Quantifying Bacteria Levels in Water Categories 1–3

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In any water intrusion situation, typically, one of the most important questions to answer is: What was the quality of the intruding water? The IICRC S500 "Standard and Reference Guide for Professional Water Damage Restoration" contains qualitative, descriptive definitions of intruding water, dividing the substance into three categories.

The descriptive nature of definitions of Categories 1, 2 and 3 offers a handy guide for remediators who need to make expedient judgment calls on water quality and remediation protocols. The qualitative nature of these definitions may be adequate for smaller remediation jobs where the cost of bacteria testing could exceed the remediation and relocation costs or when the length of time necessary to analyze bacteria samples is not acceptable to the parties involved.

However, in some larger water intrusion incidents, the quality of the water involved and the subsequent required level of remediation may be in question and significantly impact the cost of remediation. In such cases, a more definitive and quantitative characterization of water quality and its residual contamination could be useful. At this point in time, S500 provides no guidance on what specific microbial or chemicals levels are present in these water categories.

A recent large loss occurred in the Chicago area where the issue of the water category was a very significant question. The water intrusion occurred during a storm-related, four-hour power outage in a very large apartment complex. All of the ground-level apartments were flooded with a few inches of water. Once the power returned, the sump pumps removed the majority of the water from the buildings. A drying crew responded within 12 hours to dry the affected areas completely in less than 24 hours.

During the flooding, most people reported that the water came from the sump pump in the laundry rooms in the buildings. The gutter downspouts from the roof were directly connected to the sump pump pits in the laundry room. When the power outage occurred, the roof water flooded the buildings.

However, the property owners claimed some people reported that it was a sewage backflow. This complex was below grade and had its own main ejector station. It was not directly connected to the local sewer main. Hence, there was no backflow from the sewer main. In addition, since this power outage occurred in the middle of the night, the amount of sewage generated by occupants at that time would have been minimal. Therefore, it was unlikely that sewage backflow was a major source of the intruding water.

The property owners rejected the argument that the roof water was the main water source and insisted that even a small amount of sewage made this a black water incident. They wanted everything in the 50 affected apartments replaced, even the major appliances.

Actually, S500 provides conflicting interpretations in this particular case. According to S500, if the incident was sewage-related, then this would be a Category 3 water situation. However, most of the water was rainwater from the roof that flowed into a sump pit. Since foundation perimeter drainage water is "seepage due to hydrostatic pressure," S500 says this is Category 2 water. Was this situation seepage, or could this water be considered falling rainwater – Category 1? S500 has no specific categorization for roof run-off. Did all of the furnishings need to be disposed of or not? The insurance company decided to retain an environmental consultant to resolve the water quality question.

In classifying the category of water in this situation, it was assumed that the major concern was microbial contamination and no other sources of contamination were involved. This was an apartment complex, not an industrial site, so there should be no significant chemical contamination questions. Based on this assumption, it was decided to use the quantitative

microbial levels in the research literature and bacterial water quality regulations to develop appropriate bacterial level classifications for S500 Category 1, 2 and 3 water. These numbers could then be used categorize the quality of water involved in this incident.

Before we review the various bacterial water quality standards, we should review some of the typical bacterial test methods that are used to determine water quality. These are:

1. Heterotrophic plate count, or HPC, also known as total plate count: This is the most common test method used to analyze water. It estimates the total amount of bacteria in the water.
2. Coliform bacteria: This test was initially developed to look for cross-contamination between the water in a sewerage system and well water. It looks for bacteria that live in the lower intestines of warm-blooded animals (including birds and mammals) that are necessary for the proper digestion of food. The assumption was that if these bacteria are found in potable water, then there must be a connection between sewer water and potable water. However, coliform bacteria can also be found in soil and natural waters, so a sewerage system is not always the source.
3. Escheria coli (E. coli) Bacteria: This is a test for a specific coliform bacteria known as E. coli. Some strains, such as O157, are infective and can cause serious disease. Initially, it was thought that E. coli came only from human waste. Today, we know that there are many other sources that can contaminate both food and water. Table 1 shows some examples of typical levels of E. coli from humans and other species. (What this table indicates is that in evaluating potential bacterial contamination in dwellings, the existence of pets can radically skew background or preexisting measurements of E. coli in an environment.)

Table 1: Viable E. coli bacteria levels for common animals feces

Human	5,000,000 cfu/gram
Cat	40,000,000 cfu/gram
Dog	32,000,000 cfu/gram
Goose	310,000 cfu/gram

4. Fecal coliform: This is another test for a specific coliform bacteria known as fecal coliform. As the term implies, these are coliform bacteria that are directly related to fecal contamination.
5. Fecal streptococci: These bacteria are members of the Enterococcus and Streptococcus groupings of bacteria. They are characterized as being round in shape and, again, fecal in origin.

Now that we have covered the basic definitions of the standard bacteriological water quality tests, we can review the relevant regulatory water quality standards and research literature to see how this information can be used to quantify the three categories of intruding water.

Category 1 Water Standards

S500 defines Category 1 water as originating from a sanitary water source that does not pose a substantial risk from dermal, ingestion, or inhalation exposure. Some examples are broken water supply, tub or sink overflows with no contaminants, melting ice or snow, falling rainwater, broken toilet tank, and broken toilet bowls with no contaminants or additives.

The first place to start identifying bacterial standards for Category 1 water are microbial standards for potable water or water that originates from a sanitary source. The most common source of sanitary water is potable or drinking water. Table 2 shows the applicable HPC bacterial limits for potable drinking water. The consensus is that potable water should contain less than 50,000 colony-forming units per 100 milliliters.

Table 2: Applicable standards for potable water interpretation (a.k.a. Category 1)

Standard-setting body or law	Maximum level for HPC
U.S. Environmental Protection Agency Drinking Water Safety Act*	<50,000 cfu/100 ml
Brazil (potable drinking water)	<50,000 cfu/100 ml
Hong Kong Food and Hygiene Department	<50,000 cfu/100 ml
Pharmaceutical/medical device industry (acceptable incoming potable water)	<50,000 cfu/100 ml
American Water Works Association ANSI Standard C651.92	<50,000 cfu/100 ml

* Although the Drinking Water Safety Act is not a legal U.S. standard per se, the EPA recognizes that properly chlorinated and maintained potable water systems will have less than 500 cfu/ml. The EPA also states, "An informal standard of 500 [cfu/ml] of potable water has been used as an indicator of the integrity of distribution systems."

The second criterion listed in S500 for Category 1 water is that it "does not pose substantial risk from dermal, ingestion, or inhalation exposure" (emphasis added). Clearly, water from a properly maintained swimming pool does not pose a substantial risk from these types of exposure; so, swimming pool standards should be applicable to Category 1 water as well. Tables 3, 4 and 5 show various regulatory standards for HPC, E. coli and coliform standards, respectively, for swimming pool water.

Table 3: Heterotrophic plate count standards for swimming pools

Agency	Maximum level (in cfu/100 ml)
U.S. Army	< 20,000
Massachusetts	< 20,000
Arizona < 20,000	< 20,000
Australia	< 10,000

Note: The standard for HPC in drinking water is higher than for swimming pools.

Table 4: Thermotolerant coliform plate count standards for swimming pools

Agency	Maximum level (in cfu/100 ml)
United National Environment Programme/World Health	< 100 (50% average)
Organization (1985) interim criteria for recreational waters	< 1,000 max. (1 in 10 samples)
Maine	< 2
Arizona	< 2

Table 5: E. coli standards for swimming pools

Agency	Maximum level (in cfu/100 ml)
New Hampshire	$\leq$ 88

Another useful "minimal" risk example is the Texas Natural Resource Conservation Commission, which has bacterial standards for Type I reclaimed water. Type I reclaimed water "can be applied on crops when workers are present." This means that Type I reclaimed water also does not pose a substantial risk from dermal, ingestion, or inhalation exposure; so, these standards would also apply to Category 1 water.

Other uses of Type I reclaimed water include reservoir tanks for toilet bowls and urinals. These uses are examples of Category 1 water is the S500 definition. Table 6 shows the fecal coliform bacterial standards for Type I reclaimed water.

Table 6: Fecal coliform standards for Type I reclaimed water

Type I reclaimed water	Maximum level (in cfu/100 ml)
Fecal coliform (average)	< 20
Fecal coliform (not to exceed)	< 75

Source: Texas Natural Resource Conservation Commission

In summary, based on the regulatory standards in Tables 2–5, Category 1 water should contain less than 50,000 cfu/100 ml HPC bacteria, less than 100 cfu/100 ml coliform bacteria, less than 75 cfu/100 ml fecal coliform, and less than or equal to 88 /100 ml E. coli.

Category 2 Water Standards

S500 defines Category 2 water as water that "contains significant contamination and has the potential to cause discomfort or sickness if contacted or consumed by humans." Some examples include discharges from dishwashers, discharges from washing machines, overflows from washing machines, overflows from a toilet bowl that contains urine, groundwater seepage due to hydrostatic pressure, broken aquariums, and punctured waterbeds. Such water, S520 says, "can contain potentially unsafe levels of microorganisms or nutrients for microorganisms, as well as other organic or inorganic matter."

Some ambiguity exists in this definition with its use of the term "contacted" in "if contacted or consumed by humans." This would not appear to include an inhalation risk. However, since inhalation risk is already included in the Category 1 definition, it would seem to imply that an inhalation risk could also be present for more hazardous Category 2 water.

For some perspective on the "contact risk" concept, the Texas Natural Resource Conservation Commission has bacterial limits for Type II reclaimed water standards for irrigation. Type II water can only be applied to crops when people are not present. This implies a "contact risk" from this type of water. The bacterial limit standards for Type II reclaimed water are shown in Table 7. These standards clearly fall into the Category 2 water definition and provide a "contact risk" bacterial limit between Category 1 and Category 2 water.

Table 7: Fecal coliform and total coliform standards for Type II reclaimed water

Type II reclaimed water	Maximum level (in cfu/100 ml)
Fecal coliform	(average) < 200 *
Fecal coliform	(not to exceed) < 800 *
Total coliform	< 2,000 **

** Texas Natural Resource Conservation Commission*
*** Valentina Lazarova Akiçça Bahri, "Water Reuse for Irrigation, Agriculture, Landscapes, and Turf Grass," CRC Press.*

Another example in the S500 Category 2 water definition is that consumption of the water may cause sickness or discomfort. The World Health Organization has established HPC standards for edible ice. The concern here is when ice containing high levels of bacteria melts in a beverage and makes people sick. Table 8 shows the WHO's HPC standards for edible ice for both healthy and immunocompromised people.

Table 8: Heterotrophic plate counts for edible ice

Standard-setting body or law	Maximum level (in cfu/100 ml)
World Health Organization standard for edible ice*	< 5,000,000
World Health Organization standard for edible ice for infants and elderly with suppressedimmune systems **	< 300,000

* Geldreich, E. E. et al., 1975
** Richardson, 1998

In summary, based on the regulatory standards in Tables 6 and 7, the bacterial limits between Category 1 and Category 2 water appear to be well defined.

Category 3 Water

S500 defines Category 3 water as "grossly contaminated" with harmful agents that may be

pathogenic or toxigenic. Some examples of this category include sewage, toilet overflows originating from beyond the trap (regardless of visible content or color), all forms of flooding from seawater, ground surface water, rising water from rivers or streams, and wind-driven rain from hurricanes, tropical storms or other rain events. (Water from rain events may contain silt, organic matter, pesticides, heavy metals, regulated materials, or toxic organic substances.)

In dealing with Category 3 water, the worst-case microbial situation is sewage. Since there are no regulatory standards for sewage bacterial levels, the reference literature was reviewed to identify the typical levels of bacteria in sewage. Table 9 shows the typical microbial level of sewage for total coliforms, fecal coliforms and fecal streptococci found in various U.S. municipal sewage systems.

Table 9: Coliform and streptococci levels in typical sewage

Sewer source	Total coliforms	Fecal coliforms	Fecal streptococci
	(in cfu/100 ml)	(in cfu/100 ml)	(in cfu/100 ml)
Esparto, Calif.	23,500,000	6,200,000	-
Shastina, Calif.	9,600,000	2,300,000	-
Los Banos, Calif.	62,000,000	23,000,000	-
Anaka, Minn.	47,400,000	10,200,000	-
Newport, Minn.	13,600,000	3,580,000	-
Red Wing, Minn.	17,700,000	4,050,000	-
Mankato, Minn.	5,525,000	2,630,000	-
Oakwood Beach, N.J.	13,250,000	4,240,000	-
Perth Amboy, N.J.	1,600,000	387,000	-
Middlesex, N.J.	12,900,000	1,070,000	-
Keyport, N.J.	2,210,000	641,000	-
Omaha, Neb.	45,800,000	5,360,000	-
Anderson, Ohio	17,200,000	4,600,000	-
Cincinnati, Ohio	34,800,000	4,900,000	-
Moorhead, Minn.	-	1,600,000	-
Linwood, Ohio	-	10,900,000	2,470,000
Preston, Idaho	-	340,000	64,000
Fargo, N.D.	-	1,300,000	290,000
Lawrence, Mass.	-	17,900,000	4,500,000
Monroe, Mich.	-	19,200,000	700,000
Denver, Colo.	-	49,000,000	2,900,000
Minimum value	**1,600,000**	**340,000**	**64,000**
Median value	**15,400,000**	**4,240,000**	**1,585,000**

Source: Edwin E. Geldreich, “Microbial Quality of Water Distribution Systems,” 1992.

As one can see in Table 9, the range of total coliforms for typical sewage water varies from 1.6 million to 62 million cfu/100 ml. Comparing the range of fecal coliform bacteria in sewage to the level in Type I reclaimed water (Table 6), shows that the fecal coliform levels in sewage are approximately 2,000 to 200,000 times higher than Type I reclaimed water. Similar differences exist for the other types of bacteria. Therefore, if we take the lowest bacteria levels found in this research literature of sewage, these level lowest levels should be a conservative minimum bacterial classification range for Category 3 sewage water.

In summary, based on the research literature, Category 3 water would contain greater than 1.6 million cfu/100 ml of total coliform and greater than or equal to 340,000 cfu/100 ml fecal coliform.

Application of Category 1, 2, and 3 Bacterial Water Quality Guidelines

Table 10 summarizes the total plate count, total coliform and fecal coliform bacterial limits for water that meet the definitions in S500 of Category 1, 2 and 3 water. Water being tested should comply with all three of the standards to meet a specific category definition. Here is how to do it.

Table 10: Summary of suggested Category 1, 2 and 3 bacterial ranges in water

Water category	Total plate count	Total coliform	Fecal coliform
	(in cfu/100 ml)	(in cfu/100 ml)	(in cfu/100 ml)
Category 1	< 50,000	< 100	$\leq$ 75 *
Category 2	$\geq$ 50,000 and <50,000,000	$\geq$ 100 and <1,600,000	$\geq$ 75 * and < 340,000
Category 3	$\geq$50,000,000 and TNTC**	$\geq$1,600,000	$\geq$340,000

* Uncontaminated recycled water used in toilets and urinals
** TNTC = too numerous to count. This varies depending upon the serial dilutions employed by the lab but typically is 50,000,000 cfu/ 100 ml.

At the start of your water removal process, take at least three pint-size samples of the intruding water. The samples should be taken using sterile water sample bottles. These bottles are available at very low cost from water analysis laboratories. After taking the water samples, keep the samples in a cooler with an ice pack and ship them to the laboratory within 24 hours. Have the laboratory analyze each sample for total plate count, total coliform and fecal coliform. The analysis will usually take five to seven days. By this time, the building should be dried.

Compare the laboratory analysis results to the numbers in Table 10. If the results show bacteria levels in the Category 1 range, then very little cleaning and disinfection will be needed. On the other hand, if the numbers are close to Category 3 levels, significant cleaning and disinfection will be needed to reduce bacteria levels to normal ranges.

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