

WATER CONTAMINANT PREVALANCE AND FILTER SYSTEM  
EFFECTIVENESS FOR HOMES IN THE EAGON/BUFFALO CREEK COMMUNITY

A Report of a Senior Study

by

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Spring, 2009

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## ABSTRACT

Drinking water from wells in rural areas is not monitored, and wells in regions of coal mining have been shown to have elevated contaminants that harm human health. The purposes of this study were (1) to characterize regional contaminant trends in the well water quality of private homes in the Eagon/Buffalo Creek community of northeastern Tennessee and southern Kentucky and (2) to evaluate effectiveness of filtration systems installed by the non-profit organization Living Waters for the World. Water samples for total dissolved solids (TDS), pH, and iron analyses were collected in thrice-rinsed wash bottles and variables measured with equipment from the Hack Company, and samples collected for lead, copper, and arsenic analyses were taken according to the protocol from the Environmental Quality Institute. Bacteria samples were analyzed using a WhirlyPack from the Hack Company. Collection time was not found to influence results ( $p=??$ ). Analyses revealed that upon first draw of water from the tap, lead and iron concentrations exceeded the EPA maximum contamination level, and more than half of the homes tested positive for bacterial contamination. Filtration systems were significantly effective at reducing iron ( $p = 0.0075$ ) and marginally significant at reducing lead ( $p=0.0693$ ) at first draw. Bacteria was reduced, but not significantly ( $p=?$ ). A more comprehensive analysis of the bacteria present in private well water is recommended, and programs should be initiated to inform residents of the risks involved in drinking unfiltered well water.

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## CHAPTER 1

### BACKGROUND AND HISTORICAL INFORMATION

For at least the past 4000 years, contaminated drinking water has been a human health concern. Early accounts attest to the measures taken by the Egyptians, who developed special apparatus for the clarification of their drinking sources, wine and water (Raucher 1995). The first major water treatment facility in the United States was an experimental system in Lawrence, Massachusetts, designed in 1887 to decrease the occurrence of typhoid fever. Using sand filtration, the system successfully resulted in a 79% decrease in the fever's death rate. In the next two decades, mechanical filters were in place in 33 US cities, and 13 additional cities employed simpler sand filters (Raucher 1995). As the 20<sup>th</sup> century progressed, water purification techniques gained both acceptance and widespread use.

Post-world war II industrialization brought new problems for water safety, namely the creation of anthropogenic toxicants, such as pesticides and industrial byproducts. As studies in the late 1960s and early 1970s highlighted deficiencies in the quality of drinking water, the U.S. Congress responded to societal pressures and created federal water standards. The Safe Drinking Water Act (SDWA) was passed in 1974 (EPA [mod 2004]). The SDWA delegates responsibility to the United States Environmental Protection Agency (US EPA) to set standards for contaminants, both naturally occurring and man-made, in the nation's public drinking water (EPA [mod

2004b]). The US EPA currently has regulations and limits in place for more than 90 possible water contaminants, ranging from microorganisms to pesticides to metals (a partial list can be seen in *Table 1*).

The US EPA follows a preordained paradigm to determine what contaminants should be governmentally regulated. Contaminant regulation is initiated by an evaluation of a possible water threat's environmental incidence rate, human exposure, and health effects (EPA mod 2005). Once a contaminant has been determined to be a significant threat requiring regulation, the US EPA establishes a Maximum Contaminant Level Goal (MCLG). The MCLG is the maximum amount of a contaminant that can be present in water with no known health risk (EPA mod 2005). However, as implied by its name, the MCLG is merely a goal and not necessarily a realistic possibility once cost and detection abilities are considered, as the ideal level may be below the threshold that current technology can measure or too expensive for most facilities to afford. Thus the EPA further establishes a Maximum Contaminant Level (MCL), a more cost efficient and feasible contaminant level that further outlines the procedure for testing and eradication of the impurity in question (EPA mod 2005). For any contaminant, the enforced MCL is as close to the ideal MCLG as possible.

All of the contaminants identified by the EPA can be categorized into one of six classifications: disinfectants, disinfection byproducts, radionucleotides, microorganisms, inorganic chemicals, and organic chemicals EPA [mod 2009]. Each category has its own contaminants with adverse health effects and sordid histories of how each came to be a concern to the Environmental Protection Agency, but for simplicity and the purpose of this study, focus will be placed on the final three. Microorganisms include the bacteria

Table 1. A partial list of the contaminants regulated by the US EPA along with their possible sources and health effects. (Supplementary information in addition to literature referenced accessed through www.epa.gov.)

	Contaminant	Possible Sources	Health Effects	References
	Antimony	Petroleum refinery discharge; fire retardants; ceramics; electronics; storage plastics	Blood cholesterol increase; blood sugar decrease;	Shotyk, Krachler and Chen 2006; EPA [mod 2009]
	Arsenic	Coal mining; agricultural application; wood preservation; glass production	Increased cancer risk; increased risk of non-insulin dependent diabetes mellitus; hypertension; cardiovascular diseases; carotid atherosclerosis	Smith, Lingas, and Rahman 2000; EPA [mod 2009]
	Benzene	Leaching from gas tanks; industrial discharge	Increased cancer risk	Hayes, Yin, Dosemeci, Li, Wacholder, Chow, Rothman, Wang, Dai, Chao, Jiang, Ye, Zhao, Kou, Zhang, Meng, Zho, Lin, Ding, Li, Zhang, Li, Travis, Blot, and Linet 1996; EPA [mod 2009]
	Beryllium	Discharge from metal refineries and coal-burning factories; discharge from electrical, aerospace, and defense industries	Intestinal lesions	EPA [mod 2009]
Chemicals	Carbofuran	Insecticide, most notably used on corn	Increased cancer risk	Bonner, Lee, Sandler, Hoppin, Dosemeci, and Alavanja 2005; EPA [mod 2009]
	Carbon tetrachloride	Used industrially; possible fire extinguisher component	Increased cancer risk	EPA 1980; EPA [mod 2009]
	Ethylene dibromide	Pesticide	Increased cancer risk	Ratcliffe, Schrader, Steenland, Clapp, Turner, Hornung 1987; EPA [mod 2009]
	Lead	Corroded home plumbing systems; natural deposit erosion	<i>Infants/Children:</i> delays in physical and/or mental development  <i>Adults:</i> kidney problems; high blood pressure	EPA [mod 2009]
	Mercury	Erosion of natural deposits; factory waste; landfill and crop runoff	Kidney damage	EPA [mod 2009]
	Styrene	Factory discharge	Liver, kidney, or circulatory system problems	EPA [mod 2009]
	Tetrachloroethylene	Factory discharge; used at dry-cleaners	Liver problems; increased risk of cancer	EPA [mod 2009]
	Thallium	Leaching from ore-processing sites; discharge from electronics, glass, and drug factories; draining from base metal	Hair loss; kidney, intestine, or liver problems; changes in blood	Kazantzis 2000; EPA [mod 2009]

		mining		
	Vinyl chloride	Leaching from PVC pipes	Increased cancer risk	EPA [mod 2009]
Microorganisms	<i>Cryptosporidium parvum</i>	Human and animal fecal waste	Gastrointestinal illness; possible death in persons with compromised immune systems	Goldstein, Juranker, Ravenholt, Hightower, Martin, Mesnik, Griffiths, Bryant, Reich, and Herwaldt 1996; EPA [mod 2009]
	<i>Escherichia coli</i>	Human and animal fecal waste; often from improperly treated manure	Diarrhea; hemorrhagic colitis; hemolytic-uremic syndrome	Solomon Yaron and Matthews 2002; Friedrich, Bielaszewska, Zhang, Pulz, Kuczius, Ammon, and Karch 2002; EPA [mod 2009]
	<i>Giardia lamblia</i>	Human and animal fecal waste	Gastrointestinal illness	EPA [mod 2009]
	<i>Legionella</i>	Found naturally in water; multiplies in heating systems	Legionnaire's Disease	EPA [mod 2009]

and protozoans such as *Cryptosporidium parvum*, a protist common in lakes and rivers and known to cause gastrointestinal illnesses, and *Giardia lamblia*, the gram-negative bacteria as the source of Legionnaire's Disease (Goldstein *et al.* 1996) (See *Table 1*). Organic and inorganic chemicals are grouped together and include contaminants such as benzene, an organic chemical widely used as an industrial solvent despite being a known carcinogen, and ethylene dibromide, a chemical that is largely synthesized for use as a pesticide although it increases cancer risks (Hayes *et al.* 1996; Ratcliffe *et al.* 1987) (See *Table 1*). Here two of the most problematic contaminants from each category will be examined due to their potential prevalence in the location of the study, rural Appalachia of the Cumberland Mountains: *Escherichia coli*, a notorious microorganism, and arsenic, a newly emerging problematic chemical for the EPA. *E. coli* was chosen because of its association with animal and human waste that has reached groundwater, which is likely to occur in regions with a lower education level and limited access to indoor plumbing (EPA [mod 2009]). Arsenic has become a concern due to strip mining in the Cumberland Mountains, as strip mining disturbs the minerals and releases them into the ground to be absorbed by groundwater (Shiber 2005).

## CONTAMINANTS OF CONCERN

The fecal coliform *Escherichia coli* gained notoriety in 1993 when undercooked and contaminated hamburger meat from a Jack-in-the-Box restaurant chain caused hundreds to get sick, primarily children, resulting in the death of four people (Holton 2002). The strain of *E. coli* responsible for the Jack-in-the-Box incident was O157:H7, believed to cause 70,000 illnesses and 60 deaths annually in the United States alone in addition to recorded outbreaks worldwide (Holton 2002; Varma *et al.* 2003). The main

source of this strain comes from the gastrointestinal tract of healthy cattle and other livestock, and as a facultative anaerobe it can survive when released into the environment to seek a new host (Varma *et al.* 2003; Blattner *et al.* 1997). After an incubation period of 3-5 days the bacterium's toxins cause abdominal cramps, vomiting, bloody diarrhea, and sometimes fever (Holton 2002). Acute infections can develop into hemolytic uremic syndrome (HUS), which can result in renal failure and potentially stroke, seizure, and death (Holton 2002).

Despite the aforementioned problems associated with *Escherichia coli*, strains other than O157:H7 are vital and useful. At least one strain is a necessary microbe of all animal intestines, humans included (Ram *et al.* 2008). In the human gastrointestinal tract, *E. coli* aids in suppressing the growth of pathogenic bacteria, such as *Salmonella*, and synthesizing vitamins (Hudault *et al.* 2001; Holton 2002). *E. coli* also functions as an indicator of water quality; they indicate that other harmful microorganisms, such as other fecal coliforms, are also likely to be present (Ram *et al.* 2008; CDC [mod 2008]).

Arsenic has a longer history, beginning with when it was linked to lung cancer in English miners in 1879 (Smith *et al.* 2002). Since then it has been shown to increase the rate of numerous cancers, such as that of the skin and urinary tract, as well as raising the percentages of cardiovascular diseases, hypertension, carotid atherosclerosis, and non-insulin-dependent diabetes mellitus (Shiber 2005). Chronic exposure to arsenic from drinking water results in elevated rates of spontaneous abortions, stillbirths, and preterm birth rates (Ahmad *et al.* 2001). After reviewing the mounting evidence of arsenic's adverse effects on human health, the US EPA lowered the MCL of arsenic from 50 parts

per billion (ppb) to 10 ppb in 2003, a drastic reduction that many believe is not yet low enough (Ahmad *et al.* 2001; Shiber 2005).

The concern for ensuring the protection from contaminants such as *E.coli* and arsenic is a serious one, and there are currently more than 170,000 public water systems that service almost all Americans during at least some portion of their lifetime to ensure drinking water safety (EPA [mod 2004]). Yet outside of SDWA and US EPA protection are nonpublic water systems, such as those that service 90% of rural Kentuckians and 40% of the entire population of Ohio (Shiber 2004). Private wells serving less than 25 people each still service 10% of the population. Private well owners are themselves responsible for ensuring the quality of their drinking water. While some states set standards for private wells, it remains the duty of the individual to be self-informed of state requirements and test water annually (EPA [mod 2005]).

Private wells existing outside of government regulations are typically found in rural areas. In the southeastern United States, these rural areas are often regions of the Appalachian Mountains equally likely to be in close proximity to coal mining. Health status is inversely related to proximity of coal mining production, with data showing residents of West Virginia experiencing increased rates of cardiopulmonary disease, lung disease, cardiovascular disease, diabetes, and kidney disease (Hendryx and Ahern 2008). Coal waste and byproducts, or coal slurry, placed in an impoundment negatively impacts area water by elevating the concentrations of heavy metals such as arsenic and cadmium above US EPA standards (Stout and Papillo 2004). The world average of arsenic concentration for bituminous coals, such as those found in the Appalachians, is  $9.0 \pm 0.8$  ppm, but the coal of West Virginia has been found to exceed this average by testing at a

concentration of 17.13 ppm (Yudovich and Ketris 2005; Shiber 2005). The occurrence of arsenic in drinking water may also be augmented by unregulated waste dumping from mining companies and private builders (Shiber 2005).

Although arsenic concentrations are known to be high in the bituminous coal of the Appalachians and arsenic is equally known to cause health problems, data on the occurrence of arsenic in private well water of Central Appalachia is scant compared to that of the remainder of the United States. A map created by a statistician and hydrologist for the US Geological Survey, Sarah Ryker, analyzing the national occurrence of arsenic showed insufficient data for much Kentucky and northeastern Tennessee (Ryker and Welch 2005). The Eagan/Buffalo Creek community of Tennessee near the Kentucky border lies within this poorly explored range and is the sample area chosen for the purpose of this study.

The Eagan/Buffalo Creek community is situated in the western portion of Claiborne County, which abuts the Kentucky border and encompasses the southeastern segment of the Cumberland Mountains. The general population of this rural area is predominately white (97.4%) with an average density of 68.8 persons per square mile; while this density may seem high, it is far below the national average of 138 persons per square mile and is centered heavily on the cities of Harrogate (685 persons/mi<sup>2</sup>), Tazewell (496 persons/mi<sup>2</sup>), and Cumberland Gap (630 persons/mi<sup>2</sup>) (USCB [mod 2009]). The education level is below nation standards, with only 60.3% obtaining a high school diploma (USCB [mod 2009]). A meager 8.9% of persons 25 or older have a bachelor's degree or higher compared to 19.6% for the state as a whole (USCB [mod 2009]). As of 2007, the median household income hovered just below \$30,000 and

nearly a quarter of the county is below the poverty line. To provide additional perspective, in 1999, 21.1% of Claiborne county households had an income less than \$10,000 (USCB [mod 2009]).

Given the extremely secluded nature of the Eagon/Buffalo Creek region, this area is outside of city water regulations and protection. Many if not most of these households are maintained with private wells or collect water from a nearby water source such as a stream. Any contaminants found in those water sources, which may be polluted with natural pollutants, strip mining or agricultural runoff, or human and animal waste problems, are easily transferred to the local population. With the general lack of education in the Eagon/Buffalo Creek community, many residents are not aware of the harm they may be causing themselves or their families. The EPA makes recommendations to homeowners for the regulation of private water, but this information is primarily available online; it is unlikely that the population of this area has easy access to this information. EPA recommendations include information of laboratories that could be utilized for water testing. Given the socioeconomic status of the population, it is not likely the extra funds would be available to be used for evaluating the water the family has been living on for generations should knowledge of the testing exist.

#### PURPOSE

The lack of government involvement in regulating private wells coupled with the health issues from drinking water impacted by contamination problems have created the need for an investigation into the specific water problems encountered by populations in potentially impacted areas. One such area is the Eagon/Buffalo Creek community, a poor rural area of the Cumberland Mountains of northeast Tennessee. A survey of the

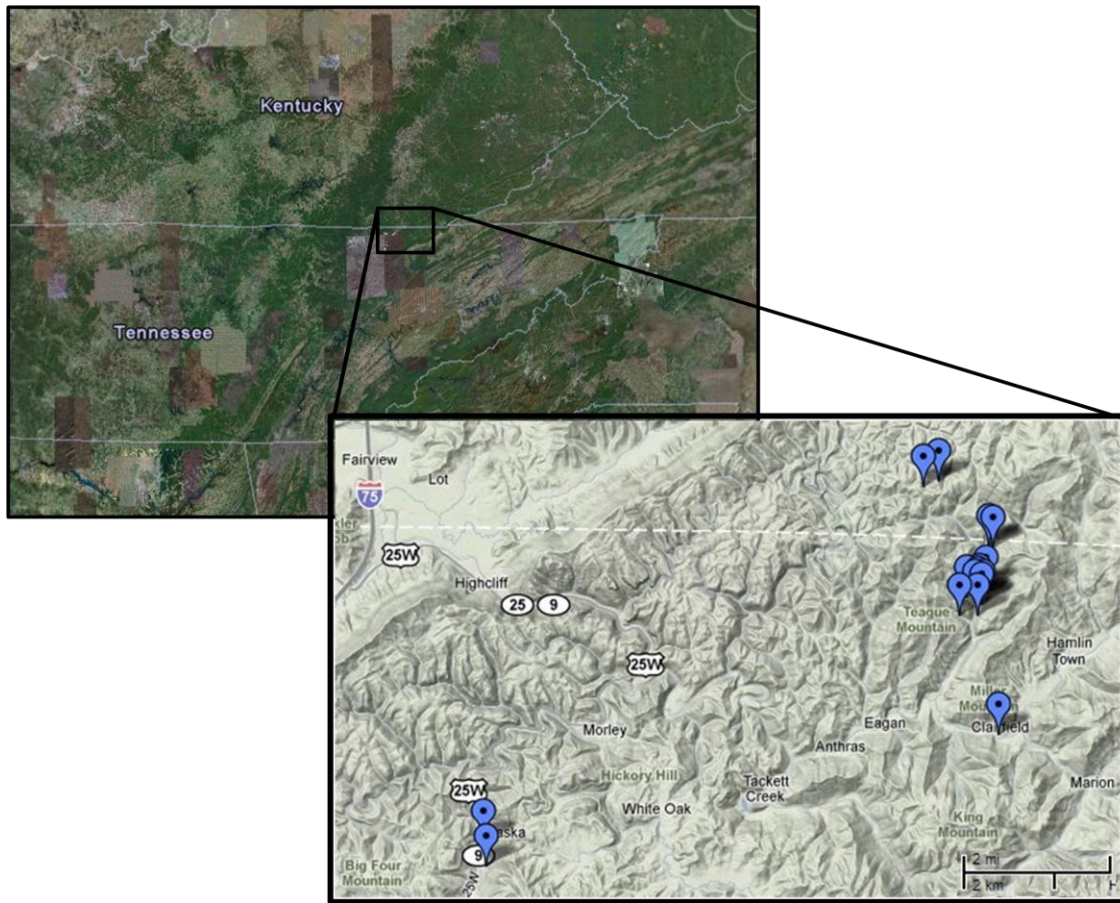
occurrence of drinking water contaminants in the private wells and springs of homes in the Eagan/Buffalo Creek community will help increase the scant body of knowledge on the area's water problems and determine if increased awareness of water related health issues is needed. Private water from homes in the Eagan/Buffalo creek area will be evaluated for the usual water indicators (salinity, conductivity, pH, Ca<sup>2+</sup> concentration, iron) as well as arsenic, copper, and lead, and analyses will gauge the effectiveness of current filtration systems in place in some of the homes.

## CHAPTER 2

### GEOGRAPHICAL INFORMATION

The geographical area involved in this study has been previously well documented by Hampson, Treece, Johnson, Ahlstedt, and Connell (2000). Water was collected from 19 home well systems located with the Clairfield, Eagon, and Buffalo Creek communities of Northeastern Tennessee and Southern Kentucky bounded by the coordinates of  $-83.96^{\circ}\text{W}$  on the east and  $83.95^{\circ}\text{W}$  on the west, as well as  $36.58^{\circ}\text{N}$  on the south and  $36.60^{\circ}\text{N}$  on the north. The specific locations can be viewed on the topographical map in Figure 1 along with their specific global positioning system coordinates.

As can be seen in the map in Figure 1, the testing sites are located in the Cumberland Mountains, part of the region described by Hapson *et al.* (2000). The climate of the area is temperate, with noticeable seasonal differences that can exhibit large variations due to elevation. The elevation for the homes of the sample range from 338 – 508m. For each 305 m gain in elevation, the average annual temperature decreases approximately  $3^{\circ}\text{F}$ , and precipitation is fairly evenly distributed throughout the year with no outstanding wet or dry season (Hapson *et al.* 2000). The underlying physiographic nature of the region consists of folded and faulted limestone, dolomite, shale, and sandstone, and underground water storage is typically found in carbonate based dolomites and limestones (Hapson *et al.* 2000).



**Figure 1.** Maps depicting the area of Kentucky and Tennessee involved in the study (top) and an enlarged viewing with bullets marking the specific testing sites. (Google Earth [mod 2009]).

The study site is known for its biological diversity, which can be evidenced by the species living in the area's surface waters. The largest waterway in the region is the topmost section of the Clinch River, which is known to have 126 native fish species and 52 species of water mussels (Hapson *et al.* 2000). However, the waterway is also considered one of the country's most biologically threatened systems. Of the native fishes, 12 are protected federally and 41 are listed by the state (Hapson *et al.* 2000). Twenty-eight species of water mussels are federally listed and an additional 10 species are state protected (Hapson *et al.* 2000).

## DATA COLLECTION

In 2007, the non-profit organization Living Waters for the World (LWW) identified the study area as one where poor water quality overlapped with a low income region that could benefit from an inexpensive purification system. Through town hall meetings and networking influential members of the community, LWW compiled a list of interested homes. After a series of water analyses and a manageable payment system was in place, LWW volunteers installed or are in the process of installing a filtration system and/or well to target the specific problems in the water supply of 23 homes. Due to sampling constraints, only 19 of these homes are included in the present study. Ten of these homes had filtering systems while the remaining nine were used only to determine the general trend of contaminants in the region.

Funding for the wells and filtration systems for the Appalachian region was from three main sources. The first was private donors who gave to the program as individuals. Second were churches, who generally take on the fiscal responsibility for a group of installations. The third was from a USDA grant as part of the government's Household Water Well Systems program, designed to support installation of wells and treatment systems for low income homeowners. The first part of this grant was received in 2008 for \$50,000, and LWW was approved for a second round in 2009 set at \$100,000. Families benefiting from the government loan pay back LWW for a portion of their services as finances allow over a 20 year time span, with this money going into a recycled loan fund that will allow then become the upfront money required for future installations.

Water samples were collected from both homes with current LWW filtration systems in place and those being considered for future installations. Before water samples were taken from a particular home site, the owner was contacted at least three days prior to inform them of the event and determine a suitable time. Water from all homes was collected from the kitchen sink. The water was allowed to run for two minutes and a 250 mL clean wash bottle was rinsed in the water three times before being filled. Homes with LWW filtration systems in place had a second sample taken following the same protocol from a water source not connected with the system, typically an outdoor spigot, which was also allowed to run for two minutes before collection in a thrice washed acid bottle.

Homeowners who had LWW filtration system in place were asked to fill out a questionnaire either verbally or written, per personal preference. This questionnaire can be seen in full in [Appendix A](#), and asks information such as the age and approximate depth of well, the number of houses and people the water supply serves, the components of the filtration system, and other general knowledge about maintenance of the system. Part of the questionnaire also examines the homeowner's comfort with the system and his/her ability to maintain it independent of aid from LWW. At this time, any questions he/she had about the system were answered and necessary updates to the system were either undertaken or explained.

Homes identified for arsenic, copper, and lead testing had additional water samples taken according to the protocol outlined by the Environmental Quality Institute (EQI). Testing kits were ordered from EQI and water collected in the bottles they provided. Two bottles were sent per collection, a "first draw" sample and a "purged"

sample. The first draw sample was taken before any other samples to test for possible build-up in the non-flowing water. For the purged sample, the tap was allowed to run for three minutes and the bottle was rinsed in the water three times before being filled.

## WATER ANALYSES

For each sample, the total dissolved solids (TDS), salinity, conductivity, temperature, pH, calcium ion concentration (hardness), iron concentration, and bacteriological level were determined. Due to financial constraints, only eight homes were selected for lead, copper, and arsenic water analysis.

A sensION5 Conductivity Meter from the Hach Company (product #:5180013, <http://www.hach.com>) was used to evaluate the temperature, TDS, salinity, and conductivity by placing the electrode in the sample, swirling for a homogenous mixture, and recording the data from the appropriate setting. The pH was determined using an HQ11d Portable pH Meter from the Hach Company (product #: HO11D53000000, <http://www.hach.com>) by swirling the electrode in the sample and recording the result.

Iron was determined using a Hardness, Iron, and pH Test Kit, Model HA-62A (product #: 183701, <http://www.hach.com>), also from the Hach Company. The 5-mL viewing tube was filled with the sample water and a FerroVer reagent powder pillow mixed in. An orange color developed in the presence of iron, which took up to a few minutes depending on the form of iron in the water. The tube was inserted into the comparator next to a viewing tube of sample water with no FerroVer reagent, and the color disc was rotated until the color of the two samples matched. The iron concentration in mg/L was recorded from the scale window.

A WhirlPak with Dechlorinating Agent (Product #: 2075325, <http://www.hach.com>) was used to determine the presence or absence of sulfide-producing bacteria such as *Salmonella*, *Citrobacter*, *Proteus*, *Edwardsiella* and some species of *Klebsiella*. The sterile bag was opened and filled to the full mark before a PathoScreen Medium Pillow (Product #: 2610696) was added. The bag was sealed and incubated at room temperature, and any color changes recorded after 12, 24, and 48 hours. If no change was noticed in 48 hours, the sample was considered negative for sulfide-producing bacteria.

Arsenic samples were labeled and sent to Clean Water Testing Inc. at the Environmental Quality Institute (EQI) (<http://orgs.unca.edu/eqi/arsenic.html>) at One University Heights, CPO #2350, Asheville, NC 22804. Upon receipt of water samples at EQI, they were acidified to put metals that may have adhered to the bottle or water particulates into solution and incubated at room temperature for 16 hours prior to analyses. Lead concentration was determined by EPA Method 200.9, involving graphite furnace atomic absorption. Standard Method 3111B, Flame Atomic Absorption Method, was used for copper determination, and arsenic concentrations were tested by Standard Method 3114B, a Manual Hydride Generation/Atomic Absorption Spectrometric Method ([CWLTI] *Who We Are*).

#### STATISTICAL ANALYSES

To determine if specific water contaminants are of concern for the test region, the average value for each contaminant was taken from the total number of test sites (n=19) and compared to the MCLs (maximum contamination levels) set forth by the EPA as the standard threshold for determining significance.

In testing the effectiveness of the filtration systems, data from homes with current LWW filtration systems were used (n=10 or 8, depending on contaminant). A paired two sample t-test for means was performed for each contaminant comparing water from a non-filtered source with a filtered source in the same home, typically the kitchen sink, to determine if filtration leads to a statistically significant decrease in the prevalence of each contaminant ( $\alpha < 0.05$ ;  $H_0: \mu_{\text{unfiltered}} = \mu_{\text{filtered}}$ ). As filtration is assumed to decrease the level of any given contaminant, the one-tailed p-value was used to evaluate significance.

The water samples collected for the above analyses were obtained over a period of several months. To ensure that variation in collection date had no impact on the water quality variables measured, a two sample paired t-test was used to compare samples obtained from the same homes on different dates. The water variables assessed in this analyses were TDS, iron, and pH, and all were examined both before and after filtration ( $\alpha = 0.05$ ).

## CHAPTER 3

### REGION TRENDS

In determining what, if any, water contaminants are prevalent in the area, the average value for each contaminant was and compared to the appropriate standard set forth by the EPA (see Table 1). For total dissolved solids (TDS), the average concentration ( $193.1 \pm 78.9$  mg/L) was found to be considerably less than the secondary standard of 500mg/L recommended, but the average iron concentration ( $2.35 \pm 3.20$ mg/L) was more than seven times higher than the EPA standard (0.3mg/L). The average pH ( $7.41 \pm 0.55$ ) fell within the EPA's suggested range. Lead concentration at first draw on the water line ( $0.0200 \pm 0.0344$ µg/L) was above the EPA action level (0.015µg/L), but once the line was purged the concentration decreased considerably ( $0.0026 \pm 0.0019$ µg/L). Copper experienced the same decrease in concentration between the first draw ( $0.2322 \pm 0.5480$ µg/L) and purged line ( $0.0286 \pm 0.0229$ µg/L), but neither were above the EPA action level (1.3µg/L). The average arsenic concentration ( $0.00079 \pm 0.00031$ µg/L) was also below the EPA action level (0.01µg/L). Additionally, over half of the homes tested positive for bacterial contamination (n=19).

**Table 1.** Average of the concentration or value measured for each contaminant in the untreated water samples compared to the standard set forth by the Environmental Protection Agency.

Contaminant	Sample size	Untreated sample average shown with standard errors	EPA Standard	Number above standard or outside range
<b>Total Dissolved Solids (TDS) (mg/L)</b>	19	193.1 ( $\pm$ 78.9)	500	0
<b>Iron (mg/L)</b>	19	2.35 ( $\pm$ 3.20)	0.3	12
<b>pH</b>	19	7.41 ( $\pm$ 0.55)	6.5-8.5	1
<b>Lead on First Draw (<math>\mu</math>g/L)</b>	10	0.0200 ( $\pm$ 0.0344)	0.015	2
<b>Lead on Purged Line (<math>\mu</math>g/L)</b>	10	0.0026 ( $\pm$ 0.0019)	0.015	0
<b>Copper on First Draw (<math>\mu</math>g/L)</b>	10	0.2322 ( $\pm$ 0.5480)	1.3	1
<b>Copper on Purged Line (<math>\mu</math>g/L)</b>	10	0.0286 ( $\pm$ 0.0229)	1.3	0
<b>Arsenic (<math>\mu</math>g/L)</b>	10	0.00079 ( $\pm$ 0.00031)	0.01	0

#### FILTRATION EFFECTIVENESS

For samples obtained from homes with filtration systems, a two sample paired t-test was used to determine if filtration resulted in a significant decrease in the concentration of each contaminant (Table 2). The mean for TDS showed an increase rather than the expected decrease, and was not found to be significant (p-value = 0.128). Filtration caused a significant decrease in iron concentration (p-value = 0.007), but had no significant effect on pH (p-value = 0.315). Marginal significance was found for the first draw of lead (p-value = 0.069), but strong significance was found once the line was

purged (p-value = 0.009). For copper, neither the first draw of the purged line showed significance (p-values of 0.124 and 0.125, respectively). Arsenic and bacteria showed marginal significance (p-values of 0.054 and 0.096, respectively).

**Table 2.** Paired two sample t-test on water samples from homes with purification systems to determine if filtration led to a variation in contaminant concentration.

Contaminant	Sample Size	Mean Unfiltered	Mean Filtered	P-value ( $\alpha=0.05$ )
<b>Total Dissolved Solids (TDS)</b>	10	197.81	206	0.128288
<b>Iron (mg/L)</b>	10	3.25	0.36	0.007484
<b>pH</b>	10	7.323	7.358	0.314737
<b>Lead on First Draw (units)</b>	8	22.2125	13.225	0.069303
<b>Lead on Purged Line (units)</b>	8	4.15	1.1875	0.008601
<b>Copper on First Draw (units)</b>	8	283.5125	55.15	0.123512
<b>Copper on Purged Line (units)</b>	8	32.1875	21.025	0.125246
<b>Arsenic (units)</b>	8	0.79375	0.565	0.054221
<b>Bacteria (units??)</b>	10	0.5	0.2	0.096711

#### COLLECTION TIME

To determine if contaminant concentration varied based on the water sample collection date, pre-filtration and post-filtration samples obtained from the same home at different times were compared using a paired two sample t-test (Table 3). No significance variation due to varying collection times was found for any of the variables (TDS, iron, and pH).

**Table 3.** Comparison of water quality variables in water samples collected from homes (n=4) on different dates using a paired two sample t-test. Neither non-filtered nor filtered samples significantly differed by date.

Contaminant	p-value for samples not filtered ( $\alpha=0.05$ )	p-value for filtered samples ( $\alpha=0.05$ )
<b>Total Dissolved Solids (TDS)</b>	0.14828	0.483348
<b>Iron</b>	0.295839	0.460544
<b>pH</b>	0.202985	0.310755

## CHAPTER 4

### DISCUSSION

Little information was previously known concerning the water quality of the Eagan/Buffalo Creek community as private well water is outside of governmental regulation. Unfiltered water samples were analyzed for total dissolved solids (TDS), iron, pH, lead, copper, arsenic, and bacteria, but the only contaminants with levels of concern with respect to a health impact were bacteria, iron, and lead. More than half of the homes tested were positive for bacterial contamination, and the average iron concentration was more than seven times the EPA action level. The only other contaminant that may be of interest was lead, which was above the action level set by the EPA at first draw but below the action level once the line was purged. Arsenic was expected to be found in high concentrations due to coal mining in the region but was found to be well below the EPA's action level. As the water samples were collected over a period of several months, a paired two sample t-test was used to verify that collection date did not influence the results, and no significance was found for any of the variables measured (TDS, iron, and pH;  $n=4$ ;  $\alpha=0,05$ ).

The EPA has action level set for lead due to the health problems exposure can cause, such as delayed physical and mental development in children in addition to an increase in chronic kidney disease and high blood pressure in adults (EPA [mod 2009]; Munter et al.2003). Long term lead exposure in children even at levels below the EPA standard have been correlated with a decrease in IQ, and these exposures have further

been shown to have a statistically significant relationship with an increase in arrest rates (Schwartz 1994; Hornung 2009). In pregnant women, lead exposure cause miscarriage and is correlated with increased infant mortality (Uzych 1985). The EPA has determined that lead is a probable human carcinogen, and absorption by the body is increased by low dietary iron, especially in children (Public Health Statement: Lead 2007; Hamman et al., 1996). WHY LEAD HIGH???? PIPES????

While the first draw levels of lead were high, the physical effects of lead alone may in part be offset by the high iron levels that would inhibit the body's lead absorption. However, the high iron levels have their own health implications, especially at such high levels. Even at modest levels iron is suspected to contribute to the development of cardiovascular disease, recognized as the leading cause of death for both males and females in developed countries (Alpert 2004). A clear link has been established between cardiovascular disease and excess liver iron, thought to be due to the inflammatory immune response and iron's regulatory role in redox-sensitive signaling pathways (Yuan and Li 2003; Yuan and Li 2008).

Previous studies in nearby and surrounding regions had found arsenic contamination levels to be much higher than what was determined experimentally in the Eagan/Buffalo Creek community. For instance, Shiber (2005) found an arsenic concentration of 1 ppb or more in over half the samples taken from 15 different counties in Eastern Kentucky and included private water supplies, suspected to be caused by the heavy coal mining the region experiences. As the Eagan/Buffalo Creek region also has coal mining, similar results were expected. COME UP WITH A REASON WHY... BE

CREATIVE Although no trend for arsenic contamination was found, it is still recommended that all private well owners have water tested before consumption.

The effectiveness of the filtration systems were analyzed by comparing the concentration level of each contaminant before and after filtration. Filtration did not show a significant change in TDS, pH, or copper in either the first draw of purged line, but this was expected as these contaminants were not elevated before filtration. The concentrations of iron and lead in the purged line were significantly decreased through filtration, and marginally significant decreases were seen in the first draw sample of lead as well as for bacteria and arsenic. Thus, the filters are successfully removing the contaminants of concern for this region.

In future studies of LWW filtration systems and in this study, it is important to recall that homeowners are personally responsible for the maintenance of the purification units. This should include knowledge of how and when to change each the filter cartridges, UV bulbs, UV lamp, and addition of salt to the water softener, as well as a general concept of how the system works. When any one system is thought to be ineffective, the upkeep of the unit should be evaluated before the equipment itself is considered faulty. As a lack of contaminant decrease could easily be due to improper upkeep rather than a poor system, LWW should continue to insure that homeowners are aware of their individual liability in keeping the system updated and have easy access to the materials and knowledge needed to do so.

Very little data exists to assess the water quality of the northeastern Tennessee and southern Kentucky area, and a larger and more comprehensive study of the region is recommended. Bacteria levels were found to be high, and future work should be taken to

characterize the specific species found to be regional contaminants. Significant contaminant variation was seen in the wells across the study region, and residents ought to be repeatedly informed of their responsibility to have private water supplies tested, especially when this water is used for drinking. A part of informing residents of the need for water testing should include laboratories capable to perform the appropriate tests as well as the contact information for organizations like Living Waters for the World. Additionally, awareness campaigns should extend to area health professionals who need to be alert for health problems and/or diseases that may be caused or magnified by poor water.

Appendix A:

## Living Waters for the World Appalachian Network

### *Sustainability Questionnaire*

1. Name \_\_\_\_\_

2. Address -

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

3. Type of Water Supply :

(a) \_\_\_\_ Your own spring

(b) \_\_\_\_ Your own well

Approx. well depth \_\_\_\_\_

Approx. age of well \_\_\_\_\_

Rated yield of well if known: \_\_\_\_\_ gallons per minute

(c) \_\_\_\_ City or community water supply

Name of supplier \_\_\_\_\_

4. Your water supply serves \_\_\_\_\_ home(s) and approximately \_\_\_\_\_ people.

5. Approximate age of your home (in years) \_\_\_\_\_

*Water Purification System Details:*

6. What components are included in your Living Waters purification system:

- |                         |                       |
|-------------------------|-----------------------|
| _____ filters           | _____ water softener  |
| _____ UV light          | _____ reverse osmosis |
| _____ green sand filter | _____ don't know      |

Additional components: \_\_\_\_\_

7. Approximately, when was your system installed?

\_\_\_\_\_

and by who? \_\_\_\_\_

*Water Purification System Maintenance:*

8. How often are your filter cartridges changed? \_\_\_\_\_

9. How often is your UV bulb changed? \_\_\_\_\_  
(if applicable)

10. How often is your UV lamp cleaned? \_\_\_\_\_  
(if applicable)

11. How often do you add salt to your water softener? \_\_\_\_\_  
(if applicable)

12. For maximum system performance, how often should you...  
Change the filter cartridges \_\_\_\_\_ Don't know \_\_\_\_\_

Change the UV bulb \_\_\_\_\_ Don't know \_\_\_\_\_

Clean the UV lamp \_\_\_\_\_ Don't know \_\_\_\_

Add salt to the water softener \_\_\_\_\_ Don't know \_\_\_\_

13. How comfortable are you with performing the system maintenance activities above? Please circle a number between 1 and 5 with 1 being not comfortable at all and 5 being very comfortable.

Not comfortable at all   1   2   3   4   5   Very comfortable

Do you have any concerns with performing system maintenance? Yes \_\_\_\_ No \_\_\_\_

If yes, please explain

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14. Do you understand how your water purification system works? Please circle a number between 1 and 5 with 1 being don't have a clue and 5 being completely.

Don't have a clue   1   2   3   4   5   Completely

15. Do you have any additional questions or concerns about your water purification system, maintenance, costs, or anything else?

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