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The Impact of Composting on Air Quality in the Jordanian Badia

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Abstract

The Jordanian Badia, which makes up almost 80% of the Jordanian territories, is becoming an important source for food production due to the rapid population growth and the large demand for food. Low precipitation slows down the production and decomposition of organic material, which leads to poor soils which lack basic elements that are necessary to maintain a lavish agriculture in the Badia. The composting of organic material is believed to be a good option to improve soil conditions in the Badia and to reduce the burdens on domestic landfills. However, composting may induce odors and air contaminants including NH_3, CH_4 and N_2O in the vicinity of composting premises. This paper is carried out in order to assess air quality under the impact of composing in the Jordanian Badia by applying the well-known AERMOD Model. It studies the dispersion of odors and other pollutants from a proposed composting facility to be located at the campus of The Hashemite University in Jordan. The selected location is a good representation of the Jordanian Badia due to similarities in the climate, soil type, and fragile ecosystems. The study reveals that the predicted concentrations of the contaminating gasses vary between 5.0-8.0 ppb, 1870-2110 ppb, and 110-170 ppb for H_2S, CH_4, and NH=, respectively. The calculated odor concentrations were found to be in the range of 110-250 Ou_E/m^3. The findings of this paper emphasize the importance of composting as a good practice to manage agricultural and domestic solid waste, and to produce valuable composts which are highly needed to improve the soil conditions in the Badia with minimal consequences on air quality. The vast area of the Badia offers a myriad of places far from sensitive receptors to establish compost facilities without causing any nuisance to the (Bedouins) nomads, the main inhabitants of the Badia.

Keywords: Aermod, Air quality, ammonia, composting, hydrogen sulfate, methane, odors.

1. Introduction

Air pollution continues to receive a great deal of interest worldwide due to its negative impacts on human health and welfare. Several studies reported significant correlations between air pollution and certain diseases including shortness of breath, sore throat, chest pain, nausea, asthma, bronchitis and lung cancer (Dockery and Pope, 1994,). Extreme effects of air pollution include high blood pressure and cardiovascular problems (Pope et al., 2002; Sanjay, 2008). Correlations between air pollution and increased morbidity and mortality rates were also reported (Laden et al., 2000; Pope et al., 1995). The World Health Organization states that 2.4 million people die each year from causes directly attributable to air pollution (WHO, 2007). Epidemiological studies suggest that more than 500,000 Americans die each year from a cardiopulmonary disease linked to breathing fine particles of polluted air (Marsh and Bernstein, 2008). Another study has shown a strong correlation between pneumonia-related deaths and air pollution from motor vehicles in the UK (Knox, 2008). In addition to its negative impacts on human health, air pollution is known to cause injuries to animals, forests and vegetation, and aquatic ecosystems. Its impacts on metals, structures, leather, rubber, and fabrics include cracks, soiling, deterioration, and erosion (Boubel et al., 1994).

The Jordan Badia is classified as a semiarid to arid steppe environment and falls within the arid climate zone (Dutton et al., 1998). Most of the Badia area is bare and lacks a vegetation cover (Cope and El-Eisawi, 1998; Dutton and Shahbaz, 1999). Land use in the Badia region is mainly restricted to agriculture (rained or irrigated), animal husbandry, and mining. These areas have also been important grazing lands for the local population over the years (Juneidi and Abu-Zanat, 1993).

Badia is facing severe soil deterioration and fragile natural resources due to climate change, overgrazing, and the impact of several waves of refugees to this region. There have been few studies to address these challenges. Al-Ayyash et al. (2012) studied the feasibility for storm water harvesting in the northern Badia for the purpose of using collected water in raising cattle. They have found that the estimated runoff that could be harvested varies between 0.2 Million Cubic Meters at Alaasra and 0.82 MCM at Al-Manareh, which indicates that these sites have a good potential for water harvesting to be utilized by local farmers and livestock owners.

Rawajfih et al. (2005) investigated soil samples collected at four different areas in the Azraq basin of the northern Badia, and reported that most of the studied soils contain considerable amounts of carbonates. This leads to an alkaline reaction of the soils with pH values mostly being above eight, resulting in low availability of certain nutrients such as phosphorus. The authors recommended the usage of organic-based composts to improve the physical and chemical characteristics of the Badia soils in order to achieve

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a sustainable agricultural production. The use of compost can be beneficial to improve the organic matter status in the Badia. Composts are rich sources of nutrients with a high organic-matter content. The physical and chemical properties of the soils are improved by adding compost, which ultimately increases the crop yield (Hussain et al., 2001).

There are two main types of composting: Vermicomposting and aerobic composting. Vermicomposting is usually used to decompose food materials using a bevy of microorganisms, insects, etc. Vermicomposting uses red worms, fungi, bacteria, and other insects to break down the materials or to produce food for others. It requires a medium level of maintenance. Proper moisture and constant monitoring are needed to keep the compost healthy.

Aerobic compost is composting by treatment with air and bacteria. The microorganisms disseminating the organic waste, that is high in nitrogen, will create high temperatures, breaking it down quickly without any odors. This type of composting needs constant attention and care as the matter needs to be overturned at periodic intervals for air supply and to keep the temperature up. This type of composting works very well for large amounts of waste. Proper moisture and air circulation are needed to make sure that the compost does not dry up.

Anaerobic composting, is composting without the need of air. Herein, one has to make a pile of waste products and wait for several years for a compost to occur. This requires little or no maintenance; as slow moving bacteria inside the waste does not require air to break down. This type of compost is normally found in landfills. The compost matter decays creating a smell. That is the reason why most landfills create awful odors.

Composting has several air quality consequences; mainly odors and fugitive gasses including H_2S, NH_3, CH_4 and N_2O. Pagans et al. (2006) reported that the emissions of volatile organic compounds VOC from lab-scale composting of various organic wastes exhibit maximum emissions early in the composting process. Spencer and Alix (2006) recommended controlling the dust at compost facilities by maintaining sufficient moisture content because dust can be a fire hazard at the facility, and may clog drainage systems and give odor and BOD to the leachate. They argued that the optimal moisture during decomposition is 60-65%; if compost gets too dry, dust will be created. Goldstein and Goldstein (2005) showed that insufficient carbon and insufficient turning caused leachate and odor problems. Schlegelmilch et al. (2005) suggested that main odorous emissions from compost facilities occur during the movement of materials. They have recommended minimizing odors by avoiding anaerobic conditions such as the storage of feedstocks which can be odor-producing. Rosenfeld et al. (2004) suggest that chemicals responsible for odors include ammonia, methane, hydrogen sulfide, and sulfur dioxide. They found that aerated static pile composting reduced ammonia by (72%), and aeration followed by biofiltration, reduced odor by 98%. Prasad et al. (2004) presented a review of the data on bioaerosols from various compost studies, where a setback of 200 m is recommended since background concentrations are achieved within a few hundred meters. Heroux et al. (2004) argued that odors were significant within 500 m of the yard waste composting facility. In addition to odors and gasses, the composting facilities generate fugitive PM10 via several mechanisms including composting operations, screening and grinding operations, and vehicles transporting feed stock from the site and picking up compost for distribution.

Muller et al. (2004) measured microbial-generated odorous volatile organic compounds (MVOCs) in the vicinity of two enclosed facilities composting a mixture of plant waste and sewage sludge in Germany. MVOCs were not found in the background air, but were detected downwind. Terpenes were the dominant compounds, and were detected to a distance of 800 m (the farthest point measured) at 103 nanograms/m^3. Concentrations varied over three orders of magnitude in the eight sampling events. At one facility, the concentrations were higher at a greater distance, which is likely due to air circulation patterns.

Herr et al. (2004a) found that total bioaerosols (total bacteria, molds, and thermophilic actinomycetes) were found at >105 CFU/m^3 in the outdoor air in the vicinity of an outdoor composting facility, dropping to background concentrations within 550 m. They also reported an association between irritative respiratory symptoms and general health complaints and distance to the site. Herr et al. (2004b) measured total bacteria and molds in the air downwind from an outdoor composting site and noticed a drop to the near background within 300 m.

A physician-administered survey found airway symptoms in residents with the highest exposure (150-200 m downwind) compared to those further away (400-500m). An association was demonstrated between residential bioaerosol pollution and irritative airway complaints as well as excessive fatigue and shivering (Herr et al., 2004b). Bunger et al. (2006) found that exposure to organic dust at composting workplaces is associated with adverse acute and chronic respiratory health effects. They have reported high concentrations of fungi and actinomycetes. Compost workers report significantly higher prevalence of mucosal membrane irritation of eyes and upper airways as well as more conjunctivitis. Muller et al. (2006) reported that short-term exposure of healthy young subjects to organic dust at composting facilities had mild but measurable effects in eliciting acute systemic alterations.

This paper aims at studying the impact of composting on air quality at the Jordanian Badia by employing AERMOD to study the dispersion of odors and gasses released from the composting site. The findings of this paper provides comprehensive insight of how composting is impacting ambient air quality in the vicinity of the composting facilities. The investigations of this study would enable stockholders to take necessary precautions and mitigation measures that would prevent or minimize adverse consequences of envisioned large-scale composting on atmospheric environment at the Jordanian Badia.

2. Composting Technology

In order to make good compost, there are five main factors to be controlled during the process: nutrient balance, particle size, moisture content, oxygen flow, and temperature.

Maintaining a reasonable balance between green organic materials such as grass clippings, food scraps, and manure, which is rich in nitrogen; and brown organic materials that have a higher carbon content including dry leaves, wood chips, and branches is very important in order to get a fertile and sweet-smelling compost. Typically, carbon to nitrogen ration (C:N) has to be in the range of 25-30:1. A higher carbon content slows down decomposition, whereas a lower carbon content may lead to a stinky compost pile.

Microbial activity during early composting stages can raise the temperature at the core of the pile to above 60° C. High temperatures promote rapid composting and destroy pathogens and weed seeds. However, very high temperatures are not favored as they may kill microorganisms or constrain their activities. Therefore, a certain temperature range has to be maintained to ensure optimal microbial productivity. In addition to temperature, oxygen and moisture contents have to be controlled in order to sustain a healthy and productive microbial environment in the compost pile. Water facilitates the transport of substances within the pile and makes nutrients in the organic substances available for microbes. Aerating the compost speeds up the decomposition. It can easily be done by turning the pile or placing the pile on a series of pipes. However, too much oxygen can dry out the pile and hinder the composting process. Having a mixture of large and small particles is critical. Small particles improve the pile insulation to help maintain optimum temperatures and produce a more homogeneous compost mixture. They also increase the surface area on which the microorganisms can feed. However, any excess of tiny particles would obstruct aeration into the pile and lead to anaerobic conditions.

There are several composting techniques that are employed in different parts of the world depending on waste type and volume. Techniques include vermicomposting, in-vessel composting, and aerated static piles. Vermicomposting uses red worms in bins to feed on food scraps, yard trimmings, and other organic matter to create compost. In-vessel composting can process large amounts of waste without taking up a large space, and can accommodate virtually any type of organic waste including meat, animal manure, biosolids, and food scraps. This method involves feeding organic materials into a drum, silo, concrete-lined trench, or similar equipment. This allows for good control of the micro-environmental conditions such as temperature, moisture, and airflow. The material is aerated by mechanical turning.

The proposed composting facility will employ the aerated pile technique. It involves forming organic waste into rows of long piles and frequently turning the piles for aeration. The ideal pile height is between one to two meters with a width of four to five meters. The pile will be aerated by turning. Adding layers of loosely-piled bulking agents (e.g., wood chips, shredded newspaper) facilitates air percolation through the pile. This method produces compost within three to six months. It is suitable for a relatively homogenous mix of organic waste and works well for larger quantity-generators of yard trimmings and compostable domestic solid waste, which includes food scraps and paper products.

3. Compost Site

The Hashemite University (HU) is a Jordanian university which includes nineteen colleges that offer Bachelor and Master degrees in numerous disciplines including medicine, engineering, science, arts, education, etc. It spans over a vast campus (850 hectare) in a semi-arid region with a smooth terrain. The campus is located about 15 km to the east of Zarqa, the second mostly populous city in Jordan. It is bordered from the east by Zarqa-Free Zone (ZFZ). The compost site is proposed to be located at the North-Eastern portion of the campus (Figure 1). Wind mainly blows from West and North West, therefore odors and toxic gases emanated from the composting will be dispersed in empty arid land downwind from the composting site before entering into ZFZ.

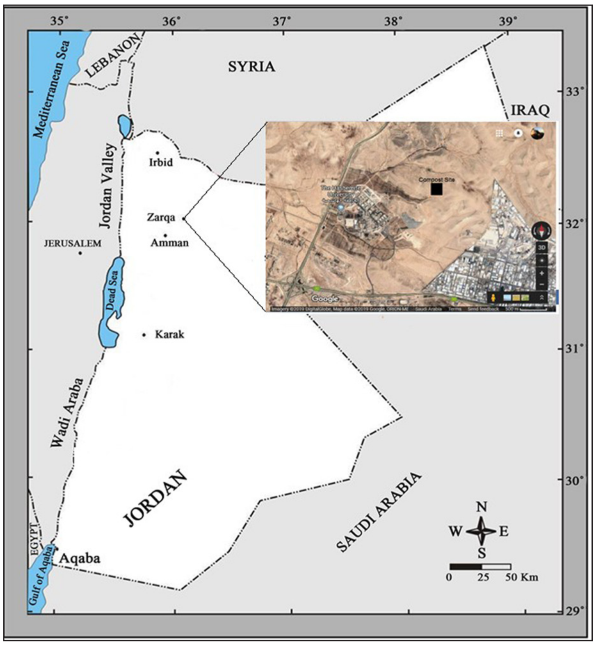

Figure 1. Study Area, modified after Abuqubu et al., 2016. Coordinates (32°06'24.7"N 36°11'59.3"E) and the satellite image is retrieved from www.google.com.

4. Environmental Baseline

Historical meteorological data were collected from an automated station during the years 2010 to 2014 (Table 1). Instruments were programmed to read and record weather parameters at five-minute intervals. Data were then downloaded and subjected to statistical treatment including checking for blanks and calculating monthly arithmetic means. Upper sounding is acquired from Almafraq weather station. It is evident that weather conditions at the site of the proposed facility are perfect for composting stages. Mild to warm air temperatures throughout the year speed up different thermophilic and maturation stages. Low numbers of precipitation days and accumulative annual precipitation provide a natural shelter against excess rain that would otherwise enhance the formation of anaerobic conditions, which lower the compost grade and enhance emissions of methane, hydrogen sulfide, and other odor agents. According to windrows (Figure 2), North-West Wind dominates the wind direction at the campus of The Hashemite University. Consequently, the compost facility, which is proposed to be constructed at the North-Eastern sector of the campus, would have no impact on students or staff as odors will be transported away to the empty-desert spaces in the Eastern part of the campus.

Table 1. Meteorological data for The Hashemite University station over the period (2010-2014). Temperature is reported in (°C).

Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Yearly
Mean Air Temperature (Max. +Min.) /2	6.5	6.8	9.3	15.0	19.3	21.7	23.5	23.7	22.1	18.6	13.3	8.5	15.7
Mean Max. air temperature	9.3	10.0	13.1	19.8	24.6	27.3	28.9	29.0	27.2	23.0	16.9	11.5	20.1
Mean Min. air temperature	3.6	3.6	5.2	10.1	14.0	16.2	18.1	18.3	17.0	14.2	9.6	5.6	11.3
Absolute Max. air temperature	23.0	22.8	24.8	32.6	36.7	37.0	38.3	39.5	36.8	33.4	29.0	24.5	39.5
Absolute Min. air temperature	-3.8	-6.6	-1.8	-2.2	4.5	6.4	11.3	13.5	11.6	7.0	-3.2	-3.2	-6.6
Mean wind speed (knot)	7.1	6.9	7.0	6.3	5.4	6.3	6.3	5.9	5.0	4.9	6.4	6.4	6.2
Max. wind speed (knot)	30.0	36.0	40.0	40.0	20.0	25.0	25.0	30.0	20.0	21.0	25.0	30.0	40.0
Daily mean Relative Humidity %	78.1	74.8	68.2	53.4	44.7	46.5	49.5	52.5	54.5	58.3	63.6	74.6	59.9
Mean sunshine hours	4.0	5.0	6.5	8.7	10.3	12.1	12.4	11.6	9.2	7.7	5.7	3.7	8.1
Total Rainfall amount (mm)	40.6	38.3	30.6	5.9	2.4	0.0	0.6	0.0	0.2	5.1	19.9	33.6	160.2
Mean no. of days with precipitation >= 1.0 mm	9.8	8.9	7.1	1.5	1.3	0.0	0.1	0.0	0.1	2.8	4.3	7.8	43.7

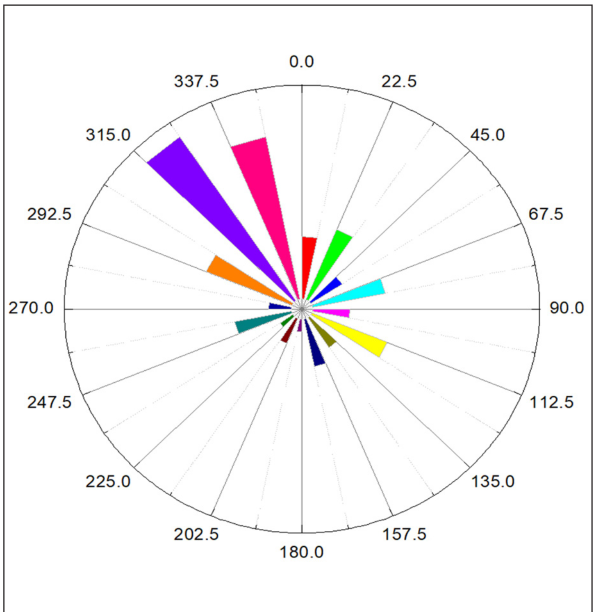

Figure 2. Windrows for The Hashemite University over the period from 2010 through 2014.

Ambient particulates and gaseous air pollutants (particulate Matter (PM), SOx, NOx, and CO) were monitored over the period from (12-14/8/2018) using the air quality monitoring station of The Hashemite University. They were found to be well below corresponding Jordanian standards of ambient air quality specified in JS-1140/2006 (Table 2). The monitoring station is equipped with analyzers (Thermo Environmental Instruments Inc.) which are capable of measuring sulfur dioxide (pulsed fluorescence method, model TEII 43C), nitrogen oxides (chemiluminescence, model TEII 42i), ozone (UV optical absorbance, model 49), and carbon monoxide (gas filter I.R. absorption, model 48i), in addition to air temperature, wind speed, wind direction, and relative humidity. The concentration of ambient Ammonia was also measured, and was found to be 76µg/m^3, which is below the Jordanian standard of 270 µg/m^3. Analyzers were programmed to record readings at five-minute intervals. The collected data were automatically and continuously downloaded into a companion PC. Analyzers were calibrated at the sampling site prior to starting the experiment in order to ensure proper functioning.

Table 2. Concentrations of particulates and gaseous air pollutants monitored at the proposed location of the composting facility

Date	TSP (µg/m^3)	PM10 (µg/m^3)	PM2.5 (µg/m^3)	CO (1-hr) (µg/m^3)	CO (8-hr) (µg/m^3)	NO_2 (1-hr) (µg/m^3)	NO_2 (Daily) (µg/m^3)	SO_2 (1-hr) (µg/m^3)	SO_2 (Daily) (µg/m^3)
2018/8/12	98.6	48.57	23.2	1.2	<1.0	35.19	35.9	20.5	16.9
2018/8/13	114.8	57.61	29.4	1.1	<1.0	34.048	34.81	38.5	36.7
2018/8/14	174.6	86.96	42.9	1.13	<1.0	32.74	31.36	32.72	31.36

5. Impact on Air Quality

The impact of composting on air quality was calculated by employing the AERMOD regulatory model, which is developed and maintained by The U. S. Environmental Protection Agency (EPA) in conjunction with the American Meteorological Society (AMS) (EPA-454/R-03-004).

Model Validity and Input

The prediction of impacts on air quality during the operation phase has been carried out using the AERMOD Regulatory Model which is based on the famous Gaussian Plume Dispersion. AERMODE has many important features which make it the preferred model for air-dispersion modeling studies worldwide.

Model Validity

The American Guideline on Air Quality Models (40 CFR Part 51, Appendix W, Federal Register, November 9, 2005) and the NYSDEC Guidelines on Air Dispersion Modeling Procedures for Air Quality Impact Analysis (DAR-10, May 9, 2006) recommend the use of AERMOD in air dispersion modeling studies for stationary industrial sources. It is developed by The U. S. Environmental Protection Agency (EPA), in conjunction with the American Meteorological Society (AMS). The model is capable of handling multiple sources, including point, volume, and area source types. Line sources may also be modeled as a string of volume sources or as elongated area sources. Several source groups may be specified in a single run, with the source contributions combined for each group. This is particularly useful for applications in which combined impacts may be needed for a subset of the modeled background sources that consume increment. The combined impacts from all background sources (and the permitted source) are needed to demonstrate compliance with the National Ambient Air Quality Standards (NAAQS). The model contains algorithms for modeling the effects of aerodynamic downwash due to nearby buildings on point source emissions. AERMOD does include algorithms for modeling depositional effects on particulate emissions. The AERMOD model has considerable flexibility in the specification of receptor locations. The user has the capability of specifying multiple receptor networks in a single run, and may also mix Cartesian grid receptor networks and polar grid receptor networks in the same run. This is useful for applications in which the user may need a coarse grid over the whole modeling domain, but a denser grid in the area of maximum expected impacts. There is also flexibility in specifying the location of the origin for polar receptors, other than the default origin at (0,0) in x,y, coordinates. For more information, refer to the model description document (EPA-454/R-03-004).

Modelling Input

Surface meteorology and upper sounding are prepared in format that can be read by AERMOD using AERMET, a companion model designed to handle meteorology. The two files in addition to emission rates are used by AERMOD in order to estimate concentrations of odor and other air contaminants at the earth surface in the vicinity of the proposed composting site. Emission rates of released odor, gasses, and particulate matter (PM10) are presented in Table 3. They are calculated based on published data. The composting site will contain ten windrows. Each row is 40m long, 4m wide, and 1.5m high. The entire composting would last for about one year: nine months for active phase and three months for curing phase. Total volume and surface area of windrows are calculated to be about 1200 m^3 and 2060 m^2, respectively (Figure 3). Compost density is assumed to be 600 kg/m^3 ; therefore, the total mass of the processed compost will be (density * volume) 720 ton/year.

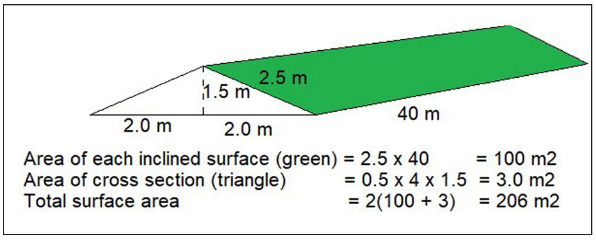

Figure 3. Calculating surface area of a compost windrow.

Table 3. Emission rates of odors and other air contaminants released from the proposed composting facility.

Contaminant	Reported Emission Rate	Converted Emission Rate	Source
PM10	3.03 3.03 ton/ year	0.67 **(g/s)**	USEPA, 2006
CH4	13.5 g/ m^2day	3.22E-01 **(g/s)**	Leytem et al., 2011
NH3	1.6 g/m^2day	3.81E-02 **(g/s)**	Leytem et al., 2011
N2O	0.9 g/ m^2day	2.15E-02 **(g/s)**	Leytem et al., 2011
H2S	0.08 g/ kg.day	1.8 E-03 (g/s)	Yuan et al., 2015
Odor	1.19 E+07 Ou_E/ton	2.72E+02 **(Ou_E/s)**	Capelli et al., 2014

6. Aermod Findings

The highest 24-hour and annual PM10 concentrations in the vicinity of The Hashemite University's proposed composting facility (HUPCF) is illustrated in Figure 4. The highest predicted concentration is expected to be slightly higher than 70 $\mu g/m^3$ within a "circular" area of radius 200m surrounding the HUPCF, which is well below the national standard for PM10 in ambient air (120 $\mu g/m^3$).

The impact of the HUPCF plant on the gaseous air pollutants including Hydrogen Sulfide (H2S), Methane (CH4), and Ammonia (NH3), are also estimated (Figures 5-8). It is clear that the concentrations of these gasses show relatively high values within the borders of the compost site and drop to background concentrations in less than 2000m downwind. The predicted concentrations of these gasses vary from 5.0 to 8.0 ppb, 1870 to 2110 ppb, and from110 to 170 ppb for H2S, CH4, and NH3, respectively.

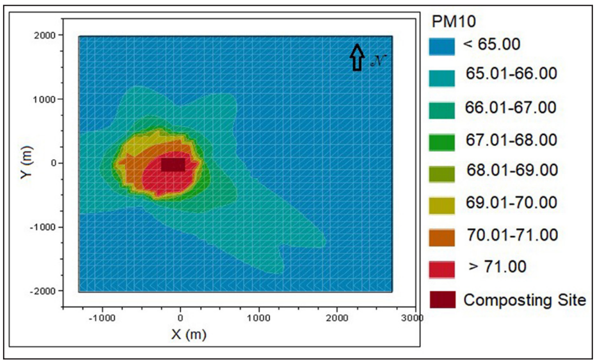

Figure 4. The highest 24-hour PM10 concentration in the vicinity of the HUPCF. The X-axis indicates a West-East direction.

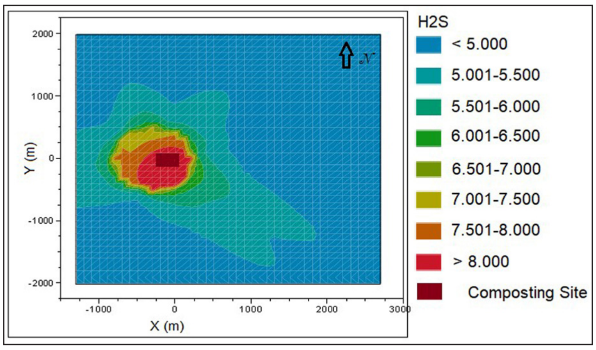

Figure 5. The highest 24-hour H2S concentration in the vicinity of the HUPCF. It is noted that the Jordanian 24-hour H2S standard of 10 ppb (JS-1140/2006) is attained.

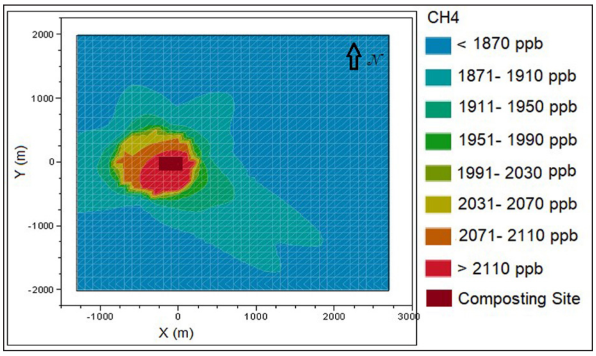

Figure 6. The highest 24-hour CH4 concentration in the vicinity of the HUPCF.

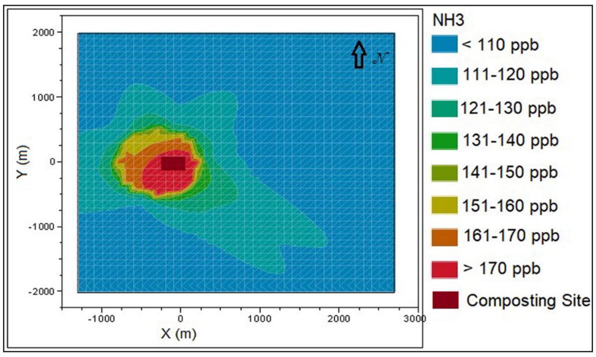

Figure 7. The highest 24-hour NH3 concentration in the vicinity of the HUPCF.

Odors

Odor concentration is expressed in terms of odor dilution ratio or odor units (Ou_E/m^3) per cubic meter of air (Ou_E/m^3), where the odor is no longer perceptible by 50% of the panelists. Odor is associated with odorant molecules, which imply that they cannot be physically or chemically measured. Therefore, their concentration is measured in odor unit per cubic meter (Ou_E/m^3).

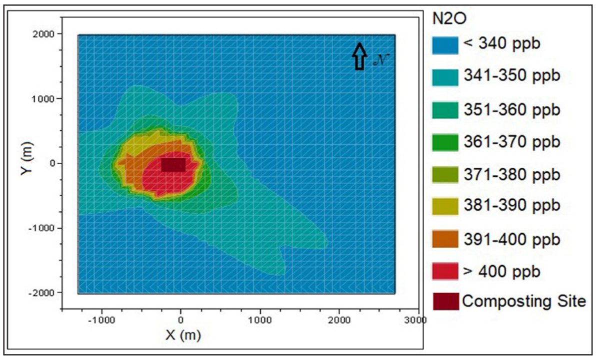

Figure 8. Highest 24-hour N2O concentration in the vicinity of HUPCF

The odor perception by humans is proportional to the instantaneous peak concentration of the odorant rather than to mean values (Latos et al., 2011). AERMOD, similar to other dispersion models, is set for the calculation of at least hourly mean concentrations. The sensation of odor, however, depends on the momentary (peak) odor concentration, but not on a mean value. In order to calculate the five-second average concentration, the hourly averaged concentrations predicted by AERMOD are first converted to three-minute average concentrations using the formula below (Duffee et al., 1991):

$$C_{3\ minute} = C_{30\ minute} \left(\frac{30\ minute}{3\ minute}\right)^{0.2} \quad \ldots\ldots\ldots\ldots\ldots(1)$$

The three-minute average concentration is converted to five-second average concentrations by multiplying by a factor of five (OME, 1996). The findings are illustrated in Figure 9. It is now evident that odor concentration could be slightly higher than 250 Ou_E/m^3 inside the borders of the composting site itself, but the concentration drops exponentially to less than 10 Ou_E/m^3 downwind the site.

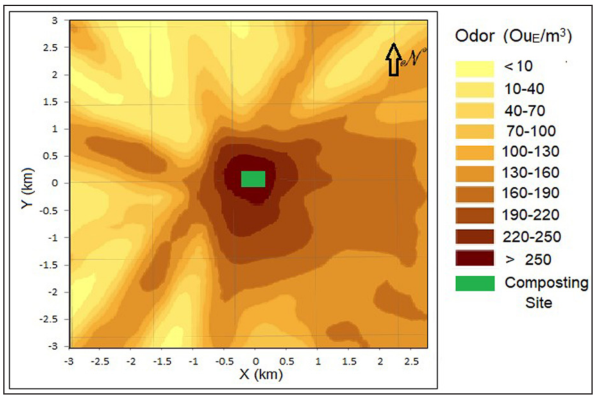

Figure 9. The highest five-second odor concentration (Ou_E/m^3) in the vicinity of the HUPCF.

7. Discussion

It can be seen that the odor dynamics are similar in almost all directions; the concentrations drop rapidly in the first 400 m and then they decrease slowly to values close to 10 Ou_E/m^3. The concentration towards the East direction presents very high values (open sheds). The area close to the composting site is in critical conditions, and odor can be perceived also at a significant downwind distance (more than 1.5 km). The impact on workers and staff is often assessed in terms of odor-exposure duration per year. However, exposure time (day or night) is an important factor that needs be considered. The results showed that the unfavorable events happen often in the early morning because dilution is halted during the night due to the absence of natural convection. Nights undergoing thermal inversion are therefore expected to yield a poorer air quality with high levels of odors and other contaminants. In December and January, wind direction reverses; therefore, odors would be transported westward of the composting site toward the developed area of the university campus. Therefore, early-morning classes in the Eastern building would be subject to annoying odors. Consequently, the composting site has to be located at least 2000 m to the east of classrooms, and 2000 m to the west of ZFZ.

8. Conclusions

The compost site that is proposed to be established at the campus of The Hashemite University would have several advantages as it offers affordable and sound management for organic waste. Composting has many advantages compared with landfilling and incinerating. It does not require the allocation of vast land, nor does it release vast quantities of greenhouse gasses including carbon dioxide and methane. The final product will be distributed throughout the cultivated part of the campus. This is anticipated to improve soil texture and organic content.

The project will have minimal impacts on air quality (odors) in areas located downwind from the site, which is mainly composed of a barn semi-arid plateau. During the events of the night thermal inversion, odors may reach Zarqa Free Zone, but this should not be a problem because the Free Zone is active only during the daytime where convection is strong enough to dilute pollution by carrying air contaminants upward. Academic and administration buildings might be exposed to odors in the early morning during December and January. Most of these impacts are eliminated by simply placing the composting site at the southeastern part of the campus, where odors and gasses would be transported and dispersed in an empty land that does not have sensitive receptors.

Based on these findings, it is recommended to adopt composting as a sound environmental practice throughout the Badia region in Jordan. The final product is highly needed in the region because it is a natural soil conditioner that is rich in organics and other elements that are essential to enhance soil quality in the Badia, which is becoming a main area for growing vegetables and fruits as well as livestock fodder.

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