Microorganisms are a large group of diverse organisms which are normal in our environment. Some microorganisms are needed to maintain health of people, animals, plants and soil. These microorganisms are called normal flora and under usual circumstances do not cause illness. Other microorganisms cause disease by direct infection or production of toxic compounds, these are called pathogens. In this presentation, I will focus situations and a few specific microorganisms which are of indoor health concern as well as background information on how and why these microorganisms impact us.

**Bacteria**

Bacteria are divided into groups by their shape and how they look under the microscope. One way to put bacteria into groupings is by staining the organisms with a stain called gram stain. Gram positive organisms stain a purple/ blue color and gram negative organisms stain a pink / red color. Another way to divide them up is by their shape. The most common shapes are rods (bacilli) which are usually thin rectangles, and cocci, which are circular. You may have heard of bacteria called Staph, really *Staphylococcus*, these are gram positive cocci, so when stained with gram stain they look like purple/blue circles. *Escherichia coli* (*E. coli*) are gram negative rods which when stained with gram stain look like thin pink / red rectangles.

Gram positive cocci in clusters (17)  
Gram negative rods (18)

Gram negative rods can be divided into groups, one group is called coliforms. Coliforms are further divided into a group called fecal coliforms. Fecal coliform
bacteria are gram negative rods which thrive in the gastrointestinal tract and needed to keep many warm blooded animals (humans) healthy. Common fecal coliforms are: *Escherichia coli*, *Citrobacter*, *Enterobacter*, *Hafnia*, *Klebsiella* and *Serratia*. Other bacteria common in the gastrointestinal tract are a group of gram positive cocci called Fecal *Streptococci*. Examples of Fecal *Streptococci* include: *Enterococcus faecalis*, *Enterococcus facium* and *Enterococcus durans*. (16) The presence of these bacteria outside the gastrointestinal tract are an indication of fecal contamination.

Different bacteria grow best at certain temperature ranges and in certain environmental conditions. Aerobic bacteria require oxygen for growth, facultative bacteria can grow with or without oxygen (reduced oxygen) and anaerobes can’t grow in the presence of oxygen. Bacteria have a broad range of temperatures they are able to survive in, most human pathogens prefer a range surrounding body temperature, 37 degrees C. (1) Temperature ranges have been put into categories, such as thermophillic, for bacteria which grow well at higher temperatures. (19)

The first thermometer shows a mesophilic bacteria’s survival at differing temperatures. The second thermometer indicates the temperature ranges for each category.

Bacteria can survive on surfaces from a few days to several months depending on the type of bacteria and the environmental conditions. The majority of pathogenic bacteria can live for months in humid conditions greater than 70%. Some bacteria produce spores called endospores which increase their chances of survival when environmental conditions are not adequate for growth.

Examples of endospores shown as white inside bacteria (19)
In general, bacteria grow much more quickly than fungi. Some bacteria can reproduce so quickly in a matter of a few hours one bacterium could produce thousands of “offspring”, unlike fungi which could take days to weeks to reach that number. Because of this, bacteria found indoors need to be dealt with on a more urgent schedule than fungi. (2)

<table>
<thead>
<tr>
<th>Time (min)</th>
<th>Bacteria (#)</th>
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<tbody>
<tr>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>20</td>
<td>2</td>
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<tr>
<td>40</td>
<td>4</td>
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<td>60</td>
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<td>80</td>
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<td>180</td>
<td>512</td>
</tr>
<tr>
<td>240</td>
<td>4,096</td>
</tr>
<tr>
<td>300</td>
<td>32,768</td>
</tr>
<tr>
<td>360</td>
<td>262,144</td>
</tr>
<tr>
<td>420</td>
<td>2,000,000</td>
</tr>
<tr>
<td>460</td>
<td>16,000,000</td>
</tr>
</tbody>
</table>

Example of growth rate of bacteria with a growth rate of 20 minutes. (19)

Some bacteria produce chemicals called endotoxins and exotoxins which can cause illness. Other bacteria produce odors called volatile organic compounds (VOC’s). It is unknown if VOC’s cause illness but the odors can be offensive. (1)

Problems occur when bacteria contaminate our food; water and indoor environment. Illness can range from gastrointestinal symptoms of nausea, vomiting and diarrhea to more severe illness or death from toxin producing microorganisms. A strain of E. coli called O157:H7 is a toxin producing bacteria which have caused outbreaks of severe infection.

Bacteria can enter a building in several ways. Sources could be the building materials, building contents, HVAC system, aerosols from outdoor sources, humans and animals. One method of transmission of bacteria throughout a building is accomplished by an infected person or animal contaminating the air (sneezing, coughing) and by touching surfaces. Elevated levels of bacteria normally found on people encountered indoors could indicate insufficient ventilation. This creates a concern in areas that are not crowded or where there is little physical activity. High levels of fecal bacteria, in clean well ventilated areas, may indicate fecal contamination. High levels of Pseudomonas, a gram negative rod, can cause odors and could suggest a source of standing water nearby. (1) Air sampling both indoors
and outdoors, and surface sampling can be beneficial in determining if an indoor concern is present. Outdoor samples are collected to use as a comparison to the indoor results. If a problem exists indoors, there may be a higher number of specific bacteria indoors than outdoors.

**Viruses**

Viruses are smaller than bacteria and unlike bacteria, need to be inside a host cell in order to multiply in numbers. Most viruses require a specific host cell to infect, such as viruses which cause respiratory illness need a host cell in the respiratory system. The virus attaches to the host cell and the viral genes (DNA) are injected into the host cell. The viral DNA becomes part of the host cells genetic information. The viral genes take over the host cell and turn it into a “virus factory”. Once a large number of viruses are made, the host cell releases the new viruses to infect other host cells. Some viruses cause the host cell to release new viruses without damaging the host cell, allowing the original host cell to remain a “viral factory”. Other viruses cause the host cell to burst open releasing the new viruses and destroying the original host cell. (11) Bacteriophages are viruses which require bacteria as the host cell.

Bacteriophage attaches to E. coli and injects the viral DNA into the bacteria (20)

Viruses enter the body through eating and drinking contaminated foods, person to person contact, surface contact and breathing. If a viral particle comes in contact with their specific host cell an infection can result. As with bacteria, environmental factors such as temperature and humidity, determine the length of time a virus can survive without a host cell, ranging from as little as a few minutes to months. (2) (11)
Natural Disasters

Natural disasters have the potential to be a microbiology challenge with possible contamination from bacteria, viruses, parasites and molds (fungi). Flood water is assumed to contain raw sewage as well. In responding to natural disasters, such as the recent hurricanes, some precautions need to be taken to protect you from injury and illness. The hazards you need to consider are sharp and jagged debris, flood water exposure, electrical hazards, chemicals and contact with blood/body fluids from handling animal and human remains. Depending on the circumstances, you need to consider which vaccinations you may need and what type(s) of personal protective equipment (PPE) to use.

You should seek professional advice as to which vaccinations are recommended or required. For disasters in the United States, the CDC requires responders to have current Tetanus and Hepatitis B vaccinations. If you are responding outside the United States, you may also need vaccinations for Hepatitis A, Typhoid, Cholera, Meningococcus or Rabies (14).

PPE are used for 2 reasons, the first is to protect you from the environment. This is the approach you need to follow in cases such as natural disasters, sewage clean-ups, baseline investigations and the removal stages of a remediation project. The level and type of protection necessary varies with the potential exposure to contaminants. Heavy, non-porous suits, boots, gloves and respiratory protection may be required. Self contained breathing apparatus (SCBA) may even be necessary. The second reason for selecting your PPE is to protect the environment from you. You don’t want to carry contaminants into a cleaned or remediated space. During these situations, you may need to use protective coveralls, shoe covers, respirators, gloves and eye protection. This level of PPE protects the remediated area as well as yourself, just in case all the contaminated materials have not been removed.
Sewage Spills

Raw sewage can contain a variety of contaminants such as bacteria, virus, fungi, parasites and chemicals. These microorganisms enter the body through the nose, mouth, wounds and inhalation of contaminated aerosols and dust. Make sure your vaccinations for tetanus and hepatitis are up to date. Appropriate PPE should be used to protect yourself from infection including eye protection, rubber boots, rubber gloves and impervious coveralls or old clothing that will be discarded. Assume everything that has come in contact with sewage water is contaminated. Don’t touch your mouth, nose, eyes, ears or eat, drink or smoke without washing your hands with soap and if available, hot water.

A few examples of your possible biological exposures include:

- **Tetanus** caused by the bacteria *Clostridium tetani*. The symptoms include neuromuscular disease.
- **Leptospirosis** caused by the parasitic worm *Leptospira*. The symptoms include neurological and gastrointestinal disease.
- **Hepatitis**, a liver disease caused by viruses.
- **Giardia** and **Cryptosporidium**, both protozoan parasites, can cause gastrointestinal symptoms.
- **Gram negative bacteria** can cause many illnesses including gastrointestinal and airway symptoms.

The survival time for these microorganisms depends on many factors including the growth requirements for that particular organism. Mild temperatures and high humidity increase the survival time. UV radiation reduces the survival time. As these microorganisms multiply rapidly, immediate response to clean up the contamination reduces the risk of infection as there will be fewer numbers of infectious agents. Make sure the area is safe to enter before beginning clean-up efforts. The areas should be evacuated, if possible windows should be opened and fans or dehumidifiers used to reduce the humidity. Excess water and solid particles should be removed. Items removed from the contaminated area should be placed in plastic bags. Discard any items that can’t be cleaned. Depending on the type of material being cleaned, disinfection can be done with bleach (diluted 1:10) and disinfectants following manufacturer’s instructions for dilutions and exposure time. If possible allow items to dry in a sunny location. Antibacterial cleaners kill bacteria but do not kill viruses and parasites. Some professionals state it is adequate to clean a bacterial contaminated surface with soap and water and air dry. Contaminated soil, sand and lawns will decontaminate naturally if exposed to sunlight. If crawlspaces have become contaminated, some professionals state placing lime on the soil is adequate remediation. (15)
Clearance testing is done by screening for the presence of coliform bacteria. Coliform bacteria include gram negative rods found in the gastrointestinal tract such as *E. coli*. *E. coli* is used as an indicator organism for fecal contamination as it is found in high numbers in feces.

**Standing Water and Legionella**

Standing water is also a source of microorganisms. Many are the same as those found in natural disasters, water losses and sewage spills. Standing water is not aerated and as the level of oxygen in the water goes down, the types of bacteria that reproduce change from aerobic bacteria (requires oxygen), to facultative bacteria (can reproduce with or without oxygen or reduced levels of oxygen), and later to anaerobic bacteria (oxygen not required). Anaerobic bacteria can be the cause of bad odors present near standing water.

Legionella is a type of bacteria which can be found in standing water. It is a gram negative rod which is normally found in water and soil. It becomes a health concern when it grows in water supplies such as cooling towers, water distribution systems, spas and fountains. It is named after an outbreak which occurred during an American Legion convention in 1976. In healthy people, it can cause infection in about 90% of those exposed to a common source and causes a disease known as Pontiac Fever. Pontiac Fever is a flu-like respiratory infection for which most people need no medical treatment and have a full recovery in about a week. In people with other medical conditions, immunocompromised people, it can cause Legionnaire’s Disease in 1 to 5% of those exposed to a common source. Legionnaire’s Disease is a life threatening pneumonia condition which requires immediate appropriate antibiotic treatment. Symptoms develop 2 to 14 days after exposure. Symptoms are high fever, chills, cough, muscle pain and headache. (3) (5)

Public / municipal water systems are often the source of the bacteria. Chlorination techniques used by these facilities does not kill *Legionella* bacteria as the chlorine concentration is not high enough. Legionella grows well in hot water in the range of 80-110 degrees F, which are the same temperatures used by hot water heater systems. When the bacteria enter a water heater system the bacteria can grow. If there is sediment and scaling present in the system and the water flow is slow the growth requirements are present for *Legionella* to prosper. Eating / drinking contaminated water or breathing aerosolized water containing the bacteria are the methods of becoming infected. (4) (5)
Once the water heater system has become contaminated there are several techniques which can be used to reduce the number of bacteria. The methods are superheating the water and flushing the system, hyperchlorinating and flushing the system, installing a copper silver ionization system or installing a monochloramine system. Once the systems have been contaminated periodic monitoring should be performed. (4)

**MRSA**

*Staphylococcus* bacteria are gram positive cocci and are commonly referred to as “staph”. There are several species of *Staphylococcus* bacteria, one of which is *Staphylococcus aureus*. *Staphylococcus aureus* can be found in healthy individuals on the skin and in the nose. About 30% of the population have *Staphylococcus aureus* in their noses and have no illness associated with it. (6)

MRSA is an acronym for methicillin-resistant *Staphylococcus aureus*. What this means is that the bacteria known as *Staphylococcus aureus* has become mutated in a way that it can no longer be killed by certain types of antibiotics such as methicillin. Most strains of (*Staphylococcus aureus* are not MRSA. There is an increase in the documented cases of MRSA infection and it is reported by the CDC that more people in the U.S. die from MRSA than from AIDS. (6) (7)

MRSA infections are usually skin infections which are red, swollen, painful, warm to the touch, filled with pus and accompanied by a fever. Infection is spread through contact with an infected person or contact with objects contaminated by an infected person. The infections are usually due to skin trauma, cuts and scrapes. Infections can also appear on areas of the body covered with hair. Most cases of skin infection can be easily treated.

On rare occasions serious infections such as pneumonia, blood stream infections (septicemia) and bone infections can occur in healthy individuals. (6)

MRSA infections used to be associated with hospital settings, but now there have been infections in other settings among healthy individuals. These community associated infections have put MRSA in the news. These illnesses have been associated with situations of crowding. MRSA is spread by skin to skin contact with an infected person, touching an object an infected person touched, and lack of adequate cleaning. These criteria put schools, dormitories, gyms, locker rooms, military barracks, day care centers, airports and public transportation among the areas of potential infection sources. (6)

MRSA can survive on surfaces from hours to months depending on the type of surface, temperature, humidity and cleanliness. You can help protect yourself from infection by using good hygiene. Wash your hands with soap and hot water, rubbing vigorously for at least 15 – 20 seconds. The soap does not have to be antibacterial, but liquid soap is better than bar soap as there is a lower exposure risk. If soap and water are not available alcohol based hand sanitizers containing at least 60% alcohol are useful. Shower after exercising and do not share bars of soaps or towels. Wash
exercise clothing with the warmest temperature recommended by the manufacturer after each use and dry completely in a dryer. Cover skin trauma with a clean dry bandage until healed. Avoid sharing objects or cover shared items with a protective barrier (ex: cover skins on computer keyboards, placing towels on exercise equipment and saunas). Clean touched surfaces regularly with detergent based cleaners or EPA registered disinfectants, see epa.gov/oppad001/chemregindex.htm for a list of approved cleaners and follow the manufacturer’s recommendations for cleaning methods, concentrations and exposure times. (6) The California Department of Public Health and the CDC does not recommend any additional precautions when there are multiple cases of MRSA in a public location other than a thorough cleaning and education on proper hygiene and wound care. (10).

(27)

There is controversy as to whether antibacterial consumer products, soaps, household cleaners, etc., are helpful or a hindrance to the environment and our health. Most antimicrobial soaps and household cleaners have low concentrations of the chemical triclosan, between 0.1 and 0.45% weight/volume. Some studies have shown this concentration of triclosan has little or no effect on killing bacteria. Still being studied is the possibility that this chemical is allowing some bacteria to develop resistance to triclosan and even to some antibiotics which target the same receptors on bacteria. This in turn could lead to increasing the number of bacteria resistant to some antibiotics. (8) Also being studied, is the possible association between exposure to microorganism during childhood and a decrease in allergies later in life. It is possible the immune system needs to be challenged at an early age to allow for the immune system to mature adequately. (9)
Norwalk Virus

Norwalk Virus and Norwalk –Like Viruses, can contaminate food and water and cause gastroenteritis. These particular viruses can survive over a large range of temperatures and high concentrations of chlorine which allows water sources to become contaminated. In an outbreak of infection, the first cases of infection are usually caused by fecal contamination of food or water by an infected person or food grown or prepared with contaminated water. Shellfish such as oysters and clams have been associated with infections because cooking with steam may not destroy all the virus particles. Later cases in the outbreak are usually caused by person to person contact through inhalation of the virus particles and touching contaminated surfaces. Illness begins from 12-48 hours after becoming infected and symptoms include nausea, vomiting, diarrhea, headache, fever, chills and weakness lasting 12-60 hours. Normal healthy individuals have no long term health effects from the infection. On rare occasions, severe dehydration can cause death in the elderly, the young and immunocompromised people. (12)

Low number of virus particles can cause infection so the infectivity rate is high. People can be carriers and are contagious without ever having symptoms of the disease. It is unsure how long people are contagious after recovering from the illness. Outbreaks have occurred in restaurants, nursing homes, hospitals, schools, day care centers, prisons and vacation settings such as cruises. (12)

Cruise ships are a perfect setting for outbreaks. These ships often dock in countries where sanitation may be inadequate. Contaminated supplies such as food and water from these ports are brought aboard and the close person to person contact on ships increases the risk of infection. With the ever changing population of passengers, there is also the risk that asymptomatic infected passengers can spread the infection. (12)

Persons involved with cleaning during and after an outbreak should be educated in good hygiene and wear masks and gloves. In situations where repeated outbreaks have occurred it is possible the facility may have to be closed until adequate cleaning can be performed. (12)

Conclusion

In closing, we have covered some introductory information about bacteria and viruses. We covered in more detail a few specific species of bacteria remediation workers need to be aware of. We also addressed the potential risk to yourself when responding to emergency situations. Remember, it is important to protect yourself from the environment and to protect the environment from you.
References