

Land Application Odor Control Case Study

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ABSTRACT

The Western Lake Superior Sanitary District (WLSSD) operates a 40 MGD wastewater treatment plant in Duluth, MN which produces 27,000-29,000 wet tons of cake biosolids annually using a temperature phased anaerobic digestion (TPAD) process followed by dewatering with high solids centrifuges. These biosolids are spread on 1800-1900 acres of agricultural land (80-85%) and mine land reclamation sites (15-20%) annually in a year-round land application program.

During the spring of 2003, WLSSD received several comments from farmers expressing that biosolids odors were upsetting neighbors surrounding land application sites. To gain a better understanding of biosolids odors in the field, WLSSD conducted a study during the summer of 2003 to document odor strength, extent and duration at 18 agricultural land application sites. The study was conducted using a Nasal Ranger field olfactometer developed by St. Croix Sensory.

Biosolids odor strength at and around land application sites was influenced by a variety of factors, including distance, time, weather conditions, and application method. In order to minimize biosolids odor impacts to the people living around land application sites, WLSSD will develop an odor control and response plan based on the data collected and will continue to track the circumstances surrounding odor complaints.

KEYWORDS: biosolids odor, olfactometer, land application odor

INTRODUCTION

Background

WLSSD operates a 40 MGD wastewater treatment plant receiving 50% industrial and 50% domestic wastewater. The primary industrial contributor is a kraft paper mill. The treatment process train consists of screening, grit removal, and pure oxygen activated sludge. After clarification, the clean water is filtered and discharged to the St. Louis River Bay. The settled activated sludge is thickened with dissolved air flotation, digested using a temperature phased anaerobic digestion (TPAD) process, and dewatered with high solids centrifuges.

The primary digester of the TPAD process is maintained at 131 degrees Fahrenheit. The secondary digesters are operated at cooler temperatures. Depending on the season, the temperature range of the secondary digesters is 100 to 125 degrees Fahrenheit. The typical volatile solids reduction for the digestion system is 44%.

To control the hydrogen sulfide levels in the digester gas, ferric chloride is added to the primary digester. The ferric doses typically range from 60 to 80 pounds of ferric chloride per dry ton digested solids. The resulting sulfide levels in the digester gas stream are less than 30 ppm.

Digested sludge is dewatered with high solids centrifuges using emulsion polymer as a flocculant. The cake solids are typically 29% total solids.

Typical digester and centrifuge parameters are summarized in Table 1. Biosolids characteristics during this study are summarized in Table 2.

Table 1 - Typical Digester and Centrifuge Operating Parameters

Operating Parameter	Averages or Range
Ferric dosage, lb ferric chloride/dry ton digested solids	60-80
Primary Digester Temperature, degree Fahrenheit	131
Secondary Digester Temperature, degree Fahrenheit	100-125
Primary Digester Solids Retention Time, days	7
Secondary Digester Solids Retention Time, days	21
Polymer dosage, lb active polymer/dry ton solids	30-50

Table 2 - Biosolids Characteristics

Biosolids Characteristics	Average	Range
Total Solids	29.2	28.8-29.6
Volatile Solids, % dry weight	64.1	61.5-67.1
pH	-	8.8-8.9
Kjeldahl Nitrogen, %	4.8	4.5-4.9
Ammonia Nitrogen, %	1.0	0.94-1.1

Dewatered biosolids are typically stored at the WLSSD facility for less than a week, although occasional weather related shut downs have increased the storage time to several weeks. The biosolids are staged at land application sites for short periods, in general, one day to one week. Minnesota Sewage Sludge Management Rules (Minnesota, Chapter 7041) allow a maximum storage at an application site of 30 days.

WLSSD biosolids are applied year around primarily on agricultural land. The exception is during the spring thaw, at which time, biosolids are used in mine land reclamation projects.

Reason for Study

WLSSD successfully completed the start up of its digestion system in July 2001, at that time decommissioning their former incineration system and biosolids lime stabilization processes. Since then, WLSSD has operated a year-round land application program.

Until recently, WLSSD had received minimal complaints from farmers about the odor associated with the TPAD biosolids. In the spring of 2003, WLSSD received several comments from farmers expressing that biosolids odors were upsetting neighbors surrounding land spreading sites. Farmers and WLSSD staff became concerned about a possible change in odorant production associated with the biosolids.

To gain a better understanding of biosolids odors associated with land application events, WLSSD conducted a study during the summer of 2003 to document odor strength, extent and duration at agricultural land application sites.

METHODOLOGY

Odor measurements were recorded at all of the WLSSD land application sites receiving biosolids between May 16 and July 16, 2003. Using a field olfactometer, the odor strength was measured at these sites as Dilution to Threshold (D/T) ratios, a dimensionless measure of odor concentration. Other odor parameters were also noted, including descriptions of the odor's character, intensity and offensiveness. Weather conditions were recorded.

Dilution to Threshold Odor Measurements - Field Olfactometer

Odor measurements were recorded using a field olfactometer.

In 1958, 1959, and 1960 the U.S. Public Health Service sponsored the development of an instrument and procedure for field (ambient) odor measurement through Project Grants A-58-541, A-59-541, and A-60-541. The instrument, originally manufactured by Barnebey-Chaney Company and subsequently manufactured by Barnebey Sutcliffe Corporation is known as a "Scentometer" (Huey, et al., 1960).

A field olfactometer dynamically dilutes the ambient air with carbon-filtered air in discrete "dilution ratios." The U.S. Public Health Service method defined the dilution ratio (dilution factor) as "Dilution-to-threshold," D/T. The Dilution-to-threshold is a measure of the number of dilutions needed to dilute the odor to the threshold. The method for calculating the "Dilution-to-threshold" (D/T) is:

$$D/T = \frac{\text{Volume of odor free (filtered) air}}{\text{Volume of Odorous Air}}$$

Odor strength for this study was determined using a Nasal Ranger Field Olfactometer developed by St. Croix Sensory (Lake Elmo, MN). Figure 1 is a photograph of the Nasal Ranger field olfactometer.

The Nasal Ranger measures odor D/T values of 2, 4, 7, 15, 30, and 60. An air flow sensor allows the user to use a standard inhalation rate to ensure that the volume of air used for each measurement is between 16 and 20 liters per minute.

Odor detected at the orifice setting for 2 D/T, but not at 4 D/T, is assigned a value of 2 D/T. This is similar for other settings. Odors recorded at the orifice setting of 60 are at least 60 D/T but could be significantly higher.

St. Croix Sensory recently developed a high value D/T dial which measures Dilution to Threshold Ratios of 60, 100, 200, 300, 400, and 500. The high D/T dial is still being tested. It is uncertain whether or not such high values can be measured accurately in the field. WLSSD utilized this dial at several sites near the end of this odor study.



Figure 1 -The Nasal Ranger® Field Olfactometer (St. Croix Sensory, Inc.). The inset picture shows a close-up of the orifice dial, which is located to the right side of the Nasal Ranger in this photo.

Odor Regulations

Currently several U.S. states regulate nuisance odors based on the field olfactometer method. For example, the state of Colorado has Regulation No. 2, “Odor Emissions”, where Part A states “...it is a violation if odors are detected after the odorous air has been diluted with seven (7) or more volumes of odor free air.” This means that if the field olfactometer user detects the odor at the position $D/T = 7$ or higher at or beyond the property line, then the facility is in violation of the odor rule.

Other states which have a limit of $D/T=7$ include Connecticut (Reg. 22a-174-23), Illinois (Title 35, Subtitle B, Chap.1, Part 245), Kentucky (Reg. 401 KAR 53:010), Missouri (several sections in Title 10), Nevada (NAC 445B.22087), and Wyoming (Ch. 2, Sec.11)

“Nose” Calibrations

In order to standardize the olfactometer measurements, all users have their “noses” calibrated to determine their olfactory threshold or level of odor sensitivity. This calibration was conducted using an Odor Pen Testing Kit, which includes “Sniffin’ Sticks” odor pens (Burghart - Germany) and the “Standard Procedure for Testing Individual Odor Sensitivity” developed by St. Croix Sensory. These odor pens contain 14 levels of increasing concentration of n-butanol. The test uses an ascending concentration series, triangular testing procedure. At each concentration level, the individual being tested is blindfolded and must sniff one of the odorous pens and two blanks

in a random order and indicate which pen contained the odor. The test is repeated several times with different strength odors to determine the test subject's olfactory threshold.

For this study, one person collected the field data at all land application sites.

Odor Characterization

Odors encountered in the field were characterized by description, offensiveness, and intensity. Biosolids have a distinct earthy, ammonia like odor which can easily be identified. Odors that were not caused by biosolids, or that were a mixture of biosolids and non-biosolids odors, were identified and described. Odors were rated in intensity and offensiveness as either low, moderate, or high.

The olfactometer measurements for non-biosolids odors were recorded during this study.

Locations of Odor Readings

In order to determine what conditions are conducive to high odors, sampling was deliberately carried out under a variety of weather conditions and during varying times during the day and early evening. During the course of the summer, samples were taken at least one day a week and many times two or more days during a week. All sites were visited during different stages of the land application process and in the weeks following until they repeatedly produced little or no odor. The length of time the biosolids were staged at the site, as well as whether biosolids were stockpiled, surface applied or incorporated was noted.

Odor data were taken at standard locations at each site. For every biosolids field site, measurements were taken at each property boundary, the nearest road, and the nearest house. In cases where the property boundary could not be determined or accessed, the furthest field boundary was used for the property boundary measurement point. In one case, the nearest receptor was a church. Since all of the houses in the area were protected by windbreaks or too far away to be affected by odor, the church property was used for the nearest house data measurement.

Additional odor data were collected when more than one receptor was close to a land application site. After the biosolids were spread, odor measurements were collected only at accessible property or field boundaries.

If a stockpile of biosolids was present, measurements were taken directly upwind and downwind of the stockpile in order to characterize the odor plume line. Odor measurements for the plume line were taken at points 2 ft upwind of the pile, 2, 20, 40, and 60 ft downwind of the stockpile and at the downwind property boundary. In cases where the property boundary was unknown or inaccessible, the last plume line measurement was taken at the field boundary. Since the plume line changes with the direction of the wind, measurements were taken at different locations each day the plume was analyzed.

Multiple Olfactometer Measurements at the Same Location

To reduce the chances of high odors being missed due to fluctuations in wind speed, wind direction, or other odor affecting factors, three or more D/T readings were taken at each

measurement location. All readings were entered into the database, but unless otherwise noted, only the highest of the three readings per measurement are used in data analysis presented in this report. Readings less than 2 D/T are shown in charts as 1 D/T.

Weather Conditions

Weather conditions were recorded using a Skymaster Weathermeter. Data collected included the average wind speed, maximum wind speed, temperature, relative humidity, and barometric pressure. Weather data were collected each day at each site. Other atmospheric conditions, such as presence and amount of clouds, fog, or precipitation were also recorded.

RESULTS

Eighteen land application sites were monitored for odor strength during this study. The sites ranged in size from 5 to 37 acres, receiving 95 to 450 tons of biosolids. During this period, most of the biosolids were top dressed on grass hay. On six of the sites, the biosolids were incorporated. At two of these sites, the crop was corn and the other four sites were renovations using a grass mix.

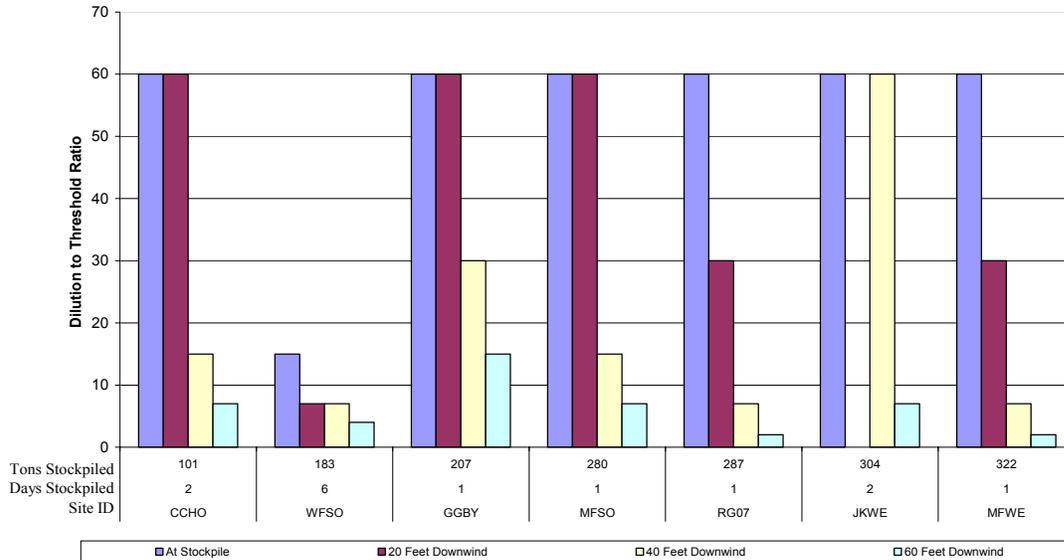
Table 3 - Land Application Site Summary

Site ID	Staging Start Date	Spreading End Date	Acres	Biosolids Quantity, tons	Field Management	Crop
BG01	7/14/03	7/21/03	36.7	450	Surface Application	Grass/Hay
CCHO	6/9/03	6/13/03	8	101	Incorporated	Grass/Hay
DG40	5/28/03	5/30/03	21	280	Incorporated	Rye
FP20	5/29/03	6/2/03	9.5	122	Incorporated	Grass/Hay
GG03	6/24/03	6/24/03	5	81	Surface Application	Grass/Hay
GGBY	6/24/03	6/27/03	14.5	207	Surface Application	Grass/Hay
GP10	5/29/03	5/29/03	9	95	Incorporated	Corn
JKWE	5/14/03	5/22/03	12.4	168	Surface Application	Alfalfa Grass
JL73	6/16/03	6/19/03	29.7	308	Incorporated	Grass/Hay
JP01	5/14/03	5/28/03	11.7	161	Incorporated	Corn
JP04	5/14/03	5/23/03	14.8	221	Surface Application	Grass/Hay
KJEA	5/14/03	5/22/03	19.3	257	Incorporation	Alfalfa Grass
MFNO	6/3/03	6/4/03	22	299	Surface Application	Grass/Hay
MFSO	6/4/03	6/5/03	50	279	Surface Application	Grass/Hay
MFWE	6/2/03	6/4/03	7.7	104	Surface Application	Grass/Hay
RG07	7/9/03	7/14/03	36	389	Surface Application	Grass/Hay
RG08	7/7/03	7/9/03	27.4	368	Surface Application	Grass/Hay
WFSO	6/19/03	7/18/03	24.5	383	Surface Application	Grass/Hay

Odor Observations Associated with Field Stored Biosolids

During this study, the odor strength associated with field stored biosolids was variable. Figure 2 shows the strength of the odor downwind of the stockpiles of biosolids in 20 foot intervals. Generally, at the stockpile the odor strength was equal to or greater than 60 D/T. The differences in odor strength adjacent to the stockpiles of biosolids were not distinguishable because of the limit on the standard field olfactometer dial. Select measurements collected with the high value D/T dial show odor strengths up to 200 D/T near the biosolids stockpiles existed.

Figure 2 - Odor Strength with Distance from Field Stored Biosolids



At 40 feet from the stockpiles, variability in odor strength was apparent and ranged from less than 2 D/T to greater than 60 D/T. By 60 feet, the odor strength had dissipated significantly, generally to less than 7 D/T.

Figure 3 shows the odor data collected at WFSO where the stockpiles were monitored over time. These data indicate that the odor strength associated with the field stored biosolids is generally strongest on the day the biosolids are delivered and then the odor diminishes.

Monitoring at other sites showed a similar trend. However, when the stockpiles are disturbed, elevated odors are experienced. Figure 4 presents data collected at BG01. On July 15th when the stockpiles were disturbed for spreading, odors persisted at or above 60 D/T up to 40 feet from the field stored biosolids. Disturbing the biosolids increased the release of odorants from increased surface area in contact with the air. Further, a significant rain event around July 10th caused re-wetting of the biosolids. Re-wetting of biosolids have been associated with increased odorant generation (U.S. EPA, 2000).

In summary, Figure 5 shows all the data measurements associated with the field stored biosolids. Although the odor strength reached 60 D/T within 40 feet of the stockpiles, the odor strength at the property boundary was at or less than 7 D/T. More than half the time, the odor strength was at or less than 2 D/T at the property boundary.

Figure 3 - Odor Strength with Distance from Field Stored Biosolids at WFSO

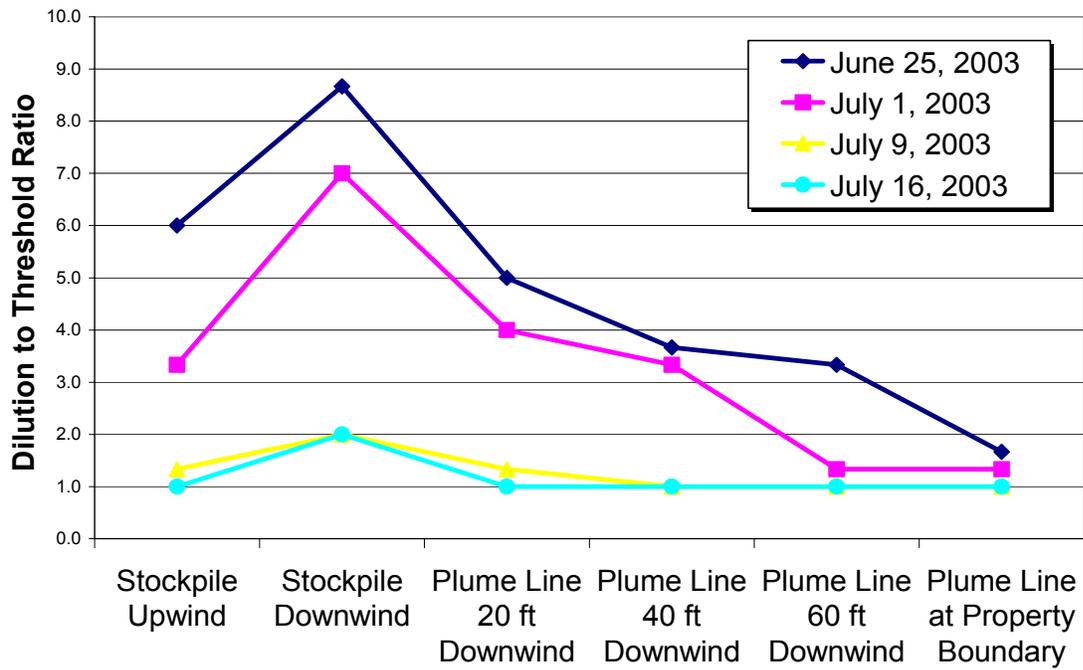


Figure 4 - Odor Strength with Distance from Field Stored Biosolids at BG01

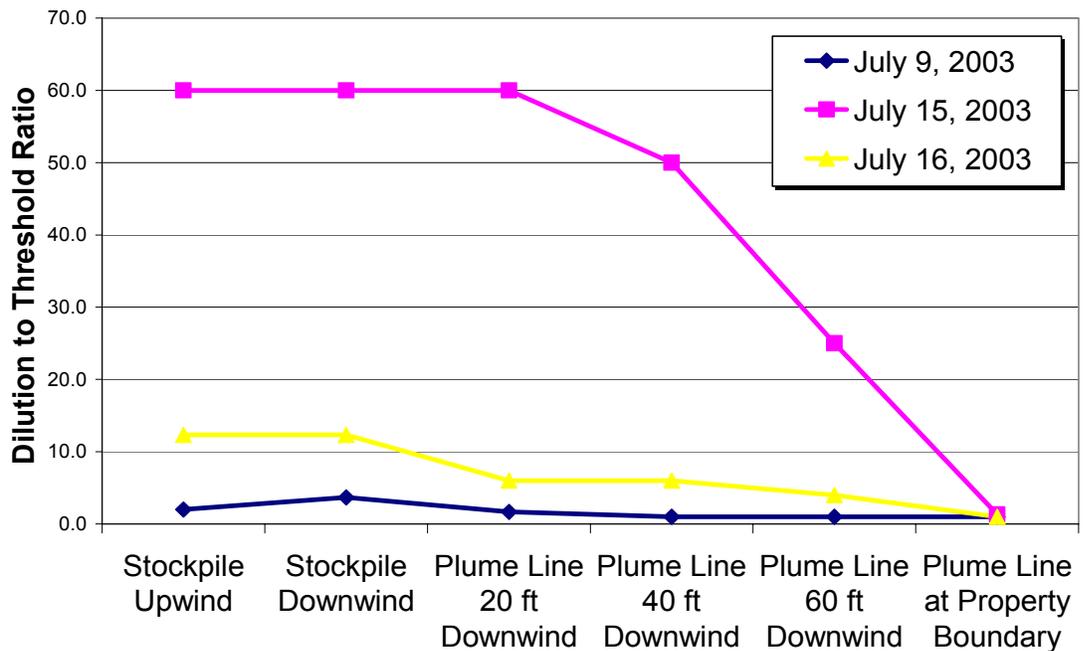
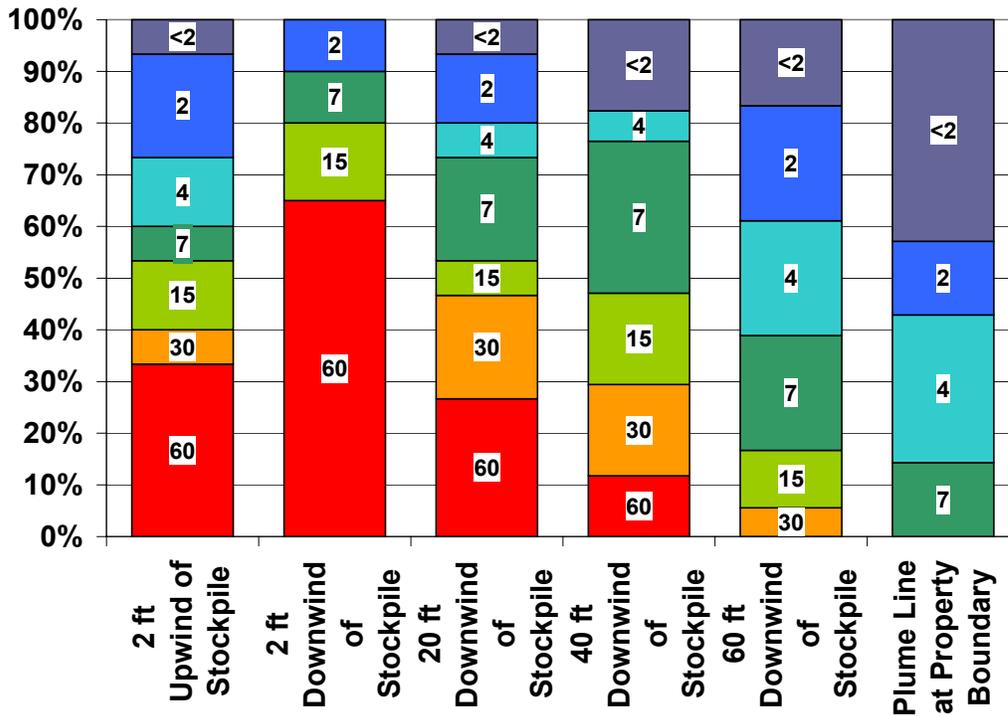


Figure 5 -Percent of Measurements at each D/T value with Distance from Field Stored Biosolids



Odor Observations after Spreading Complete

Odor strength was measured at the property boundary of eleven sites following the completion of the biosolids land application event. The sites were re-visited up to five times during a 6 to 35 day period following the event.

Figure 6 shows the odor strength data collected at the downwind property boundary of sites CCHO, FP20 and MFSO. The fields at CCHO and FP20 were incorporated; MFSO was surface applied. The odor is detectable at the downwind property boundary at 4 D/T for approximately a week. By the end of the second week, the odors were generally not detectable.

The exception to this trend occurred at sites JKWE/KJEA. These sites are part of one large field. One set of odor measurements was recorded for these sites. As shown in Figure 7 the odor strength at the downwind property boundary was extremely elevated at 15 D/T 6 days after the land application was completed. The following day the site was again monitored and the odor strength was significantly reduced.

The elevated odor strength at the downwind property boundary of JKWE/KJEA is likely due to re-wetting of the biosolids and the meteorological conditions on that day. It rained at JKWE/KJEA on May 22, the day the land application of biosolids was completed. On May 28, the day of the high odors, winds were gusty at 5 to 12 mph, the relative humidity was slightly elevated and the barometric pressure was down. The weather conditions changed significantly the following day and the odor was only slightly detectable.

Figure 6 - Odor Strength with Time at Downwind Property Boundary at Sites CCHO, FP20 and MFSO

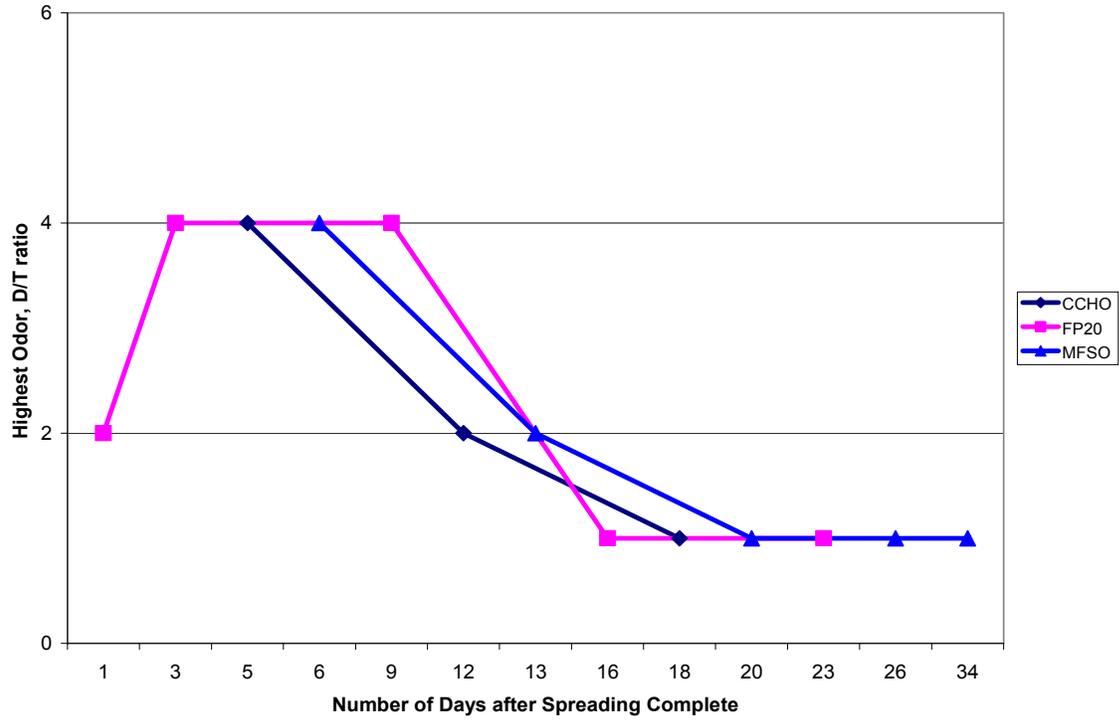
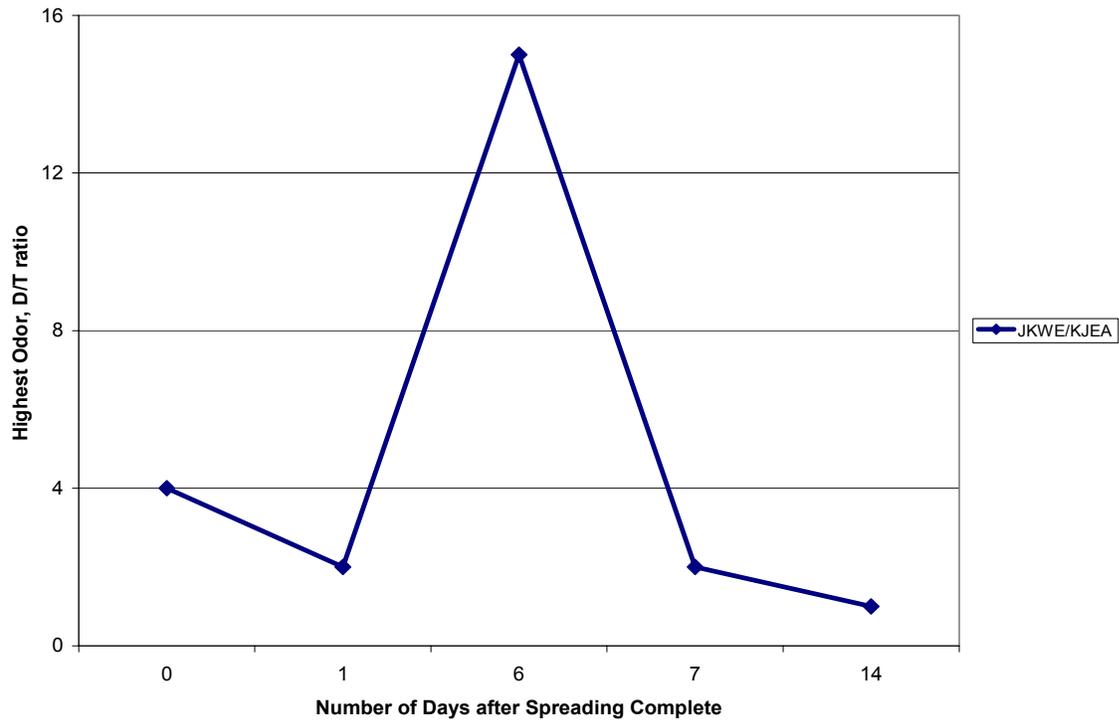


Figure 7 - Odor Strength with Time at Downwind Property Boundary for Site JKWE/KJEA



Odor Impact to Nearby Receptors

The pie chart in Figure 8 summarizes all the odor strength data collected at the nearest house to the land application sites. These data include measurements collected while biosolids were field stored and after the land application event was completed. It is noteworthy, that no measurements were recorded at the receptors greater than 7 D/T.

Figure 8 - Odor Strength in Dilution-to-Threshold (D/T) at Nearest House to Land Application Sites

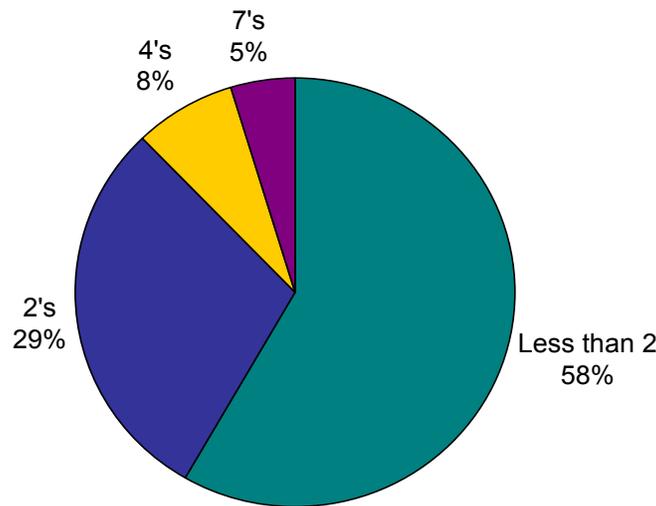


Figure 9 shows the odor strength at the nearest house to sites GP10 and FP20. These were the only sites where the odor strength was measured at 7 D/T at the residential receptors. At FP20, the odor reached 7 D/T on one day and 9 days after spreading was completed.

Figures 10 and 11 show the odor strength data at the nearest house to sites DG40, MFSO, JKWE, and JP01. The houses nearest these sites had odor measured at 4 D/T. At DG40, the peak odor occurred 1 day after spreading biosolids was completed, at MFSO on the last day of spreading, at JKWE during spreading, and JP01 one day after spreading.

These data indicate that low levels of detectable odors in the 4 - 7 D/T range can impact nearby residences and can re-occur at a site on multiple occasions.

Other Odor Variables

Odors at a site will vary throughout the day based on meteorological conditions. Although there was not sufficient data collected during this study to measure these variations, comments were

received from farmers during this study indicating biosolids odors were detected by them in the morning and evenings up to ½ mile from the application site.

Figure 9 - Odor Strength at the Nearest House to FP20 and GP10

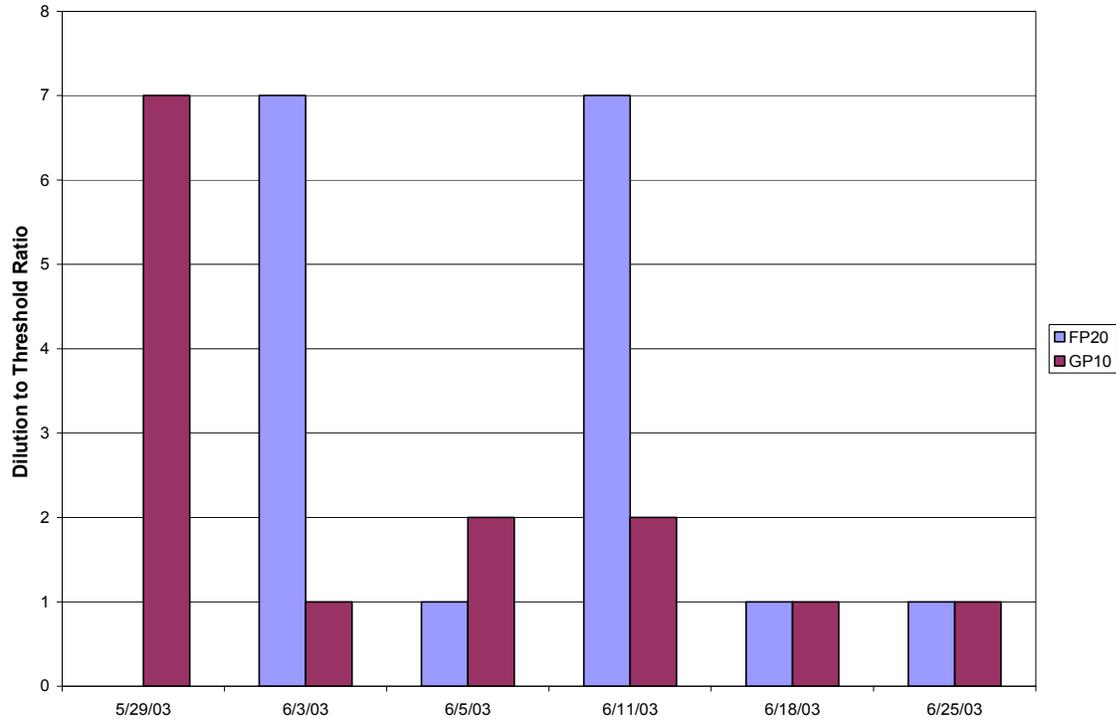


Figure 10 - Odor Strength at Nearest House DG40 and MFSO

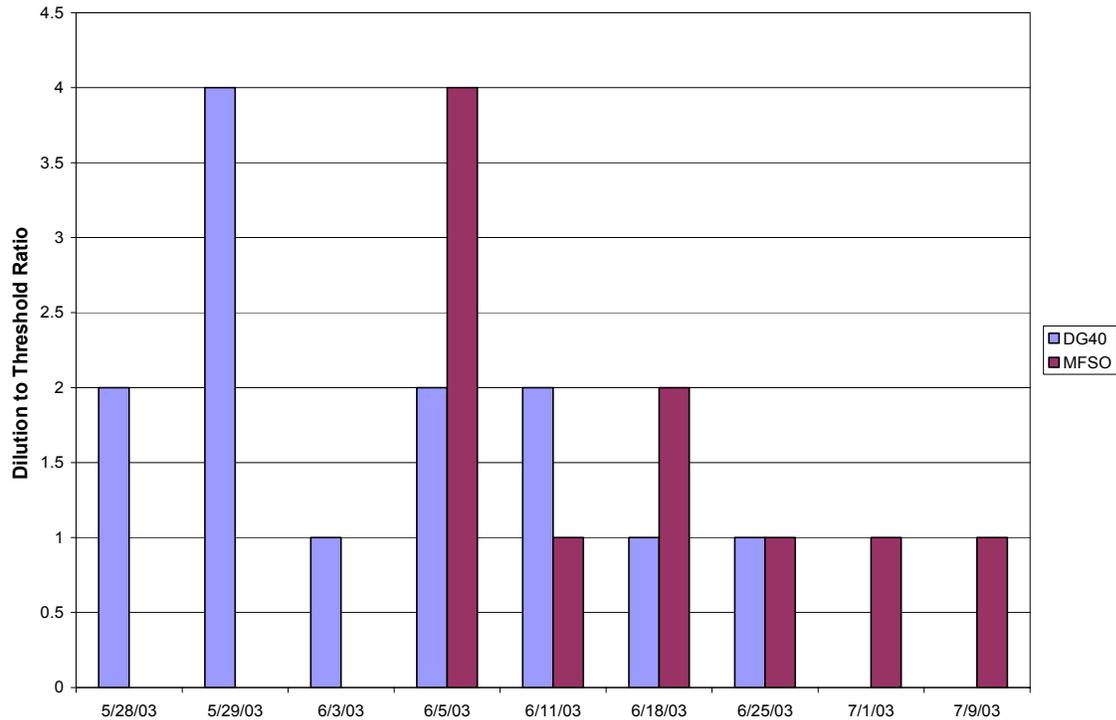
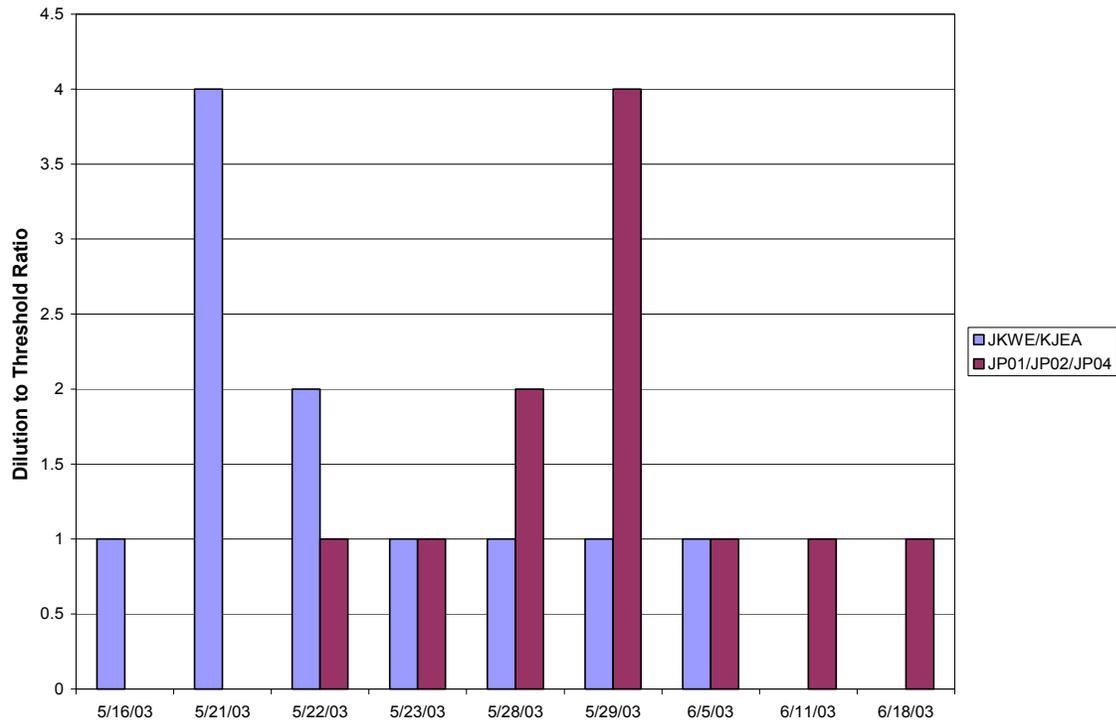


Figure 11 - Odor Strength at Nearest House JKWE and JP01



CONCLUSIONS

Field stored biosolids produce a strong odor over a small area downwind of the stockpiles of biosolids. If the stockpile is undisturbed, the odor will gradually diminish. But, it can be very strong once the pile is spread. If the stored biosolids get wet, then the material can produce unusually strong odors when spread.

After biosolids are spread, weak to moderate odors can last from 1 day to more than a week. The odor dissipates more quickly when biosolids are incorporated on a field. In most cases, the odor is minimal 2 to 3 days after the site is finished.

Biosolids odors are detectable at nearby houses and in some cases can be at levels that cause concern for the residents with the highest odor strength occurring within days of the biosolids application.

Weather conditions influence odor impacts. Although not well documented during this study, the following observations were made: 1) winds spread odorants over a greater area and increase the strength of the odor away from the field; 2) strong winds and winds that change directions tend to dilute the odor; and 3) weak or moderate strength winds or gusts can carry odor to receptors and increase the likeliness of odor complaints.

Odors associated with field stored or land spread biosolids are stronger during the early morning and evening. This can be more pronounced when there is a significant temperature change.

In summary, the data collected during this study provides the following conclusions:

- Odors are strongest within 20 feet downwind of the field stored biosolids
- By 60ft of the stored biosolids, odors are usually minimal
- Odors are strongest during spreading
- Odors decrease rapidly within days after spreading
- Re-wetting can cause high odors to occur after periods when the odors have been minimal.
- Odors can reach 7 D/T at nearby houses from time to time
- Odors can reach 15 D/T at a property boundary from time to time.

This study was the first step in WLSSD understanding biosolids odor impacts surrounding land application sites. The results support the need to develop an odor response plan to address individual concerns, monitor odor levels, address changes in odor levels, and development of field practices that minimize odors. In addition, process optimization and odor reduction measures during the biosolids treatment process need to be understood better.

ACKNOWLEDGMENTS

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