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# Clean Water, Clean Life: Promoting Healthier, Accessible Water in Rural Appalachia

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**Abstract:** In the rural Appalachian region of the United States, thousands of residents struggle with issues of water quality and accessibility. Vulnerabilities of poverty, isolation, and rough geographical terrain complicate life for Appalachians who need access to adequate water supply and septic systems. In 2013, an inter-professional team of nursing, architecture, engineering, and law enforcement faculty and students developed a water-focused collaboration with community members in southeastern Kentucky. Greater accessibility to clean drinking water is a critical need in the area. Collaborative community engagement yielded effective and sustainable interventions. Inter-professional teams completed N=30 comprehensive home assessments examining factors such as water source utilization, septic system management, health status, and disaster preparedness. While the majority of homes evaluated had functional water supply and septic systems, the team observed straight piping as a means of waste disposal for several homes. Homeowners who did not have a residential water supply identified common gathering places where they typically obtain drinking water. To expand environmental assessment, the team collected water samples at 16 different sites where residents obtain drinking water or use it for recreational purposes. Testing of collected samples revealed 15 of 16 sites contained fecal coliforms, *Escherichia coli*, or both. Because of the findings, the team and community key informants collaboratively developed interventions, such as relaying findings to community leaders, developing a WASH (Water, Sanitation, and Hygiene)-related education program, and improving access to clean, safe water through the design and construction of a water kiosk. Outcome of interventions included greater awareness and knowledge of WASH related topics, improved access to clean water sources, and sustainable solutions to enhance overall quality of life, health and well-being.

**Keywords:** *Appalachia, community-based inter-professional research, environment, health*

Local environment, the air we breathe, and the water we drink, can enhance or harm the health risk and disease burden of a community. Humans are in constant interaction with their physical and natural surroundings; therefore, the quality of environmental conditions can have a significant impact on public health status. According to Healthy People 2020 (2016), environmental quality is a leading health indicator and considered a national priority. Healthcare providers typically treat symptoms of gastrointestinal illnesses, but rarely assess for compromised environmental sources that contribute to bacterial exposure and contamination.

Water quality is a primary concern for many residents of rural isolated communities, particularly in Appalachia, where critical infrastructure for water utilities is minimal to non-existent. Piping municipal water to neighborhoods in remote mountain hollows is expensive due to difficult terrain or geographic distance between hollow communities. Impoverished residents may lack sufficient funds to maintain existing infrastructure or even install indoor plumbing. Residents who lack access to municipal water in their homes rely on alternative sources for water, such as wells, natural springs, or expensive bottled water from a remote convenience store. Another unfortunate

alternative is to drink sugary substitutes such as sodas or energy drinks, leading to further financial and medical consequences.

Several sampling events took place from 2012-2014 in the Red Bird River Watershed, including Clay, Leslie, and Bell County, KY. Samples from as many as 64% of testing sites exceeded the Environmental Protection Agency (EPA) threshold for *Escherichia coli* (*E.coli*), a contaminant known to cause mild to severe human illness (Red Bird River Watershed Plan [RBRWP] 2014). Microbial source tracking is necessary to determine actual causality; however, invasion of human waste into surface and/or groundwater is the presumed issue. Poor sanitation practices can, unfortunately, release contaminants into nearby watersheds that can lead to adverse health when humans contact affected streams. This makes the water unsafe for recreational contact like swimming/fishing; and especially for use as a potable water source.

*E.coli* contamination, primarily spread through human waste, is prevalent in rural Appalachia regions with inadequate sewage maintenance. Residents who live in densely populated areas have limited availability of property for installment of adequate septic systems and drainage beds. Therefore, straight piping sewage onto ground surface or into streams is a common means of waste disposal. Fecal pollution results in elevated *E. coli* levels in drinking water or recreational water sources (CDC 2015). Consuming *E. coli* bacteria can cause abdominal cramping, diarrhea, dehydration, and even death, if not treated (CDC 2015). Therefore, the cost to human health is high.

**Sources of Drinking Water**

According to the Centers for Disease Control (CDC), public water systems and private wells are two of the most common sources of drinking water in the United States. Public water systems supply over 286 million Americans with drinking water on a regular basis (CDC 2014). Consumed drinking water is from both surface and ground sources. Surface water consists of open-air sources, such as rivers and streams. Ground water includes sources that are primarily underground, and not open to the atmosphere (EPA 2015c). The Environmental Protection Agency (EPA) regulates public water systems with strict guidelines and testing (EPA 2015b). EPA guidelines, however, do not apply to private water systems, such as residential ground water wells that function as a primary drinking water supply. Homeowners are responsible for maintenance and testing of their private wells (CDC 2014).

**Federal Guidelines**

The federal government determines requirements for water quality, namely through the Clean Water Act of 1972, which established standards for quality, regulations for pollutants, instituted authority to set pollution standards and develop programs, and allowed grant funding for sewage treatment plant construction (EPA 2015e). States and other territories establish their specific policies, but they are subject to EPA approval. The EPA standards consist of four main parts: 1) designated uses of water; 2) criteria for protection; 3) anti-degradation requirements; and 4) general policies. Designated uses of water sources include wildlife, recreation, and drinking water (EPA 2015a).

**Impact on the Ecosystem**

The amount of pollutants in freshwater sources, including microorganisms, heavy metals, and other chemicals, has risen since the 1970s. Land development and other changes in land use have altered the flow of both surface and ground water. Water management is a cooperative effort, as everything occurring at one site in the system affects the environment downstream (World Health Organization 2016). Low levels of pH, high levels of fecal coliform, low dissolved oxygen, and high specific conductivity are indicators of poor water quality, which could directly affect aquatic life and ecology (Boettner et al. 2014).

Point and nonpoint sources comprise pollution. Point pollution comes from a single source, and includes industrial wastes, treatment plants, pipes, and drains. Nonpoint sources can be difficult to identify due to the resultant diffuse pollution. These sources include runoff from rain and agricultural use (EPA 2012). Criteria for protection include both numeric and narrative standards, ranging from allowable levels of pollutants to descriptions of ideal water sources.

Anti-degradation requirements help protect and improve upon the current state of a water source. General policies include both federal regulations and state-level guidelines (EPA 2015a). Sources of *E. coli* pollution include water treatment plants, septic systems, agricultural practices, upstream municipal sewer systems, and wildlife (Jenkins et al. 2005). Human activity is responsible for almost all sources of ground water contamination (EPA 2015d). Many states, however, do not have policies that consider sources of both human and wildlife contamination (Gostin et al. 2000). Interventions to aid in water quality improvement include the protection and treatment of water sources and maintenance of water distribution systems (Plummer and Long 2007).

**Impact on Human Health**

Consumption of contaminated water can lead to a wide variety of illnesses including cholera, hepatitis A, typhoid, and arsenic poisoning (Barbour et al. 2009) from bacterial and viral pathogens, pathogenic protozoa, and other water-borne pathogens (Legall 2005). Over 5 million people are estimated to die each year from water-borne disease resulting in diarrhea and fluid/electrolyte loss (Legall 2005). Evidence suggests diseases spread through increased exposure to human and animal waste near water sources (Sorenson, Morssink, and Campos 2011).

*E. coli* is a significant water quality indicator. The bacteria can survive in drinking water for 4-12 weeks depending on the environment (Edberg et al. 2000). In humans, *E. coli* infections can lead to colitis, renal disease, and death (Ram, Vajpayee, and Shanker 2008). Typically, symptoms appear within 2-4 days, but could still appear one week after exposure, with recovery usually occurring in 5-10 days (Connecticut Department of Public Health, n.d.). Potential sources of *E. coli* contamination include agricultural runoff, wildlife, waste treatment plants, and septic systems (Lewis 2016).

**Access to Clean Water**

VanDerslice (2011) investigated the relationship between water access and quality and the socioeconomic and demographic characteristics in the United States. He found that many low income and minority communities did not have access to piped water. It is difficult to determine if there is a statistically significant relationship between income and access to water because many water systems do not collect demographic information from customers (VanDerslice 2011). However, this would still not include those who rely on private systems for drinking water. While a 2007 survey estimated that 0.5-1% of U.S. households lacked access to piped water, in some low income and minority areas, entire communities did not have piped water. In California, counties with a high percentage of minorities had a greater percentage of drinking water violations, 42% compared to 16% (VanDerslice 2011).

Many people in rural communities rely on private wells and/or natural springs for drinking water supply. Periodic testing for contaminants should be standard practice; however, the EPA does not regulate private wells and natural springs. The responsibility for scheduled testing falls to the homeowners, which could be a costly deterrent for low-income residents. Many people in these areas lack the means for regular water testing and may be consuming unsafe water. Boiling does not remove all harmful substances from the water, and contaminants may remain present in wells for years without the owner's knowledge (Shiber 2005). An unfortunate result is that privately owned wells and natural springs can be common sources of gastrointestinal illness outbreaks in the United States (Raina et al. 1999).

McSpirit and Reid (2011) studied the use of bottled water in areas with poor water access and quality, such as Appalachia. Residents who perceived the quality of tap water as poor purchased more bottled water regardless of socioeconomic level, leading the researchers to conclude that while buying bottled water may be a financial hardship, many people considered it a necessity and factored it into monthly expenses. Thus, money earmarked for water may prevent people from buying other nutritious food. Residents' trust in their water treatment facility was associated with their decision to purchase bottled water. Those who trusted the facility were less likely to use bottled water, while those who did not have a high level of trust were more likely to purchase bottled water (McSpirit and Reid 2011).

### Sanitation

Inadequate waste management is an additional contributor to poor water quality. Rural Appalachian areas lack access to waste water systems and septic tanks due to lack of adequate land space, steep rough terrain, and poor soil conditions. As a result, straight piping is common, which further deteriorates the water quality (Cook et al. 2015). Some states are trying to help residents eliminate the use of straight piping. North Carolina established a project that would provide financial assistance to help citizens install proper septic systems. Before initiating the program, the researchers collected data, demonstrating over 17% of the homes surveyed used straight piping to eliminate waste from the home. Initially, the program's goal was providing funding for 130 households to replace their straight piping, but follow-up data on subsequent homes is not available (Baldwin n.d.).

Eastern Kentucky Personal Responsibility in a Desirable Environment (PRIDE) is a program established in 1977 that focuses on environmental protection, as well as on community education and resources. PRIDE provides grants to citizens for a variety of environmental projects, including the installation of septic systems. Requirements include proof of income (must be under 55% of federal poverty guideline), deed of property ownership, and electric bill (Eastern Kentucky PRIDE 2016). Septic system installation can range from $6,000 to $15,000, depending on soil, topography, and other site conditions. Land with a significant slope and wet or wooded areas all increase the price of installation (Kentucky Septic Service 2015) making it financially impossible for some without the aid of grant programs.

The rural community in southeastern Kentucky expressed a clarion call for help to address the need for improving access to clean water. In response, a university based inter-professional team, with expertise in nursing, architecture, civil and environmental engineering, and law enforcement began a synergistic process of knowledge sharing and joint planning to identify and address issues impacting community health and disaster readiness. The university team listened to the needs of the community and incorporated community input throughout a collaborative engagement process to design and implement innovative solutions. The mantra, Clean Water/Clean Life, became a shared value. As a result, a vision for creating a healthier, equitable community has become a reality.

## Methods

### Community-Academic Partnership

The *Appalachia Community Health & Disaster Readiness Project*, funded in July 2013 by the U.S. Department of Health and Human Services, Health Resources and Services Administration (HRSA grant #UD7HP26205-01-00), is an inter-professional collaborative practice (IPCP) effort to identify, evaluate, and address the health, safety, and disaster readiness needs of rural Appalachian communities in southeastern Kentucky. The IPCP team included professionals from the disciplines of nursing, architecture, engineering, and law enforcement innovation associated with the University of Tennessee. Site coordinators from Red Bird Mission (RBM), a local faith-based organization, and the local emergency management service were included on the team as well.

### Community Engagement

A novel process of community engagement was necessary to understand contextual issues surrounding water quality. The IPCP team used an integrated, social-ecological approach to develop a synergistic partnership with the community. An overarching goal of the IPCP team partnership with the community was to share knowledge of problems affecting the health and readiness of the community. The socio-ecological systems approach considers factors such as biological, social, and environmental determinants of health (Wilcox and Colwell 2005). Site coordinators at RBM and members of the local community first highlighted the urgency of getting access to clean water due to lack of piped water supply and potentially contaminated common water sources, such as wells or natural springs. Further assessments revealed factors contributing to disease, such as poor water quality caused by ground and soil contamination. Environmental factors leading to the root cause of illness was the necessary impetus to align culturally driven and appropriate interventions.

Engagement of stakeholders was crucial to understanding and improving health outcomes at the community level. In this model of interaction depicted in Figure 1, community was central. Community stakeholders and residents were experts in their own history, culture, community challenges and strengths; therefore, joint meetings and listening sessions provided an opportunity for the IPCP team to understand historical solutions to community problems attempted in the past, and to discuss priorities and collaboratively develop strategies to address pressing community issues. Site coordinators identified key stakeholders who had an interest and responsibility in addressing community concerns. IPCP team members joined representatives from Kentucky Waterways Alliance to participate in Red Bird River Watershed planning meetings. In addition, the team met with individual local leaders (County Judge Executive, County Attorney, Director of Emergency Management Services, County Directors of Water and Utilities for both Clay and Leslie Counties). Meetings with state and federal leaders (U.S. Forestry Service, Area Director of the U.S. Department of Agriculture [USDA] Office of Rural Development, and Director for Office of Rural Health) permitted discussion of concerns. Each encounter with stakeholders provided an opportunity to share knowledge, establish culturally driven goals, and determine available resources to assist with implementing active solutions.

Residents of the community were also prime stakeholders for water quality issues that were affecting their health, well-being, and disaster readiness. The IPCP team used their specialized knowledge and skill to engage with each other, as well as the community, to share knowledge and identify and solve critical problems that were compromising the health of the community. Community voice was vital throughout the process. Residents needed to know that the IPCP team listened and truly heard them, and appreciated health as a shared value. Essential priorities were to: 1) engage community stakeholders to determine needs; 2) build trust between academic-community partners; and 3) develop greater cultural awareness of communities in rural Appalachia.

### Community-Based Assessments

Community-based assessments of community neighborhoods and critical infrastructure helped to identify target neighborhoods, individual




**Figure 1.** Inter-Professional Collaborative Practice (IPCP) Project Model for improving wellness and disaster readiness through community engagement and knowledge-sharing. Image copyright [2013] by M. McArthur, S. Speraw, and J. Darragh.

households, and community/public facilities that needed more focused evaluation or intervention. As a result, the team was able to prioritize critical needs and develop strategies for intervention to create sustainable solutions to the challenges facing the rural Appalachia community. Community-based assessments included *community health and disaster readiness needs assessments*, and specific environmental evaluation requiring *water sampling*, *water testing, and a water knowledge survey*.

***Community Health and Disaster Readiness Needs Assessment.*** Upon approval of the Institutional Review Board at the University of Tennessee, the IPCP team evaluated structural soundness of homes, environmental safety, and vulnerability to health and security threats for individual community residents. Data collection included: 1) face-to-face interviews with individual residents, small family groups, or focus groups; 2) surveys using A *Health and Emergency Preparedness Assessment Survey* tool, an assessment tool adapted from the Center for Disease Control and Prevention (CDC) *Community Assessment for Public Health Emergency Response (CASPER) Toolkit* (2012); and 3) topographical, environmental, and architectural observations documented on an observation tool developed by the IPCP team.

In the spring and fall of 2014, community partners led the IPCP team to specific areas in the community to broaden cultural awareness of community need. Inter-professional teams of nursing and architecture students and faculty conducted 30 individual health, home, and environmental assessments. Survey data included demographic information, home ownership, number of people living in the home, sources of worry, presence of health conditions, type of home structure, and length of time in the home. Specific questions focused on resident access to water (source and amount consumed) and source of power, heat, and air. Assessment also included presence or absence of indoor toilets, septic infrastructure, and foundation and stability concerns around the home. Significant flooding in 2013 devastated the area; therefore, questions were intentionally designed to assess previous and current water/flood damage to the home, as well as the presence of mold.

Assessments revealed that community members who did not have access to water from a municipal water supply used other sources for drinking water, such as natural springs, wells, or simply a pipe extending from an embankment with flowing surface water. Residents expressed concerns about potential contamination of alternative water sources due to pollutants from mining practices, failing septic systems, and/or inappropriate practices of straight piping waste onto the ground or into nearby streams. Community members conveyed suspicions that the same impurities compromised public areas used for recreational purposes such as swimming, fishing, or performing local baptisms.

***Water Sampling.*** An investigation of local water quality was necessary to evaluate environmental safety. Thus, a team member who is an environmental engineer with expertise in water quality, facilitated training on proper techniques to collect and store water samples. Training included information about the collection kits, proper fill levels for various containers, and paperwork to maintain chain of custody, as well as proper labelling of specimens. After receiving training, nursing students and faculty divided into three groups to collect water samples from specific locations residents identified as drinking water sources or recreational areas.

The team collected water samples according to proper procedures and guidelines. Sample collectors labeled, sealed and documented to assure chain of custody and promptly delivered them to University of Tennessee engineering faculty on the same day of collection. Water samples were tested for standard parameters including: pH, conductivity, sulfate ($SO_4^{2-}$), nitrate ($NO_3^-$), ammonium ($NH_4^+$), orthophosphate ($PO_4^{3-}$), chloride ($Cl^-$), sodium ($Na^+$), potassium ($K^+$), calcium ($Ca^{2+}$), and magnesium ($Mg^{2+}$). Bacterial tests included fecal coliform and *Escherichia coli*. Due to local mining practices, analyses also included testing for the presence of heavy metals, including aluminum (Al), copper (Cu), iron (Fe), manganese (Mn), silicon (Si), zinc (Zn), arsenic (As), and mercury (Hg).

***Water Testing.*** At the University of Tennessee Water Quality Laboratory, samples were analyzed for pH and specific conductance (μS/cm) using

a ManTech™ autotitrator. Major base cations and trace metals ($Ca^{2+}$, $Na^{+}$, $K^{+}$, $Mg^{2+}$, Al, Cu, Fe, Mn, Si, Zn) were analyzed using a Thermo-Electron™ inductively coupled plasma optical emissions spectrometer (ICP-OES). Major anions ($SO_4^{2-}$, $NO_3^{-}$, $Cl^{-}$) and $NH_4^{+}$ were measured using a Dionex™ ion chromatograph (IC). All laboratory test procedures were conducted in accordance with standard methods (Table 1). A separate set of grab samples were collected for As and Hg and sent to Test America, Inc. in Nashville, Tennessee, where standard EPA methods were used. Bacterial tests were conducted at the University of Tennessee using the IDEXX Colilert™ method.

State of Kentucky and EPA water quality standards were used to assess the water analysis results; they were the warm water aquatic habitat, primary contact recreational waters (fishing and swimming), and drinking water limits (Table 2). EPA (1986) criteria for fecal coliform were promulgated as 200/100ml, although *E.coli* has replaced most recreational standards used by state environmental regulatory agencies. A recent U.S. EPA rule on elevated specific conductance from coal mining activities has been proposed with a limit in the range of 300 to 500 µS/cm, as some evidence suggests levels exceeding this range may harm aquatic life.

***Water Knowledge Survey.*** In addition to water testing, the IPCP team sought to understand the community's knowledge of WASH-related topics such as water collection, purification, storage, the protection of water from contamination to prevent water-borne disease, hygiene, hand-washing, and health benefits of water consumption. Community knowledge was assessed through baseline data surveying and focus group discussion. In collaboration with community leaders, the IPCP team developed a water knowledge survey to evaluate effectiveness of a clean water education program implemented in a variety of different venues throughout the community.

## Results

### Qualitative Insight

At the very first focus group session, community stakeholders expressed an urgent need to address the lack of clean water accessibility. Chronic poverty, isolation, historical neglect, and systemic vulnerability have impeded very basic needs, such as access to potable water. Piped water supply had been limited and inaccessible to hollow enclaves within the community. Sparse population density and rugged terrain make the cost of providing basic services prohibitive. Those who have no access to tap water in the home use local wells and springs, which are often contaminated because of inadequate human waste management throughout the county. Due to geography and poverty, raw sewage was often straight piped under foundations (contaminating ground water) and into waterways, contributing to widespread pollution. Yet, this was the only water available to local residents, since there is limited or no municipal supply to each individual home.

Discussions with local water district managers and community leaders confirmed that there were

**Table 1.** Analytical procedures performed for chemical analyses, and cited methodologies.

| Analysis | Procedure | Equipment | Method |
|---|---|---|---|
| pH | Potentiometric | PC-Titration Plus™ | USEPA Method 150.1 |
| Conductivity | Potentiometric | PC-Titration Plus™ | USEPA Method 120.1 |
| Anions | Ion Chromatography | Dionex™ IC | AWWA Standard Method 4110 (Easton *et al.* 2005) |
| Cations, Metals | Inductively Coupled Plasma Spectrometry | Thermo-Elemental Ins Intrepid II™ ICP | USEPA Method 6010B & 6010C |
| Fecal coliform, *Escherichia coli* | Enzyme Substrate 24-hr presence/absence | Idexx Colilert Quanti-Tray | AWWA Method 9223B |

**Table 2.** Summary of water quality standards for the state of Kentucky, Division of Water (KDOW) and the USEPA.

| Parameter | Standard (Source) | Standard Type | KDOW Benchmark |
|---|---|---|---|
| Temperature | 31.7°C (KDOW) | WAH* | |
| pH | >6.0 to <9.0 (KDOW) | WAH | |
| Dissolved Oxygen | ≤4.0 mg/L (KDOW) | WAH | |
| Specific Conductance | <119 µS/cm (KDOW) | WAH | X |
| Sulfate | <19.5 mg/L (KDOW) | WAH | X |
| Nitrate-N | <0.16 mg/L (KDOW) | WAH | X |
| Total P | <0.02 mg/L (KDOW) | WAH | X |
| Alkalinity (as $CaCO_3$) | 12-54 mg/L (KDOW) | WAH | X |
| Total Dissolved Solids | <500 mg/L (US EPA) | Drinking** | |
| Total Suspended Solids | No numeric standard | | |
| Hardness (as $CaCO_3$) | No numeric standard | | |
| Total Aluminum | 0.05-0.20 mg/L (US EPA) | Drinking | |
| Total Calcium | 0.005 mg/L (KDOW) | Drinking | |
| Total Cadmium | <0.0005 mg/L (KDOW) | Drinking | |
| Total Iron | <0.30 mg/L (KDOW & US EPA) | Drinking | |
| Total Magnesium | No numeric standard | | |
| Total Manganese | <0.05 mg/L (US EPA) | Drinking | |
| Total Lead | <0.015 mg/L (US EPA) | Drinking | |
| *Escherichia coli* | <240 colonies per unit (KDOW) | Primary contact recreational waters | |

* WAH = State of Kentucky, Division of Water, Water Quality Standards for the Designated Use: Warm Water Aquatic Habitat.
** Drinking = Drinking water regulations for either the USEPA National Secondary Drinking Water Regulations or the State of Kentucky (KDOW) Drinking Water Standards.

few plans to run either water lines or sewers to the remote hollows. Extensive and expensive barriers prevented access to city water, even in areas where city water lines are present. Municipal water lines exist along main roads, but the homeowners are responsible for a water meter fee in the realm of $600 and for paying for installation of water lines over 1000 feet away from the main roads, across bridges, streams, and rivers. The homeowners are also required to locate a contractor and pay for installation of the lines, fittings, and connection to the home. Families rarely have disposable income to afford this. Consequently, residents live with the financial and medical sequelae of drinking contaminated water, using water substitutes (such as soda or sweetened drinks), purchasing expensive bottled water, and living in close proximity to raw sewage. Socio-economic disparity, environmental contamination, inaccessible resources, and inequity are factors influencing health and quality of life for community residents.

### Quantitative Measures

***Survey Assessments.*** Descriptive data collected from the *Health and Emergency Preparedness Assessment Survey* tool with sample size (N=30) revealed 50% of residents had lived in their home more than 30 years. Thirty-six percent used wells as the primary source for drinking water and 57% used public municipal water. The remaining 7% used bottled water for drinking purposes. Over 50% of residents complained their water "tasted bad

like chlorine." Five out of eleven residents (45%) who used wells for drinking water revealed their well water had not been tested and certified as safe. Eighty-three percent of residents had a flushable working indoor toilet and 17% did not; therefore, use of an outdoor toilet was required. All residents who had indoor toilets indicated sewage disposals were via septic system. Flooding in spring 2013 caused damage to some septic systems that needed repair or replacement. The IPCP team directly observed straight piping into a local stream on two occasions, but residents did not self-report. During the data collection period, Red Bird Mission, Inc. generated a list of over 200 community residents needing septic tank installation or repair due to lack of or failing systems.

***Water Testing***. A total of 16 grab samples were collected on October 20, 2014 at locations numbered 1 through 18 (no samples were provided with numbers 10 and 12). This was a snap shot of sampling. There were no sampling criteria for a particular date to obtain information. The objective was to gather baseflow water quality information. All grab samples were collected in LDPE plastic bottles that had been triple rinsed in the lab with de-ionized water. All sample locations except Site 18 at Red Bird Mission were surface water. Site 18 at Red Bird Mission was the only drinking water sample. Figure 2 depicts water sample collection sites.

Table 3 summarizes results of chemical parameter analysis from the October 20, 2014 sampling efforts. Recreational water pH limits were exceeded at one site, Oneida junction, with a pH of 5.92 (range required is between 6 and 9). No other chemical parameter exceedances were identified. Nine sites had specific conductance that exceeded 300 µS/cm and of the nine, four of those exceeded 500 µS/cm. Two samples from the Chas Coal site were found to be 985 and 1072 µS/cm, which is considered very high for water approaching brackish conditions. Site 18 at the Red Bird Mission was 566 µS/cm, which was a drinking water source. The team recommended that this water be tested again. When conductivity is high, $SO_4^{2-}$ concentrations may be elevated and the results indicate this may be the case because other contributing ions such as $Ca^{2+}$ and $Mg^{2+}$ were much lower comparatively. In addition to $SO_4^{2-}$, $Na^+$ and $Cl^-$ were generally elevated. $SO_4^{2-}$, $Na^+$, and $Cl^-$ have no EPA limits for recreational use.

Results of bacterial parameter analysis of October 20, 2014 sampling efforts are summarized in Table 4. Recreation limits were exceeded for *E. coli* at four sites based on a threshold of 126/100ml (geometric mean); they were Granny's Branch, Jacks Creek, Jesse's Fork, and Montana

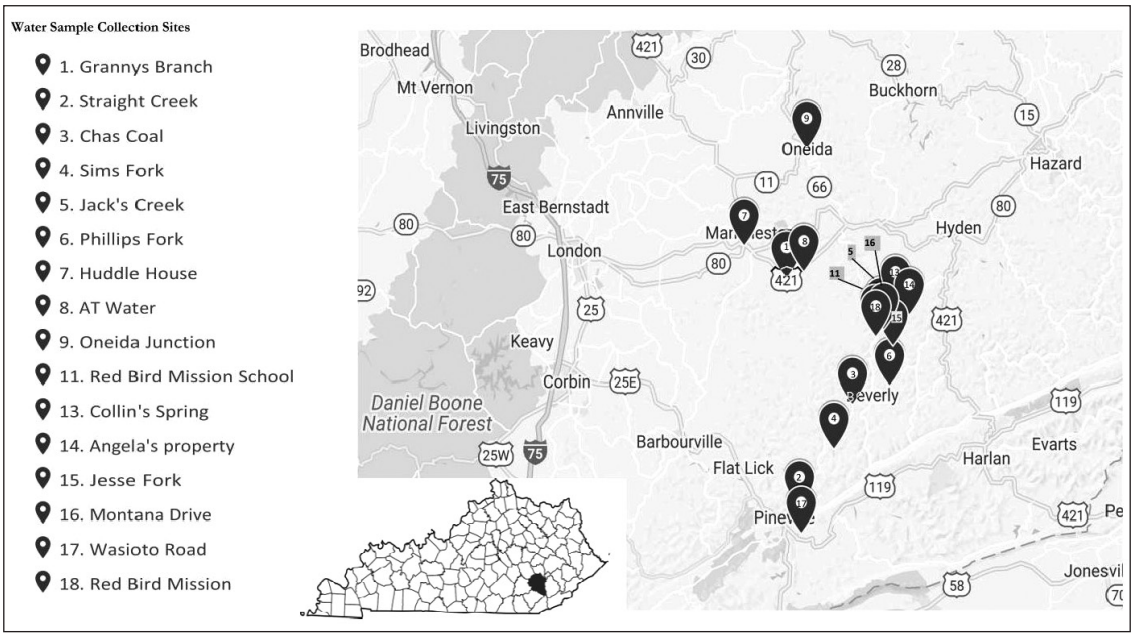



**Figure 2.** Water sample collection sites.

**Table 3.** Water quality analyses results from the surface waters in Clay County, Kentucky, and one drinking water sample at Red Bird Mission. Samples taken on October 20, 2014.

| | Sample Locations (No samples at #10 & #12) | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Chemical Parameter | 1. Granny's Branch | 2. Straight Creek | 3. Chas Coal (Sample 1) | 3. Chas Coal (Sample 2) | 4. Sims Fork | 5. Jacks Creek | 6. Phillips Fork | 7. Manchester Huddle | 8. AT Water | 9. Oneida Junction | 11. Red Bird School | 13. Collin's Spring | 14. Angela's Property | 15. Jesse's Fork | 16. Montana Drive | 17. Wasioto Road | 18. Red Bird Mission |
| pH | 7.37 | 6.84 | 8.06 | 8.14 | 6.80 | 7.17 | 7.61 | 6.81 | 7.03 | 5.92 | 6.56 | 6.64 | 6.40 | 6.88 | 7.23 | 7.13 | 7.01 |
| Conductivity | 145 | 44 | 985 | 1072 | 172 | 310 | 772 | - | 271 | 380 | 490 | 49 | 115 | 344 | 307 | 24 | 566 |
| Sulfate | 16.8 | 8.4 | 257.7 | 447.3 | 40.5 | 92.0 | 292.8 | 207.5 | 14.8 | 153.4 | 180.2 | 10.1 | 15.2 | 98.2 | 85.5 | 6.2 | 158.8 |
| Nitrate | 3.1 | 2.0 | 17.7 | 17.8 | 2.3 | 4.8 | * | 3.4 | * | 5.9 | * | * | * | 2.4 | 2.2 | * | 2.5 |
| Chloride | 3.1 | 1.5 | 20.0 | 21.0 | 2.4 | 3.4 | 1.7 | 27.6 | 4.8 | 2.2 | 2.5 | 1.3 | 1.5 | 2.4 | 2.9 | 1.5 | 16.3 |
| Ammonium | * | * | 0.6 | 1.0 | * | * | * | * | * | * | * | * | * | * | * | * | * |
| Phosphate | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * |
| Sodium | 5.6 | 1.6 | 327.0 | 292.0 | 8.2 | 27.0 | 111.0 | 60.3 | 51.1 | 52.7 | 33.1 | 2.0 | 2.8 | 65.3 | 41.7 | 0.9 | 63.3 |
| Potassium | 3.0 | 1.8 | 11.8 | 11.5 | 2.2 | 3.9 | 6.4 | 9.2 | 2.7 | 4.9 | 2.4 | 1.1 | 2.9 | 4.2 | 3.4 | 1.6 | 6.4 |
| Magnesium | 6.5 | 2.6 | 11.9 | - | 11.3 | 18.8 | 39.3 | 47.9 | 9.3 | 16.7 | 24.6 | 2.8 | 8.8 | 10.5 | 10.0 | 1.9 | 33.4 |
| Calcium | 30.3 | 5.2 | 79.9 | 90.7 | 20.5 | 44.7 | 82.1 | 85.3 | 27.7 | 31.2 | 67.8 | 4.6 | 14.7 | 36.9 | 39.0 | 1.1 | 72.5 |
| Silica | 6.7 | 4.5 | * | * | 5.6 | * | * | * | 3.6 | * | * | 3.4 | 8.2 | * | * | 4.4 | * |
| Aluminum | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * |
| Copper | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * |
| Iron | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * |
| Manganese | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * |
| Zinc | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * |
| Mercury + | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * |
| Arsenic + | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * | * |

Note: + = parameters conducted by Test America; * = < instrument detection limit; - = abnormal instrument output.
Units: pH in standard pH units; conductivity in µS/cm; all other chemical parameters in mg/L.

**Table 4.** Water quality analyses (bacterial parameters) results from the surface waters in Clay County, Kentucky, and one drinking water sample at Red Bird Mission. Samples taken on October 20, 2014.

| Bacterial Parameter | 1. Granny's Branch | 2. Straight Creek | 3. Chas Coal (Sample 1) | 3. Chas Coal (Sample 2) | 4. Sims Fork | 5. Jacks Creek | 6. Phillips Fork | 7. Manchester Huddle | 8. AT Water | 9. Oneida Junction | 11. Red Bird School | 13. Collin's Spring | 14. Angela's Property | 15. Jesse's Fork | 16. Montana Drive | 17. Wasioto Road | 18. Red Bird Mission |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ----------Sample Locations (No samples at #10 & #12)---------- | | | | | | | | | | | | | | | | |
| Fecal Coliform | + | 894 | 805 | x | 241 | + | 395 | 219 | 116 | 6 | 805 | 601 | 326 | 660 | + | 109 | 0 |
| *Escherichia coli* | 308 | 60 | 109 | x | 4 | 136 | 3 | 3 | 0 | 0 | 98 | 7 | 2 | 149 | 263 | 5 | 0 |

+ = parameters above detection estimates; 0 = method detection limit; x = no sample.
Units: MPN (per 100 ml).

Drive. Note, the limit is for a geometric mean, and these values represent only one sample, so findings should be viewed as an indicator and potential location of concern only. EPA (1986) criteria for fecal coliform were promulgated as 200/100ml, although *E.coli* has replaced most recreational standards used by state environmental regulatory agencies. Nonetheless, 11 sites were found with fecal coliform levels above 200/100ml.

Water quality results were also compared with drinking water standards. No exceedances occurred with dissolved metals, e.g., Cu, Zn, As, and Hg. The only chemical parameter exceedance was at the Chas Coal site for $NO_3^-$, in which the limit is 10 mg/L for adults and 1 mg/L for infants. $NO_3^-$ concentrations were found to be high from two samples taken at this site, consisting of 17.7 and 17.8 mg/l. These $NO_3^-$ concentrations, together with ammonium found at this site, indicate a sewer problem that has the potential to cause local stream eutrophication within a receiving stream.

The EPA sets bacterial drinking water standards at zero for both fecal coliform and *E.coli* indicators. Fecal bacteria was detected at almost all sites, so it is best to note the few sites absent of counts. The Red Bird Mission site (Site #18) was the only site with an absence of both fecal coliform and *E.coli*. The AT Water (Site # 8) and Oneida junction (Site # 9) sites had fecal coliform, but no *E.coli*. Fecal pollution is a known problem for waterbodies in the Clay County area. The source of the fecal pollution is believed to be from failing septic tanks or "straight piping" sewage onto the surface or into a drainage. The other possible sources, such as cattle, were not present and levels exceeded natural background levels from wildlife.

## Evidence into Action

### Model of Inter-professional Practice

Innovation was the hallmark of this community-academic partnership. Foundational to the success of the project was community engagement and knowledge sharing. The project brought together disciplines that rarely work together in collaborative practice, and operated on an integrated socio-ecological model of community engagement, knowledge sharing, inter-professional practice, and joint planning between the IPCP and the

community. This framework replaces the disease, cure, intervention model common to healthcare, and fundamentally transforms clinical practice. This IPCP partnership, focusing on the community as client, brought community members and leaders together throughout all aspects of intervention development. University professionals valued local community members as experts in their own history, culture, community challenges, and strengths, and demonstrated that respect through joint meetings, listening sessions, and discussions about priorities and community needs. This in turn created increased community buy-in and sustainability to increase community health and improved quality of life. Figure 1 illustrates the movement and synergy of vertical and horizontal integration, combined with active, continuous community involvement and feedback.

The model represents: 1) socio-ecological systems influencing health for the area; 2) strategies for horizontally integrating nursing, architecture, civil and environmental engineering, and law enforcement disciplines to create an inter-professional team; 3) plan for engaging community members, local organizations, and government leaders; and 4) *process* of how knowledge sharing between both axes leads to community participation, planning, and inter-professional practice. Momentum created by vertical/horizontal synergy became the driving force for improving accessibility of clean water resources and providing education to promote better health outcomes.

## Community-based Interventions

***Water Kiosk***. Triangulation of several data sources, including individual and focus group interviews, community assessments of critical infrastructure and individual households, and resultant findings from water sampling of local streams, natural springs, and well water, together confirmed the need for intervention to supply increased access to clean water to the area.

Years ago, a well-water kiosk was built by a local church. Two problems surfaced in that endeavor: due to heavy usage, the church could not afford expensive well water monitoring that the state required, and overuse drained the well. These barriers were insurmountable at the time, but the usage experience affirmed that residents would value and use clean water if it was available, and that the kiosk approach was welcome and acceptable in the community. An environmental engineer expert on the IPCP team, who had experience with implementation of water kiosks in developing countries, guided discussions with community partners and the local water district to gain approval for an alternative Water Supply Kiosk system. The intent was to tap into an existing county water line that was routinely monitored for purity and fluoride content.

In fall 2014, architectural experts on the IPCP team led an inter-professional academic course involving architecture, engineering, and nursing students to design a water kiosk structure. Student teams developed five unique kiosk designs, including input from the community and considering concerns such as health, security, location, accessibility, and incorporation of a community gathering space for events, such as a weekly farmer's market. Community members formatively reviewed designs with students. Selection of a final design was made with extensive community input. Students, faculty, and community partners built the water kiosk over a one-week period as an alternative spring break service learning activity in spring 2015. Figures 3 and 4 depict progression of the build and final rendering of the water kiosk structure.

***Education.*** In conjunction with the water kiosk design/build, students and faculty from nursing and architecture worked in close collaboration with community members to develop materials and tools that encouraged use and highlighted the importance of water and sanitation. The IPCP team provided interactive, culturally and literacy appropriate education to target community groups within the school, senior center, and larger community. Assessment of WASH-related knowledge before, immediately after, and six months post-education revealed there was a 14% increase in overall knowledge of WASH-related principles retained at six months post education. Supplemental materials disseminated at larger community events and programs provided indirect education. The IPCP team, as listed in Table 5, provided direct education. A total of 1,020 community members were directly trained with the average household of $n$=4, resulting



**Figure 3.** Build progression on water kiosk; Red Bird Mission, Beverly, KY.



**Figure 4.** Final water kiosk photo; Red Bird Mission, Beverly, KY.

in an estimated 4,080 people served. At the conclusion of the project, the IPCP team provided community leaders resources and tools to achieve sustainability and to provide continuing outreach to more community members through an interactive presentation and evaluation of achievements.

## Discussion

### Ethical Significance

***Ethical Principles.*** The American Nurses Association (2016) describes six ethical principles: Autonomy, Beneficence, Non-maleficence, Respect, Fidelity, and Justice. Autonomy encompasses respecting others' decisions, even if one does not agree. For this project, the researchers relied on the community for decisions and respected their feedback. By committing to better access to clean water, and thereby healthier lives, we participated in an act of beneficence because we sought to make positive changes in the community. Non-maleficence involves the intention to do no harm. In following other ethical principles, we demonstrated our desire not to harm the community

**Table 5.** Clean Water Education.

| Venue Description | Event | Number of Persons Encountered |
|---|---|---|
| Older Adult Health Fair | Silver and Gold Fair | 50 |
| Community Hospital Health Event | Spring Fiesta | 128 |
| Community Partner Event | WASH Education at RBM School | 116 |
| Community Partner Event | Farmer's Market Education | 20 |
| Community Partner Event | Tri-County Health Fair | 163 |
| County Event | Creation Health Fair | 50 |
| Community Partner Event | Commodities Day | 112 |
| Community Partner Event | Christmas Box Distribution | 133 |
| County Event | Frakes Health Fair | 184 |
| County Event | Grow Appalachia Meeting | 52 |
| County Event | Clay Co. Community Prevention Council Meeting | 12 |
| **Total** | **11 Direct Education Events** | **1,020*** |

*People directly trained were 1,020 persons representing households of average N=4 persons, representing 4,080 persons.

or its members. Fidelity involves honesty and dedication (American Nurses Association 2016). The research team and kiosk design teams were open and honest with the community and were dedicated to developing interventions in the best interest of the region. We demonstrated justice by working with all members of the community who were agreeable to home assessments and water testing.

***Ethical Concerns.*** There are many ethical concerns regarding access to clean water in rural Appalachian communities. A positive correlation exists between lack of access to clean water and low socio-economic status (VanDerslice 2011). The availability of federal funding could help alleviate some of this disparity. Indoor plumbing and septic system installation can be extremely costly and out of the reach of many families in rural Appalachia without this assistance. However, there are some region-specific challenges, namely the terrain and the isolation of some communities. Often sources of funding are available, but they cannot keep up with the need.

In our study sample, many of the participants who had private well water did not have it regularly tested or certified. This could be due to a variety of reasons, but citizens have to pay for the water testing if it is a private well. Often, people may not be aware of the process to have their wells tested nor have the financial means to test the water quality routinely.

The Clean Water/Clean Life project extended from needs identified by the community, and residents frequently provided feedback on interventions. This community focus helped establish trust and gave members some control over programs and education, leading to a successful project and culminating in widespread community education and the construction of the water kiosk. Community leaders now have resulting findings for dissemination to residents.

## Implications for Ongoing Practice, Education, and Research

***Practice.*** Few, if any, community-based projects have been developed by the type of inter-professional team demonstrated in this project. Members from each discipline were able to learn from and share with each other. This helped contribute to a better program, more effective

education, and beneficial interventions. The unique contributions of each field were invaluable. Not only was the overall project more successful, but specialists in each field learned a great deal from each other. Inter-professional communication and collaboration grew over time and was facilitated by courses, which brought students from the various disciplines together. The combination of inter-professional practice and community participation led to knowledge sharing and collaborative planning throughout the project.

***Policy.*** Currently, residents are responsible for testing and certifying their private wells. Policies could be developed which would help encourage people to have their wells tested, as well as programs to provide assistance for testing and treatment, if needed. Water sources that were found to have contaminants above EPA guidelines should be clearly marked and residents should be notified of any changes in water quality. Straight piping is not well-measured in this area of Appalachia. There is a lack of data regarding the proportion of people who employ this method of waste disposal, which complicates enforcement of septic systems and community interventions.

***Education.*** Community education is ongoing and resources were distributed to partners for continued education. Many of the tested water sources, though not used for drinking water, were frequently used for fishing, recreation, and baptisms. This presents a unique challenge because the site of baptisms may hold deep significance in the community, which is why consistent communication with, and input from, members is vital. Programs could also be developed with a focus on protecting the environment and sources of drinking water.

The IPCP team created a how-to manual titled, *Bringing a Water Kiosk to Your Community*, describing the holistic process of community engagement, assessment, intervention, evaluation, and empowerment. The how-to manual can help communities locally, nationally, and abroad to understand how to meet water accessibility needs in a culturally driven way.

***Research.*** Numerous interventions arose from this project, namely educational programs and the water kiosk. Both have the potential of long-term positive effects on the health of the community. Population health measures could be followed in a longitudinal study to help determine the effectiveness of both the kiosk and community education. The water testing was one occurrence, and repeat testing is recommended. Follow-up should continue and residents with private wells should receive information and reminders for testing. Additionally, it would be beneficial long-term to determine the source of contamination and develop education for those both up and downstream of contamination points. Targeted education should focus on topics related to proper waste management and trash disposal.

Disaster preparedness was considered during the home assessments. However, education interventions were focused on WASH-related topics. Future interventions should focus on in-depth analysis of disaster preparedness and community education. The area under study was prone to flooding; particularly many residents had to shelter in place for several hours or days in the aftermath of the spring 2013 flood. Residents should receive education on how to adequately plan for times of disaster, and how they might accumulate disaster supplies, as well as where to go for assistance should disaster strike.

## Conclusion

The importance of clean water is vital and access to water is a global priority. In the United States, there are still communities that lack access to clean water. The aim of this project was to work with a rural Appalachian community to understand community priorities and provide interventions. Community-based assessments and interventions such as educational programs and design/build of a water kiosk facilitated achievement of the overall project goals, which were: 1) to improve the health of this community by providing improved access to clean water; 2) to increase education about the importance of clean water; and 3) to serve as an exemplar of effective community-academic partnership and inter-professional practice for other areas in the region, nation, or abroad. Effective multi-sectoral partnerships and collaborations are required to address critical issues facing rural communities that often feel isolated and powerless.

Community-academic partnerships built upon a shared value of health, trust, and visionary

thinking can produce successful outcomes. In rural communities such as these, it is essential to have partners that residents trust. Bilateral trust and commitment facilitates a greater bond for successful change. Community empowerment is key to promoting long-term positive change and sustainability. The IPCP team provided educational tools and resources to community partners during an interactive presentation at the conclusion of the project. Sustainability of the project is ongoing as community partners continue to promote water kiosk utilization, and provide continued education through community programming. The impact of community-based intervention on population health outcomes requires longitudinal assessment over time. Funding long-term efforts becomes problematic when funding agency priorities inadequately align with community-based models of care. Strong innovative partnerships are critical in today's environment of limited funding and resources, especially to make an impact on health-related quality outcomes. This newly developed model of IPCP broadens the potential for future endeavors to include disciplines of public health, economics, law, policy, social work, and others whose expertise could help improve health and societal outcomes in the Appalachian region.

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