Detecting Contaminated Drinking Water: Harnessing Consumer Complaints

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Introduction

Based on previous contamination incidents, civilian and military water supply personnel have improved their drinking water surveillance practices. One of the biggest challenges though is that no single device can detect all chemical, biological, and radiological contaminants in the distribution system. The absence of a universal detector has forced water utility managers to increase their awareness and rely on conventional and unconventional system indicators. In particular, managers rely upon monitoring physiochemical parameters (e.g., chlorine, pH, conductivity, and turbidity), pressure readings at various points in the distribution system, and visual surveillance of water system assets. While these monitoring practices are useful, many water utilities do not have the funds to install real-time monitoring devices at every point or even a few points throughout their system.

This paper provides (1) insight into why consumers report complaints, (2) a list of chemical and biological contaminants and their physiochemical and aesthetic water quality effects, (3) examples of how consumer complaints have been used to identify intentionally and unintentionally contaminated water, (4) a structured approach for investigating complaints, and (5) guidance on harnessing consumer feedback to better gauge water quality and potential for contaminations in the distribution system.

Why Consumers Complain

If terrorists contaminate a water distribution system and the attack goes undetected by the water utility, consumers will likely be the first to detect the problem. In fact, many public health officials have speculated that the first warning of water system contamination would be an increased number of people admitted to the emergency room, increased purchases of influenza medicine, or increased absences from school or work (Barthell et al., 2002; Green and Kaufman, 2002; Hess, 2002). Based on this realization, public health officials have begun developing syndromic surveillance systems, which specifically track the occurrence of reported signs and symptoms of disease (Lazarus et al., 2001; Barthell et al., 2002; Green and Kaufman, 2002). Public health officials realize that the water utility may receive consumer complaints, the first indicators of contaminated water, before effected people seek medical assistance.

One of the most important qualities of drinking water consumers is that they inform their utility when they are concerned about their drinking water. Consumer concern usually is based on fear that the water might be unsafe or due to consumer dissatisfaction with the product (McGuire, 1995; Levallois et al., 1999; AwwaRF, 1996; AwwaRF, 2003). These concerns are classified into four main categories and are described below.

- Aesthetic Complaints. Sensory properties of drinking water are the first observation of a problem by consumers. Aesthetic complaints include taste, odor, color, and clarity. While many of the

unusual aesthetic properties detected do not have health effects (e.g., earthy-musty odors), several true acute health threats have been discovered through aesthetic complaints.

- Water Pressure Complaints. Consumers can notice water pressure fluctuations during cooking and bathing. Pressure fluctuations can occur due to unintentional or intentional breaks in water system infrastructure. Also low and loss of pressure complaints could indicate terrorist attempts to over pressurize and backflow contaminants into the distribution system.

- Illness Complaints. Consumers contact the water utility when they feel the water is making them sick. Vomiting, nausea, diarrhea are some disease symptoms that have been reported to water utilities. Normally these complaints are not water-related although in some instances illness complaints have been the first sign that the drinking water was contaminated.

- Suspicious Activity Reports. Consumers contact the water utility when utility personnel are working around or on their property. This occurs usually during distribution system maintenance activities such as hydrant flushing and storage tank inspection. Fortunately for water utilities, consumers also report any suspicious activities they believe are occurring near water system assets. Suspicious activity complaints include those where individuals are seen conducting surveillance or tampering with water system assets. Assets that could be targeted include pump stations, storage tanks, chlorination stations, and hydrants. Consumer reports are useful in detecting intrusion into the water system.

Specific Complaints Signaling Contaminated Water

Generally consumer complaints are not health problems, but there are instances when a health problem has occurred and the consumer detected it before the water provider. Several public, private, and military water utility contamination incidents have been discovered because consumers have called utilities and complained about one of these anomalies. On the battlefield soldiers have recognized unusual water quality properties and their cause has been determined to be a process malfunction or tampering. For these reasons, the EPA and US Army Center for Health Promotion and Preventive Medicine (CHPPM) recommend that drinking water providers and medical authorities closely monitor consumer complaints because they could signal contaminated drinking water (EPA, 2003; US Army, 2003; Whelton, 2003; US Army, 2004; Whelton, 2004).

Consumers are valuable water quality monitors because they complain when the free chlorine residual (FAC) concentration changes, whether the change is an increase or a decrease in the flavor intensity. If a toxicant is injected into the water, it is likely that the FAC concentration will decrease. This change may be noticed by consumers and reported to the utility in the form of a water quality complaint. Also, if FAC die-off occurs underlying odors could be revealed (Worley et al., 2003) and customers might complain. Water utility managers should be on the lookout for any unusual complaints because they may be indicators that unwanted contaminants may be present.

Typical drinking water complaints should be also scrutinized. Just because a consumer contacts the water utility about a common complaint (e.g., chlorinous smell) does not mean that that water is free of contamination. In fact, most waters have descriptors or chlorinous, earthy, musty, and metallic (AwwaRF, 1987). If problem contaminants are present or have descriptors close to these, the complaint report might not trigger an immediate warning or investigation. For these reasons, all complaints should be handled appropriately and their causes determined.

Chemicals Detected by Consumers

Several chemical agents change water quality properties when present. The consumer can detect these changes in water quality. Consumers will most likely suspect water as unsafe and file a complaint when chemical contaminants are present (Sanchis, 1946). Table 1 contains the aesthetic attributes of the several chemical warfare agents (Sanchis, 1946; US Army, 1985; OTSG, 1997). Of those listed in Table

1, cyanide has historically received a large amount of notoriety as a chemical that can be used to contaminate drinking water (Whelton et al., 2004). Cyanide has been used for thousands of years as a drinking water poison and has recently been found in the possession of terrorists (Whelton et al., 2003).

Table 1. Chemicals in Water have Detectable Aesthetic Attributes

Compound Name	Taste Descriptor	Odor Descriptor	Color Descriptor	Turbidity Present[1]
Cyanogen chloride	Sharp, metallic	Pepperish	Colorless	No
Diazinon (insecticide)	Not found	Faint ester-like	Colorless	No
Fluoride	Salty, soapy	Sharp, pungent, irritating	Colorless	No
Free chlorine	Astringent	Chlorinous	Colorless	No
Hydrogen cyanide*	Bitter, metallic	Almond, peach kernels	Colorless	No
Malathion (insecticide)	Not found	Skunk, mercaptan, garlic	Yellow	No
Mercuric chloride	Bitter, metallic	Almonds, peach kernels	Colorless	No
Naphthalene	Not found	Mouthball-like	Colorless	Yes
Parathion pesticide	Not found	Rotten Onion, garlic	Colorless	Yes
Petroleum products	Not found	Pungent, hydrocarbon	Varies	Yes
Sewage	Salty	Septic	Gary, brown	Yes
Soman	Not reported	Fruity, camphor	Colorless	No
Sulfur mustard	Not reported	Garlic, mustard	Pale yellow	Yes

1. Turbidity is not always present with naphthalene, parathion, petrol products are poorly soluble organic compounds, but, if present below their solubility limit, would not produce turbidity. Depending on the component, several 100+ mg/L can be solubilized. Gasoline/petroleum contamination generally produces an odor before it results in turbidity.

Drinking water than contains harmful levels of pesticides, herbicides, and fungicides has unusual water quality aesthetics (e.g., taste, odor, and appearance). Actual unintentional and intentional contamination incidents have occurred and involved the use of these contaminants. Rouge individuals have chosen to use these commercial poisons because they are easier to obtain and transport than chemical warfare agents. As illustrated in Table 1 many organic and inorganic chemicals have associated odors. Also, ingestion of the contaminants in Table 1 at acute concentrations would result in consumers experiencing negative health effects (e.g., nausea, vomiting, diarrhea, and possible death).

Biological Contaminants Detected by Consumers

Public health officials have speculated that the most likely biological agent choices are botulinum toxin and *Cryptosporidium*. While biological agents have not been found to cause objectionable tastes, odors, or colors in drinking water, they are similar to chemical agents in that consumers will experience discomfort or severe health effects (Burrows and Renner, 1999; Craun and Calderon, 2001). In contrast to chemical exposure, the major concern with biological agents is that incubation periods vary from hours to days to weeks. Therefore, ingestion of biologically contaminated water may be revealed days after the system intrusion. Table 2 contains the ingestion symptoms of water containing some well-known microbiological contaminants. The most common complaints are nausea, vomiting, and diarrhea. Consumer complaints such as these could be prime indicators of biologically contaminated drinking water.

Table 2. Ingestion Symptoms for Biological Contaminants

Contaminant	Disease	Microorganism	Clinical Symptoms
E. coli 0157:H7	Dysentery	Bacteria	Diarrhea, abdominal pain, bloody stools
Cryptosporidium parvuum	Cryptosporidiosis	Protozoan	Nausea, diarrhea, and stomach cramps
Giardia lamblia	Giardiasis	Protozoan	Nausea, diarrhea, bloating, headache, stomach cramps, weight loss
Salmonella typhimocrius	Salmonellosis	Bacteria	Vomiting, diarrhea
Vibrio cholerae	Cholera	Bacteria	Diarrhea, rapid dehydration to a state of collapse

Examples of Complaints Used to Identify Contaminated Water

Consumer complaints have been useful for identifying problems in water systems. Several examples are given below to show the usefulness and applicability of consumer complaints to water system surveillance. Several of the reports below were provided to Whelton (2004) and have not been formally published.

- On an early 1980s Sunday morning in the State of Washington, water utility consumers began to complain about a kerosene-insecticide smell and taste and milky drinking water appearance. The utility dispatched investigative personnel immediately and based upon onsite sensory evaluation, and the number and location of the complaints, the utility suspected contaminated drinking water. The effected water system served about 10,000 people. Using complaint information, valves were closed to contain the contaminated water. Health agency surveys determined sickness incidence in the area. One out of three residents reported nausea and diarrhea and other symptoms reported include sore throat, headache, and skin and eye irritation. The survey results suggested that the consumer's health in the affected area was influenced by the contamination incident. Investigation revealed that this incident was caused by backflow of a pesticide through a hydrant (Whelton, 2004).

- In the mid 1980s, a water utility in Illinois received consumer complaints regarding gasoline and solvent odors in their water (Whelton, 2004). Upon investigation by the utility, it was discovered that fuel from tanks owned by a nearby tool rental agency had leaked into the soil near the consumers' service branch. Subsequently, the petroleum products permeated through the plastic service line and into the drinking water. Today this utility closely monitors consumer complaints.

- At a Connecticut water utility in 1988, consumers began complaining of abnormal drinking water tastes, nausea, vomiting, diarrhea, and skin irritation. Additional complaints included that the water turned blue on contact with soap. Once the utility staff realized that they were receiving an unusually high number of complaints, they investigated and found that the fluoride feed system had dumped 40 times the normal concentration of fluoride into the distribution system (Peterson et al., 1988).

- In the 1990s a contractor superchlorinated a US Army water system storage tank which serves approximately 25,000 consumers (Whelton, 2004). A 100 mg/L free available chlorine dose was used. Because the tank valve was not completely shut, highly chlorinated water leaked into the distribution system. The utility manager became aware that superchlorinated water leaked into the system after an unusual number of taste and odor drinking water consumer complaints were filed. A field investigation revealed that water at consumer taps had a 4.0 mg/L chlorine residual concentration in contrast to the normal 1.0-2.0 mg/L. After this incident, the water utility began closely monitoring consumer feedback.

- In 1993, drinking water consumers in Milwaukee, Wisconsin called the water utility and persistently reported various taste, odor, and color complaints two weeks prior to the full-scale public health investigation for the *Cryptosporidium* Outbreak (Whelton, 2004). While this information was not scrutinized at the time, in hindsight public health officials have realized its usefulness.

- In 2003, at 1030 AM on a workday morning in the Pennsylvania green water consumer complaints were called into the utility complaint desk (Whelton, 2004). Water was being used to make coffee in a fast-food establishment, but the green color caused the establishment to stop production. By 11:45 AM utility representatives were onsite at the office building and collected samples for laboratory testing. At 3:00 PM lab testing was completed and confirmed the green color confirmed and a response team was assembled. An hour-and-a-half later, experts in cross connection control arrived at the residence and the local health agency was notified. Investigation revealed that the problem was only affecting the consumer's building. The next day, the cause was identified and confirmed to be corrosion inhibitor chemicals used in the HVAC system for corrosion control. Workers had been on site emptying, repairing, and filling a part of the HVAC system on the roof of the building, which backflowed into the water system. Affected consumers were notified and flushing was used to remedy the situation.

Handling Consumer Complaints

General Investigation Process

Water systems personnel must initially consider every complaint pertinent and important and give each complaint immediate attention. Persons receiving the complaint may need to reprioritize tasks and or reassign personnel as needed to quickly resolve complaints. Complaints can be an indicator of significant health risks and could affect the complainant or multiple consumers. Some complaints may be resolved during the initial contact with the consumer, while others will require further investigation. A basic complaint investigation decision wheel is provided in US Army (2003) entitled *Drinking Water Consumer Complaints: Indicators from Distribution System Sentinels.* Figure 1 provides an example pathway for handling complaints by water utility personnel.

Communication outside the water utility may be required for some complaint investigations. If an unusual water quality problem is reported to the utility and the cause cannot be determined, the utility should contact the local and State health agencies as well as the State drinking water primacy agency (e.g., DEP). Also, the Safe Drinking Water Act requires immediate notification of the State drinking water primacy agency if a waterborne disease outbreak is suspected or uncovered. These agencies have substantial resources and personnel that can help in the investigation. In addition, these agencies may know of a specific threat to water systems in their region which could help determine if the unusual incident is related to a terrorist attack. If the complaint reported is one of illness, health agencies should be notified. By notifying the health agency, the utility will improve the relationship and prevent the health agency from being uniformed. Figure 2 describes a potential communication structure for investigating consumer complaints with organizations outside the water utility.

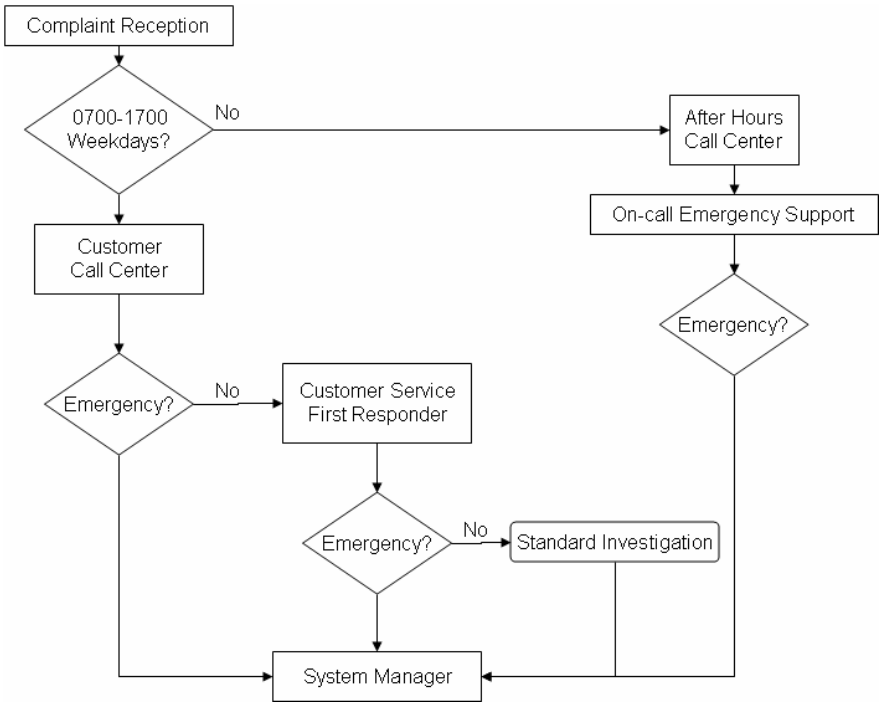

Figure 1. Management of Communication Pathways when a Complaint or Water Quality Incident Becomes Significant

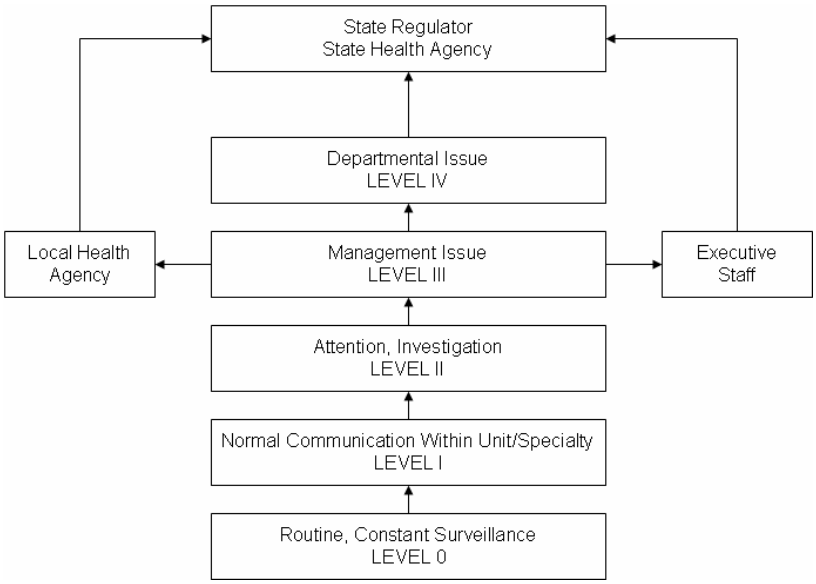

Figure 2. Consumer Complaint Communication Structure for Water Utilities.

Potential Personnel Brought in to Investigate

Effectively handling consumer complaints requires teamwork and communication. Every person involved in the complaint reception and investigation must work together to identify the cause of the problem and solutions for its elimination. Should the water be contaminated with a toxic chemical or

biological agent, communication with the persons submitting the complaint, internal to the utility, and with local medical and emergency response personnel is critical.

Having the right personnel help investigate the complaint is essential. The Philadelphia Water Department has found that the following personnel may have to be brought in when a complaint progresses to a more serious level.

1. Consumer service representatives (for the utility)
2. Water quality manager and staff
3. Laboratory staff
4. Cross connection control inspectors in case it could be a backflow event
5. Treatment managers in case it is related to treatment
6. Distribution/conveyance managers and crews in case it is related to distribution
7. Public relations staff in case the media is called in for news coverage
8. Health department staff for the local area in case illness is involved or consumer premises need to come into compliance
9. State regulatory agency staff that also might get complaint calls. (Note: The Safe Drinking Water Act requires immediate notification of State Agency if a waterborne disease outbreak is uncovered. If diseases are suspected as being linked to tap water then the drinking water Primacy Agency must be notified.)

Large utilities may find a team of this size easy to assemble, while small water utilities may designate one person to execute many of the aforementioned tasks. Regardless of the utility's size, all persons involved in a consumer complaint investigation should be well-versed in standard communication and onsite investigation procedures.

Onsite Investigation

Investigating the consumer problem should be conducted at the incident site and cover a wider area. The investigator will want to determine if the problem is restricted to a single faucet in a building, to a single consumer, to a specific length of water main, to a certain distribution system grid or service area, or to a whole system supplied by a treatment plant. Information that is needed from a consumer are: exact location of the problem such as the kitchen tap on the second floor; a description from the actual complainer of the problem; an idea as to how long the problem has been happening and whether it still occurs and occurs all the time or just at certain times (e.g., first thing in the morning); if others in the facility notice it and do other services nearby complain.

Even something as simple as collecting samples of the actual problem is not usually done. Analyzing water samples onsite and at a laboratory are important pieces during an investigation. If the problem can be captured and is clearly recognizable, the investigator should collect plenty of water samples to allow for diverse and complete laboratory analyses.

Area wide surveys should be conducted to determine how far-reaching the problem extends. Hydrant sampling is one way to conduct an area wide survey. The use of hydrants depends on the type of water quality analyses that will be done. Sampling for chlorine residual and pH is easy to do from a hydrant. Hydrant samples though are easily contaminated and give false readings for such analyses as heterotrophic plate count bacteria and turbidity.

The following analytical and sensory tests should be considered when investigating unusual distribution system problems.

1. Water odor, color, and clarity inspection
2. Water pH
3. Water temperature
4. Turbidity
5. Metals analyses (e.g., copper, zinc, iron, manganese)

6. Total dissolved solids
7. Colorimetric or amperometric titration for chlorine residual
8. Microscopic examinations for particulates and macroorganisms

Complaint Tracking and Logging

The importance of documenting the consumer complaint cannot be over emphasized. By creating an information library of consumer complaints and follow-up actions and results, water utility personnel will be more able to detect any acute water quality health risks, such as those caused by terrorist contamination. Also, documentation will provide the utility with a baseline understanding of where chronic water quality problems are located (e.g., service lines with low chlorine residual concentrations and high iron and copper concentrations). Consumer complaints should be documented in electronic format or in the less desirable paper log.

Data evaluation is required for a consumer complaint system to be effective. Complaint data is useless unless periodically reviewed for trends and commonalities. The electronic format provides for easier data analyses and display. A Microsoft® Excel spreadsheet or Access database are just two of the available tools. Data analysis using paper logs is more difficult and extremely time consuming. For small water utilities though, paper filing may be the most cost effective and easiest means of documentation. Paper maps and geographic information system (GIS) mapping should also be used to display the location site of all complaints.

Once the cause is determined, the investigators should document all findings in the database and annotate the location on the consumer complaint-tracking map. The investigators should also notify the consumer about the cause, health risk, and any follow-up actions that the water system will take (that is, water main replacement, flushing, and increased chlorine residual concentrations). The investigator's recommendation should be placed in the database along with the time and date the consumer was contacted.

Conclusions

Harnessing consumer feedback is becoming increasingly necessary as water utilities strive to improve their contaminated water detection capabilities. Consumer complaints are a critical surveillance resource for drinking water systems and should be appropriately handled. Information contained in this paper can be used to improve drinking water complaint systems. Research should be conducted to improve the understanding and integration of consumer complaint information into a larger public health surveillance tools. The following list of ten lessons learned was generated by the authors for case studies discussed in this paper.

1. Unintentional and intentional contaminated drinking water can be detected by a consumer's sense of smell, taste, and sight.
2. Taste, odor, color, clarity, and illness complaints can signify the presence of contaminated drinking water.
3. Chlorine residual, pH, and turbidity water quality parameters can be used to detect problems with water quality.
4. Onsite utility investigations that include sensory analyses are helpful at verifying the existence of a problem and determining the cause. Thought, care must be taken when determining if sensory analyses should be used because of contaminant exposure concerns (e.g., tasting is discouraged).
5. Consumers that receive contaminated drinking water may seek medical treatment. Water utility responders should request health agency assistance when a consumer reports illness caused by drinking water exposure.
6. Drinking water illness complaints should be jointly investigated by the water utility and public health agency.

7. Complaint samples should be screened immediately and tested in the lab with priority over other routine samples.
8. A rehearsed consumer complaint response protocol to consumer complaints can save 3 to 5 hours and reduce the number of people exposed to the contaminated water.
9. Consumer complaints can be helpful in determining the location of and isolating contaminated drinking water.
10. Water utilites should Immediately notify the State drinking water Primacy Agency if a waterborne disease outbreak is uncovered.

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