Are you really gonna drink that?

An investigation of factors that influence risk prevention in drinking water.

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> "Water, like religion and ideology, has the power to move millions of people. Since the very birth of human civilization, people have moved to settle close to it. People move when there is too little of it. People move when there is too much of it. People journey down it. People write, sing and dance about it. People fight over it. And all people, everywhere and every day, need it."
>
> —Mikhail Gorbachev, President of Green Cross International
> quoted in Peter Swanson's Water: The Drop of Life, 2001

Abstract

Water is becoming increasingly scarce across the globe. Organizations are working to increase access to water as a proxy for increasing human health. However, not all water is safe, and if left untreated many water sources are hazardous to human wellbeing. These organizations often provide educational support to teach consumers about the importance of water treatment; however, this advisement can go unnoticed if the facts are not persuasively presented to the individual responsible for treatment. Research on water quality and risk indicated that in individual treatment schemes, people have a relatively high risk tolerance. This comes in contrast to municipal schemes, which have relatively low risk although consumer opinions are less cohesive. When it comes to decision making about treatment options, municipal schemes again remain divided, while individual treatment schemes often choose not to treat despite understanding that treatment could protect from disease. Ultimately, choices about water treatment are based on a variety of variables including not only the perception of risk, but also cultural expectations, trust in information providers, and the cost of avoiding the risk.

INTRODUCTION

Water: A Human Right

In 2002, the United Nations Committee on Economic, Cultural, and Social Rights stated that: "The human right to water is indispensible for leading a healthy life in human dignity. [Water] is a pre-requisite to the realization of all other human rights" (UN 2003). That congress meeting explicitly recognized water as integral to human health. This declaration set forth new initiatives to increase access to safe water as a mechanism for improving livelihoods and human health. The average person can only survive for three to four days without water before suffering from dangerous health consequences, such as strokes or seizures. This makes water a prerequisite for both life and civilization; civilizations flourish where water is plentiful and disappear when those sources dry up. The survival of culture depends on sustainable access to water sources.

When it comes to human health, however, not just any water will do. Water can be a dangerous source of pathogens. From living bacteria and parasites to dormant viruses and a variety of chemical pollutants, water can be lethal. Often, formerly clean sources become contaminated with increased human activity. When New York City was still a British Colony, residents depended on the "collect", a spring that was originally used by Native Americans (NYCEP 2014). As more individuals and industries moved into the area, the spring became increasingly polluted. An article in 1798 reported: "[the water grows less and less wholesome everyday… the larger the city grows the worse this evil will be", and the author urged the city to seek out alternate water sources (Salzman 2012). Increased population led to increased outbreaks of disease, including yellow fever in 1819 and 1822 and cholera in 1832 and 1834 (SUNY 1997). These outbreaks led to the installation of infrastructure to provide clean water to the residents of New York. This problem was anthropogenic and solved through the advent of technology to eliminate bacteriological contaminants in the water. As time passes and research continues, more and more contaminants are being identified and larger numbers of water sources are found to be unsafe.

Sometimes solutions to avoid anthropogenic contamination can cause exposure to natural contaminants that were previously unconsidered. One case study comes from Bangladesh, a small Southeast Asian country that is still suffering from the side effects of imperfect water solutions. In the 1970's, Bangladesh became prone to bacterial contamination of surface water sources (WHO 2013a). To increase access to safer water, aid organizations funded the drilling of millions of shallow tube wells, which tapped into ground water. Typically, ground water is safer because it is protected from bacterial contamination that is common in surface water. Unfortunately, many of the tube wells were exposed to naturally occurring arsenic in the substrate. Arsenic is not very common and was not tested for when the wells were originally drilled; as such, local residents consumed arsenic-contaminated water for decades until high rates of skin lesions, internal cancers, and spontaneous abortions were noted in the early 1990's (Kapaj *et al* 2006). After a few rounds of testing, researchers estimated that 60% of wells contained more than 10 times the World Health Organization's maximum standard for arsenic contamination (Smith *et al.* 2000, Flanagan *et al* 2012). Today, almost 32 million Bangladeshis still lack access to safe drinking water (CIA 2014). This incident is considered a mass poisoning that rivals the nuclear disaster in Chernobyl (Smith *et al* 2000). As time passes, more water contaminants are being identified, and large numbers of water sources, previously considered safe, are now classified as unsafe with further testing.

Simultaneously, international governments and organizations are working to increase access to safe drinking water. The International Drinking Water Decade from 1981-1990 (now called the First Water Decade) provided water and adequate sanitation to 1.2 billion and 770 million people respectively (Black 1998). After the First Water Decade, small-scale projects were enacted as the international community focused on other issues like ending poverty, education on human rights, African empowerment, and cultural development (UNDESA 2014). Then, in 2000, the UN began creating "Millennium Development Goals" (MDGs), which included targets for increasing access to sanitation, decreasing disease exposure, increasing access to basic educations, and maximizing access to improved water sources, especially in rural areas. This last goal became a part of the Second Water Decade from 2005-2015, which is formally referred to as the International Decade of Water for Life. The MDG hoped to empower women as water users and conservers.

The official target for this MDG was to halve the number of individuals who do not have access to safe drinking water by 2015 (UN 2014). The success of this goal will be compared to baseline access estimates from 1990; and while 1.9 billion people have been afforded access since 1990 an estimated 2.5 billion still lack access to improved water sources (WHO 2013b). Access is more restricted in rural areas, where installing infrastructure to provide improved water is made difficult by decreased population density increasing the per capita cost of water sources (Mwendera 2009). These findings indicate that access to safe drinking water has increased but it is not yet universal. Furthermore, the definition of improved water sources is loosely defined by the UN and largely left up to individual nations for interpretation. This presents the issue that although more safe drinking water was provided to individuals and is presented as clean, the improved sources may remain unprotected and potentially exposed to contamination.

Argument

Countries and international aid organizations are striving to provide equal access to human rights, which include access to safe drinking water. To promote the right to human health, these organizations must not only provide the water but also ensure that it is being treated to be safe for human consumption. These treatment methods can be as basic as boiling or adding chlorine, to more extreme measures like irradiation with ultraviolet light. The final hurdle in increasing access to human health is not simply providing water, but persuading individuals that it is necessary to treat water sources in order to have potable drinking water.

In these studies, I asked: "how do risk perceptions align with actual water quality and how do individuals deal with those perceived risks?" I assessed the actual water and perceived water qualities in Swaziland and Portland, an individual water treatment scheme and municipal water provider, respectively. These two scales of treatment informed how individuals feel about water treatment when they are personally responsible and when they are paying for a service. I found that it takes more than just knowledge of facts, but instead a comprehensive understanding of what those facts actually mean to incite the actions necessary to treat water and make it potable. Modern technology can be used to increase the fact base with which we can inform our decisions, however, it is the story that is used to communicate these seemingly irrefutable facts that complicates our understanding. Choices about water treatment are based on a variety of variables including not only the perception of risk, but also cultural expectations, trust in information providers, and the cost of avoiding the risk.

Contaminated Consciousness

Perception is defined as the process of becoming aware or conscious of a specific object or a general concept; as such, perceptions are a psychological interpretation of environmental stimuli (OED 2014). These perceptions feed into consumer confidence in products, like drinking water. As water becomes increasingly scarce (UNISDR 2007), researchers and policy makers have been searching for new water sources. Some of these sources meet conservative, high water treatment standards, however, they are still rejected by consumers. One example comes from California, where reclaimed wastewater that could be a solution to the current water crisis has made waves. "Reclaimed wastewater" is sewage that has been purified to be cleaner than average tap water (Haddad 2000). Wastewater reclamation schemes are technologically advanced systems that fine-filter, treat, and irradiate water with ultraviolet radiation; these processes can remove particulates as small as viruses and even residual pharmaceutical drugs (Stanten 2013). However, despite the proof that this water is clean (maybe even cleaner than the water consumers currently receive) most people still reject reclaimed water as a future potable water source (Speigl 2011). This is because consumers are unable to cognitively separate the concepts "sewage" and "reclaimed wastewater".

This aversion has been attributed to contagion theory, a concept in which objects are composed of not only their present state but also the *history* of what they have been in the past (Dingfelder 2004). This can be beneficial, for instance, increasing the value of heirloom jewelry because an ancestor owned it previously. However, for water, this means that once water has been wastewater it will always carry the stigma of waste to the consumer. Research on contagion theory has shown countless times that even when individuals know a substance is sterile they will not consume it, especially in the context of beverages. In one study, individuals were presented with glasses of water containing sterilized cockroaches and 98% rejected the water, even when admitting to being thirsty (Rozin 1986). For another study, individuals watched researchers pour freshly opened containers of apple juice into sterilized bedpans and also refused to drink it (Rozin 1990).

In hopes of making reclaimed water a viable option for the future, researchers have conducted studies on how to nullify the "yuck" factor of reclaimed water. They have found that the easiest way to improve individual's perceptions of reclaimed water is to "comingle the water and nature" (Speigl 2011). When consumers imagine the water has been pumped into a river or underground aquifer, individuals are more likely to acquiesce to drinking it (Haddad, *et al*. 2009), even though exposing reclaimed water to the natural world could undoubtedly increase the presence of contaminants (Haddad 2000). Another possibility comes from the fact that technically all water is recycled in some fashion. For instance, if pollution occurs upstream of a city all the river water that passes through that town is technically sewage. Or, on a more basic level, natural streams and rivers technically serve as the bathroom for fish, birds, and other wildlife. Some researchers believe that explaining the natural cycle to consumers could mitigate the fear and anxiety associated with drinking "poo-water" (Miller 2012). The real problem in this case is overriding a natural tendency towards contagion theory.

In the case of reclaimed wastewater, understanding the facts hinges on how they are presented. With the advance of technology, there must be a complementary advance in communication to overcome natural aversions to perceived contaminants. However, the decision to not treat water is rooted in more than just perceived contamination. As perception is the collection of multiple stimuli influencing thoughts, it is affected by a number of independent environmental factors. These include the individuals' prioritization of importance of water quality in terms of daily life. If the individual doesn't believe that water treatment is useful or effective, then they will not invest in treatment.

Priorities over Perceptions

In daily life, individuals make choices that are dependent on time and money. These options can be ranked in order of importance to the individual. The quintessential example of this prioritization can be seen with global climate change. Straw polls indicate that global climate change is a topic of interest in the United States. However, when respondents were asked to rank climate change among 15 other issues that they are concerned about (including the economy, unemployment, federal debt spending, illegal immigration, etc…) climate change was only ranked as the 14^{th} largest concern (Riffkin 2014, Calabria 2014). Surveys like this one show that individuals have diverse concerns and despite recognizing climate change as an important issue, in the larger context, this particular issue can fall by the wayside.

These surveys were conducted in the United States, where a majority of respondents have access to municipally provided water. In individual treatment schemes, those collecting water may have a different set of priorities. Similarly to how climate change is deemed less important than other issues, water treatment may seem less pressing in light of other daily situations. As of 2011, just over 60 % of the population in Africa had access to improved water sources, leaving almost 40% to source water individually (WHO 2013b). Typically, in such schemes, women and girls are in charge of sourcing and treating water. These women are often also in charge of collecting firewood for cooking, maintaining the home and vegetable gardens, and caring for children (UNICEF 2014). Women must prioritize activities based on allotted time, available resources, and the assigned importance of each issue. Therefore, in order to make changes, the individual in charge of treatment must be convinced that treatment is important enough to be worth the investment.

Purity & Risk

If water treatment is integrated into daily life as a priority, then the question becomes to what degree will we treat the water. If we function under the assumption that treatment is done to make water safe, then a standard for safety must be determined. When deciding what constitutes "sufficient" quality in water sources, individuals want to have water that they perceive to be pure. The rejection of reclaimed wastewater serves as an example for how individuals are unable to look past the history of contamination to the current, pure state. The distrust of technology's ability to produce pure water could stem from the perceived divide between nature and culture. As Richard White said in a Tanner Lecture at UC Davis in 1999, "the environment is a deep cultural, political problem" (White 1999). White cited a variety of environmental problems where a variety of disciplines collided in situations that seemed "natural"; White called the separation of nature and culture the greatest hurdle for conquering complex environmental problems. Similar to the contagion theory, the divide between nature and culture is more psychological than physical.

Purity is culturally derived and dictates an individual's acceptance of risk (Levi-Strauss 1969). Because it is socially constructed, purity exists in a binary against "disorder" or "danger" (Douglass 1966, Levi-Strauss 1969). Since water is often associated with cleaning, it also becomes synonymous with purity. In many cultural settings, a need for ceremonial purity served as the foundation for the idea that individuals are incomplete or "unfinished bodies" that become whole after ritual (Smith 2007). This includes the use of holy water in Christian baptisms or the Hindi tradition of bathing in holy rivers like the Ganges. Water is an integral part of cleansing and combating the disorder of dirt, thus, it is not only necessary for life, but clean water is important for fulfilling cultural expectations. This links water, a natural resource, with the societal concept of purity.

Individuals feel the need to treat water when it is contaminated (or impure). When deciding how much to invest in treatment, a proxy for how much to invest in purity, individuals evaluate risk and vulnerability. Risk is the convergence of individual knowledge and the consent to accept the potential danger of a situation (Douglass 1992). Vulnerability is often defined as the probability of experiencing risk in the future (Palm 1990). In terms of water treatment, the risks are contracting diseases in the short term or suffering long term consequences (cancers and other illnesses) in the future, depending on the contaminant. Thus, the decision to treat or not treat water is based on the individual's mental perception of purity, perceived vulnerability, and evaluation of risk. Individuals develop a concept of "acceptable risk", which is essentially a tolerable level of contamination.

Developing Standards

"Acceptable risk" is based on the notion that every individual will have a point where the cost of improvement will outweigh the cost of contamination, and at that threshold contamination will be accepted (Clarke 1989). This acceptable level of risk is produced, in part, by limitations in technology, which may not be able to assess contamination completely and increase the accepted amount of risk (Fischhoff 1977). These standards are a product of individual preference, as individuals weigh the costs and benefits of further treatment. As such, acceptable risk is highly cultural and varies by location. These cultural differences make it difficult to develop international or even national guidelines (Hunter 2001).

Despite the challenge of generalizing acceptable risk, as cities grew, municipal governments became responsible for providing water and other services with an acceptable level of risk. This risk level is often simplified to be the 1 in 1,000,000 chance of having a negative result from an interaction with the contaminant (Hunter 2001). As governments developed these standards, they represent the level of risk that each government is comfortable accepting for their constituents. As the number of individuals depending on a single water source increases, so does the risk associated with the contamination of that source (Johnson 2006).

Despite complications from highly individualized perceptions of acceptable risk, national and international organizations are still developing standards that dictate water safety. These standards are meant to represent a reasonable contamination level that limits risk to human health but still achievable by the populations they are meant to serve (UNDESA 2014). While these standards may be applied as communities install infrastructure necessary to treat water, in the individual water schemes these standards compete with the individual's conception of acceptable risk. Furthermore, explaining standards and protocols is made even more complex as each individual is able to choose an individual treatment method (be it boiling, bleaching, or irradiating). Thus, as aid organizations, like the World Health Organization or UNICEF, attempt to ensure water is provided to a certain standard, they must compete with not only the individual's concept of "acceptable risk" but the variety of treatment methods used to achieve those standards.

CASE STUDY: SWAZILAND

Background

Swaziland is a small landlocked country sandwiched between Mozambique and South Africa (Figure 1). The terrain ranges from mountainous to hilly to wide rolling plains as one moves east across the country. The climate ranges from tropical to arid along that same trajectory. Politically, Swaziland is controlled by the last autonomous monarchy in Africa. The historical monarchy power trickles down through the regional powers to village level chiefs. Chiefs keep order and mediate conflicts in their communities. It is home to approximately 1.4 million Swazis. Of those, almost 40% are younger than 14 years old; this is due to the high prevalence of

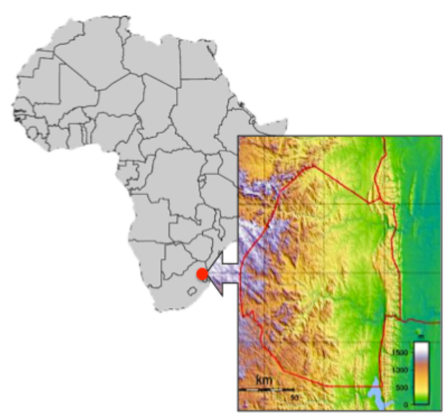

Figure 1. Map of Africa (World Atlas 2014) with inset showing topography of Swaziland ("Swaziland" 2014) in Southern Africa

HIV/AIDs, (Swaziland has the highest HIV/AIDs rate in the world at 26.5% of the population in 2012). Those infected with HIV have depressed immune systems and are at a higher risk for contracting other, usually innocuous, diseases. These include those contracted from biological water contamination, like *E. coli*. (CIA 2014)

In Swaziland, there has been a dramatic increase in access to drinking water through both governmental and non-governmental programs. In the year 2000, approximately 49% of Swazis had access to safe drinking water. With the goal of decreasing the number of individuals who do not have access to safe drinking water by half (UN 2014), the MDG target was 75% coverage by the year 2015. In 2010, Swaziland reported 67% coverage (UNICEF 2011), with 100% coverage projected by 2022 (Mwendera 2006). Even with these developments there is still some question as to the quality of water access in rural parts of the country. Some reports suggest that even with the improved infrastructure, an estimated one in three water schemes may be broken or contaminated at any given time (Peter 2010). Despite approximately 67% coverage in Swaziland overall, there is a disparity in access between rural and urban communities. It is much easier to provide improved water sources to densely populated areas because a single spigot can serve multiple homesteads. In more rural areas, as populations become more dispersed, it is more difficult to provide water access. In Swaziland, it is estimated that 40% of rural dwellers still access water from unimproved water sources (UNICEF 2011), indicating that Swaziland requires further attention in water development.

Ezulwini Valley, Swaziland

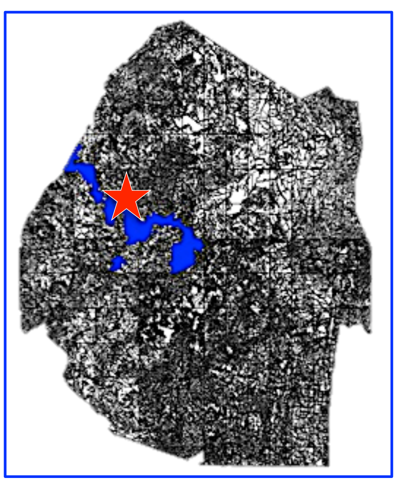

Figure 2. A map of Swaziland with the peri-urban corridor highlighted in blue and the

Swaziland is experiencing an uneven distribution in development and population increase. Some formerly rural areas are quickly urbanizing. Nestled in between Mbabane and Manzini, the Ezulwini valley is a part of this rapidly developing landscape also called the peri-urban corridor (Proctor 2014, Figure 2). While still technically rural, Ezulwini must use limited resources (including water) to support a growing number of homesteads. Within the Ezulwini Valley, research was focused in four communities, Ezulwini, Mlindazwe, Lobamba, and Mahlanya (Figure 3). These four communities were chosen because they each contain Neighborhood Care Points (NCPs) that provide day care and meals to local children. Individuals who conducted the surveys worked at NCPs in the morning to establish positive relationships with the local community. I was stationed in Mlindazwe, a small rural community located in the Eastern Hills of the valley. In Mlindazwe, water is supplied to homesteads by damming the small streams that run down the hillside. Each dam provides a homestead with a small personal reservoir to collect water for daily use.

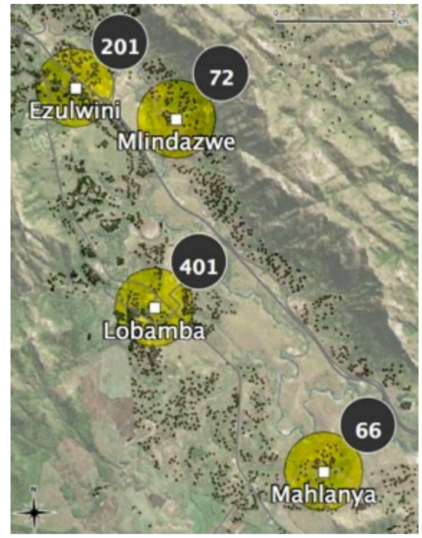

Figure 3. Four communities in the Ezulwini Valley (yellow) with estimated numbers of homesteads (gray), (Proctor 2013).

Because the water flows down the hillside, the quality fluctuates not only with seasonal availability but also with the location of the homestead on the hill. During the wet season, run off and rainfall contribute to high turbidity despite the possibility of dilution from the extra water. In the dry season, any contaminant that reaches the streams is more concentrated because there is less water available. Thus, downhill residents may have to use contaminated runoff from uphill neighbors or may not have enough water reaching their personal dams. Individuals in these crowded "rural" water schemes make choices about where to source water and how to treat it before consumption. Such decisions are made based on individual experiences, and are often informed by personal preference or perception of risk rather than the actual quality of the water (Spence 2011). And, it is these decisions that impact human health, improvement of which is the ultimate goal of the MDGs.

The most immediate threat of contamination comes from coliform bacterium, which can cause diarrhea, dehydration, and even death. Not every coliform bacteria is dangerous; however the presence of any colony is indicative of the possibility for contamination by the more harmful strains. Water sources with high levels of foot traffic and that are shared with other animals creates not only the possibility of contamination but also the spread of the contamination between individuals. The easiest way to avoid these threats is to treat water, either through boiling or chemical treatment. These simple protocols kill the dangerous bacteria while leaving the water potable to humans.

Infrastructure for large-scale water treatment exists only in urban areas and Lobamba, the only community in the peri-urban Ezulwini Valley with access to treated water. While still formally designated as rural by the Swaziland government, Lobamba is the cultural capital of the country and is home to many government buildings and the king's residence. In these areas the Swaziland Water Services Corporation (SWSC) collects, treats, and distributes water. Individuals can pay to have water pumped to individual homesteads with personal meters or can buy water from community pumps and carry it back to their homesteads. In the rest of the Ezulwini valley and some parts of Lobamba, all other individuals rely on water from natural sources (like ground springs, streams, rivers), which are never tested or regulated.

Assessing Actual Water Quality

Methodology

I collected water samples three different days across the valley. Survey results from the Environmental Health Assessment (EHA 2013) helped identify water sources to test across the valley (Figure 4). All samples were collected into sterile bottles and kept on ice (< 10°C) to comply with international standards for water testing (SWSC 2013). Before sampling, each tapped source was allowed to run for 2 minutes to control for exposure to environmental contaminants. Samples were collected in the morning and delivered to the laboratory for testing within 6 hours of collection. I contracted out to the Swaziland Water Services Corporation Laboratory, in Mbabane, SZ, to perform total coliform and E. coli assays. The laboratory is accredited by the South African National Accreditation Systems (SANAS) for Laboratory Testing and is a part of the International Laboratory Accreditation Co-operation (ILAC), testing all SWSC water samples (Nkambule 2012).

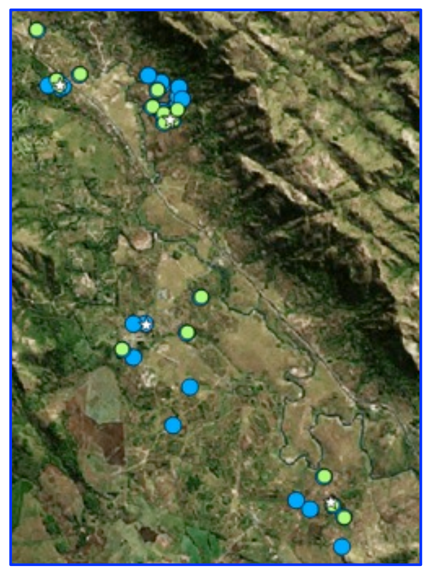

Figure 4. All water sources are geo-located in blue, tested water sources are green.

Results

Of the samples collected, all were tested for total coliform (n=20) while only the final round of samples were additionally tested for E. coli (n=12) (Appendix A, Figure 5). All but two samples, one from an SWSC tank in Lobamba and one from the NCP in Ezulwini, tested positive for total coliform contamination. Of those that were positive for total coliform contamination, seven tested positively for E. coli. In Mlindazwe, all sources were positive for total coliform contamination and 75% were positive for *E. coli.*

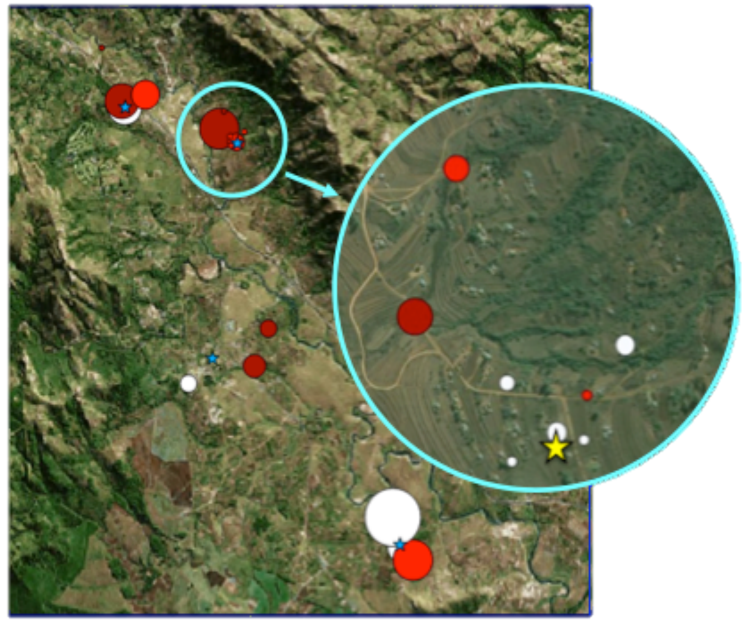

Figure 5. Sampled sources. Diameter indicates the number of homesteads per source, darkness indicates concentration of total coliform contamination. Inset highlights *E. coli* contamination levels in the Mlindazwe community. The yellow star indicates the Mlindazwe NCP.

These samples are independent and characterize only a single day. They are not longitudinal which means there is no confirmation that my samples are accurate representations of water quality over time. All my samples were taken in June, the heart of Swaziland's dry season. This means contamination and increased turbidity from storms was limited. Also, the contamination levels were so pervasive (especially for total coliform) within my samples, I am confident in the assessment that all the untreated water sources I tested have total coliform and are subject to E. coli and other dangerous bacteriological contamination.

Assessing Perception of Water Quality

Methodology

Individual confidence in water quality was assessed through surveys in the Environmental Health Assessment (Ezulwini Valley: n=210, Mlindazwe: n=37) and individual homestead visits (n=9). These interviews were conducted in siSwati and translated by Swazi students studying at Lewis & Clark College. Lindo Simelane served as a translator in Mlindazwe. Information from the Environmental Health Assessment (EHA) was recorded on iPads in Fulcrum, a surveying application that administers a step-by-step protocol to be followed in the field. Fulcrum allowed different groups to ask standardized questions in a designated order, controlling for some variation in methodology. The complete EHA intended to use these survey results to answer "what is the condition and perception of water, energy, and human/solid waste among households in communities surrounding four NCPs in the Ezulwini Valley?" (EHA 2013). From this survey, I focused on questions that centered the water quality and treatment portion. These included three main categories: (1) where the water was sourced from, (2) how homesteads chose to treat water, and (3) adequacy for both quality and quantity. Answers to these questions can be found in Appendix B. Surveyors also asked follow-up questions to contextualize any variations in perceptions around water; interesting notes or recommendations from households were also recorded.

Results

Data from the EHA indicated that individuals were not confident in the quality of their water. Over 70% of respondents believed their water was of low quality and only one in ten believed their water was clean (Figure 6A). The same survey indicated that fewer than 10% of respondents chose to treat their water, even though respondents express an understanding that treatment could eliminate risk factors that reduce water quality (Figure 6B,C). This means that while consumers think their water is unsafe, they still choose not to treat it.

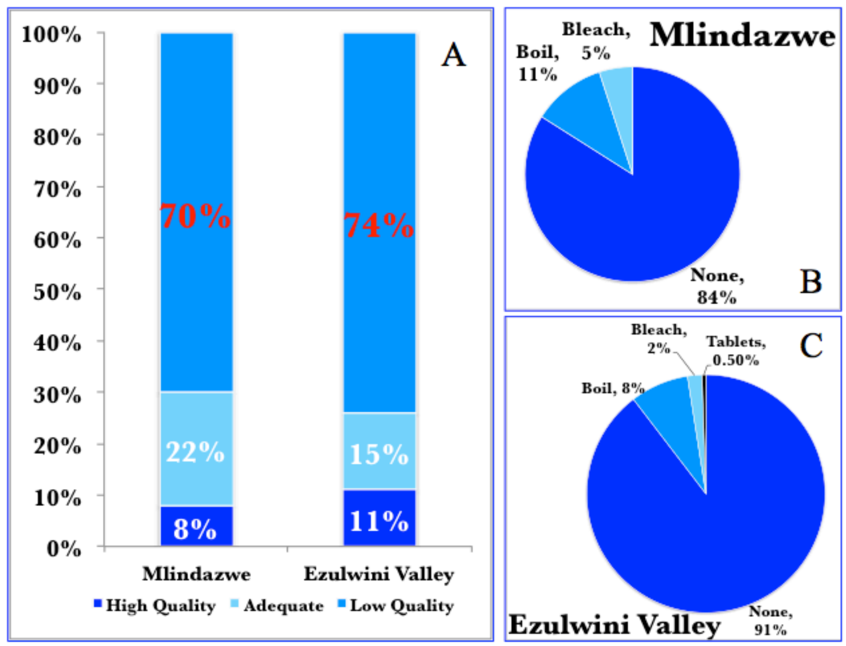

Figure 6. Perceptions of water quality in Mlindazwe, Ezulwini Valley. (B&C) Percentages of homesteads that choose to boil, bleach, or not treat water.

At individual homestead visits, I conducted in-depth interviews (n=9) to ascertain how individuals came to make specific decisions around drinking water. These interviews indicated that individuals were aware of the dangers from drinking unclean water and knew the necessary precautions to limit personal risk. However, these individuals also had many other responsibilities and competing interests to consider. Homesteads are told to treat water by either boiling or using chlorine bleach. While simple and effective, either of these methods can be costly. Firewood is a dwindling natural resource that is becoming increasingly valuable as individuals must go farther and work harder to procure enough fuel to cook means, let alone boil water. Bleach is an effective treatment method but it must be bought and money can be a limiting factor in rural areas that could benefit most from water treatment. Furthermore, despite understanding the benefits of treating water before consumption, individuals were unwilling to invest in treatment because they had never actually experienced the benefits of water treatment.

Conflicts between Traditional Beliefs and Technological Solutions

During homestead interviews in Mlindazwe, I also learned about traditional and emerging beliefs about water. Traditionally, water from the ground is considered pure because it comes from the earth and, with the recent introduction of Christian thought, is from God. This includes water from natural springs, ground springs and boreholes. This belief places water that comes out of springs in the ground above other sources. If these springs originated from ground water, they would be safer than other options; however, often the springs are too shallow and the substrate is not protected enough to protect the water from contamination. The rationale being that water is provided by God decreases the probability of treatment because if God is providing the water, He will provide it in a condition He sees as sufficient. This makes subsequent water treatment unnecessary to believers.

While traditional beliefs prioritize spring water, there is also an understanding that water treatment is beneficial. In the Mlindazwe community, there is a pipe that runs water from a reservoir high in the hills down to Ezulwini in the valley below. Several Mlindazwe residents voiced the desire to have access to the pipe water, as they believed it was treated and safer than their personal reservoirs. They associated the pipe with technology and treatment. Testing from the piped source indicated it was still susceptible to contamination, and conversations with the SWSC indicated that the water source was never treated. An interesting note on this piped source is that although there was an investment in its installation, there has been no investment in treatment. Furthermore, interviews with some SWSC water sample collectors indicated that there was no intention to treat that water. This source could potentially be tapped into by the SWSC in the future if a municipally supplied water system is ever installed in the valley. The goal of the pipe is simply to transport water down from a mountain reservoir into the dry valley below. Despite the lack of treatment, the water is exposed to less potential contamination than personal reservoirs because the water is enclosed within a pipe. In Mlindazwe, I sensed tensions between faith in natural water sources and a growing, perhaps misplaced, confidence in water treatment and technology.

Summary from Findings

In this developing community, there is tension between traditional and technological treatments of water. There is an understanding that when left untreated, the natural water sources often contain contamination. Simultaneously, there is an understanding that water treatment could improve quality of life. While individuals know that technology could be used to improve water quality and tend to want access to higher quality water, there is little individual action to take the steps necessary to treat water. There is a notable interest in modernizing water treatment over simply treating traditional water access. However, the exact form that the treatment takes is unclear. Individuals *know* their water is of low quality. At the same time, those I interviewed indicated that they had evaluated the hazards of not treating their water and decided to take the risk and hope for the best. People may want their water to be cleaner, but they do not take the individual action to treat water to prevent disease.

CASE STUDY: PORTLAND

Background

Portland is a mid-sized city located at the junction of the Willamette and Columbia Rivers. The Portland Water Bureau (PWB) sources water from the Bull Run Watershed, located approximately 30 miles east of the city center (Figure 7). When the PWB initially started sourcing water from the Bull Run in 1895, public health officials noticed a marked decrease in rates of Typhoid fever. Since shifting to the Bull Run water there have been no recorded outbreaks of waterborne disease (PWB 2014). The PWB is a publicly operated company that is owned by the City of Portland and provides approximately 35 million gallons of water to consumers annually. In 2012, the PWB directly served 556,000 individuals and indirectly, primarily via bottled water, served close to one million consumers (almost a quarter of the state of Oregon) (PWB 2014).

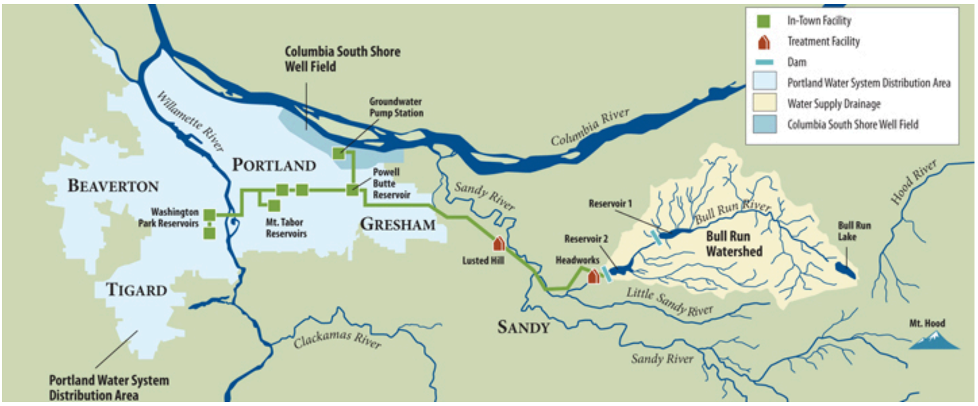

Figure 7. This map geographically situates the PWB distribution area with the Bull Run Watershed protected area, as well as the location of open reservoirs within Portland. (City of Portland 2014)

As an established city in the developed world, Portland residents do not face the same bacteriological concerns as those in Swaziland. Instead, the average Portland consumer pays for water and expects the commodity to be safe for consumption. The PWB has a minimal treatment scheme; the water from the Bull Run Watershed is not even filtered. Instead, the Bureau treats the water with chlorine and ammonia (PWB 2014). The chlorine kills basic bacteria that are naturally occurring in natural water. The ammonia ensures the chlorine stays in the water until it reaches the consumers tap, otherwise the chlorine could evaporate out of the system and the water could be contaminated with bacteria again (PWB 2014). Treated water is then stored in open reservoirs scattered throughout the distribution area (Figure 7). The water then flows directly from the reservoirs to individual homeowner's taps.

Cryptosporidium and the Grant of Variance

Portland's minimal treatment scheme has drawn attention recently as the Environmental Protection Agency (EPA) changed protocols to protect against *Cryptosporidium*, a dangerous parasite that is transmitted along the fecal-oral pathway. This policy change, which was drafted in early 2003 and adopted in 2006, is called the Long Term 2 Enhanced Surface Water Treatment Rule (LT2 rule) and was initially stimulated by an outbreak of *Cryptosporidium* in Milwaukee, WI that killed 104 individuals and affected 400,000 people over the course of two weeks (Mac Kenzie, *et al* 1994). *Cryptosporidium* is a pathogen, which most individuals' immune systems are capable of fighting off. Symptoms include abdominal cramping, diarrhea, malnutrition, and malaise (general discomfort and tiredness) (Dugdale, *et al.* 2012). The parasite primarily affects immuno-compromised individuals, such as children, AIDs-positive individuals, the elderly, and organ transplant recipients (Hunter 2002). Recently, the FDA approved a treatment protocol for immune-compromised patients; however, it has yet to be proven effective (Das *et al.* 2013). The LT2 rule is a national policy that is meant to ensure access to water provided by all municipal governments is safe from *Cryptosporidium*.

Portland requested a Grant of Variance (GoV) to avoid installing an ultraviolet (UV) treatment plant and further to avoid the requirement of covering the city's open finished-drinking water reservoirs. The GoV was sent from the PWB to the Oregon Health Authority (OHA), which oversees public health issues in Oregon. Once approved by the OHA, the request was forwarded to the EPA for final approval. Portland founded their request on the fact that the Bull Run watershed is so protected that these new treatment protocols are superfluous, especially considering no outbreaks of *Cryptosporidium* in Portland have ever been associated with the public water distribution system (OHA 2011). In 2012, the EPA accepted portions of Portland's requests. The PWB will not have to install the UV treatment plants, but will be responsible for disconnecting all open-air reservoirs by 2020 (Leland 2013).

This is interesting because all systems that use surface water or ground water that is fed by surface water sources are being required to build UV treatment plants; this adds up to approximately 14,000 systems across the US (EPA 2013). But, there has been some success in receiving GoV's for maintaining open finished-drinking water reservoirs (Cowen 2014). In the US there are only 43 open-finished drinking water reservoirs left in use (Fought 2011). One example comes from Rochester, NY, which received a 10-year reprieve on covering their three historic uncovered reservoirs but will be installing a UV treatment plant (Crawford & Flory 2012). Portland is in the opposite situation; the PWB is not required to build the treatment plant but will have to install covered reservoirs.

According to the EPA, Portland's water provision scheme differs enough from that of Rochester to warrant different requirements. Rochester received this grant by citing financial hardships, population decreases, and the historic nature of the reservoirs (Crawford & Flory 2014). Rochester's reservoirs are more remote while Portland reservoirs serve as public recreation areas that are subject to more visitors and a higher potential for accidental or intentional contamination. Furthermore, the city of Rochester has experienced an economic downturn in recent years and did not feel able to pay for the installation of what they deemed redundant water treatment. Many local community groups and organizations have rallied in support of keeping the reservoirs uncovered. Supporters of keeping the open-air reservoirs in Portland have cited Rochester's successful reprieve as a reason enough for Portland to maintain the current water storage system. New evidence suggests that covered, underground reservoirs are prone to contamination and can be petri-dishes for bacteria (FOR 2013). Recent studies also provide evidence that the precautions required by the LT2 rule would not have been enough to stop the *Cryptosporidium* outbreak in Milwaukee, WI (Ellis 2007). The LT2 rule is up for re-evaluation in 2016, and despite comments from the EPA (Cowen 2014), many communities with operating open-air reservoirs, including Portland and Rochester, are hopeful that stipulations made in the LT2 are deemed unnecessary and overturned (FOR 2013, Ellis 2007).

Despite some critique, the LT2 rule is intended to ensure that all surface water systems provide clean, safe water. Portland's GoV indicates that the current system is sufficient, with room for some improvement. A large reason behind Portland receiving the GoV came from regular testing to measure the actual water quality that the PWB is providing to consumers.

Assessing Actual Water Quality

Methodology & Results

Portland water is tested regularly to ensure it is safe for human consumption. The National and Oregon Environmental Laboratory Accreditation Programs have both accredited the Portland Water Bureau laboratory (PWB 2014). Last year, the PWB took 11,000 samples and ran 49,000 different analyses to ensure the water was safe for public consumption. These analyses are compliant with standards set and variances approved by the EPA, indicating that the risk has been deemed negligible and, thus, acceptable. As stated above, there have been no recorded outbreaks of disease attributed to the Portland water distribution system.

Due to the rigor and frequency of testing, we know that the water currently provided by the PWB is potable and safe. This safety, however, is subject to uncertainty because it does not exactly match the EPA's national standards for water treatment protocols. Misunderstandings over the

GoV developed as individuals processed information from different sources. These differences in perceptions were assessed by quantifying concerns presented in public forums.

Assessing Perceptions of Water Quality

Differences in Methodology

In Portland, I focused on the general issues that concerned individuals rather than conducting a household survey to inform perceptions of water quality. There were many reasons for not conducting individual household surveys. One difference is that individual Portlanders do not make decisions around water treatment they simply receive treated water. Another is the feasibility of producing a representative sample comparable to the one collected in Swaziland. The PWB provides water to over 500,000 individuals (PWB 2014), approximately one half of Swaziland's total population (CIA 2014). Instead of household surveys, I read through Public Comment transcripts, news articles, and associated on-line commentary to assess the concerns around the PWB and its Grant of Variance. Those who participated in the Public Comment Period Hearings were invested enough in voicing concerns to present them to the Oregon Health Authority. Individuals who commented on news articles were slightly less invested, but still interested enough to engage in a public forum.

These sources have a response bias for attracting only interested, opinionated parties. While typically response bias is not ideal for surveys, in this case it was beneficial. In developed countries, water provision is systematically planned and executed. This means that individuals have grown to expect the water to be of high quality and are generally satisfied with the water they are provided. Widespread contentment with water quality is strikingly different from the sentiments expressed in the developing world, where almost all homesteads had specific issues with water quality and quantity. Therefore, to find concerns about water quality in Portland, I could not conduct a random survey because it may miss the anxieties that are present; instead, I had to look for forums that would be discussing these worries. Both venues I chose served as places for individuals to go to express concern and become informed on the topic. These provided the data that I needed to assess both what makes individuals concerned and how they access information.

Methodology

To gauge public understanding of, and concerns about, the needs for water treatment I examined documents from the "Public Comment Hearings" for the Notice of Intent (NOI) on Portland's GoV as well as comments from online news articles on the subject. I read through the entirety of each document and gauged sentiments of broad concerns. I then categorized responses under generalized themes by the document type, either the NOI hearings or Oregon*Live* articles (Appendix B).

Individuals who contributed to the Public Comment Hearings fell into one of three categories: supporting, neutral, or against the GoV. Support was often explicitly stated; for instance, "we strongly support the stated intent…" or "I believe the possibility of cryptosporidium in the Bull Run source of Portland's drinking water is not a problem because…". Examples of anti-GoV sentiments included statements like: "the proposed monitoring program seems quite inadequate" or "those who don't remember the past are condemned to repeat it" – this case was referring to past outbreaks of *Cryptosporidium* in other cities. Finally, the neutral input was primarily presented to clarify concerns that had been previously noted. The neutral comments did not particularly side for or against, but instead commented on methodologies or wording of the document. I was also able to categorize commenters as "experts" or "citizens" by how they introduced themselves in the comment periods and supplemental documents.

The article comments were more difficult to readily categorize. However, they generally fell into the same three categories, mimicking the sentiments quoted above. For both sources, individuals typically turned to citing the importance of "rational" answers in problem solving. Those that supported the GoV often pushed the financial side of the argument, stating that the costs of installing the plant would be more than the benefits of treatment. Those against the GoV focused on the risk, defending the idea that an outbreak of *Cryptosporidium* would cost more than just installing the plant. On the basis of both sources, individuals in support of the GoV cited the importance of remaining rational and analyzing the reality of costs and benefits of installing the treatment plant. Individuals who were against the GoV justified the building of the treatment plant and used scientific facts to emphasize the importance of treatment to mitigate risk. The use of rationality and fact was universal in garnering support from individuals, however, they were used in different ways which shows an irrationality in interpreting results. Finally, neutral individuals were simply concerned individuals who generally asked clarification questions.

Results

In the NOI's Public Comment Hearings, most individuals (n=24) expressed support for the Grant of Variance (Figure 8). Of those present, all the experts (n=9) were in support of the variance, contrasting the negligible concentrations of *Cryptosporidium* oocytes on record and with the extreme cost of building treatment facilities. One man said it would be like having everyone get a complete physical every day: potentially useful but not necessary and definitely expensive. Some referenced how increasing treatment may lessen protective laws in the upper watershed. This is because the watershed is currently highly protected because there is so little treatment on the water. However, if they installed a UV treatment plant, that area could become more developed, as the treatment would protect the water from the higher probability of contamination exposure. The concern here would be that the increased pollution could expose the watershed to contaminants that the UV plant would not protect against. They also argue that without the GoV there could be increased development within the watershed exposing the stream and pre-treatment reservoirs to more contaminants for which the PWB does not currently treat. Many of those in support of the GoV were particularly attuned to potential expenses, echoing the idea that while the treatment plant would reduce the probability of contracting *Cryptosporidium* the cost of installation did not balance when considering the low probability of disease.

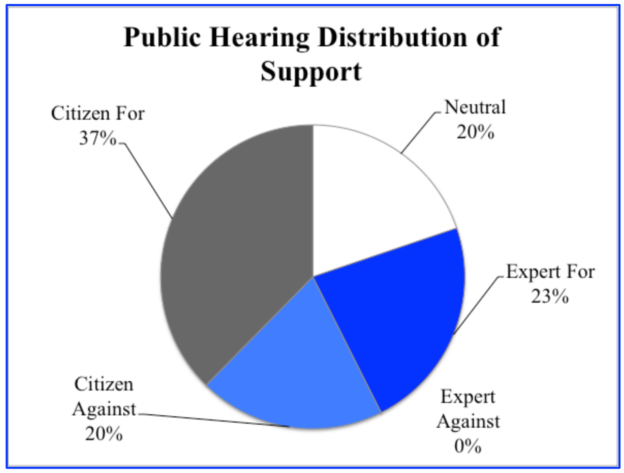

Figure 8. Indicates the distribution of sentiments among those that spoke or presented at the Public Comment Hearings in December 2011. 61% of those supported the Grant of Variance, which included all experts and medical professionals present.

While proponents for the GoV referenced that "positive findings may be unsettling, [the findings] should not be considered unexpected", non-supporters (n=8) were anxious about the recent findings of oocytes in the water. They were unwilling to risk exposure to *Cryptosporidium* and did not trust the current detection schemes in place, even though the methodology is prescribed by the EPA and follows appropriate scientific protocols. Both sides used facts, and sometimes even the same facts. For instance, those for the GoV referenced that they only found two oocytes while those against it were concerned that, given the small fraction of water that was tested (~0.00075%), they were able to find two oocytes. They each cited two oocytes, however, the number was framed differently, and thus supported opposite sides of the argument.

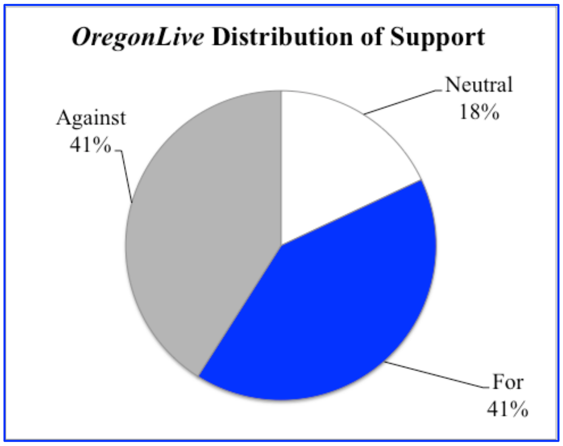

Figure 9. Illustrates the polarity of the OregonLive commenters. Those who had opinions were evenly split between supporting and mistrusting the Grant of Variance.

To find a greater variety of "non-expert" opinions, I looked to comments on OregonLive articles, which cataloged the major events or changes in the processing of the GoV. Unlike the Public Comment Hearings, there was no consensus of support, instead equal numbers of individuals (n=23) wrote for and against the GoV and a smaller, neutral portion (n=11) asked questions or commented on an unrelated topic (Figure 9). The issue most often brought up in support of the GoV was the concept that there was nothing to fear and the data presented by those who wanted testing were just a "scare tactic". These individuals cited rising costs for limited benefits and wanting to keep the water as "pure" as possible as supplemental reasons for not adding in a treatment plant. The preference for keeping water "pure" of treatment is similar to Portland's decision in 2012 to not fluoridate the municipal water supply, which will be discussed more below. The commenters who wanted to install the plant were primarily concerned with the possibility of contracting *Cryptosporidium* or having their children or loved ones get sick. One commenter even referenced the outbreak that struck Milwaukee, WI in 1993. Generally, these individuals were willing to pay for the assurance that every precaution was being taken to avoid the threat of *Cryptosporidium*, no matter how slight the threat might be. These feelings come despite expert opinions cited in the articles highlighting the low probability of contamination and advocating against the treatment process.

Interestingly, individuals almost unanimously wanted to keep the finished-drinking water reservoirs, despite the fact that the EPA supported the installation of covered storage tanks.

There is evidence to support both open and covered reservoirs. Some reasons for keeping reservoirs open are the public preference for open reservoirs, their historic nature, the costs associated with construction, and potential increases in contamination by trapping contaminants in the water within the tanks (FOR 2014). The support for covering reservoir is primarily protection from unwanted contamination to the finished-drinking water. This could protect from acts of terrorism aimed at poisoning the population through the water supply or simply protect from accidental contamination as individual use the area around the reservoirs for recreation. It is interesting that the EPA chose to cover the reservoirs, despite potential dangers associated with covering reservoirs and the public preference for keeping reservoirs above ground (NOI 2011).

Summary from Findings

The discrepancy between the desires of Portlanders and the EPA's final ruling on the Grant of Variance are interesting. Individuals were torn on the best course of action for water treatment and storage in Portland. Experts unanimously rejected the proposed treatment protocols, while the citizen opinion was less cohesive and more scattered. No one wanted to cover the reservoirs, despite the fact that ultimately, the EPA determined that covering the reservoirs would be necessary to limit unwanted risk to the population. Some cite lobbying from local industries who would benefit from covering the reservoirs as a reason why this section of the GoV wasn't passed (FOR 2014). However, overall, there was no real consensus among the citizens of Portland for or against the implementation of the LT2 rule.

DISCUSSION

Research and development present possibilities for positive gains in human health worldwide. Studies could indicate more effective or efficient treatment methods and even tease out the intricacies of different types of contamination. As new understandings develop, it will be important to consider how those findings are communicated to individuals, as the science alone does not inform comprehension or action. New innovations and technologies are increasingly complicated, and often require a deeper level of explanation to fully grasp concepts presented. Without these clarifications, it can be easy to misinterpret facts and develop misconceptions about the validity or necessity of different treatment options.

Fact or Fiction?

Science is often presented as nothing more than rational facts. The reasoning being that if studies are executed properly, they leave little room for debate over their accuracy. However, scientific facts are defined as much by their presentation as by the protocols followed to develop them. Throughout my time at Lewis & Clark, I have learned to be analytical when examining figures in biology papers; sometimes, authors can extrapolate and exaggerate findings that are related to the figure but not actually grounded in science. For instance, a figure may indicate correlation yet be cited for causation, a much stronger relationship that is harder to prove. By paying attention to nuances in word choice and presentation, concepts that are stated as being "facts" can actually be much less substantiated. In terms of water treatment, advocates for a new technology may try to support their position with "science" facts. And, the evidence they cite may truly be fact, but it is important to keep in mind that facts can be pushed past accuracy, just as correlation can become confused with causation.

The Portland debate on fluoride is an example of how facts can be twisted by the context within which they are presented. In 2012, Portland residents voted against the addition of fluoride into the drinking water supply. This action made the PWB the largest municipal supply system to not fluoridate the public water supply (Grabar 2013). Fluoridation is often advocated for because it supports tooth enamel, decreasing decay and preventing cavities (Kirschstein 2010). In Portland, the anti-fluoridation campaign selected studies that highlighted serious health risks from long-term fluoride exposure (NRCNAC 2006). These risks included everything from increased chance of cancer to recorded decreases in IQ (Novella 2012). They suggested that treating with fluoride would not only be a poor use of resources, but also potentially detrimental to one's health and wellbeing (CWP 2012).

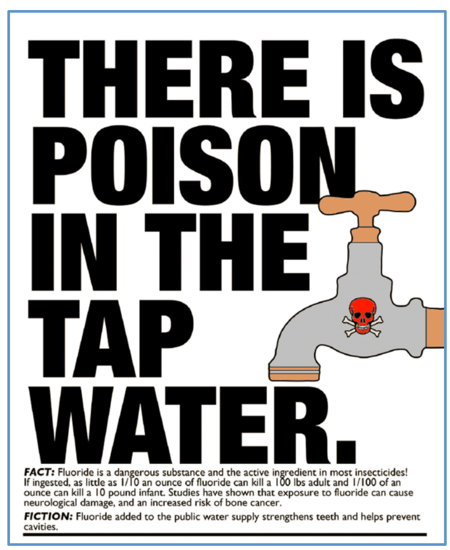

Figure 10. This poster was used in the anti-fluoridation campaign in Portland (Hill 2013)

The anti-campaign also used graphic posters (Figure 10) to instill fear and doubt in the Portland population (Hill 2013). While fluoride is technically poisonous at high concentrations, chlorine, which is readily added into water systems, is also toxic. Even the oxygen we breathe can be damaging to health in excessive concentrations. The information provided by the anti-fluoride campaign sowed doubt that the pro-fluoridation campaign could not overcome. In the end, many attribute skepticism over the necessity and benefits of fluoridation rooted in facts presented by the anti-fluoridation campaign as the reason why the residents of Portland voted against fluoridation of their water system (Grabar 2013, Novella 2012, Hill 2013).

Coupled with this misrepresentation of facts comes the fact that individuals tend to have a preference for keeping water sources pure. This comes from the psychological preference for keeping nature and culture separate (White 1999) and associating nature with purity or perfection (Douglass 1966). This comes in contrast to the general understanding that some additives are necessary to maintain water quality and safety. Individuals have grown accustomed to chlorine in the drinking water supply; however, they are resistant to the addition of potentially superfluous chemicals being added unnecessarily. While in the Swaziland scheme, individuals grapple with treatment of traditional water sources, those receiving municipally provided water must struggle with not knowing what exactly goes into their water or how it could affect them.

In order to produce the most meaningful, lasting change, information presented must not only be accurate but also convincing. The facts must be laid out to be persuasive enough to actually inspire action. One of the largest hurdles to action is ameliorating costs with benefits. If the individual cannot rationalize risk reduction as worthy of the financial investment, then no behavioral changes will be made.

Cost of Treatment

To have an effective water policy, the cost of risk mitigation should not exceed the cost of the risk itself. In areas where bacterial contamination is still prevalent, using chlorine bleach to purify the water is a reasonable treatment method. A majority of the time, the cost of purchasing the bleach outweighs the negative effect of consuming contaminated water. This, of course, varies depending on the average household income and the cost of bleach. If one gallon costs $5 USD and each gallon can treat water for approximately 100 days, a family could treat all their water for approximately $20 USD per year. However, in Swaziland, approximately 70% of the country lives below the poverty line with an average adjusted income projected to be below

$5,000 USD (CIA 2014). That being said, the price of bleach is still relatively low and could be used by concerned individuals. This transforms the question into how much does not using bleach effect life at individual homesteads.

Despite the fact that individuals think their water is dirty, they have grown accustomed to the level of wellbeing that consuming contaminated water delivers. I believe that this acceptance of contamination eliminates the perceived cost of disease (time spent caring for sick children, visiting the clinic, or taking care of oneself) from the equation. High rates of disease cause increased child mortality rates, as children's' immune systems are less able to fight off diseases (UNICEF 2011). The highest child mortality rates are in Sub-Saharan Africa, where one in nine individuals dies before turning five; this number is sixteen times higher than in industrialized countries (UNICEF 2012). On subsistence farms, women run the house, tend fields, fetch water, prepare meals, and oversee childcare. These individuals have many other priorities and time commitments, making it unreasonable to expect additional treatment of water if they have already incorporated caring for sick children into daily life. The costs of disease are no longer costs but considered aspects of daily life.

In developed countries, there is a different standard. On the most basic level, water treatment schemes all treat with chlorine to eliminate the risk of contracting bacterial diseases, as individuals are advised to do in developing countries. Since treatment systems were established, the rate of bacterial diseases has decreased dramatically. For instance, when Londoners stopped sourcing water from the Thames and shifted to a managed water scheme, the rate of cholera outbreaks were reduced by 50% in the first few months (Johnson 2006). As stated earlier, Portland's switch to Bull Run water was marked by an immediate decrease in cases of typhoid fever (PWB 2014). The provision of clean water leads to a decrease in the mortality rate for children under the age of five (WHO 2013a). The survival of infants and young children has come to be expected; as such, the loss of life to a treatable pathogen would be counted a cost of not treating water.

In a place like Portland, however, where the municipality has access to high quality water from a well-preserved watershed, the need for treatment is different than in many other regions across the USA. This makes national treatment plans, which protect against contamination concerns that are widespread in the rest of the country, redundant for the city. While the EPA dictates treatment protocols and standards, it is the city of Portland and local residents that bear the cost of installing a superfluous treatment plant. For *Cryptosporidium,* a treatment plant would cost the city of Portland $68 million and while some individuals would see the value of treatment to protect their children, others who also carried the cost would not be so happy. The Portland Water Bureau enacts municipal scale treatment methods to produce water that meets national water standards.

Maximizing Human Health Benefits

Access to potable drinking water is now recognized as a human right. To increase access to human rights, governments have been creating policies and enacting initiatives to make potable water available to more and more people. In the short run, many of these projects simply bring water to communities and individuals are still responsible for purification (UNICEF 2011). However, from my research in Swaziland I found that individuals were receptive to the idea of treatment but rarely actually preformed the steps necessary to purify their water. This creates a hurdle to actually improving human rights since simply providing access does not ensure the water is potable without treatment. Individuals typically choose not to treat their water because they are not sufficiently convinced that health improvements from bleaching or boiling their water will offset the initial investment in purchasing the chlorine or harvesting firewood. While seemingly a foreign concept, this is a rational decision primarily directed by the value of time and money, especially in subsistence farms.

Meanwhile, in Portland, the debate on the Grant of Variance showed that facts can be shaped by the background against which they are presented. Individuals synthesize information into stories that can shape their opinions based on the context from which they learn. Portland has been chlorinating their water since the first large dam and reservoir system was completed in 1929 (PWB 2014); it is a treatment method that individuals do not think twice about. However, as new changes are proposed, advocates for and against those new methods select and present specific facts. This concept is basic: supplement your argument with persuasive facts to convince others to join you. However, the impact of this form of publicizing information can be polarizing as individuals are confronted with conflicting stories from either side of the argument.

When information is communicated to individuals, those disseminating the information must focus on how the content is expressed. Often, however, it is neither the “what” nor the “how”, but the “who” that is the most convincing piece of the story. One example of this comes from Steven Johnston’s recent book, “The Ghost Map”. This book chronicles the experience of two men as they respond to the cholera outbreaks in London during the 1850’s. One man, John Snow, traced the source of the pathogen to a water pump on Broadstreet. Despite his best efforts to persuade the Broadstreet community to use other, less convenient pumps, Snow’s story did not gain any traction. That changed when he explained his ideas to Henry Whitehead, a prominent local minister. By backing Snow’s ideas, Whitehead was able to sway the community to use a different water source (Johnson 2006).

In terms of maximizing human health through water treatment: if individuals do not trust the person presenting the facts enough, then they will not make the suggested changes. For Swaziland, this means that instead of having NGOs simply enter communities and dictate protocols, instilling community trust (either from employing local leaders or reliable community members) could be more convincing than simply explain facts to individuals. The goal is to find the right methodology or an individual with an appropriate angle to make the greatest impact.

The Role of Institutions

As institutions strive to maximize human health, they push forward initiatives meant to improve individual livelihoods. In terms of water treatment, institutions play different roles depending on the treatment scale. In individually sourced water schemes, oftentimes non-governmental organizations are responsible for disseminating information. In the case of Swaziland, UNICEF has tasked itself with promoting water treatment in rural and rapidly-developing areas. Historically, UNICEF has promoted individual treatment with boiling, UV radiation (through leaving clear plastic bottles in the sun) and filtration (UNICEF 2008). In the future, however, UNICEF is planning to shift from these traditional treatment methods to inoculating water sources and storage units with chlorine bleach (Dhladhla 2013). Recognizing the limited success of simply telling homesteads to treat water, UNICEF is considering other possibilities for proving the benefits of individual homestead treatment.

Interviews with directors of UNICEF and the employees at the SWSC indicated that there may be attempts to employ the “show-not-tell” method in expressing the benefits of water treatment. One man expressed the potential benefits of supplying a few homesteads with enough bleach to chlorinate the water for a few months. This would provide communities with mini case studies where the benefits of chlorination could be observed daily. The positive impact of a single family chlorinating water could spread from one homestead to an entire community. This scenario depends on the experimental family receiving the chlorine to religiously treat water and only consume water that they know as been treated. If individuals accidently consume contaminated water and become sick, it could invalidate the worth of chlorination for the entire community.

In municipal water treatment schemes, there are institutions to ensure water is treated to a government mandated standard. However, in cities like Portland, there are many special interest groups who each lobby for specific preference (e.g. keeping reservoirs open or fluoridating the water supply). These institutions advocate for distinct policies, which may or may not be complicity with the beliefs of the general population. Individuals may draw inspiration from a variety of these sources, however, there is no guarantee that a single organization will encompass all the opinions of a single individual. These different factors that color individuals perceptions of the need for treatment can also play a key role in the water treatment options for a population.

In Portland, there is evidence that despite public preference for uncovered reservoirs, the PWB and EPA ultimately decided to cover the historic reservoirs due based on high levels of support from local construction and engineering firms. Although public comment periods are used to gauge the opinions of consumer, the PWB, OHA and EPA are the governing bodies responsible for making the final decision on what type of water treatment scheme Portland receives. These special interest groups have the ability to sway the institutions in charge of treatment, which ultimately impacts the treatment scheme that is installed. Furthermore, these organizations can ignite public support by promoting different facts in publicity campaigns (similarly to how the fluoride campaign was able to capitalize in the fears of uncertainty in Portland).

Other institutions can be equally influential outside of the water context. For instance, the Sierra Club is a national institution with the mission "to help educate, inspire and empower humanity to preserve the natural and human environment" (TSCF 2014). The Sierra Club is one of the largest grassroots environmental organizations operating in the United States (OSC 2014). The Sierra club has been recognized as the most influential organization (Aspen 1999, OSC 2014). This is often attributed to the institution's ability to focus on daily issues that cross socio-economic and political boundaries. Some motions include advocating for fresh air, exploring the outdoors, and maintaining standards for drinking water (Aspen 1999, TSCF 2014). By appealing to a variety of constituents, the Sierra Club draws a wide audience and is able to make motions with support from a broad base of interested individuals. The Sierra Club has been able to cultivate consumer confidence and thus create initiatives that produce lasting change. Unlike Swaziland, where convincing only a single individuals can improve quality of life, in the United States, many initiatives are developed at the government scale. This means that for an institution to have an influential impact institutions need a wide enough scope to convince a large portion of the population.

A BROADER CONTEXT

Disaster Preparedness

Now that we have established the influence of many factors on water treatment, we can begin to apply this concept to other contexts. One complex argument is the natural disaster. Disasters are defined as catastrophic events that are not favorable to the natural order (OED 2014b). A natural disaster is the unfavorable fall out of normal processes, for instance, high levels of rainfall disturbing the soil and causing landslides or earthquakes from the ocean floor causing tsunamis on land. Hazards from natural events can be categorized as the interactions between the actual event and the human generated response to that event (White 1974, Burton 1978). In reaction to these perceived hazards, individuals can either take physiological precautions to protect themselves or physically abandon areas that are vulnerable to natural hazards (Tierney *et al* 2001). Just like water treatment, these responses can be individual undertakings or municipally provided public projects. These two scales represent bottom-up and top-down approaches, respectively.

When considering disaster preparedness and response, it is also important to consider that there is a difference between natural environmental variation and a disaster (Palm 1990). Frequency and severity are two major factors when classifying an event as a disaster or a part of normal variation. If areas are expected to have high levels of variation and associated risks then the populations that are accustomed to those areas will have a lowered sensitivity to those events (Palm 1990, Tierney *et al* 2001). For instance, in the United States the Asiana plane crash that killed three received more national press than car accidents that claim over 30,000 lives each year (Naylor 2013). In the context of natural disasters, volcanoes with fairly frequent activity often receive less press than those with more sporadic eruptions. Areas that experience fewer events are more likely to have a higher range of variation between those events and less likely to be properly prepared to deal with the aftermath (Palm 1990).

Similarly to water treatment, preparing for disasters is controlled by a variety of factors other than simply the perceived probability of the risk itself occurring. For instance, the cultural background or personal histories with the events both influence the probability of preparing for disaster. When preparing for disasters, therefore, institutions must consider more than just the probability of the event occurring and the fact that the event may be catastrophic. Instead, different cultural groups ought to be targeted in relation to specific, localized concerns of the individuals. And, as governments and organizations install large-scale infrastructure (like levees for flooding or breakers for tsunamis, the benefits of the success and the dangers of the failure of those structures must also be communicated to individuals.

However, unlike water treatment, disaster preparedness requires time and financial commitments that do not have immediate benefits. When water is left untreated, dangerous contaminants can create human health issues within a few hours and the effects can last from days to months, depending on the severity of the contamination and if the contaminant persists in the water source (Rosbury 1971). Thus, the benefits of water treatment should be identifiable in a matter of days and recognized within a few weeks. Natural disasters, on the other hand, are defined as extreme variations in natural processes. This means that the probability of an event having a large impact on normal environmental conditions is relatively low. And, as such, the benefits of investing in preparedness will be more difficult to recognize. Individuals will not be able to appreciate the benefits of preparing until after the event has occurred and they are left unprotected. Therefore, in contrast to citing the benefits of water treatment, individuals must be convinced of the potential risks of not preparing. Only then can the benefits of mitigating those risks be understood and responsible investment in disaster preparedness be undertaken.

CONCLUSION

Ultimately, the goal of international governments is to increase human health and wellbeing. This can be done by investing in increasing access to drinking water or by promoting disaster preparedness. These organizations spread facts and information about the benefits of the risk-limiting actions. However, I found that this is only one piece of the equation. Simply providing the knowledge necessary to improve quality of life is not enough; individuals must be convinced that those risk mitigation methods are worth investing in. The benefits of water treatment can be recognized across short time periods, so short time scale case studies in local communities (like those suggested by Swaziland's UNICEF director) could be sufficient to prove the efficacy of water treatment. However, longer-term issues like disaster preparation are more difficult to support, as they are not as prevalent in daily life. To create maximal benefits, organizations must ameliorate the costs and benefits of action in different timescales to maximize individual wellbeing.

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APPENDICES

Appendix A.

Water testing data from Swaziland (Summer 2013). Tests were conducted by the Swaziland Water Services Corporation Laboratory in Mbabane, Swaziland.
Blue shading indicates that no colonies of bacteria were detected in those samples.

	Locations	Total Coliform Count (24 hrs) / 100 mL	*E. Coli* Count (24 hrs) / 100 mL
Ezulwini	NCP Tap	0	-
	"Protected" Stream	1872	-
	Open Stream	162	-
	Tap #1010	1445	0
Lobamba	NCP Borehole	7	-
	Open Spring	2420	816
	"Protected" Spring	2420	0
	SWSC tank	0	0
Mahlanya	NCP Tap	5	-
	"Protected" Meadow Spring	172	-
	"Protected" Tap	5	-
Mlindazwe	Open Spring	1337	308
	NCP Tap (6/14)	44	-
	NCP Tap (6/19)	288	0
	Homestead 4002	324	0
	Homestead 4003	935	12
	Homestead 4005	659	2
	Homestead 4007	344	1
	Homestead 4014	531	8
	Homestead 4025 Reservoir	4780	89

Appendix B.

Data collected in Swaziland (Summer 2013) as a part of the Environmental Health Assessment. This study was coordinated by James Proctor (Proctor *et al* 2014).

Figure B1: indicates the water source (piped, improved, spring) by community in the Ezulwini Valley (Ezulwini, Lobamba, Mlindazwe, Mahlanya, and the overall percentages of treatment)

Water source type and water treatment practice in percent of households surveyed by community					
Item	Ezulwini	Lobamba	Mahlanya	Mlindazwe	Overall
Piped Water	86	76	31	89	70
Improved Water	20	79	20	0	37
Spring/Stream	18	21	73	16	32
Any household treatment	14	3	10	13	9

Figure B2: the general satisfaction with water quality and quantity in the Ezulwini Valley (1=inadequate; 3=adequate)

Resource adequacy comparison by community					
Item	Ezulwini	Lobamba	Mahlanya	Mlindazwe	Overall
Water Quantity	2	2.5	2.1	2.6	2.3
Water Quality	2.6	2.8	2.5	2.6	2.6

Appendix C.

Figure C1: Comments from the NOI Public Hearing with evidence cited as relevant

Public Hearing Reports- December 14, 2011				
General			Concern	
Respondent	Status	Pro/Against	Sentiment	Evidence
Theodora Tsongas	Expert	Pro	Water is so clean that treatment is not necessary, requiring treatment could lessen the controls upstream	
Merritt	Expert	Pro	Treatment would increase risk of contamination by increasing traffic in the watershed	
Michael Morgan	Citizen	Pro	Crypto is not a problem, increase quality and safety concerns	
Jerzy Giedwoyn	Physician	Pro	Treatment helpful but unneccesary	
Sharon Neski	Citizen	Against	Current practices are not sufficient	"programs should have the capability to do what it is set up to do"
Mary Saunders	Citizen	Pro	She mistrusts government (transparency) and wants to know more about the methodology of testing	
Rhieger and Wiest	Citizen	Pro	same as Tsongas	
Erik Fernandez	Citizen	Pro	Fix method 1623	
Kathryn Notson	Citizen	Against	She cited a variety of corrections that ought to be made and was skeptical of the adequacy of the proposed methodologies	The USEPA's acceptable risk of infection from drinking water is 1:10,000 infections per yer. It means that Portland's untreated bull run surface water has more than 100-fold higher infection risk that the USEPA guidelines
Michael Bussell	Expert	Pro	Provided backgroun information on the EPA's rules and requirements (provides suggestions for consideration)	EPA encourages OHA to consider a pulbic notification requirement for any oocyst detections
Floy Jones	Citizen/ Community Organizer	Pro	testing only necessary if they change the protection requirements on the Bull Run	"greatest risk…install[ing] and unnecessary treatment plant"
Helen Kennedy	Citizen	Pro	Monitoring flaws and oocyt cataloging requirements	
Sieversten	Citizen	Pro		
David Shaff	Expert	Pro	Admin for PWBf	
Scott Fernandez	Expert	Pro	Milwaukee proved the treatment is unsuccessful	
Anonymous	Citizen	Pro	Has reservations about the transparency and standards	

Michael Coe	Citizen	Pro	Unnecessary	
Jim	Citizen	Neutral	Should provide information on types of oocyts	
Stephanie Potter	Citizen	Pro	Cost is too high	
Timothy Henwood	Citizen	Against	Not a one size fits all solution	
Becky Rose	Citizen	Pro	Expensive and unnecessary	
Susan Smith	Expert (Law Prof)	Against	Postpone until genotyping is a part of the law	
Joe Brown	Citizen	Pro	Continue testing as they have been	
Sue Beardwood	Citizen	Against	Contracted Crypto once…	personal history
Katie	Citizen	Against	Wants the government to have follow through, stop allowing delays	"'those who don't remember the ast are condemned to repeat it.' Do not make the same mistake again by allowing the PWB to delay covering/burying open distribution reservoirs"
Olaf Bauer	Ctizen	Against	Skeptical of the Technology	
Beth Giansiracusa	Citizen	Pro	Wants to keep open reservoirs open	
James Doane	Citizen	Pro	Only needs more treatment if the oocyts are actually dangerous	UV treatment will only solve some of the problems with the bull run
Thomas Ward	Expert	Pro	We can't depend on new treatment methodologies to further reduce risk. What we have works.	"There is more "science" in laboratory-based testing versus traditional epidemilogical apporaches that has too often been a failed approach in past governmental responses"
Dave & Carol	Citizen/HOA	Pro	Its worked so far, don't want reservoirs covered	
Joe Glicker	Expert	Pro	Provided "propaganda" to resolve any concerns that individuals may have	
David Spath	Expert	Pro		Although the positive finding may be unsettling, it should not be considered unexpected
Yone Akagi	Citizen	Against	Water is unsafe, methodology insufficient	

Figure C2: title, release date, and number of commenters by Oregon Live article

Code	Date	Article Title	# of comments
OL1	1/5/12	Portland finds cryptosporidium in Bull Run testing but officials hopeful they won't need to build $90 million treatment plant	12
OL 3	1/11/12	Portland finds more cryptosporidium in Bull Run water: Portland City Hall roundup	7
OL 4	1/11/12	Portland leaders play down third positive test for cryptosporidium	14
OL 6	1/25/12	State health authorities delay decision on Portland's water-treatment waiver	9
OL 5	3/15/12	Bull Run water runs as fresh as ever	7
OL 5	3/15/12	Bull Run water runs as fresh as ever	7

Figure C3: Articles, by code referenced above, with the overall want, stated sentiment, and interesting quotations as relevant.

Oregon*Live* Comments				
General			Concern	
Article	Respondent	Wants	Sentiment	Quotes
OL 1	Satchson	Concern (wants)	Even if it is expensive shouldn't we do it because it would be safer for us as a whole	Yes, treating the water is expensive, but do you want to volunter you or your child to be the token victim so the rest of us can save a few bucks? It isn't hysteria to calmly figure out a practical way over many years to protect ourselves from a real threat.
	Jenngorasm	Concern (wants)	They tested only a small fraction of the water, had they tested more they would have found more	
	EasternAlly	Doesn't want	Just trying to keep us scared	
	reflexblue	Wants	Our water is too expensive and they still won't treat it	
	NativeGal	Concern (wants)	Unanswered questions	Is Crypto natural, how does it get into the system? How much does it take to be fatal?
	Onyx	Neutral	Dissatisfied, believes it is due to overpopulation, see quote	"Overpopulation of humans. Ain't it a bitch?"

	jjj	Doesn't want	Disease is a product of our overprotection of ourselves. Treatment isn't necessary because we create problems for ourselves.	
	westwoodman	Wants	They keep taking the cheap route and the risk of contamination is so high they need to comply with regulations	
	watermaker	Wants	it is costly but it will pay off in the end	
	firstthings	Doesn't want	Too costly and only will affect a small portion of the population (old, sick already, and children)	
	loloregon	Neutral	Amused at education	
	Captain K	Doesn't want	Would rather the money go to bike paths	
OL 2	Pseudo	Neutral	It is really expensive	
	Jackalacka	Neutral		
	Nobsvet	Doesn't want	Vulnerable populations can be warned and be responsible for protecting themselves	
	PDXwings	Neutral	Water is expensive	
	Vitaminz	Wants	Cryptosproidium is dangerous and could be even more costly in the long run	
	Doswheels	Doesn't want	"scare tactic", pollutors want it so they can continue polluting the water	
	Kurmudgeon00	Wants	Personal history, Crypto sucks	
	Beantown Badger	Doesn't want	Allowing treatment will increase the probability of pollution upstream	
	Kommon Sense	Snarky	Seems to not want treatment because the price will go up anyways	
	westwoodman	Wants	They will continue to increase prices so they may as well treat the water	
OL 3	Total Bummer	Wants		"Drink Hearty" snarky
	Arrestedddevt 2012	Wants	Portland officials don’t want it, but they should	
	bumpercar	Doesn't want	Keep the water natural	"Portland loves nature"
	PDXhypocrite	Doesn't want	Water is expensive, this is unnecessary	
	Jenngorasm	Wants	They don't test the water enough	

	madcarpenter	Doesn't want	They just want to be able to charge us more, scare tactic	
	forwater	Doesn't want	Difference between detection and infection	
OL 4	Jubei	Doesn't want	Difference between detection and infection	
	Save the Tax Payers	Doesn't want	Human involvement may cause the contamination, we should pay for increased anthropogenic population	
	rayjan	Wants	Personal history, husband got sick	
	want vs need	Doesn't want	Stay rational	
	Rag Top Guy	Doesn't want	Skeptical of the PWB who may have planted the bugs to make the plant necessary	
	Remeyrune	Wants	Skeptical of evidence presented by "experts"	"are any o these people doctors or scientists? They are just city employees with no real knowledge of how this will affect the drinking water. It would be comforting for htem to at least cite some scientific facts or have real scientists speak out on how safe it is?
	NativeGal	Neutral	Thankful for having the facts answered	
	footofpride	Wants	If it is still in the water they should install the treatment plant	
	Jrsouthgate	Want	Pay for the treatment because eventually it will pay off	
	Greshamdadjohn	Neutral	Wants testing for more than just crypto	had giardia…
	madcarpenter	Doesn't want	Snarky	"There is nothing to fear, people. Unfortunately however, your water bills will be going up again in the very near future."
	firstthings	Doesn't want	thinks it is all political bs	
	Drill Baby Drill	Wants	Portland water is dangerous enough, we should also test it	Cited Milwaukee, WI's crypto outbreak
OL 5	Jade Queen	Wants	Frustrated with limited information presented in the editorial	
	Clackamas Captive	Doesn't want	Protects forest around the watershed	

	kumpression	Wants	It could increase economic value of land around the watershed through development	
	prexstermnal	Doesn't want	Wants to keep the trees around the watershed	
	Greshamdadjohn	Wants	Would like to know more about testing protocols and the health of the water supply in general	
	Taxed	Wants	Disgruntled with Portland not complying with a national law	
	Nutmeg31	Doesn't want	Happy with Portland's ability to personalize a national mandate	
OL 6	steavis	Want	Doesn't like the tax increases with no action	
	J_Swenson	Neutral	Dissatisfied with costs	
	gnuut	Neutral	Dissatisfied with costs	
	FreshStew	Neutral	Dissatisfied with costs	
	eastcomom			
	total	Wants	Dissatisfied with detection standards and efforts	
	forwater	Doesn't want	Concerns about the OHA's application for variance but otherwise happy with the concept of not installing treatment	
	exciteddelirium	Neutral	Dissatisfied with costs	
	Peasant Pundit	Doesn't want	Unnecessary with current treatment practices	

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