Sample Questions and Answers
by Dr. Aaron Margolin, PhD Microbiology

Prepared for the Shenandoah County, Virginia Sludge Panel

1. What kinds of pathogens are associated with sludge?

There are many different types of pathogens in sludge. For classification purposes, they can be divided into three groups. The bacteria, viruses, and intestinal eukaryotic organisms (usually known as the intestinal protozoa, even though all are not in the protozoa grouping).

The attached memo dated 3 June, 1997 from the US EPA National Exposure Research Laboratory adequately addresses the different types of bacterial pathogens. As per viral pathogens, this group includes: the enteroviruses (Poliovirus types I, II, & III, Coxsackie viruses A & B, Echovirus and Hepatitis A virus {there are more that make up the enterovirus group, but these are the major human pathogens in that group}); Rotavirus; Norwalk virus; small round structured viruses; Astrovirus; Adenovirus and probably Reoviruses.

There are most likely other viruses in sludge which are shed in fecal material but have not been documented either due to poor analytical techniques or because no one has ever bothered to look for them. The last group are the intestinal eukaryotic organisms. These include, but are not limited to the helminths and protozoans.

The major human pathogens in this group that are usually considered include *Ascaris*, *Cryptosporidium*, *Giardia* and *Toxoplasmosis*. Once again, there are probably others such as *Cyclospora*, *Mycrosporidia* and a host of other organisms which can cause intestinal "amoebic like" infections and end up in sludge, such as *Entamoeba histolytica*. These others may not occur on a regular basis and may be influenced by the geographic area to where the sludge is produced, i.e., proximity to third world countries such as Mexico or the amount of immigrants living in a specified area and where the immigrants have migrated from. Also, these pathogens are not routinely checked for in the 503 examination of sludge and I personally due not know their frequency of occurrence or studies that have demonstrated their frequency of occurrence, but these studies may exist.

The technology for detecting the above mentioned pathogens is always advancing and is never in a state of "absoluteness". As the technology improves, so does the research identifying the different pathogens. For example, it is still impossible to grow Norwalk virus in cell culture. While molecular techniques such as PCR are able to demonstrate the presence of viral nucleic acid, without the use of a living host, it is not possible to determine if the virus is infectious or not, i.e., presents a penitential public health risk.

Determining the concentration of pathogens in sludge is also not an absolute science. Many of the pathogens of interest are associated or complexed with the sludge, so it is very difficult or even impossible to get accurate concentrations of the pathogen. In addition, all analytical techniques have a lower limit of sensitivity for pathogen detection. This also prevents absolute enumeration and hence, when pathogens are not detected it is more accurate to say that pathogens were not detectable based on the current technology rather than saying that they are not present.

2. What are the possible diseases transmittable by pathogens in sludge?

There are health risks associated with exposure to pathogens present in sludge--ranging from sub-clinical (barely detectable) to life-threatening, including generalized viremia, aseptic meningitis and myocarditis.

As set forth above numerous organisms of concern to health in biosolids, including Salmonella, Shigella, Vibrio, Yersinia, Camylobacter, hepatitic A, Norwalk virus, roravinis, coxsacuckii viruses, and Croptosporidium.

Pathogens in sludge include pathogens as to which compromised individuals typically succumb to--including pneumocystic carnii pneumonia, disseminated mycobacterium avium and M. kansasii, eoxoplasomosis, histoplasmosis, cryptococcosis and coccidioidomycosis.

Other identified diseases caused by enteric viruses and protozoa in sludge include epidemic and acute gastroenterities with severe diarrhea, fever, cold-like symptoms, respiratory infactions, dysentery, giardiasis, encephalitis, paralysis, poliomeyelitis, pneumonia, toxoplasmobis and infectious hepatitis.

It is important to realize that society is made up of different groups of individuals which present different levels of susceptibility such as the immunocompromised, very young and the elderly.

3. Who is most at risk when exposed to pathogens in sludge and what are those risks?

Considerable literature indicates that children, the elderly and those with compromised immune systems are at the greatest risk. The same literature indicates that compromised immune systems include individuals who have taken steroids (allergy suffers, athletes and others who have suffered injuries) as well as those suffering certain illnesses. Death is thought to be the most serious risk as well as an outcome of infection.

4. Is there currently a way to measure or fully assess pathogen risks related to land sludge applications?

Assessing pathogen risk in land application of sludge is extremely difficult and is further confounded by the lack of adequate funding to do the necessary studies. It has been demonstrated in the laboratory that depending upon the type of pathogen, the resulting outcome will be different once it is applied to the land. This is due to the characteristics of the pathogen, the land, the soil and the surrounding environmental conditions .

For example, bacterial pathogens have the ability to multiply outside of the human host, where viruses cannot, they require a living human host. All of the pathogens are susceptible, to varying degrees, to inactivation from UV light, heat, dessication, pH and to the surrounding microbial flora. Additionally, different pathogens move through the soil in different ways.

This should not be confused with movement through fissure or openings in the surface of the earth that provide a direct passage of the pathogen to the underground aquifer. This is not considered movement of pathogens through the soil.

Pathogen movement through the soil is usually confined to only the viruses. Most of the other pathogens are retained by the top layer of the earth, assuming that the layer is sufficient to retain bacterial, protozoal and helminth pathogens. It is difficult to determine how thick this top layer should be because in large part, other factors such as type of soil and the inactivation factors mentioned above contribute to the survivability of such pathogens once applied to the soil.

But in general, the bacterial, protozoans, and helminths are thought to be too large to migrate very far into the soil. The viruses on the other hand behave much differently. They are small enough that they can penetrate the soil and are retained not by size exclusion properties, but by electrostatic interaction of the outer protein coat of the virus and the soil particles. This electrostatic interaction is in part, influenced by the overall cation concentration. As the cation concentration changes, i.e., decreases due to a large rain event which would dilute the overall cation concentration, viruses can be released by the soil particles they are attached to and move through the soil.

Additionally, since viruses are not living organisms, as we define life, once they become associated with particles found in the soil and under the correct environmental conditions, they can survive much longer then the bacteria, protozoan or helminth pathogens.

5. What are the possible ways of pathogen transmission following land application of sludge?

Essentially there are three ways pathogens found in sludge can enter the body, either by ingestion, inhalation or through penetration of the body. i.e., through the skin. Depending on the type of pathogen, route of entry can influence the resulting infection.

6. How long can pathogens survive following land application of sludge?

See Answer #4.

7. How far can pathogens travel following land application of sludge?

See Answer #4.

Scientific studies have shown some pathogens to have broken through 6 or 8 foot packed soil columns after about 45 days. Field tests have shown migration several feet through the soil. Pathogens have been shown to travel long distances in ground water and aquifers. Pathogens have been found in deep wells near land application sites. The impact of airborne transmission distances or other sources such as birds and mice is not clear.

According to a University of Arizona Study, significant numbers of pathogens can exist in sludge even after stabilization and treatment. If they remain viable for extended periods of time, land applications sites and groundwater beneath such sites can become contaminated.

8. Why does 503 prohibit human public access to land application sites for 3 years; prohibit animal grazing (30 days for cattle, 18 months in some states); and restrict eating of food grown on land where sludge applications have been made.

I can only comment on the pathogen part of this. Pathogen survivability in soils as I stated earlier is influenced by many factors. I will not try to second guess where, why and how the EPA came up with their figures.

9. To what extent are pathogen risks reduced if 503 standards are followed?

Assuming 503 requirements are met, it remains unclear how much risk remains. Apparently 503 does not provide for any test indicator for pathogens other than bacteria, and bacteria has the shortest life span. There also appears to be little science to demonstrate the impact of 503 when it comes to many pathogens in sludge. Accordingly to Dr. David Lewis of US EPA, consideration should be given to prohibiting applications during weather conditions that are conducive to transporting microbial contaminants via air and water.

10. What is the impact if sludge is stored after it was treated to meet 503 standards?

Bacteria can multiply during periods of storage. The extent to which they may multiply depends on conditions. Further testing is the only way to determine how much they may have multiplied during storage.

11. Is it a reasonable precaution to provide immune compromised individuals living in the areas with notice of scheduled land sludge applications so they have the opportunity to remove themselves from harm's way?

Warnings to immunocompromised individuals is a social rather than a scientific issue. Others have made such recommendations, including US EPA officials. In theory, it would be applicable to warn those at the greatest risk prior to the land application of sludge. In practice though, how does one define who is at greatest risk?

The term immunocompromised is a very nice term, but how would this be defined. Studies have shown that factors such as nutrition, stress and the overall state of health do alter ones immune system, are these individuals then considered immunocompromised? Additionally, how does a parent determine what age their child's immune system is capable of effectively fighting off infection? And does any parent ever really want to make that decision? Does warning immunocompromised individuals create a two class society?

I do not have answers to these questions, and my own values as a parent would question any parent who might say, he/she is old enough to put into potential harms way. That is why I do not think one can realistically differentiate between immunocompromised individuals and so called healthy individuals at the level you are speaking of.