UV light, fluorescing EC-mug tubes with confirmatory colony appearance (dark, blue-black colonies with a metallic green sheen) on Eosin-Methylene Blue Agar (EMB) were counted as a positive for *E. coli*. The term fecal coliform was defined as gram-negative facultative rods that ferment lactose at 44.5 °C (Pao and Brown, 1996).

Survey Questionnaire

A survey instrument was prepared by modifying a questionnaire developed by Ross et al (2003) and used during drinking water sampling. Homeowners were encouraged to answer all questions as best as they could. The questions included social, economic, and demographic information that would help assess the relationships among these parameters and drinking water quality at undeserved farms. No member of a household was under obligation to answer any of the questions, if he or she did not feel comfortable answering. However, the significance of answering them was explained to them as being important in providing available assistance to protect drinking water quality and safety.

RESULTS AND DISCUSSION

Water Quality Indicators

Table 1 shows parameters that the USEPA uses as drinking water quality indicators along with values found in water samples collected from rural underserved households. Based on information gathered from literature and governmental sources (USEPA, 2002; Ross et al., 2000) most metals (heavy metals excluded) are not detrimental to human health. Iron in drinking 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. The concentrations of alkaline earth metals (Na, Mg, Ca, and K) were much higher than non-alkaline earth metals

**Table 1. Limits set by U.S. EPA for drinking water wells that should not be exceeded based on the Safe Drinking Water Act. Countywide wells were those sampled by other researchers (Ross et al., 2003) within the same counties but without targeting the underserved farmers. State monitoring wells are those wells frequently sampled and analyzed by the Office of Drinking Water for the southern district of Virginia's Coastal Plain.**

Parameters Measured	U.S. EPA Limits	Underserved Farms Wells	Countywide Wells	State Monitoring Wells	Underserved Farms Wells that exceeded EPA Limits
Iron (Fe)	0.3	0.26	NA	NA	15
Manganese (Mn)	0.05	NA	NA	NA	0
Copper (Cu)	1.0	ND	0.09	0.04	0
Sodium (Na)	30-60	97.0	62.1	159	22
Arsenic (As)	0	ND	ND	ND	0
Lead (Pb)	0	ND	ND	ND	0
Mercury (Hg)	0.002	ND	ND	ND	0
Fluoride (F)	2.0	1.53	1.01	2.66	11
Chloride (Cl)	250	104.7	104.7	8.97	2
Nitrate (NO <sub>3</sub> )	10	5.87	5.84	0.01	25
Nitrite (NO <sub>2</sub> )	1	0.15	NA	NA	4
Sulfate (SO <sub>4</sub> )	250	268.7	9.22	4.1	4
PH	6.5-8.5	7.08	7.22	8.19	53
TDS (mg/L)	500	322	239	346	15
Turbidity (NTU)	5	1.15	NA	NA	10
Total coliforms	0	98.4	35.98	36.87	71
Fecal coliforms	0	3.7	NA	NA	22
<i>E. coli</i>	0	21.2	4.8	0	12

NA = not analyzed  
 ND = not detected

in the water samples. This could be due to either the presence of calcite and/or dolomite in the rock formation, the effect of liming in nearby agricultural operations or, depending on well location, due to saltwater intrusion from the nearby ocean. Elements of concern in drinking water (Mn, Cu, As, Pb and Hg) were non-detectable in all well waters analyzed. 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 items, cooking utensils, and plumbing fixtures. There is no evidence to indicate that copper is detrimental to public health at levels considered to be aesthetically acceptable. The restriction of 1.0 mg/L for

copper is primarily to avoid the metallic taste and gastro-intestinal discomfort that occur at higher concentrations. In surface waters, copper is toxic to aquatic plants at concentrations below 1.0 mg/L and has frequently been used as the sulfate salt to control growth of algae in water supply reservoirs. Concentrations near 1.0 mg/L copper can be toxic to some fish (Stumm and Morgan, 1981). Arsenic is considered detrimental to public health and EPA has set an MCL value of 0.01 mg/L for drinking water. This trace element gains access to drinking water wells through mining operations, use of arsenical insecticides, and from combustion of fossil fuels. Lead poisoning has been recognized for many years primarily due to its presence in paints and piping. Until early 1980s, lead has also been used as anti-knocking agent in gasoline, which is released into the atmosphere as lead oxide. It has been identified as a cause for brain damage thus leading to retardation and kidney failure (Sawyer and McCarty, 1978). Mercury poisoning emanates from its ubiquitous use in various scientific equipment, such as the thermometer, batteries, arc lamps, in the extraction of gold and silver, and the electrolytic production of chlorine. Its oxides have been used in pesticides and in mildew proofing of walls and roofs. The presence of methylated mercury in fish sparked alarm in the early 1980s and forced the EPA to lower the Maximum Contaminant Level (MCL) standard to 0.002 mg/L for drinking water.

Oxyanions are the other group of water quality indicators assessed in well waters. Fertilizer use and intrusion from nearby ocean are suspected sources of oxyanions in well waters. In this study, approximately 68% of the wells contained

oxyanions (Cl, F, SO<sub>4</sub>, PO<sub>4</sub>, NO<sub>3</sub>, and NO<sub>2</sub>), but the average concentration, except for SO<sub>4</sub>, was lower than the federal guidelines. Chloride in concentrations below 250 mg/L is not considered to be detrimental to human health. However, above this level food and drink will have an objectionable salty taste. With the possible exception of coastal areas, natural levels of chloride are generally low, and high levels in drinking water may indicate contamination from a septic system, road salts, fertilizers, industry, or animal wastes. High levels of chloride may accelerate corrosion of metal pipes

Table 1 also shows concentrations of drinking water quality indicators in well water samples collected from the 185 underserved rural households in Virginia's Coastal Plain. All water samples were collected from September 2005 through June 2006. High sodium in drinking water may be a health hazard to people suffering from high blood pressure or cardiovascular and kidney diseases. For those on low-sodium diets, 20 mg/L is suggested as the maximum safe level for sodium in drinking water. In coastal areas, much of the excessive sodium found in well water supplies could be due to natural intrusion from nearby oceans. High concentration of fluoride in water is known to cause dental fluorosis, a process leading to teeth and gum decay. Low levels of fluoride are considered beneficial in preventing tooth decay, whereas moderate amounts can cause brownish discoloration of teeth. For these reasons, the EPA has set both the MCLG and MCL limits for fluoride at 4 mg/L (USEPA, 2004). Most of the well water samples did not exceed either standard, although about 22 samples registered

higher than the allowable limits (Table 1). High level of  $\text{SO}_4$  in drinking water might have a laxative effect, but it is not considered to be detrimental to life (Ross et al, 2003). High sulfate concentrations may also result in adverse taste. Sulfates are naturally present in most groundwater, and are usually associated with hydrogen sulfide gas. 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 when the water is heated. Nitrate in water mostly comes from contamination from fertilizers, septic influent, and animal waste runoff. The health implication of nitrate is significant in children less than 3 years old, where it may cause methemoglobinemia or "blue-baby" disease. The USEPA has set a MCL for nitrate at 10 mg/L, and suggests that water with greater than 1.0 mg/L not be used for feeding infants. If drinking water has levels greater than 3 mg  $\text{NO}_3$ /L, it might indicate excessive contamination of the water supply by commercial fertilizers and/or organic wastes from septic systems or farm animal operations.

Data in Table 1 also show other water quality parameters that were measured in well water samples. The pH is a measure of acidity or alkalinity in water. Acidic waters cause corrosion in pipelines and toxic metal buildup in drinking water. Alkaline waters cause scaling and clogging of water pipes (Sawyer and McCarty, 1978). The pH indicates whether water is acidic or alkaline. Acidity or alkalinity of water is determined by measuring its pH. Acidic waters cause corrosion in pipelines and toxic metals

buildup in drinking water. Alkaline waters cause scaling and clogging of water pipes (Sawyer and McCarty, 1978). Acidic water can also cause toxic metals leaching from the plumbing system into the drinking water (Snoeyink and Jenkins, 1980; Benefield, et al., 1982). 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 USEPA has set a suggested range of between 6.5 and 8.5 on the pH scale for drinking water. Hardness is a measure of calcium and magnesium buildup in water; it is usually associated with karst formation. Hardness was more prevalent in water samples obtained from Northampton and Accomack counties, where ancient marine deposits might have contributed to calcium buildup. High total dissolved solids (TDS) values reflect the presence of materials in the water that may cause unpalatable taste and appearance. Total dissolved solids also contribute to plumbing damage in older homes with metal piping. Consequently, high TDS in water may cause adverse taste and deteriorate household plumbing and appliances. The EPA has set an SMCL of 500 mg/L for TDS. The average TDS concentration for the water analyzed was 211 mg/L; and 22 percent of the samples exceeded the standard. The maximum TDS concentrations obtained in well waters from the Coastal Plain was 1803 mg/L. Turbidity is more of an aesthetic than a health problem in surface water; however, highly turbid

well water would suggest a need to install a filtration system. Saturation index (SI) is used in combination with pH to assess potential corrosion of water pipelines (Langlier, 1936; Sawyer and McCarty, 1978). An SI value  $< 1$  indicates potential corrosion while  $SI > 0$  would suggest scaling of the interior of water pipelines. The USEPA guideline recommends an SI between  $-1$  and  $+1$  for drinking water. The average SI for the well water samples in the Coastal Plain of Virginia was below the lower limit recommended by the USEPA.

Another critical component of drinking water assessment is determination of bacteria. Coliform bacteria are microorganisms commonly found in surface water, soil, and in the feces of humans and animals. They do not usually cause disease; however, their presence in the water indicates that fecal wastes may be contaminating the groundwater resources. If contamination occurs, pathogenic organisms may cause gastrointestinal diseases, hepatitis, or other internal discomfort (Pao and Brown, 1996). In this study we found one or more coliform bacteria per 100mL water in more than 33% of the samples collected (Table 1); indicating that many drinking water wells used by underserved households at Virginia's Coastal Plain were contaminated with unknown microorganisms. The average coliform counts of the water samples collected from the Coastal Plain were about 0.73, 0.72, and 0.20 log CFU/mL, respectively. Water samples collected in the summer had higher coliform counts when compared to other seasons of the year. Fecal coliforms, including *E. coli*, are bacteria that originate from the intestines of warm-blooded

animals (Entry and Farmer, 2000). These bacteria usually have a strong association with fecal contamination that originate from warm-blooded animals. If one fecal coliform per 100mL of water is detected, the water is considered unsafe to drink (Greenberg et al., 1992; USEPA, 2002a). In this study we found that one or more fecal coliform and *E. coli* per 100mL water in 10 and 5% of the water samples collected (Table 1), indicating a significant number of underserved farmers and families in the Coastal Plain, especially in Dinwiddie County, were using water unsafe for human consumption.

It is to be recognized that 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 can be followed by an analysis for *E. coli* bacteria. Therefore, most probable number quantitative bacteria counts can be obtained for both total coliform and *E. coli* bacteria. The fact that generic *E. coli*, indicator bacteria, was found in 23% of tested samples from the Coastal Plain, made it evident that a

significant number of drinking water wells used by underserved households in this region were directly contaminated by either human or animal fecal matters that could cause serious health problems. Additional study is warranted to investigate the source of *E. coli* and fecal coliform in affected wells; also to assess these wells for the presence of more serious pathogenic microorganisms (such as *Salmonella enteria*, *E. coli* O157:H7, etc.).

#### *Interpretations of Survey Results*

Most of the underserved lived on farms in rural areas, while some lived on remote rural lots; only 10% lived in housing developments. Out of the 179 households that responded to the survey questionnaire, 60% identified themselves as African-Americans, 34% as Caucasians, and 6% described themselves as other. The age distribution in these residences ranged from 36-45 years (54%) to over 65 years (16%). About half (48%) did not want to tell their level of education; among those who were willing to tell, 39% had completed either elementary or secondary school education and 13% had college level education. About 40% have been living in their current houses longer than 20 years. The majority of residents (92%) got their drinking water from private drilled wells while only 4% obtained water from hand-dug wells. Many respondents did not know how deep their wells were, but some (27%) indicated that depths varied from less than 40 feet to over 500 feet. The survey results also indicated that 39% of the wells tested had no wellhead protection, and 53% of the respondents were unsure if their wells had protection. A more general survey on the use of wellhead protection in Virginia's rural

waters had revealed that most wellheads were either severely damaged or grossly neglected (IEN, 1992). Almost all respondents stated that they had not experienced any shortage of water from their wells. The plumbing in these rural houses was mostly copper (23%) and plastic (44%), with a few houses having a combination of the two; however, some (27%) did not know the type of plumbing they had in their houses.

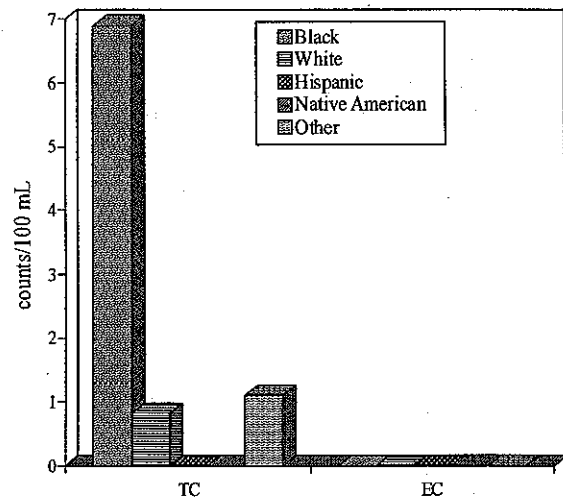
A great majority (86%) of the homeowners in the sampled area did not use any kind of treatment technologies prior to consuming their well water, even though 42% of the residents described their water as being turbid or colored with observable particulates. Only 29% of the survey results showed that residents had their water tested at least once in the last five years for water quality indicator chemicals and bacteria, which meant about 70% of the household never had their water tested. Approximately 52% of the respondents saw no staining of utensils used in carrying water, but some (14%) have seen evidence of staining due to rust, blue-green, or brown sediments. The observed rust (staining) might be due to the high iron and/or manganese content of the soil in the region, or it could be indicative of the presence of some oxidizing bacteria or blue green algae in the wells. Questions dealing with environmental impacts were not answered satisfactorily. For instance, when people were asked if they had above or below ground fuel tanks, 43% responded as having neither. Moreover, those that admitted to having storage tanks didn't know how far the fuel tanks were from the drinking water wells. Most (67%) of the respondents did not have a designated storage

facility for fertilizers and pesticides outside their houses. Normally, separate structures are recommended for storing such chemicals in farms to avoid food and drinking water contaminations. An encouraging aspect of the survey was revealed when a great majority (93%) of the homeowners did not dispose grease, oil, or leftover household chemicals down the drain. Therefore, the likelihood for petroleum-based chemicals entering the drinking water wells would be negligible.

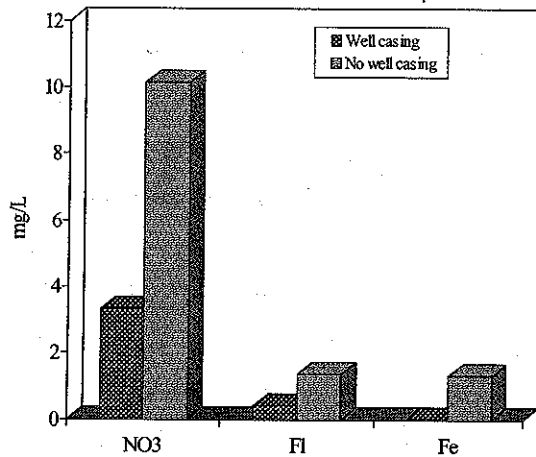
Among the water parameters tested in the well waters, the survey showed that total coliforms (TC) fecal coliforms (FC), nitrate ( $\text{NO}_3$ ), fluoride (Fl), and iron (Fe) were of concern to the respondents (Figures 2 and 3). Demographically, TC counts were the highest in water samples taken from black homeowners than other groups (Figure 2). However, there was no significant difference in TC counts when compared by income levels. Comparison by education level showed samples from households with high school education had the worse contamination of TC. The type of plumbing used in houses had significant effect on TC counts, whereby plastic piping was more conducive for TC than either copper galvanized metal or lead piping. Although 22 samples showed fecal coliforms count beyond the USEPA guideline (Table 1), these values were not discernable when compared by demography, income level, education or the type of plumbing used. However, among the 185 water samples collected from the Coastal Plain region, 71, 22, and 12 samples exceeded the EPA limits for Total coliform, fecal coliform, and *E. coli*, respectively (Table 1). Survey results also indicated that  $\text{NO}_3$ ,

Fl, and Fe levels were affected by well age, well depth, well type, and well casing (Figure 3). Well casing had greatly reduced  $\text{NO}_3$  contamination in water samples. The same is true for Fl and Fe contents. Nitrate level was predominantly higher in shallow wells (40 to 50 feet depth) than deeper (>100feet). However, variations in Fl and Fe levels were not too different regardless of depth. Well age showed variability in  $\text{NO}_3$  levels, whereby wells drilled between 1970 - 1990 indicating high  $\text{NO}_3$  content in water samples followed by older wells (1950 - 1970) and the more recently drilled wells (beyond 1990). It was interesting to note that hand-dug wells were less prone to  $\text{NO}_3$  contamination compared to drilled wells (Figure 4). This is in light of the fact that hand dug wells are much shallower than drilled wells.

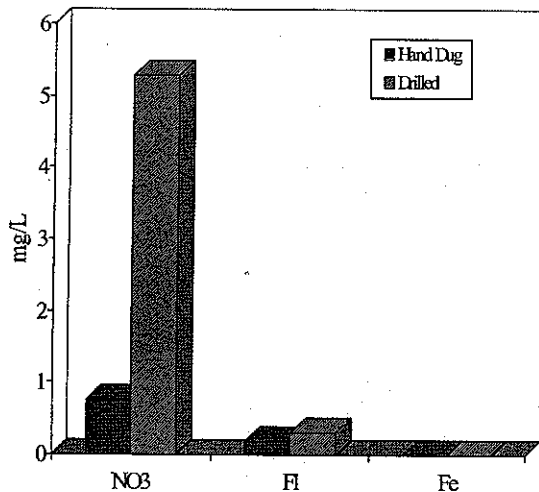
**Figure 2. Variation in total coliforms (TC) and *E. coli* (EC) counts in drinking water wells at underserved farms.**



**Figure 3. Concentrations of nitrate, fluoride, and iron in wells constructed with and without casings.**



**Figure 4. Concentrations of nitrate, fluoride, and iron in water from hand dug and drilled wells at underserved farms.**



### CONCLUSION

After analyzing the chemical and microbiological qualities of the drinking water samples, it was found that drinking water resources at underserved farms located in certain parts of the Coastal Plain of Virginia are in serious need of water safety risk prevention. The overall results showed that of the 185 locations

sampled and tested, coliform, fecal coliform, and *Escherichia coli* organisms were detected in about 33, 10, and 5% of the samples, respectively. Wells in close proximity to agricultural fields would show higher nitrate and phosphorus levels. Animals that roam in the vicinity of drinking water wells, geographic location of septic tanks, fertilizer storage, and manure disposal and storage facilities on the farm are potential sources of well water contamination.

The current findings indicated the presence of both biological and chemical contaminants in wells, although the data are insufficient to confirm that such contaminants would be detrimental to human health. A survey questionnaire filled out by farmers indicated that most complained about the color, taste, and turbidity of the water supply. Installation of filtration system could alleviate the problem, however, underserved farmers are unlikely to have the financial resources for such facilities. Nonetheless, results found from this study were provided to the homeowners along with additional information about educational and other resource assistance.

Identification of sources of contaminants to drinking water resources in these communities and finding solutions to the problems are sorely needed. Most of the residents of such communities lack sufficient income to afford expensive water treatment facilities. Consequently they are in great need of either state or federal assistance to overcome the problem. In addition, water quality education needs to be made available to the underserved

communities to better protect drinking water resources.

## REFERENCES

- Benefield, L.D., Judkins, J.F., and Weand, B.L. 1982. *Process Chemistry for Water and Wastewater Treatment*. Printice-Hall, Inc., Englewood Cliff, N.J.
- Entry, James A. and Robert Farmer. 2000. *Ground Water Quality: Movement of Coliform Bacteria and Nutrients in Ground Water Flowing Through Basalt and Sand Aquifers*. USDA-ARS, Publication No.
- Greener, A.F., L.S. Clescerl, and A.D. Eaton. 1992. *Standard methods for the examination of water and wastewater*, 18<sup>th</sup> ed. American Public Health Association, Washington, DC.
- IEN, Institute for Environmental Negotiation. 1992. "Wellhead protection: a handbook for local governments in Virginia," University of Virginia, Charlottesville.
- Langelier, W.F. 1936. The analytical control of anti-corrosion water treatment, *J. Amer. Water Works Assoc.*, 28:1500.
- Pao, S. and G.E. Brown. 1996. Reduction of microorganisms on citrus fruit surfaces during packinghouse processing. *Food Science and Nutrition*, 61:903-906.
- Poff, J. and A. Blake. 2000. A Confidential report for Virginia's ground water. Virginia Water Resources Research Center, Newsletter, February issue.
- Reichenberger, L. 1990. "Bad Wells, Bad Water". *Farm Journal*. November:13-15.
- Ross, B.B., T.K. Balderson, C.L. Lawrence, D.M. Moore, K.R. Parrott, and A.C. Bourne. 1990. *Evaluation of Household Water Quality in Essex, King and Queen, King William, and Middlesex counties, VA*, Virginia Cooperative Extension, Publication #442-932.
- Ross, B.B., T. Tabulenas, S.M. Johnosn, K.J. Liddington, K.R. Parrott, and A.C. Bourne. 2003. *Evaluation of Household Water Quality in Richmond and Westmorland Counties, Virginia*. Virginia Cooperative Extension, Publication #442-926.
- Sawyer, C.N. and P.L. McCarty. 1978. *Chemistry for Environmental Engineering*, Fourth Edition. McGraw-Hill Inc., New York.
- Snoeyink, V.L. and Jenkins, D. 1980. *Water Chemistry*. John Wiley and Sons, New York.
- Stumm, W. and Morgan, J.J. 1981. *Aquatic Chemistry: An Introduction Emphasizing Chemical Equilibria in Natural Waters*, Second Edition. John Wiley and Sons, Inc., New York.
- USDA-NRCS (U.S. Department of Agriculture Natural Resources and Conservation Service). 2003. *USDA Definitions of Some Underserved Customers*. <http://www.il.nrcs.usda.gov/outreach/Define.html>
- USDA-NRCS (U.S. Department of Agriculture Natural Resources and Conservation Service). 2006. *Cooperative Conservation Partnership Initiative- Questions and Answers*. [http://www.nrcs.usda.gov/programs/ccpi/pdf\\_files/CCPIQ&A06.pdf](http://www.nrcs.usda.gov/programs/ccpi/pdf_files/CCPIQ&A06.pdf). Accessed on January 27, 2006.
- USEPA (Environmental Protection Agency). 1981. *Procedures for Handling and Chemical Analysis of Sediment and Water Samples*. Technical Report EPA/CE-6-81-1.
- USEPA (Environmental Protection Agency). 2002. *Drinking Water from Household Wells*. Publication No. EPA 816-K-02-003,

U.S. Environmental Protection Agency.  
Washington D.C, January 2002.

USEPA. (Environmental Protection Agency).  
2002a. Safe Drinking Water Act – Protecting  
America’s Public Health. EPA 816-H-02-  
003.

USEPA. (Environmental Protection Agency).  
2004. Drinking Water Standards and Health  
Advisories. EPA 822-R-04-005. Office of  
Water, USEPA, Washington. DC. Winter  
2004.