Determination and Dispersion Modeling of VOC Emissions from Liquid Storage Tanks in Asalouyeh Zone

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Introduction

There are many environmental challenging problems for environmental scientists in Asalouyeh which is located in the south of Iran. In Asalouyeh zone, a large number of petroleum, petrochemical and natural gas industries are operating and as side effect air pollution is one of the most challengeable problems in this industrial area. Therefore, efficiently reduction and control of air pollutants are the most important programs for related organizations. In order to reduce emissions of air pollutants and their effects it is necessary to recognize the amount and spatial dispersion of air pollutants. Volatile organic compounds (VOCs) are one of the most significant pollutants in this industrial area and organic liquid storage tanks are one of the emission sources. Hence in this paper, evaporative losses of the stored liquids from tanks of an oil company in Asalouyeh zone are determined using storage tank emissions calculation software (TANKS 4.0.9d) and the dispersion of volatile organic compounds (VOCs) emissions from liquid storage tanks are simulated by AERMOD dispersion model. In this research, 16 tanks containing organic liquids are considered and dispersion of their VOC emissions are simulated over an area with dimension of $15 \times 15\,km^2$ with resolution of 150 m. Results for concentration of VOCs are presented at 5 vertical layers including ground surface, 2 m, 10 m, 20 m and 30 m layers. Model is run for 12 months meteorological data (year 2009) and results are presented for 1 hr, 3 hr, 8 hr, 24 hr, 1 month, and 12 months averaging concentrations of VOCs.

Materials and methods

The TANKS 4.0 software has been designed by The United States (U.S.) Environmental Protection Agency's (EPA) Office of Air Quality Planning and Standards (OAQPS). In this software the emissions estimating equations have been developed by the American Petroleum Institute (API). This software has been designed to estimate air emissions from organic liquids in storage tanks. TANKS 4.0 software requests specific information about a storage tank in many sections. Physical characteristics section vary depending on the tank type. For external floating roof tanks (EFRTs), construction information (diameter, working volume, turnovers per year and net throughput, internal shell condition, paint condition), roof type and roof fittings, tank construction (welded or riveted), type of primary and secondary seal, and for vertical fixed roof tanks (VFRTs) construction information (shell height, diameter, maximum and average liquid height, working volume, turnovers per year and net throughput), Shell color and condition, roof characteristics (roof color and condition, roof shape, roof height, roof slope or roof radius), vacuum setting and pressure setting are requested. In site information section, the location of the tank is selected from data base. Thus, at first step Asalouyeh zone was added to site selection menu data base and then was used. For this purpose meteorological data such as annual average ambient temperature, annual average atmospheric pressure, daily minimum ambient temperature, daily maximum ambient temperature, solar insolation factor and average wind speed, were calculated for 8 years time period (2000-2007) and were entered to software data base. For solar insolation factor 3 stages in following procedure were done.

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1) Hourly altitude of sun parameter was determined according to the longitude and latitude of the zone for period time 2000-2007
2) Solar elevation angle parameter was taken from averaging previous hour and present hour altitude of sun parameter according to the equation (1).

$$\phi = \left[\frac{\varphi(t_p)+\varphi(t)}{2}\right] \tag{1}$$

Where φ is altitude of sun and ϕ is solar elevation angle.

3) Clear sky insolation was calculated from equation (2).

$$R_0 = 990(\sin\phi) - 30 \tag{2}$$

Where R_0 is clear sky insolation.

4) Solar radiation parameter was determined by using clear sky insolation and fraction of cloud cover, from equation (3).

$$R = R_0\left(1 - 0.75n^{3.4}\right) \tag{3}$$

Where R is solar radiation and n is fraction of cloud cover.

In liquid information section, chemical name, chemical category (crude oils, petroleum distillates, organic liquids), liquid density at 60°F, liquid molecular weight, vapor molecular weight and vapor pressure at each of seven temperatures (40-100°F) were entered to the chemical data base. The liquids' thermodynamic information was determined using HYSYS software. At first step liquids' components were specified and those components that were not available in software's data base, were introduced to software as hypothetical components. For this purpose critical pressure and temperature and acentric factor of components were entered and added to components list of software. Then according to the liquid's components and its atom bonding, fluid package was selected and stream was simulated and then liquid's chemical properties were determined. In the present work, after determining the VOC emissions from storage tanks, spatial dispersion of VOCs was simulated using AERMOD dispersion model. In February 1991, the U.S. Environmental Protection Agency (EPA) in conjunction with the American Meteorological Society (AMS) formed the AMS and EPA regulatory model improvement committee (AERMIC), with the purpose of introducing current planetary boundary layer (PBL) concepts into regulatory dispersion models. These efforts resulted to provide a state of the art dispersion model for regulatory applications (AERMOD). The modeling system consists of one main program (AERMOD) and two preprocessors (AERMET and AERMAP). The AERMOD meteorological preprocessor (AERMET) organizes and processes meteorological data and estimates the necessary boundary layer parameters for dispersion calculations in AERMOD. The AERMOD terrain preprocessor (AERMAP) uses gridded terrain data to calculate receptor and source elevation data and terrain height scale that are used by AERMOD when calculating air pollutant concentrations. In this paper, precipitation amount, sky cover, station pressure, sea level pressure have been used for surface observations and dew point temperature, temperature, wind speed, wind direction, relative humidity have been used as profile parameters. Surface characteristics (surface roughness, Bowen ratio, and Albedo) were also required in order to construct similarity profiles of the relevant PBL parameters. Dispersion simulation of VOCs was done at 5 vertical layers including ground surface, 2 m, 10 m, 20 m and 30 m layers and for 1 hr, 3 hr, 8 hr, 24 hr, 1 month, and 12 months averaging concentrations.

In AERMOD model, source parameters vary depending on the source type. In this research, area emission rate, release heights above ground, radius of the circular area were introduced to the model. Area emission rate was calculated by dividing monthly emissions that were determined using TANKS 4.0.9d software to tanks area. In the present study, all of the receptors were defined at Cartesian grid network over an area with dimension of $15 \times 15\,km^2$ with resolution of 150 m.

Discussion of results

Results of this research show that liquid storage tanks of related company emit 233336987 gr (~ 233 Ton) of VOCs to atmosphere per year. External floating roof tanks (EFRTs) with 46842764 gr (~ 47 Ton), (20.08 %) and vertical fixed roof tanks (VFRTs) with 186494223 gr (~ 186 Ton), (79.92 %) participate at total annual emissions from related oil company. TANK 5 emits 183124318 gr (~ 183 Ton), (78.48 %) of VOCs annually. Maximum monthly emissions from storage tanks is 22114883 gr (~ 22 Ton), (9.48 %) in October, and minimum monthly emission is 14681782 gr (~ 15 Ton) (6.29 %) that occurs in December.
Maximum concentrations at total (51005) receptors and for total averaging periods have been shown in table 1. Spatial dispersion of VOC pollutants shows that at first half of year 2009 north westerly wind (315 degree) was more effective but at second half of the year 2009 south easterly wind (135 degree) was prominent.

Table 1: Maximum concentration for total averaging periods

Averaging Time	Concentration gr/m^3) μ (	Hour	Day	Month	Year	X (m)	Y (m)	Z (m)
1 hr	3478.08765	22	4	6	2009	150	-150	20
3 hr	1159.36255	24	4	6	2009	150	-150	20
8 hr	779.09088	24	25	8	2009	0	-150	20
24 hr	259.69696		25	8	2009	0	-150	20
1 month	809.04608			6	2009	150	-150	20
1 year	392.31140				2009	150	-150	20

Conclusions

In this paper, 16 tanks containing organic liquids of an oil company in Asalouyeh zone were considered as source pollution and evaporative losses of the stored liquid from tanks were determined using storage tank emissions calculation software (TANKS 4.0.9d). As results liquid storage tanks of related company emit 233336987 gr (~ 233 Ton) VOC pollutants to atmosphere per year. EFRTs with 46842764 gr (~ 47 Ton), (20.08 %) and VFRTs with 186494223 gr (~ 186 Ton), (79.92 %) participate at total annual emissions. TANK 5 emits 183124318 gr (~ 183 Ton), (78.48 %) of VOCs annually. Maximum monthly emissions from storage tanks is 22114883 gr (~ 22 Ton), (9.48 %) in October, and minimum monthly emissions is 14681782 gr (~ 15 Ton), (6.29 %) that occurs in December.
Then dispersion of VOC emissions from storage tanks were simulated over an area with dimension of $15 \times 15\,km^2$ with resolution of 150 m and at 5 vertical layers including ground surface, 2 m, 10 m, 20 m and 30 m layers. Model was run for 12 months meteorological data (year 2009) and simulation was done for 1 hr, 3 hr, 8 hr, 24 hr, 1 month, and 12 months averaging concentrations. Maximum concentrations occur in 20 m height. Spatial dispersion of VOC pollutants shows that at first half of year 2009 north westerly wind (315 degree) was more effective but at second half of year 2009 south easterly wind (135 degree) was prominent.

Key words

Storage tanks, Modeling, Volatile Organic Compounds, Pollutants dispersion, Air pollution