INVESTIGATING THE KEY SOURCES OF ODOURS IN AL-MULTAQA VILLAGE

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Abstract— Located in the province of Al-Amerat, Sultanate of Oman, Residents of Al-Multaqa Village have strongly complained about odours, for the past two years, at night and in early mornings. This paper focuses on investigating which of the facilities, located within the village region, is the key contributor to the odour issue in the Al-Multaqa region. To model and simulate the dispersion of odours throughout the year, The CALPUFF Modeling System was utilized. Be'ah's medical waste treatment plant odour emissions were below the complaint threshold; therefore, the facility was found not to be a major source of odour. As for the three remaining facilities, CALPUFF simulation results showed that the facilities were major contributors to the odour issue at Al-Multaqa as all three facilities violated the complaint threshold of 5 odor units (OU). Of the four facilities, the landfill was responsible for the greatest contribution. Measures must be taken in order to solve the odour issue and prevent future incidents in the region.

Index Terms— Al-Multaqa Village, Model, Odour, Sultanate of Oman.

I. INTRODUCTION

Defined as a Gaussian puff model and developed by the Atmospheric Studies Group (ASG) [1], the CALPUFF Modeling System is considered one of the most powerful modeling programs in the field of air quality assessment. CALPUFF provides an accurate simulation for the plume trajectories of pollutants as well as their concentration levels for domains with sophisticated terrain. The software has been the basis for a tremendous number of case studies due to its flexibility in selecting the modeling period, location, and investigated pollutant [2]-[3]. Multiple case studies have focused on modeling the plume trajectories and concentration levels of sulfur dioxide (SO_2) [4]-[5], Particulate matter [6]-[7], and nitrogen oxides (NO_x) [8]-[9].

Investigating the nuisance associated with the dispersion of odours has always been a major interest in research, perhaps due to the rapid increase of industrial facilities close to residential locations and the crucial effects of odour on human health when people are exposed to high odour concentration levels [10]-[11].

Al-Multaqa Village, located in the province of Al-Amerat, Sultanate of Oman, has experienced a serious situation with odours. Residents of the village have complained about strong odours at night and in early mornings for the past two years. Four major, potentially odour-emitting facilities are located close to the village: Haya's biosolids composting facility, the SITA & Al-Bashaer Environment (Suez Environment) landfill and leachate pond and Be'ah's medical waste treatment plant.

This paper focuses on utilizing CALPUFF to model and simulate the dispersion of odours throughout the year for the aforementioned facilities and clarify which was the key contributor to the odour issue in the Al-Multaqa region. The current study was carried out throughout 2014 and each of the mentioned facilities was considered an area source of odours. The second day of each month was selected for simulating the dispersion of odours and investigating the source(s) of the problem.

II. MATERIALS AND METHODS

The province of Al-Amerat is located in the Muscat Governorate, which is the capital of the Sultanate of Oman. Muscat is located on the northeastern side of Oman, close to the sea. Within the domain of Al-Amerat, Al-Multaqa Village is located near the three previously mentioned facilities: SITA & Al-Bashaer Environment (Suez Environment) landfill and leachate pond, Haya's biosolids composting facility and Be'ah's medical waste treatment plant. The domain of this study is displayed in Fig. 1, which represents Al-Multaqa Village and the surrounding facilities.

A. SITA & Al-Bashaer Environment (Suez Environment)

SITA & Al Bashaer Environment LLC, a Suez Environment Group subsidiary, has operated a sanitary landfill in Al Amerat since February 1, 2011 (http://www.suez- environnement.com). Operation was requested by the Muscat Municipality, and the contract design, landfill and monitoring is performed with the support of the Oman Environmental Services Holding Company. Al Amerat landfill is the first engineered sanitary landfill in Oman which is operated

according to local and international environmental and technical requirements. Being the first of its kind in the country, this sanitary landfill is expected to be an example for future sanitary landfills throughout the Sultanate. The landfill site as designed consists of five cells with a total capacity of 10 million m^3 and a life span of about 3-4 years. The facility also contains a pond where all extracted leachate is collected.

B. Haya's biosolids composting facility (Kala Compost)

Haya Water, launched in December 2010, developed its pioneering Kala Composting Plant located at Al-Multaqa in Al-Amerat. The plant enables the efficient re-use of sewage biosolids and green waste enabling their conversion to a compost product that can be used for agriculture, landscaping and individual gardens (http://www.haya. com.om/tabid /117/Default.aspx). As a result, almost all sewage biosolids generated by the company's water reuse treatment project are treated and converted to compost instead of being dumped into a landfill site as had been the practice in the past.

C. Be'ah's medical waste treatment plant

Constructed and commissioned by the Ministry of Health (MOH) in December 2005, Al Multaqa's medical waste treatment plant incorporates two incineration lines each capable of incinerating 2.75 tonnes of waste per day to European emission standards. The facility consists of two parallel incinerator lines each with a capacity of 250 kg/hour. Each line consists of an automatic batch waste loader, primary combustion chamber (700-900 °C), post combustion chamber (850-1100 °C), waste heat exchanger and exhaust gas treatment system. The exhaust gas treatment system consists of a three-stage air pollution control system: dry scrubbers to neutralize acid gases (hydrogen chloride; HCl, SO_2 and NO_x); active carbon absorption to remove dioxins, furans and heavy metals; and ceramic filters to remove particulates.

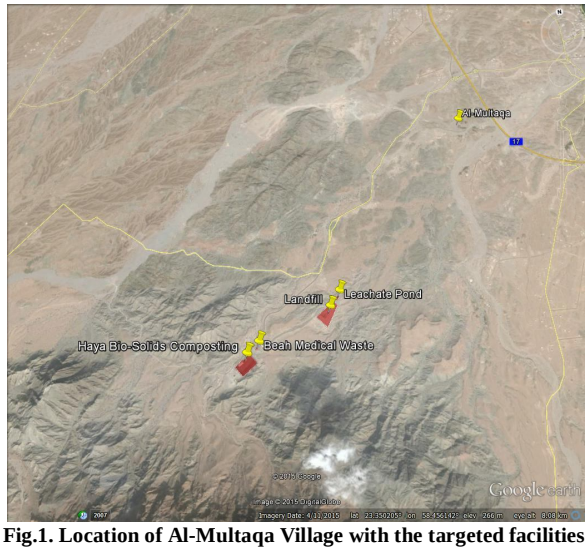

Fig.1. Location of Al-Multaqa Village with the targeted facilities

III. CALPUFF MODELLING SYETEM

CALPUFF is an air quality model utilized to process chemical transportation and the dispersion of air pollutants emitted from stacks, landfills, vehicles, and ponds. CALPUFF combines three major components: CALMET, CALPUFF and CALPOST. Additional details about the model can be found in [1]. Table 1 lists the identified shared information relative to the case study that was inserted into a common file shared amongst all CALPUFF processors prior to running the modeling software.

D. Meteorological data: upper air and surface data

Upper air meteorological data was obtainedfrom the listed radiosonde stations in the National Oceanic and Atmospheric Administration's (NOAA) official website (esrl.noaa.gov/raobs). A full period, twelve-hour interval data were extracted from the desired upper air station based on the assigned days for the study. READ62, a crucial tool provided by CALPUFF, was used for converting the prepared upper air data into UP.DAT, CALMET's readable data file format.

On the other hand, the surface meteorological data was provided by the Directorate General of Meteorology and Air Navigation (www.met.gov.om). It includes hourly-recorded surface meteorological data for the full period from the following domains: cloud height (feet), wind direction (°), wind speed (m/s), relative humidity (%), station pressure (mbar), temperature (°C), precipitation (mm) and cloud cover (tenths). SMERGE, an essential tool also provided by CALPUFF software, was used for converting the hourly prepared surface data into SURF.DAT, a data file format which is readable by CALMET. Table 2 illustrates the information related to both the surface and upper air stations associated with the case study.

Table 1: Case study identified shared information

Parameter	Selected origin
Projection type	LLC
LCC latitude of origin	23.344310 °N
LCC longitude of origin	58.461751 °E
Latitude 1	5 N
Latitude 2	45 N
False Easting	0
False Northing	0
Continent/ocean	Global
Geoid-Ellipsoid	WGS-84:WGS84
Region	WGS-84
DATUM Code	WGS-84
X (Easting)	-20 km
Y (Northing)	-20 km
Number of grid cells (X)	80
Number of grid cells (Y)	80
Grid spacing	0.5 km
Number of vertical layers	9
Cell face heights	0, 20, 50, 100, 150, 200, 300, 500, 1000, 2000 m
Base time zone	UTC + 04:00

E. Odour threshold regulations and emission rates

As for odour regulations and allowable concentrations, the most commonly used scale is the 0-5 OU scale where 0 = no odour, 1 = barely perceivable odour, 2 = faint but noticeable odour, 3 = easily perceivable odour, 4 = strong odour and 5 = repulsive odour [12]. Odour concentrations that may cause complaints range from 3–5 OU. In this study, the odour complaint threshold was considered 5 OU.

Since the focus of the study was to investigate the key contributor of odours in the Al-Multaqa region, odour emission rates for the facilities located closest to the village were essential for CALPUFF to model and simulate the dispersion of odours throughout the year. Odour emission rates for the facilities involved in the study were provided by Haya Water in OU per second (OU/s). Table 3 summarizes the CALPUFF area source input parameters for the landfill, leachate pond, composting plant, and medical waste treatment facility. The parameters include the polygon coordinates with respect to the predefined study origin, base elevation, effective height, initial sigma (z) which was derived by dividing the effective height by 2.15 and odour emission rates for each facility. Both the leachate pond and the landfill emitted odours at a greater rate than the composting and medical waste treatment plants.

IV. RESULTS AND DISCUSSIONS

Fig. 2 shows Al-Multaqa region's terrain map as demonstrated in CALVIEW. The domain covers the village and the four facilities which were the main concern for this study. The village is located 2.5 km and 3.0 km from the defined point of origin where the facilities are located.

Because Al-Multaqa is surrounded by mountainous terrain, the four potential odour sources are subjected to downslope flow after sunset. CALPUFF simulation results were analysed according to the assigned days for the case study. A comparative analysis was conducted for each modeling day, assessing odour concentrations from the four major facilities near the village in order to determine the contribution of each to the odour issue at Al-Multaqa.

According to the simulation results for the modeling days of February 2nd, March 2nd and December 2nd, 2014, no odours were detected at Al-Multaqa Village. Wind speed and direction played a major role in dispersing odours away from the village for the previously mentioned days. As for the remaining modeling days, odours were detected.

Table 4 represents the maximum odour concentration levels recorded at Al-Multaqa Village associated with their allowable threshold simulated on the second day of each month throughout 2014 except the days were no odours were detected at Al-Multaqa Village from SITA & Al-Bashaer's landfill and leachate pond, Haya's composting plant, and Be'ah's medical waste treatment facility.

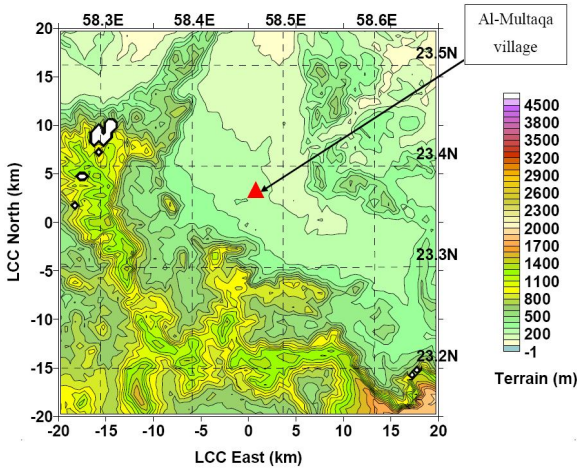

Fig.2. CALVIEW terrain map of Al-Multaqa

Table 2: Surface and upper air stations information associated with the case study

Parameter	Surface station (surface meteorological data)	Radiosonde station (upper air meteorological data)
Station name	SEEB INTL/MUSCAT 99 OM	ABU DHABI INTL 99 AE
INIT	OOMS	OMAA
WMO ID	41256	41217
UTM latitude	23.58 °N	24.43 °N
UTM longitude	58.28 °E	54.65 °E
Location X on grid	10 km	-400 km
Location Y on grid	12 km	60 km
Station elevation	17 m	27 m
WBAN	99999	99999

Table 3: CALPUFF area source input parameters for the facilities associated with the case study along with their emission rates

Parameter	SITA & Al-Bashaer's landfill	SITA & Al-Bashaer's leachate pond	Haya's biosolids composting plant	Be'ah's medical waste treatment facility
Point 1 (upper left)	-0.378 km, -0.275 km	-0.04208 km, -0.00913 km	-1.727 km, -0.892 km	-1.39050 km, -0.64938 km
Point 2 (upper right)	-0.075 km, -0.051 km	0.00965 km, 0.04006 km	-1.491 km, -0.716 km	-1.35377 km, -0.63714 km
Point 3 (lower left)	-0.223 km, -0.461 km	-0.01393 km, -0.04121 km	-1.615 km, -1.052 km	-1.38129 km, -0.67762 km
Point 4 (lower right)	-0.015 km, -0.129 km	0.03933 km, 0.00414 km	-1.375 km, -0.872 km	-1.34319 km, -0.66295 km
Emission rate	403700 OU/s	480000 OU/s	35649.5 OU/s	928 OU/s
Effective height	15 m	2 m	4 m	5 m
Base elevation	272 m	260 m	315 m	308 m
Initial sigma z	6.97	0.93	1.86	2.32

Table 4: Peak odour concentrations associated to the study modelling days in 2014 from the facilities located near Al-Multaqa Village

Modelling day	Time (HH:MM)	Average peak values (OU)			
		SITA & Al-Bashaer's landfill	SITA & Al-Bashaer's leachate pond	Haya's biosolids composting plant	Be'ah's medical waste treatment facility
January 2nd	22:00	16.499	59.160	3.0380	0.0018
April 2nd	12:00	159.82	9.6487	9.6949	0.00385
May 2nd	07:00	-	0.1487	3.2328	0.00029
June 2nd	08:00	17287	1152.9	994.64	0.55340
July 2nd	02:00	862.05	37.461	83.803	0.02542
August 2nd	04:00	1068.0	55.093	56.491	0.03517
Septemebr 2nd	10:00	327.35	20.569	23.462	0.01189
October 2nd	07:00	2868.7	1111.0	351.68	0.21391
November 2nd	09:00	3055.6	201.39	179.98	0.08705

Associated with the modeling day January 2nd, 2014, and for the four facilities, the maximum concentrations of odour occurred at 22h00 local standard time (LST). Starting with the SITA & Al-Bashaer's landfill, the maximum odour concentration was approximately 16.499 OU. This level exceeds 5 OU, the assigned complaint threshold. Moving to the leachate pond owned by SITA & Al-Bashaer, the maximum recorded odour concentration emitted and measured at Al-Multaqa was approximately 59.16 OU, overstepping the odour threshold six fold. On the other hand, Haya's composting plant odour emissions were within the allowable concentration level. The same goes for Be'ah's medical waste treatment facility, with approximately 0.0018 OU recorded at 22h00 LST.

CALPOST simulation results for the four facilities on April 2nd, 2014 show that the top maximum concentration occurred at the same time, at 12h00 LST. SITA & Al-Bashaer landfill's maximum odour concentration was 159.82 OU, which is more than the complaint threshold. Another violation in odour emissions was recorded from the leachate pond and the Haya's composting plant, with concentrations of 9.6487 and 9.6949 OU, respectively. On the other hand, Be'ah's medical waste treatment facility's odour emissions were far below the assigned criterion limit of 5 OU.

On May 2nd, 2014, no odour was detected at Al-Multaqa Village as SITA and Al-Bashaer's landfill's emitted odour dispersed away from the village. At the SITA and Al-Bashaer's leachate pond, the maximum concentration of odour was recorded at 07h00 LST with approximately 0.1487 OU. As for Haya's composting plant, the maximum concentration was recorded at 04h00 LST with a value of 3.2328 OU. Those concentrations are below the criterion limit of 5 OU. The same goes for odour emissions from Be'ah's medical waste treatment facility. The maximum recorded concentrations were significantly below the complaint threshold.

On June 2nd, 2014, CALPOST simulation results for the four study facilities revealed that the top odour emission concentrations occurred at the same time: 08h00 LST. The landfill's maximum concentration of odour was approximately 17287 OU, which is significantly beyond the 5 OU complaint threshold. Another odour emissions violation was recorded from the SITA & Al-Bashaer's leachate pond and Haya's composting plant, at approximately 1152.9 and 994.64 OU, respectively. As for Be'ah's medical waste treatment facility's odour emissions, the recorded values were below the assigned criterion limit of 5 OU.

On July 2nd, 2014, the landfill's maximum odour concentration was approximately 862.05 OU, significantly exceeding the 5 OU complaint threshold. As for the leachate pond, the maximum recorded concentration of odour at Al-Multaqa, approximately 37.461 OU, also overstepped the threshold. The same goes for Haya's composting plant, where the maximum odour concentration was approximately 83.803 OU. On the other hand, Be'ah's odour emissions were within the allowable concentration limits.

On August 2nd, 2014, The landfill's maximum odour concentration was approximately 1,068 OU, significantly exceeding the 5 OU complaint threshold. As for odour emitting from the leachate pond, the maximum recorded concentration at Al-Multaqa was approximately 55.093 OU, also exceeding the threshold. The same goes for Haya's composting plant, where the maximum concentration of odour was approximately 56.491 OU. On the other hand, Be'ah's medical waste treatment facility's odour emissions were significantly below the allowable complaint threshold.

On September 2nd, 2014, SITA & Al-Bashaer's landfill and leachate pond, Haya's composting plant, and Be'ah's medical waste treatment facility emitted maximum concentrations of odour at 10h00 LST. The landfill's maximum odour concentration was 327.35 OU, which is greater than the complaint threshold of 5 OU. The greatest recorded concentration of odour at Al-Multaqa emitting from the leachate pond, approximately 20.569 OU, exceeded the 5 OU criterion limit. The same goes for odour emissions from Haya's composting plant, with approximately 23.462 OU. On the other hand, Be'ah's medical waste facility's odour emissions were below the allowable concentrations.

On the modelling day October 2nd, 2014, SITA & Al-Bashaer's landfill maximum odour concentration was 2868.7 OU, far exceeding the 5 OU assigned

complaint threshold. At the leachate pond owned by the same company, the maximum recorded concentration of odour at Al-Multaqa was approximately 1111 OU, which also overstepped the criterion limit. Haya's composting plant followed the same pattern, with a maximum odour concentration of 351.68 OU. However, Be'ah's medical waste facility's odour emissions were within the allowable concentrations at 0.21391 OU.

CALPOST simulation results for the four facilities on November 2nd, show that the maximum odour concentration occurred at the same time-09h00 LST. SITA & Al-Bashaer landfill's maximum odour concentration was approximately 3055.6 OU, which is significantly beyond the complaint threshold. Another violation in odour emissions was recorded from the leachate pond and Haya's composting plant, with levels of approximately 201.39 and 179.98 OU, respectively. On the other hand, Be'ah's odour emissions were far below the 5 OU assigned criterion limit.

CONCLUSION

Due to complaints of the residents of Al-Multaqa Village in Al-Amerat, Sultanate of Oman, this study was initiated. The aim of the study was to investigate the key sources of the odours. Four facilities were considered in this investigation due to their proximity to the village: SITA & Al-Bashaer's landfill and leachate pond, Haya's biosolids composting plant, and Be'ah's medical waste treatment facility. CALPUFF atmospheric dispersion modeling was employed to simulate the dispersion of odours throughout the year 2014 for the previously mentioned facilities and to clarify which was the key contributor to the odour issue in the Al-Multaqa Village.

Be'ah's medical waste treatment plant was found not to be a major source of odour. Odour emissions recorded at the village from this source were below the complaint threshold. As for the landfill, the leachate pond and the composting plant, CALPUFF simulation results revealed that the facilities were significant contributors to the odour issue at Al-Multaqa as they violated the complaint threshold set in the literature (5 OU). On most of the modeling days assigned in this study, the landfill was found to emit more odour than the other facilities. The leachate pond and composting plant contributed almost equally under peak conditions.

In order to solve the odour issue and prevent future incidents in the region, developing an odour mitigation and control plan for the area is necessary. Starting with the SITA & Al-Bashaer's landfill, which emitted more odour than the other sources, measures might include landfill gas collection and flaring, capping side slopes and completed landfill cells, and inserting odour neutralizers. As for the SITA & Al-Bashaer's leachate pond, potential controls that should be evaluated include installing a semi-permeable cover on the existing leachate pond, installing a leachate treatment system and perforated pipes supplied with compressed air in the pond, and considering odour neutralizers and masking mist systems at the facility. At Haya's biosolids composting facility, installing semi-permeable covers on the uncured and most odiferous compost piles and introducing odour neutralizers would decrease the plant's emitted odours. Although Be'ah's facility is not the major contributor to odour in Al-Multaqa Village, potential controls should be considered, including monthly replacement of the incinerator's filters and inserting a masking mist system.

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