Biosolids and Odor

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Even those people who regard municipal biosolids as a wonderful resource would be hard pressed to classify their odor as innocuous. For those who question the safety of biosolids, their odor is proof that beneficial use of biosolids is an unsafe practice. There are two important aspects to this contentious issue, the particular aromas of biosolids. The first relates to how people perceive odors and the potential for bad odors to make people sick. The second relates to why biosolids can smell so bad and what can be done to make them smell better.

First it is important to understand what odors are. All compounds can exist in three different forms: solid, liquid or gas. Water is one example of this that everyone is familiar with. While the liquid form of H2O is the most common, all of us know the solid form that we occasionally see in the winter or take out of trays in from the freezer. We also know that when excess H2O is in the air, a hot day gets really uncomfortable. While water in its vapor or gaseous form has no detectible odor, many other compounds do. Our ability to detect odors and our sensitivity to them varies from individual to individual. There are some individuals who have keenly developed abilities to detect odors. And there are industries based on creating odors. The perfume industry was the first of these industries and has expanded to the flavor industry providing the aromas and flavors for the processed food that we eat. Our noses are powerful tools for alerting us to potential dangers. If food smells bad, we know that it is dangerous to eat.

Next it is important to understand if and how odors can make you sick. Many compounds that smell bad can also be very bad for you, even lethal if present at sufficiently high concentrations. However, we are generally able to smell these compounds at concentrations several orders of magnitude lower than the levels documented to cause harm. For example we can detect ammonia at levels between 0.7 and 3.8 ppm. However, the OSHA 15 minute exposure limit is much higher, 35 ppm. Ammonia concentrations in air of 400 ppm will cause immediate throat irritation and at concentrations of 5000 ppm, ammonia in air is toxic. For ammonia, toxic concentrations are close to 10,000 times higher than concentrations that are high enough for us to notice the smell.

Many household cleaning products, including this Windex, contain ammonia

However, as malodors have been a sign of danger, in our world, malodors are also linked to illness. The question is whether this association is based on a perceived relationship or whether there is an actual cause and effect between malodors and ill health. There is an anecdotal association between bad odors at sub acute exposure levels and a range of ailments. When exposed to odors that people consider unpleasant and/or unhealthy people will generally complain of a range of ailments including eye, nose and throat irritation, headaches, nausea, diarrhea, sore throat, cough, chest tightness, nasal congestion, stress and shortness of breath (Shiffman and Williams, 2005). Odors are also used by physicians as symptoms for the diagnosis of a range of ailments. People give off certain odors (characteristic of different chemicals) when they have particular diseases and doctors will take these into account when trying to diagnose a patient. However, up until recently, the potential for odors to actually cause physical health problems at levels below what is generally considered hazardous, hasn't been recognized.

In attempting to understand if odors can actually cause physical problems there are three potential mechanisms to consider. One of these mechanisms is somewhat akin to the classic chicken and the egg question. Volatile compounds that are odorous can also cause irritation. Generally the concentrations necessary to be aware of the smell are lower than the level needed to cause irritation. Once the irritation level has been reached, odor is also obvious. In this case the irritation is actual although odor is also perceived. Here, the irritation is the cause of the illness and the perception of odor works as in indicator of exposure. This mechanism often occurs when the irritation threshold is less than 10 x higher than the odor perception threshold.

Secondly, health problems can result because of learned aversions to particular odors. We have learned that certain odors are bad and are linked in our minds to health problems. When we smell those odors, we immediately associate them with illness. For this case, although the odor threshold has been reached, the compounds are below irritant thresholds. Finally, there may be something that travels with the odors that is itself the cause of the health problem. If the odor is part of a mixture of compounds that have been released into the environment, some of those compounds may be responsible for health problems rather than the ones that smell (Schiffman and Williams, 2005).

Only the nose knows

A little background on how we perceive odors may help to clarify these different mechanisms. An odor is a sensation, like sight and touch. We can perceive of odors in two different ways. In one case, odor receptors that are located in our noses at the top of the nasal cavity will be stimulated by the odor. They will send a signal using the olfactory nerve to the brain via the olfactory bulb. The sensations that are communicated to the brain are generally described with words like earthy, fishy and fecal. In the second case, odors can stimulate free nerve endings in the nose, throat or lungs. When these nerve endings are stimulated, physical symptoms including itching burning and irritation will be felt. For the first potential way that odors can be related to illness, reaching the irritation threshold as well as the odor threshold, both sets of receptors will be activated. This will occur at the irritant threshold for single compounds but can also occur when mixtures of compounds are present at sub irritant concentrations (Cometto-Muñiz et al., 1997, Korpi et al., 1999). This will also typically be the case when the concentration required to reach the irritation threshold are close to those for the detection threshold.

In some instances people report illnesses when odors are present above the detection threshold but well below the irritant threshold. One example of this is the range of dilute sulfur compounds. We can smell hydrogen sulfide (H_2S) at concentrations that are 100 to 1000 times lower than those that cause irritation (Schiffman and Williams, 2005). Six studies of communities that have been exposed to low levels of H_2S and other reduced sulfur compounds have found health effects at very low levels of exposure. There are several potential reasons why this may have occurred. One that makes a lot of sense is that when we are confronted with an unpleasant odor, our breathing habits will change. We will take shorter and shallower breaths to reduce our exposure to the bad smell. Irregular breathing can be detrimental. We will also tend to experience increased stress, tension and depression when exposed to malodors. This also makes sense as these odors are an offensive intrusion that can reduce quality of life. Shiffman and Williams (2005) also point out that that our aversion and sensitivity to compounds that contain reduced sulfur may have more fundamental roots. We generate H_2S internally through breakdown of amino acids. A small internal increase (less than 2X normal internal concentrations) in H_2S concentrations can be lethal with even smaller increases resulting in behavior changes.

Wetland soils often give off volatile reduced sulfur compounds as a result of anaerobic decomposition of organic matter. This class of compounds has been associated with health complaints at very low concentrations, well below what has been identified as the irritant threshold

For biosolids, recent work on bioaerosols has indicated that the third mechanism relating odors to illness: co transport of disease causing compounds or bacteria with odorous compounds is not a possibility. However, odors from biosolids may cause illness after short exposure via the first mechanisms- reaching the irritant threshold, and via the second mechanism- extended exposure to reduced sulfur compounds below the irritant threshold but above our detection ability. The next step is to describe the types of odors that are released by biosolids and where they come from. Finally methods to reduce odor emissions from biosolids will be described.

Biosolids contain high concentrations of sulfur, with total sulfur concentrations in biosolids ranging from 0.7 to 2.1% (Sommers et al., 1977). Over half of the total sulfur is in different organic forms (bonded to different carbon configurations that originated from microbial biomass) with the remainder of the sulfur generally bonded to hydrogen (Sommers et al., 1977). Biosolids are often anaerobically digested to both reduce pathogen concentration and volume. What this means is that the organic matter in biosolids is partially decomposed by microorganisms in large anaerobic digestors. Here different microorganisms use the carbon compounds in the biosolids for energy, the same way that we eat food for energy. In the breakdown process, not all of each compound is eaten by the microbes. In particular, much of the sulfur that is present in the organic compounds is released as different compounds that are volatile, or can become gas. In addition, the sulfur that is bonded by hydrogen is methylated. This means that as the microbes eat different compounds, they also release methyl compounds. Methyl compounds are made up of three hydrogen atoms and one carbon atom. Some of the methyl groups will form bonds with the sulfur that is bound to hydrogen. These compounds are also volatile.

After the anaerobic digestion of the biosolids is complete, the biosolids will be ready for land application. Many municipalities use different equipment to help reduce the water content of the biosolids so that they will have less material to transport to agricultural fields. Dewatering is often done using a belt filter press that squeezes water out of the biosolids. Some wastewater treatment plants also use high- speed centrifuges. These spin the biosolids around at high speeds. The heavier solids will sink to the bottom and the lighter water will rise to the top and be removed.

When the biosolids go to agricultural fields, they still consist of anywhere from 65 to 95% water. The microbial decomposition of the organic matter has slowed down, but is still going on. In some cases including centrifuged biosolids, the process of centrifuging the biosolids has broken apart the cells of the microbes, releasing a range of organic compounds that are delicious food for living microbes to eat. What this means to the nose of anyone at an application site is that volatile sulfur compounds are still being released by the biosolids and that they can smell really bad. The bad smells that come from biosolids are generally the result of a combination of different odorous sulfur compounds and ammonia. These sulfur compounds include dimethyl disulfide, dimethyl sulfide, hydrogen sulfide and carbon disulfide (Banwart and Bremner, 1975). None of these compounds smell good, with descriptions of their odors ranging from rotten cabbage (dimethyl disulfide) to rotten eggs (hydrogen sulfide). Our detection ability for these compounds is also generally very low at less than 1 part per billion (Ruth, 1986). The prevalence of these sulfur compounds also suggests that people who report feeling ill after being exposed to biosolids may be responding to the second category of how odor and illness are related: when the odor threshold is significantly lower than the irritant threshold. The example used to describe this situation by Shiffman and Willams (2005) was reduced sulfur compounds. Elevated internal concentrations of elevated sulfur compounds can be lethal. We are most likely conditioned to have such pronounced reactions to these compounds because of this. Even though these compounds are being produced far away from the interior section of our brains, our reaction to them is occurring inside our brains. Our aversion and revulsion to these compounds may be based on this phenomena.

How to make biosolids smell better

In the early days of land application of biosolids, even though program managers recognized that their product did not have a consumer friendly aroma, many considered odors to be the least of their concerns. Emphasis was placed on reducing metal concentrations as high metals were seen as one of the greatest obstacles to public acceptance. Odors were also not viewed as a high priority because most of the farmers that used biosolids were happy to tolerate odor in exchange for a high quality fertilizer and soil conditioner. Realize that for most farmers, odors are a part of normal day to day operations. All of the farmers that had had some exposure to animal manures realized that odors are just a standard characteristic of organic fertilizers.

As metal levels have drastically decreased and as farmland in many areas has become surrounded by exurbs, odors in biosolids have become a primary concern for most program managers. The Water Environment Federation, a non-profit organization that serves the water treatment industry is currently sponsoring a multi- university research initiative to understand where odors originate in biosolids treatment processes and what variables can be altered to minimize odors. Although in its early stages, this work has shown that things including iron concentration and form of iron in the biosolids can have a major impact on severity of odors. It is hoped that this research will provide a list of process variables that can be controlled to reduce odor generation.

In the meantime, different municipalities are working independently to identify ways to reduce the odors from their biosolids. For example, DCWASA (District of Columbia Water and Sanitation Authority), the wastewater treatment authority for the District of Columbia and parts of Maryland uses lime addition rather than anaerobic stabilization to kill the pathogens in their biosolids at their Blue Plains treatment plant. Chris Peot, the manager of the plant, realized how serious malodors were to the general public living near agricultural application sites. He carried out his one experiment: he put fresh fish in a number of plastic bags and kept in under his kitchen sink for two weeks. He opened the bag and compared the odor to the biosolids produced at the treatment plant. He was struck by the similarity of the odor between the rotten fish and the biosolids. Mr. Peot has since worked with the treatment plant operators to identify sources of odor in the treatment process. They have discovered that improved mixing of lime into the biosolids and more consistent rates of lime addition is an effective way to reduce biosolids odors. They have also a team of odor guys at field sites. It is their responsibility to record severity of odors during application. If a batch of biosolids is unacceptably odorous, it is sent to the landfill. This combination of in house controls and a field team has effectively reduced odor complaints and made for a better program.

Malodorous biosolids can smell very similar to rotten fish- a characteristic that wastewater treatment plant operators are trying very hard to overcome

In another case, the City of Tacoma produces a biosolids cake that first aerobically digested to kill pathogens and then anaerobically digested to reduce volume and increase stability that is sold to homeowners and landscapers in the city. Fresh of the belt filter press, the biosolids does not smell like anything a gardener would want to put their hands in. By mixing the cake with sand, sawdust and aged wood, the City is able to produce a consumer friendly product that smells of earth and ammonia. All traces of rotten cabbage and rotten eggs are gone.

TAGRO Mix components: sawdust, screened sand and biosolids.