About the Author

Bob Brandys is President of Occupational and Environmental Health Consulting Services, Inc. located in Hinsdale, Illinois.

"Dr. Bob" has a Ph.D. in Occupational Safety and Health, a Masters in Public Health, and dual undergraduate degrees in thermo-mechanical engineering and environmental engineering. He is a Registered Professional Engineer, a Certified Industrial Hygienist, a Certified Safety Professional, and a Certified Mold Remediator.

He has over 30 years of experience dealing with microbial contamination in the safety and environmental field in the pharmaceutical, medical device, biosafety research, clean room and mold remediation industries. His most recent books deal with mold, bacteria and post remediation verification.

HVAC Humidifier Contamination in Unsold Homes

Originally Published in the May 2006 issue of "Indoor Environment Connections"

It is well known that commercial and institutional HVAC humidification systems require acceptable water quality to function properly. Many of these systems use steam that is generated from filtered deionized water. In homes, however, proper water quality for humidifiers is not as well controlled and can be a significant health issue. The health literature contains numerous cases of "humidifier fever" in residential and commercial buildings. This is generally a health condition caused by exposure to various bacteria, endotoxins and fungi that are found in humidifier water reservoirs, air conditioning system evaporator coil drip pans, and even some aquariums. Recently, we were called in on what might be considered the worst-case scenario for residential humidifier water quality. The factors that created this scenario are not uncommon, and it disturbs us greatly that cases like this might be occurring nationwide. There is an old saying, "A rolling stone gathers no moss." However, an unused water supply inside a vacant house can grow all kinds of things.

Frequent use of a plumbing system generally keeps the level of microorganisms in check. Since potable water is not sterile, a background concentration of bacteria will be present in the water. Water system operators are aware of this and they chlorinate the water supply to help curb bacterial growth. The minimum level of free chlorine typically entering a home from the municipal water system is about 1 ppm, which is usually adequate. So how can water quality be a problem in newly-constructed homes?

Many builders never pay attention to the water quality inside water pipes while a home is under construction. It is assumed that the home will sell quickly and what has grown or been left in the water pipes will just flush out once the new home owners use the water systems. However, what happens if the homes do not sell? What if the home is a model home for a community or is on the market for months or years? How bad can the water quality get?

Unfortunately, when a new home is built, it is not unusual for a certain amount of dirt and debris to find its way into the water piping. This dirt and debris provides food for significant bacterial growth if adequate chlorination is not present. Unfortunately, chlorine in the incoming water supply can dissipate through various chemical reactions and lose its disinfecting properties in as little as 24 hours. This means that bacteria growth can begin in an unused potable water system

after just 2 days of inactivity.

Bacterial growth can also accelerate in the new hot water tank. During manufacturing of a new water heater, dirt and debris will often collect in the tank. This debris is not an issue after installation if the water in the tank is maintained above 110 °F and properly flushed before use. But, what if someone left the hot water heater on, but only at a minimal setting, let's say less than 100 °F? Now you have food and water at an ideal temperature for microbial growth.

Next, we add another complication. Let's hook up the humidifier in these new homes to the hot water line. This "microbial brew" from the hot water tank is now being piped directly into the humidification system for the home. (If the humidifier had been hooked up to the cold water line, which is standard practice, the level of bacterial growth would not have been as elevated.)

Finally, the homes are used as model homes for the new development. The heating and air conditioning are functioning so they can be viewed by prospective buyers but the water is seldom used. These homes sit unsold for a number of years. What you now have is a dechlorinated plumbing system full of bacteria, a not-so-hot water heater full of millions of bacteria, and a humidifier that is aerosolizing millions of bacteria into the airspace of a home for years on end. Then, after all the other homes in the community are build and sold, the crowning jewels, the model homes, are finally sold.

The new occupants are exposed to high levels of bacteria in three ways.

1. Bacteria from the humidifier is deposited in the home through the HVAC system. It becomes aerosolized by normal human traffic walking across carpeting and other surfaces.

2. The bacteria in the hot water system becomes aerosolized any time they take a hot shower or a bath.

3. They ingest large amounts of bacteria when they consume water from the tap or refrigerator water dispenser.

When the homeowners turn on their showers, there is a terrible smell. The water from the tap tastes awful and smells bad. Shortly after occupying the home, one homeowner comes down with a gram-negative bacteria infection in his lungs. His condition worsens and he begins using a home nebulizer and steroids.

Homeowner #1 talks to his new neighbor about his condition. Homeowner #2 says that soon after moving into home #2, she also developed a gram-negative bacterial infection and has been on antibiotics for months. She also reports that her children get severe abdominal cramps after drinking the water.

Homeowners #1 and #2 decide to talk to homeowners #3 and #4. These other homeowners also report at least one family member becoming ill after moving into their new homes. They also state that when friends come to visit, they become ill too. The homeowners contact the builder about the water quality, stating they believe it is making them sick.

The builder hires an environmental consultant to test the water. After the test results come back, the builder informs the new homeowners that "traces" of *Legionella* were found in the hot water tank. He says it is nothing to worry about, but he wants everyone to leave their homes, go to the hospital for a check up and move into a hotel at the builder's expense.

The builder's environmental consulting firm then continues to test the homes for mold and

bacteria. The data given to the homeowners on these follow-up tests does not appear to find anything significant. However, the builder tells the homeowners that he will replace the hot water tanks, replace all the carpeting in the homes, and clean and disinfect the homes. The homeowners begin to wonder why all this remediation work is being done at the builder's expense if the reports claim virtually no contamination problems exist. The homeowners became skeptical as their illnesses continue. They consequently decide to contact a lawyer and hire their own environmental consultant to get a second opinion.

Unfortunately, by the time these homeowners contacted us, six months had passed since the start of this situation. Can one assess microbial contamination months to years after it occurs, as in this case?

One of the best indicators of previous levels of microbial contamination is vacuum cleaner dust. There are three studies in the literature that provide guidance on this subject. They are from three different countries. Canada (Microvital, "House dust an efficient and affordable tool to assess microbial contamination in homes, 2004), Germany (Beate, et. al, "Indoor Exposure to Molds and Allergic Sensitization," Environmental Health Perspectives, Volume 110, Number 7, July 2002) and Minnesota (Swaebly, et. al, "Molds in House Dust, Furniture Stuffing and in the Air Within Homes," The Journal of Allergy, 1952). All three of these studies showed similar results: >100,000 culturable mold spores per gram is associated with unhealthy or symptomatic homes. In this case, the Minnesota study that also looked at bacteria levels was most useful. They found an average of 10,000,000 (with a maximum of 20,000,000) cfu of bacteria per gram of dust (or about 100 times higher than the mold spore levels.) This level of >10,000,000 cfu of bacteria per gram of dust is associated with unhealthy homes or symptomatic occupants.

It was fortunate that all three families had put new vacuum cleaner bags into their vacuum cleaners before moving into their new homes. The new homeowners were only in these homes for 2-3 months and the new vacuum cleaner bags were now full of house dust. Three of the four families involved in this situation agreed to have the dust from their vacuum cleaners sampled and analyzed. The vacuum cleaner dust was analyzed for both culturable mold and bacteria. Not surprisingly, the samples were grossly-contaminated. Only the bacteria results are shown in Table 1, but the mold results were also extremely high.

As one can see in this table, the newest home was slightly below the "normal healthy limit" of 10 million, while the older homes were from 20 to >44 times the "average" home level discussed above.

The next piece of evidence was the water quality in the homes. Only two of the homeowners participated in this sampling due to cost limitations. In performing tests of water quality, the methods have somewhat changed in the last 10 years. Historically, water was tested using the Standard Plate Count (SPC) method. However, this method and its type of agar allowed certain fast-growing bacteria to spread over the plate and potentially hide other colonies of bacteria that were slower-growing. Hence, a newer method called the Heterotrophic Place Count (HPC) method using AR-2 agar was developed. This agar slows down the fast-growing bacteria to get a more accurate count of the actual number in the water system. This is the preferred method to use today.

The table 2 shows the tests of the water from these homes.

In order to understand the significance of these waterborne bacteria levels, some applicable

standards for potable water are shown in the table 3.

Clearly, in this situation, the total bacteria level in the potable water exceeded the maximum recommended levels. Also, a majority of the bacteria found were Gram-Negative species. This is troublesome since Gram-Negative species are generally associated with disease in humans. Immuno-compromised persons are at a greater risk of infection from these strains of bacteria.

The next piece of evidence was the initial laboratory analysis reports (from the builder's environmental consultant) claiming only "traces" of *Legionella*. The reports were unusual in that the level of *Legionella* in the hot water heaters was shown as <1,000 cfu/ml and in the water systems it was < 100 cfu/ml. It was also reported that the city found *Legionella* in the water main, but the city did not supply the homeowners with their data. Since the limit of detection for *Legionella* is near 1 cfu/ml, this reporting format was unusual. Looking at this data, one could surmise that the actual *Legionella* concentrations were probably in the range of 50-900+ cfu/ml.

In order to provide some perspective on interpreting these levels of *Legionella* in water, Table 4 shows the US Occupational Safety and Health Administration's (Technical Manual, Section III: Chapter 7, Legionnaires' Disease) recommended limits for *Legionella*. The most usual is the limits for humidifiers. Clearly, based on these OSHA numbers, the *Legionella* present in the hot water system represents a significant exposure risk.

These findings indicate that *Legionella* posed a potential health risk to the occupants of these homes. Further, the levels listed in the Singapore regulations state they apply to healthy individuals. They are not designed to protect immuno-compromised individuals, which include the elderly. Clearly, the decision to recommend leaving these homes was a prudent one.

The last part of this situation was what to do with the homes, the humidifiers, and the water systems to correct the problems. It was recommended that they be thoroughly cleaned and HEPA vacuumed including the HVAC system. The humidifier, hot water tank, and carpeting was also replaced. The challenge then became how to clean the water system.

It was recommended was to reconfigured the hot water system into a recirculation loop with a recirculation pump (this is a common design in custom homes, hotels, and hospitals) and then fully insulate the piping (this should have been done by the builder to save energy).

Then the system should be super-chlorinated. The amount of bleach to be added would be calculated for the total volume of water to super-chlorinate the system. The water temperature would then be increased to 150 °F (maximum setting) and the system constantly recirculated for 48 hours. This should adequately disinfect the piping system and kill of the biofilm.

Then, the "line should be flushed to remove the holding water used to disinfect the line, followed by the introduction of fresh water. If the laboratory results indicate no coliforms present per 100 ml and the HPC is less than 100 organisms per ml, the line is considered acceptable for use. However, if the HPC density within 48 hours of holding at room temperature increases to 1,000 organisms per ml or more, another flushing is in order." (Geldreich, et al., "Microbial Quality of Water Distribution Systems," 1996. p. 245, US EPA, Drinking Water Research Division). If however, the system failed the test due to excessive biofilm retention inside the pipes, the entire piping system may have to be replaced.

What this case showed was that hooking up a home humidifier system to a hot water system set on a low temperature unused home an extended period of time can result in extensive microbial

contamination of a home. Secondarily, potable water systems in homes that are unused for an extended period of time can develop microbial contaminated in both the hot and cold water systems that can pose health risks upon reoccupany, especially for immuno-compromised individual such as the elderly persons and very young children.