

## Characterization of Particulate Matters and Volatile Organic Compounds in the Ambient Environment of Open Dump Sites

<sup>1</sup>\*Obuli P. Karthikeyan, <sup>2</sup>S. Murugesan, <sup>3</sup>Kurian Joseph, <sup>4</sup>Ligy Philip

<sup>1,2,3</sup>Centre for Environmental Studies, Anna University, Chennai, 600 025, India

<sup>4</sup>Department of Civil Engineering, Indian Institute of Technology, Chennai, 600 032, India

Corresponding author: ceeopk@nus.edu.sg; opkens@gmail.com

### Abstract:

Green house gas (GHGs) and particulate emissions are considered as one of the major issues in recent years from municipal solid waste dumping sites. Open burning is also very common, which emits plenty of volatile organic compounds and pose serious threat to the associated environment. Hence, characterization of air born pollutants from such dumping environment is necessary at this juncture to develop stringent regulatory rules in developing countries. Therefore, the study objective considered to characterize the ambient air samples from two municipal solid waste dumpsites *viz.*, Kodungaiyur and Perungudi in Chennai during two different seasons. The characterization study showed that dust, black carbon, ammonia, sulphate and nitrate were the major species of PM<sub>10</sub> and PM<sub>2.5</sub>. Major metal ions like Al, B, Ba, Cd, Cu, Fe, Ca, K, Mg, Ni, Pb, Sr and Zn were also identified in the particulates. Concentrations of particulates were observed to be high during the summer as compared to that of monsoon period in both the dumpsites. The respirable particulate matter in air samples varied widely between 211 µg/m<sup>3</sup> and 900 µg/m<sup>3</sup>, and exceeding the upper limits of 150 µg/m<sup>3</sup> standards prescribed by Central Pollution Control Board (CPCB), as well as United States Environmental Protection Agency (US-EPA). The concentrations NO<sub>x</sub> is much higher than SO<sub>x</sub> in Kodungaiyur samples. The ambient air samples were also contained hazardous organic compounds such as diethyl phthalate, decane, dodecane, octane, nonane, methenamine, cyclobutane, carbon disulfide and acetone diperoxide.

**Keywords:** Air pollutants, Heavy metals, Open dumps, Particulate matters, Volatile organic compounds

### 1. Introduction:

India, a developing country in Asia produces 52,000 tonnes of Municipal Solid Waste (MSW) per day with a per capita generation ranging between 0.1 and 0.6 kg/day (Inance *et al.*, 2004). Open dumping, which is still the most popular way for MSW disposal in developing countries, takes up lots of land and leads to serious pollution of its surrounding (Ding *et al.*, 2001; and Mor *et al.*, 2006). They cause bad odors and environmental risks due to the emissions of green house gas (GHGs) and hazardous organic compounds (Tchobanoglous *et al.*, 1993; and Cooper *et al.*, 1992). Due to the contribution to greenhouse effect and the toxicological relevance, the Landfill Gas (LFG) monitoring has becoming the growing environmental concern to mitigate the effects. The composition and flow rate of LFG depends on social factors such as waste composition and generation rate, recycling/ reuse practices, physicochemical and microbiological conditions such as moisture, temperature, pH, nutrient content, microbial

populations and site management factors such as type of disposal site, waste processing, leachate recycling, and age of refuse (McBean *et al.*, 1995).

Typically, landfill gas consists of 50–60 % of methane and 30–40 % of carbon dioxide, and trace amounts of numerous chemical compounds and heavy metals (Khalil, 1999). Further, it also contains small amounts of N<sub>2</sub>, O<sub>2</sub>, NH<sub>3</sub>, H<sub>2</sub>, CO, H<sub>2</sub>S and traces of toxic substances, including saturated and unsaturated hydrocarbons, acidic hydrocarbons and organic alcohols, aromatic hydrocarbons (many of them Volatile Organic Compounds), halogenated compounds, sulfur compounds (such as carbon disulfide and mercaptans), and inorganic compounds such as mercury (Allen *et al.*, 1997; ATSDR, 2001; Taleghani and Shabani-Kia, 2005).

Among them, metal ions and volatile organic compounds (VOCs) are considered as very risky (apart from NO<sub>x</sub> and SO<sub>x</sub>) contaminants due to their

acute toxicities, carcinogenicities and non-biodegradability. Gupta *et al.* (2007) provided the insight of metal ion distribution and their fate in different environments. Also, they have compiled the toxicity value for various metal ion species based on LD<sub>50</sub> calculations. Esakku *et al.*, (2003) highlighted that the heavy metal causes blood and bone disorders, kidney damage and decreases mental capacity associated neurological damages in exposed human beings. Generally, the two possible sources, through which the metal ions are getting into aerosols; (i) emission of particulates matters like PM<sub>2.5</sub> and PM<sub>10</sub> contained with metal ions of different oxidation states; (ii) open burning/self ignition due to methane production from waste degradation. Therefore, understanding/ characterization of metal ion in particulate matter thus important to assess the impact coupled with the emissions and to correlate with the bio-transformation effects.

Similarly, the emissions of some of the trace VOCs being originally present in the waste or being formed during the biological degradation of the waste is of great concern (Brosseau and Heitz. 1994). The level of VOC emitted from landfill sites has elicited concern due to the toxicological implications for workers and neighbouring residents (Deloraine and Zmirou. 1995). There are only few published data on the VOCs level in ambient air in or adjacent to open dump sites (Kgonig *et al.* 1987; Hodgson *et al.* 1992; Wilkins. 1994) and very less studies were reported from developing regions. James and Stack (1997) investigated the ambient VOCs at a landfill site with and without leachate pool. Thirty-three VOCs were identified with 11 of the most hazardous compounds quantified Srivastava *et al.*, (2003) also presented the screening results of VOCs from indoor and outdoor environments (including open dump sites). Among them, thirteen VOCs from outdoor environments found to be listed as hazardous air pollution under "Title III" of the United States Environmental Protection Agency (US-EPA) Clean Air Act Amendments of 1990. Continuous exposure to atmospheric air contained VOCs are harmful to health. Moreover, the photochemical activity of these compounds constitutes adverse effect to the ecosystem (Krol *et al.*, 2010).

Therefore, the present study intended to evaluate the extent of the air pollution due to open dumping activities, by measuring a number of polluting compounds such as Particulate Matters (PM), oxides

of sulfur and nitrogen (SO<sub>x</sub> and NO<sub>x</sub>), heavy metals as well as screening of some VOCs using GC-MS.

## 2. Materials and Methods:

### 2.1. Sampling Sites:

Studies were carried out at two major MSW dumpsites in Chennai, one of the metropolitan cities in India. The city is located at latitude 13°07' N and longitude 80°16' E, with an area of 174 Sq.km. The present generation of MSW is about 3,900 t/day and the wastes are disposed in either Kodungaiyur or Perungudi dumping grounds since 1986 (Figure 1). The Perungudi dumping ground (PDG) is low lying area and closes to the sea level. It is poorly drained and consists of an extensive area of marshy land permanently wet and seasonally inundated. The current dumping rate is about 2 000 t/day. The total area of this site is about 800 acres of which about 400 acres have been used so far for dumping. PDG lies at 12°57'13.5" North and 80°14'5.8" East.

The Kodungaiyur dumping ground (KDG) lies in the marshy lands adjacent to the alluvial low lands of Korattalaiyar River. The current dumping rate is about 1 800 t/day. The total area of this site is about 350 acres in which about 300 acres are used from 1987 to till date for dumping. It is located 2.5 km east of the Kodungaiyur village. KDG lies at 13°07'37.6" North and 80°16'48" East. Background sample, i.e., samples from non contaminated site, was collected from the Indian Institute of Technology, Madras (IITM) campus for comparison purpose.

### 2.2. Sample Collection:

Figure 2, depicts the sampling approaches in contaminated dumpsites. Two sets of air samples were collected from KDG respectively during summer (April) and monsoon (July) periods. Whereas, the samples were collected only during summer (March) at PDG. Stacked Filter Unit (SFU) (Hopke *et al.* 1997), was used to collect the particulate matter in two size fractions (between < 2.5 μm and < 10 μm). The particulate matter was collected on 47 mm diameter cellulose nitrate filter paper mounted on aerosol filter holder having inlet dispersion chamber to produce optimum particle distribution on the surface of the filter. The air was sucked through the filter paper at a flow rate of 0.9 m<sup>3</sup>/h over a period of 8 h/day. The flow rate was monitored regularly to check flow reduction due to clogging of filter paper. Total running time was multiplied with average flow rate to calculate the

volume of air passed through the filter paper. Repairable Suspended Particulate Matters (RSPM),  $SO_x$  and  $NO_x$  were also monitored in KDG using air samplers. For VOC analysis, samples were collected only from KDG in a gas bladder using portable air sampler (Make: Technovation ES-2 air sampler) at four different locations viz., ambient air (KDG AS-1), leachate pool area (KDG AS-2), area near to the open burning (KDG AS-3) and area near to the mining activity (KDG AS-4).

### 2.3. Analytical Techniques:

#### 2.3.1. Particulate Matters:

Initial and final weights of the filter paper were taken and PM (2.5 and 10) was calculated

individually. Dust and black carbon content were calculated from the PM. Particulates absorbed in filter paper were extracted using distilled water by simple agitation and their chemical analysis such as ammonia, sulfate, and nitrate were done as per the standard methods (APHA. 1998). In brief, Ammonia-N was collected using distillation method and fixed in a boric acid solution for titration with the 0.02N sulfuric acid. Nitrate ion concentrations were measured (at 540 nm) by colorimetric method following reduction of nitrate to nitrite using a cadmium column. Sulfate was measured (at 420 nm) using colorimetric method after precipitation with barium chloride.

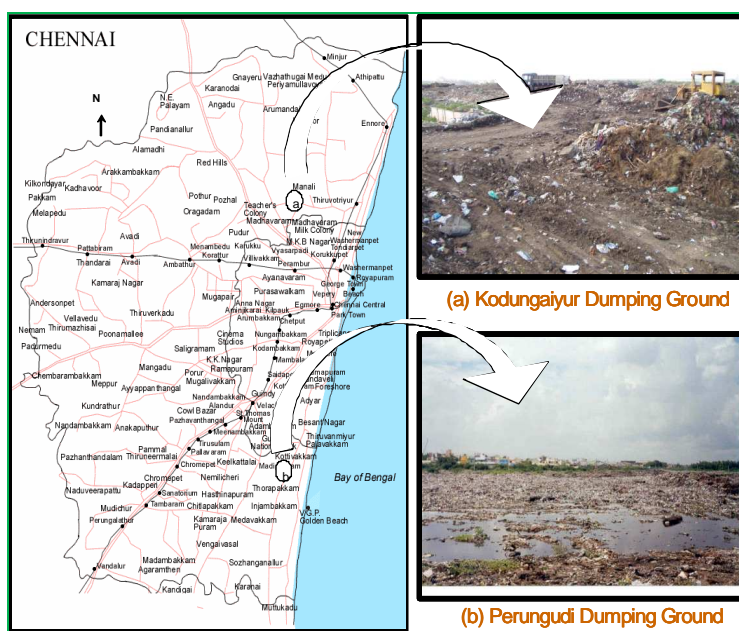


Fig. 1: Location Map of the Sampling Sites (KDG and PDG) in Chennai



Fig. 2: Air Sampling approaches in Open Dumpsites for Vocs and Particulate Matter Characterization

### 2.3.2. Metal Ions:

Around 0.5g of filter paper with the particulate matters were weighed individually in a sterile conical flask and acid digested using aqua regia (1:3 HNO<sub>3</sub> and HCl) for total metal ion extractions from PM<sub>2.5</sub> and PM<sub>10</sub>. Metal ions viz., Ag, Al, As, B, Ba, Be, Ca, Cd, Co, Cr, Cu, Fe, K, Li, Mg, Mn, Mo, Ni, Pb, Rb, Sb, Si, Sr, V, and Zn distribution in the digested, filtered and diluted samples were measured using inductively coupled plasma with mass spectrometer (ICP-MS, Make: Thermoelectron, 10x series).

### 2.3.3. VOCs:

Air samples collected in a bladder were immediately transferred to the laboratory for the analysis of VOCs using gas chromatograph with mass spectrometer (GC-MS, Make: Shimadzu, QP-2010) equipped with DB 624 capillary column of 30 m length 0.32 mm internal diameter and 1.8 microfilm in a split mode. Helium gas at the flow rate of 1.5 mL/min was used as carrier gas with the split ratio of 1:25. The initial column temperature was maintained around 35°C with the hold time of 3 min. Maximum temperature of 240°C was programmed after 3 min for retention time of 30 minutes. Each peak of chromatogram was identified using library and first three mass abundance was matched to identify the peaks.

### 2.3.4. SO<sub>2</sub> and NO<sub>2</sub>:

A known quantity of air was passed for 8 hours through the impinger containing known quantity of absorbing solution (Sodium Tetrachloro Mercurate). The absorbed solution forms a stable colour complex of dichlorosulphito mercurate with p-rosaniline hydrochloride. The intensity of color developed was measured using colorimeter at 560 nm (West-Gaeke, 1956). For NO<sub>2</sub>, a known quantity of air is bubbled for 8 hours through impinger containing NaOH solution, forming a stable solution of sodium nitrate. The nitrate ion produced during sampling is determined colorimetrically at 540 nm using sulphanilamide and NEDA (Jacob and Hochheiser, 1958).

## 3. Results and Discussion:

### 3.1. Particulate Matters (PM<sub>2.5</sub> and PM<sub>10</sub>):

Distribution of particulates in ambient air samples collected from KDG and PDG are presented in Table 1. The study results portrait that the dust, black carbon, ammonia, sulphate and nitrate are the major species of PM<sub>10</sub> (inhalable particles) and PM<sub>2.5</sub>

(fine particles) in both the dumping grounds and were observed as high compare to that of background concentrations. The particulates play a major role in environmental problems such as climate change and visibility impairment in near by areas of both the dumping grounds. In KDG samples, the concentration of dust in PM<sub>10</sub> is high (297.66 µg/m<sup>3</sup>) and other radicals such as black carbon, ammonia, nitrate and sulphate concentration are also high compared to that of PDG samples. It is mainly due to the open burning, vehicular movement in and around the dumping ground, near by industrial activities, and wind speed, directions could be the possible reasons.

Concentrations of particulates are observed to be high during the summer compare to that of monsoon period in KDG. The RSPM level in KDG samples are around 211 µg/m<sup>3</sup> and 900 µg/m<sup>3</sup> recorded during summer and monsoon periods, respectively and exceeding the limits of standards prescribed by Central Pollution Control Board (CPCB, 2000), India, for both residential and industrial activity (i.e., 100 µg/m<sup>3</sup> for residential and 150 µg/m<sup>3</sup> for industrial area), as well as US-EPA (1999 – 2004) regulatory limits (max – 150 µg/m<sup>3</sup>). Exposed peoples may be at risk and may face serious chronic health hazard problems since it has been well proven by researchers that there was direct correlation between air pollutants and morbidity and mortality rate (Bobak and Feachem, 1995; Anderson *et al.*, 1998; Hong *et al.*, 1999 and Schwartz *et al.*, 2001). For example, a case report from North America found increased incidence of cancers of the liver, kidney, pancreas (Goldberg, 1999). In contrast, there was no link found between the birth rates or health defects and nearby landfill activities was reported by various authors (Redfearn and Roberts, 2002, Dummer *et al.*, 2003, Morris *et al.*, 2003, Palmer *et al.*, 2005).

The cumulative pollution load (i.e. sum of all metal ions and radicals viz., dust, black carbon, ammonia, sulfate, nitrate etc.) in PM<sub>10</sub> of KDG samples were calculated around 457 µg/m<sup>3</sup> and 538 µg/m<sup>3</sup> respectively for summer and monsoon periods. For PM<sub>2.5</sub> the calculated pollution loads are 210 µg/m<sup>3</sup> and 148 µg/m<sup>3</sup>, respectively for summer and monsoon periods. The inhalable particulates exhibiting less pollution load during summer, and fine particles exhibiting during monsoon in KDG. In PDG, the cumulative pollution load of 209 µg/m<sup>3</sup> and

104  $\mu\text{g}/\text{m}^3$  was calculated for  $\text{PM}_{10}$  and  $\text{PM}_{2.5}$ , respectively. Compare to that of KDG samples PDG air samples having lesser pollution load. The adverse health effects of the various air pollutants on human health have been widely reported in literature (Moldan and Schnoor. 1992; Boubel *et al.*, 1994; Bobak and Feachem. 1995; Jelinkova and Branis. 2001; Benedetti *et al.*, 2001 and Brauer *et al.*, 2001). The better-known health effects due to particulate matters like respiratory diseases and reduces visibility was reported (Ponka *et al.* 1993). Other health problems investigated includes, irritation of the skin, nose and eyes, gastrointestinal problems, fatigue, headaches, psychological problems and allergies (compiled in Rushton, 2003). But, most of the published epidemiological studies related to landfill exposure were based only on distance but not on factors like, site-specific operations, dispersion of pollutants, characteristics of pollutants and climatic conditions (Dolk, 2002 and Foster *et al.*, 2006).

**3.1.1. Distribution of Metal ions:**

Distribution of metal contents in  $\text{PM}_{10}$  and  $\text{PM}_{2.5}$  of KDG and PDG samples are presented in Figure 3. Air samples collected from both the dumping grounds viz., KDG and PDG, had metal ions like Al, B, Ba, Cd, Cu, Fe, Ca, K, Mg, Ni, Pb, Sr and Zn and similar study results were reported elsewhere (Ahmed *et al.*, 2011). Among the other metal ions Ca is the most

predominant ion in both  $\text{PM}_{10}$  and  $\text{PM}_{2.5}$  from KDG and PDG samples. Heavy metals such as Pb and Zn concentrations in  $\text{PM}_{10}$  of PDG sample are high compared to that of other metal ions. Except Pb and Zn, other ions are recorded as high concentrations in KDG samples. Mixing of household hazardous wastes, electronic waste, biomedical waste, and automobile waste are expected to be the major sources for heavy metal content in any dumpsites from developing countries. From our previous study results, it was clear that the fresh MSW contained lesser metal contents than that of partially decomposed waste in both the dumping grounds (Esakku *et al.*, 2008). It can be discuss with the total mass reduction in terms of waste stabilization without any change in the amount of inorganic contents especially heavy metal ions. Therefore, these dumpsites were act like a reserve for the heavy metal ions and later create a great environmental burden when emitted into air, soil and water environments. Also, as stated earlier, burning of MSW is becoming an important atmospheric source of metals like Zn, Fe, Pb, As, Cd, Cu, Mg, Ni and Ag in both the dumping grounds and supported by Ahmed *et al.* (2011). In additions, vehicular movements, mining activities and other additional activities in dump sites may contribute to the particulate emissions with metal ions to the atmospheric environment.

**Table 1: Distribution of Particulates in Ambient air of Dumpsites**

Particulates	PDG*		KDG*		Background (IITM campus)		CPCB (2010)
	PM <sub>10</sub>	PM <sub>2.5</sub>	PM <sub>10</sub>	PM <sub>2.5</sub>	PM <sub>10</sub>	PM <sub>2.5</sub>	For industrial, residential and rural areas
Dust	88.39 (±2.0)	35.86 (±1.5)	297.66 (±4)	44.69 (±2.0)	46 (±0.5)	15 (±0.2)	-
Black Carbon	11.18 (±0.5)	5.44 (±0.2)	21.88 (±0.8)	10.72 (±0.5)	6.0 (±0.1)	4.0 (±0.1)	-
Ammonia	5.99 (±0.3)	2.58 (±0.2)	11.48 (±0.3)	4.42 (±0.1)	1.0 (±0.1)	0.9 (±0.05)	400
Nitrate	21.91 (±0.5)	13.70 (±0.3)	51.71 (±0.8)	35.14 (±0.5)	4.0 (±0.2)	1.1 (±0.1)	-
Sulphate	48.09 (±0.6)	30.02 (±0.4)	73.82 (±1.5)	54.83 (±0.9)	3.0 (±0.1)	0.5 (±0.02)	-

All values are in  $\mu\text{g}/\text{m}^3$ ; \*Average values (n = 6 for KDG; n= 3 for PDG) based on 24 hour sampling

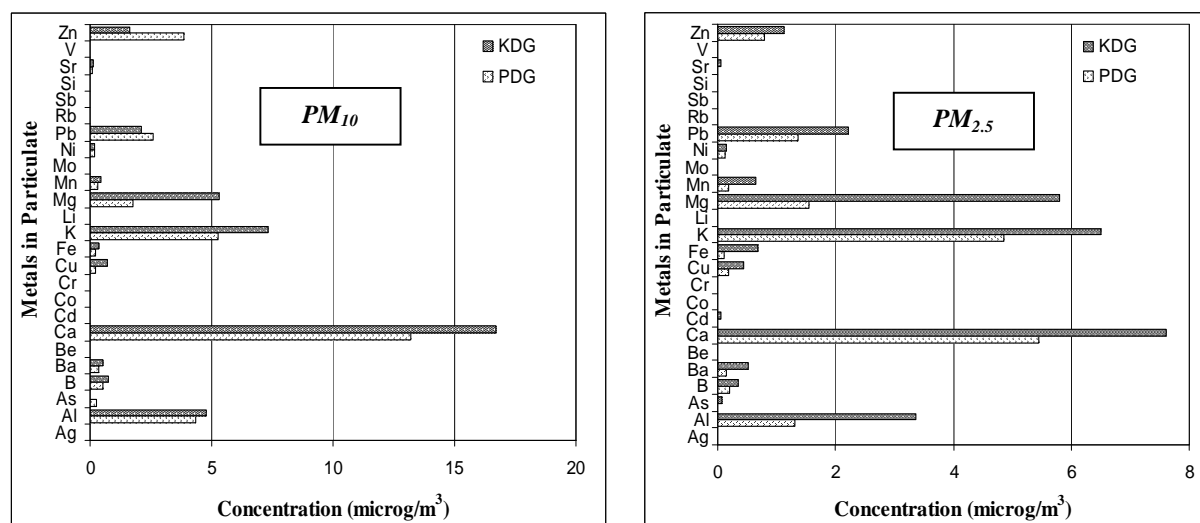


Figure 3: Distribution of Metal Ions in PM<sub>10</sub> and PM<sub>2.5</sub> of Dumpsite Samples

The higher concentrations of metals viz., Na, K, Ca, Mg and toxic elements like Pb and Zn should be taken into consideration. As per the world health organization (WHO) air quality guidelines, the potential pollutants which are of concern for public health were Ni and Pb with the maximum permissible limit of 0.5 – 1.0 g/m<sup>3</sup> (WHO, 1987). The Pb concentration is lesser than the prescribed limits in KDG and PDG, but still it may pose health risks to the nearby living habitats when they continuously exposed and bio-accumulated. Major symptoms associated with Pb pollution are that it damages central nervous system; disrupt the pathway of heame synthesis in exposed workers (Harrison and Laxen, 1981). Elements such as Cl, Cr, Ni, As and Br are also known to be toxic (Arowolo, 2004; and Aposhian, 1989), however, at present no permissible limits defined for these elements in atmospheric environment.

Metal exposure occurs from many exposure routes (inhalation, ingestion, skin transfer, transplacental, parenteral), and health effects in humans have been reported for almost all the heavy metals. Several review articles have emphasized the exposure of general population to toxic metals such as Ni, As, Cr and Cd (Bencko, 1983 and Faroon *et al.*, 1994). But the toxicity level depends on the age and sex of the human beings for different metal ion species. Gupta *et al.* (2007) highlighted that the metal ions released into the atmosphere were mainly spread over a large

area depending on the temperature, humidity, wind speed, etc. To support with that, the study results from dumpsites Abis and El-Montaza, Egypt showed highest metal concentrations near to the sites and diluted in 500 m distance (Ahmed *et al.*, 2011). Therefore, it is very clear that the living habitats in and around the dumping grounds may get expose to higher concentrations than the background levels of these hazardous metals and air pollutants. Also, there were possibilities for other people to get expose to the air pollutants due to carrying capacity of wind and particulates mainly governed by the climatic factors.

The information about metal exposure to general population in developing countries appears to be inadequate, and the environmental levels of toxic metals were expected to rise in similar cases. These uncertainties may be reduced by incorporating detailed site-specific data acquisition i.e., waste characteristics, decomposition rate, metal contents, site specific operation details along with the local climatic factors (wind speed, temperature, etc), for using it in dispersion modeling (Pierce and Stege, 2001, Morcet *et al.*, 2003, USEPA, 2004) and calibrating it to calculate the overall exposure rate (Foster *et al.*, 2006).

### 3.2. Volatile Organic Compounds (VOCs):

Total numbers of 9 different VOCs were identified in samples collected from KDG samples by primary

screening with GC-MS (Table 2). Diethyl phthalate is the major organic compound commonly detected in four different locations of KDG air samples. Other trace organic compounds *viz.*, decane, dodecane, octane and nonane were also detected. The main emission sources for VOCs in dumpsites may be contributed from plastics, pain solvents, oil, cleaning and degreasing agents, dry cleaning fluids, etc. A study report from the different disposal sites at UK measured more than 140 VOCs. Among them 90 VOCs were almost common in all the seven sites (Allen *et al.*, 1997).

Samples collected near to the mining activity at KDG detected VOCs like methenamine, cyclobutane, carbon disulfide, acetone diperoxide and diethyl phthalate. It was reported that this group of VOCs were produced predominantly from the direct volatilization of these compounds contained in the waste, and are less likely to be produced from biological degradation process. Mining the waste dumps posing risk to the workers due to emitting of these VOCs to the atmosphere and also nearby living habitats. But, the sampling of landfill gas considered as one of the major factor one should consider to get a realistic data to make an any conclusions (supported by Hamideh, 2002).

### 3.3. Distribution of SO<sub>2</sub> and NO<sub>2</sub>:

Very common that the SO<sub>x</sub> and NO<sub>x</sub> emissions are largely depends on combustion process and most important components in particulate matters of ambient. In dumpsites, open burning of the MSW, which contains sulfur and nitrogen (Watanabe *et al.*, 2003 and Gohlke *et al.*, 2010), is most common and expected to emit SO<sub>x</sub> and NO<sub>x</sub>. From the present study, the concentrations of SO<sub>2</sub> varied between 10-15 µg/m<sup>3</sup>, where as the NO<sub>2</sub> was much higher, 40-50 µg/m<sup>3</sup> in KDG samples (Figure 4). The high concentrations of SO<sub>2</sub> and NO<sub>2</sub> emissions during monsoon seasons were mainly due to the enhanced waste degradation within the fills due to rainwater

percolation. But, the SO<sub>2</sub> and NO<sub>2</sub> levels were well within the limits of CPCB (80 µg/m<sup>3</sup> –residential, rural and other areas; 120 µg/m<sup>3</sup> for industrial area – same for both SO<sub>2</sub> and NO<sub>2</sub>) and US-EPA for ambient air quality standards. The WHO (1987) guidelines for SO<sub>2</sub> suggest that for the atmosphere the average value on a yearly basis should be 40-60 µg/m<sup>3</sup>, with an upper limit of 100-150 µg/m<sup>3</sup> on a 24-h basis, while the OSHA suggest 2 ppm (5.3mg/m<sup>3</sup>). For NO<sub>2</sub>, the WHO (1987) guidelines suggest that concentrations should range from 190 to 320 µg/m<sup>3</sup>, while OSHA suggests 4.5 ppm (8.46 mg/m<sup>3</sup>) as a limiting value. Even though, the concentrations were lesser in KDG and PDG, it may go up with the increased waste dumping and burning rate in near future.

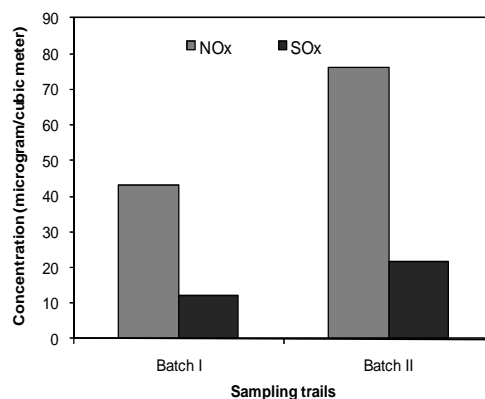


Fig.4: NO<sub>2</sub> and SO<sub>2</sub> Emission from Dumpsite

The major health effects associated with SO<sub>2</sub> pollutions are irritation of eyes, respiratory diseases, increased mucus production, cough and shortness of breath reported (Wahi *et al.*, 1992 and Howel *et al.*, 2001). Irritation of pulmonary tract affecting functioning of lungs is the major symptom associated with NO<sub>x</sub> pollution (Wahi *et al.* 1992; Mauzerall *et al.*, 2005).

Table 2: Volatile Organic Compounds in Ambient air Samples of Dumpsite

Sr.No.	Sample Code	Locations	VOCs
1.	KDG AS-1	Ambient air at dumpsite	Diethyl phthalate, decane, dodecane, octane and nonane
2.	KDG AS-2	Leachate pool area	
3.	KDG AS-3	Open burning area	
4.	KDG AS-4	Area near to the mining activity	Diethyl phthalate, methenamine, cyclobutane, carbon disulfide, acetone diperoxide

#### 4. Conclusions:

The study results showed that dust, black carbon, ammonia, sulphate and nitrate were the major species of PM<sub>10</sub> and PM<sub>2.5</sub> in both the open dumps and were observed as high compare to that of background concentrations. The major activities like open burning, vehicular movements and other mining activities in KDG and PDG were contributing to the emission of hazardous pollutants into the atmospheric environment were clearly evident. Concentration of dust in PM<sub>10</sub> of KDG was high (297.66 µg/m<sup>3</sup>) and other radicals such as black carbon, ammonia, nitrate and sulphate concentration in both PM<sub>10</sub> and PM<sub>2.5</sub> were also high in this open dump. The high concentrations of SO<sub>2</sub> (10 - 15 µg/m<sup>3</sup>) and NO<sub>2</sub> (40 - 50 µg/m<sup>3</sup>) emissions observed during monsoon period in the dumpsites. Both the dumps had metal ions like Al, B, Ba, Cd, Cu, Fe, Ca, K, Mg, Ni, Pb, Sr and Zn in particulate matters. Among the other metal ions Ca is the most predominant in both PM<sub>10</sub> and PM<sub>2.5</sub> in open dumps. The Pb concentration is lesser than the disposal limits in dumpsite samples, but it may pose health risks to the near by living habitats. The open burning of MSW in dumpsites was considered as an important atmospheric source of metal emissions in both the dumping grounds. The qualitative analysis of ambient air samples from dumpsite samples showed diethyl phthalate is the major VOC among the others. Mining activity in dumpsites may emit other VOCs like, methenamine, cyclobutane, carbon disulfide and acetone diperoxide posing health risks to the workers.

Therefore, municipal authorities and government agencies should be given more consideration in controlling the air pollutant emission from open dumpsites either by controlling the open burning activities or providing the soil covers on the top of the waste with every dumping. Controlled vehicular movements and mining activities in dumpsite with proper planning should be considered by the local authorities to reduce with the associated particulate and VOCs emissions. Further, the waste contained heavy metals, like electronic waste, house hold hazardous waste can be collected and treated separately for precious metal recovery before final disposal into open dumps. Similarly, the biomedical waste should be completely incinerated on-site and the ash contents can be further reutilized.

#### 5. Future directions:

Following study points should be considered in near future,

1. The speciation distribution of metal ions in particulate matters during different seasons along with the SO<sub>x</sub>, NO<sub>x</sub> and VOC data can be studied.
2. Photochemical effects and VOCs distribution pattern during different seasons can be considered.
3. The risk characterization can be assessed in terms of short and long term exposure basis by realistic data acquisition. This step combines information on exposure and toxicity levels, so that can get a chance to understand the adverse effects.
4. New model development for calculating the magnitude of effects individually associated with the living and non-living things and comparing with the realistic data set. Geographic information systems (GIS) offer promise of enhancing exposure characterization in epidemiological studies and can be considered.
5. Development of policy regulations in particular with the dumpsite air quality monitoring and emissions control aspects.

#### 6.0 Acknowledgement:

The authors wish to thank the financial support from Swedish International Development Agency (SIDA), and technical co-ordination from Asian Institute of Technology (AIT), Bangkok, Thailand. The cooperation of Chennai Corporation in sample collection from Kodungaiyur and Perungudi dumping grounds is gratefully acknowledged.

#### References:

1. Agency for Toxic Substances and Disease Registry (ATSDR) (2001): Landfill Gas Primer: An Overview For Environmental Health Professionals. Department of Health and Human Services. Agency for Toxic Substances and Disease Registry. Division of Health Assessment and Consultation. [www.atsdr.cdc.gov/HAC/landfill.html/toc.html](http://www.atsdr.cdc.gov/HAC/landfill.html/toc.html) (accessed on 10<sup>th</sup> July, 2009).
2. Ahmed, A.M., Salah, M.A.H., and El Adl, A.F., 2011. Assessment of heavy metals around two municipal solid waste dumpsites, Egypt. Green Pages, Editorial section. <http://www.eco->



- web.com/edi/index.html. (accessed on 11<sup>th</sup> August, 2011).
3. Allen, M.R., Braithwaite, A., Hills, C.C. 1997: Trace organic compounds in landfill gas at seven UK waste disposal sites. *Environ. Sci. Technol.* 31: 1054–1061.
  4. Anderson, H.I., Ponce de Leon, A., Bland, J.M., Bower, J.S., Emberlin, J., and Strachan D.P. (1998): Air pollution, pollens and dialy admissions for asthma in London 1987-92. *Thorax*, 53: 842 – 848.
  5. APHA, AWWA, WEF (1998): Standard methods for the examining of waste and wastewater, 20<sup>th</sup> Ed. American Public Health Association, Washington, DC.
  6. Aposhian, H.V. (1989): Biochemical toxicology of arsenic, reviews in biochemical toxicology. In. E. Hodgson, J.R.Bend, R.M. Phipot (Eds.), New York, Elsevier: 265 – 299.
  7. Arowolo, T.A. (2004): Heavy metals and health, *W.Indian. Med. J.*, 53 (2): 63 – 65.
  8. Bencko, V., (1983): Nickle: a review of its occupational and environmental toxicology. *J. Hyg. Epid. Micorb. Im.*, 27: 237 – 247.
  9. Benedetti, M., Lavarone, I. And Comba, P. (2001):. Cancer risk associated with residential proximity to industrial sites: A review, *Arch. Environ. Health*, 56 (4): 342 – 349.
  10. Bobak, M. and Feachem, R.G.A. (1995): Air pollution and mortality in central and eastern European estimate of the impact, *Eur. J. Public. Health*, 5: 82 – 86.
  11. Boubel, R.W., Fox, D.C., Turner D.B. and Stern, A.C. (1994): Fundamental of air pollution, 3<sup>rd</sup> ed. Academic press, Toronto: 102 – 103.
  12. Brauer, M., Avila-Casado, C., Fortowel, T.I., Vedal, S. Stevens, B. and Churg, A. (2001): Air pollution and retained particles in the lung, *Environ. Health Persp.*, 109 (10): 1039 – 1043.
  13. Brosseau, J., Heitz, M. (1994): Trace gas compounds from municipal landfill sanitary sites. *Atmos. Environ.* 28 (2): 285–293.
  14. Central Pollution Control Board (CPCB) (2000): Environmental standards for ambient air, automobiles, fuels, industries and noise, pollution control law series, PCLS/4/2000 – 2001, Central Pollution Control board, Ministry of Environment and Forests, New Delhi.
  15. Central Pollution Control Board (CPCB) (2010): Air quality monitoring emission inventory and source apportionment study for Indian cities. National Summary Report. [www.moef.nic.in](http://www.moef.nic.in). (accessed on 11<sup>th</sup> August, 2011).
  16. Cooper, C.D., Reinhart, D.R., Rash, F., Seligman, D., Keely, D. (1992): Landfill gas emissions. Report # 92-2, Civil and Environmental Engineering Department, University of Central Florida, 134.
  17. Deloraine, A. and Zmirou, D. (1995): Case-control assessment of the short-term health effects of an industrial toxic waste landfill. *Environ. Res.*, 68 (2):124 - 132.
  18. Dolk, H. (2002): Methodological issues related to epidemiological assessment of health risks of waste management. In Environmental and Health Impact of Solid Waste Management Activities. Hester, R.E. and Harrison, R.M., Eds. Royal Society of Chemistry: Cambridge, UK.
  19. Dummer, T.J., Dickinson, H.O. and Parker, L. (2003): Adverse pregnancy outcomes near landfill sites in Cumbria, northwest England, 1950-1993. *Arch. Environ. Health*, 58(11): 692-698.
  20. Esakku, S., Palanivelu, K., and Kurian Joseph, (2003): Assessment of heavy metals in a municipal solid waste dumpsite. Workshop on Sustainable Landfill Management, 3-5 December, 2003, Chennai, India, Proceeding Booklet, 139-145.
  21. Esakku. S, Obuli P. Karthikeyan, Nagendran. R, and Kurian Joseph. (2008): Heavy metal fractionation and leachability studies on fresh and partially decomposed municipal solid waste. Practice periodicals of Hazardous, Toxic and Radioactive waste management, ASCE, 12 (2): 127-132.
  22. Faroon, O.M., Williams, M., Connor, R.O. (1994): A review of the carcinogenicity of chemical most frequently found at national priorities list sites, *Toxicol Ind Health*, 10: 203 – 230.
  23. Foster, S.A., Chrostowski, P.C., and Hoffman, B. (2006): Methods for addressing public health concerns at municipal solid waste landfills. 21<sup>st</sup> International conference on solid waste technology and management, Philadelphia, USA, March 26-29, 2006: 1-12.
  24. Gohlke, O., Weber, T., Seguin, P., and Laborel, Y. (2010): A new process for NOx reduction in combustion systems for the generation of energy from waste. *Waste Manage.*, 30: 1348-1354.
  25. Goldberg MS, DeWar R, Desy M, Riberdy H., (1999): Risk of developing cancer relative to living near a municipal solid waste landfill site in Montreal, Quebec, Canada. *Arch. Environ. Health*, 54: 291-296.

26. Gupta, V.K., Ali, I., and Aboul-Enein, H.Y. (2007): Chapter 3: Metal ions speciation in the environment: Distribution, toxicities and analyses. In., *Developments in Environmental Sciences*, Sarkar, D., Datta, R., and Hannigan, R (Eds.), 5: 33-56.
27. Hamideh, S.A. (2002): A review of the literature regarding non-methane and volatile organic compounds in municipal solid waste landfill gas. *MSW Manage.*, 12.
28. Hodgson, A.T., Garbesi, K., Sextro, R.G., Daisey, J.M. (1992): Soil-gas contamination and entry of volatile organic compounds into a house near a landfill. *JAPCA J. Air Waste Ma.*, 42 (3): 277–283.
29. Hong, Y.C., Lecem, J.H., Ha, E.H. and Christianinc, D.C. (1999): PM<sub>10</sub> exposure, gaseous, pollutants and daily mortality in Inchon, *Environ. Health Persp.*, 107 (11): 873 – 878.
30. Hopke, P.K., Xie, Y., Raunemaa, T., Biegalski, S., Landsberger, S., Maenhaut, W., Artaxo, P., Cohen, D. (1997): Characterization of the Gent stacked filter unit PM10 sampler, *Aerosol. Sci. Tech.*, 27: 726 – 735.
31. Howel, D., Darnell, R., and Pless mulloli, T. (2001): Children’s respiratory health and daily particulate levels in 10 non-urban communities, *Environ. Res., Section A*–87: 1 – 7.
32. Inanace, B., Idris, A., Terazono, A., and Sakai, S. (2004). Development of a database of landfills and dumpsite in Asian countries, *J. Mat. Cycles Waste Mang*, 6, 97-103.
33. Jacob M.B., and Hochheiser. (1958): Continuous sampling and ultra-micro determination of nitrogen dioxide in air. *Anal. Chem.* 30: 426-431.
34. James, K.J., Stack, M.A. (1997): The impact of leachate collection on air quality in landfills. *Chemosphere* 34 (8): 1713–1721.
35. Jelinkova, J. and Branis M. (2001): Mortality during winter smog episodes, 1982, 1985, 1987 and 1993 in Czech Republic, *Int. Arch. Occup. Health*, 74: 565 – 573.
36. Kgonig, H.P., Lahl, U., Kock, H. (1987): Determination of organic volatiles in ambient air in the area of a landfill. *J. Aerosol Sci.* 18 (6): 837–840.
37. Krol, S., Zabiegala, B., Namiesnik, J. (2010): Monitoring of VOCs in atmospheric air: I online gas analyzers. *Trend. Anal. Chem.*, 29 (9): 1092-1100.
38. Mauzerall, D.L., Sultan, B., Kim, N., Bradford, D.F. (2005): NO<sub>x</sub> emissions from large point sources: variability in ozone production, resulting health damages and economic costs. *Atmos. Environ.*, 39 (16): 2851-2866.
39. McBean, E.A., Rovers, F.A., Farquhar, G.J. 1995: *Solid Waste Landfill Engineering and Design*. Prentice-Hall PTR, USA: 521.
40. Moldan, B., and Schnoor. J.C. (1992): Czechoslovakia – examining a critical ill environment, *Environ. Sci. Technol.*, 26: 14 – 21.
41. Mor S., Visscher A.D., Ravindra K., Dahiya R.P., and Chandra A. (2006): Leachate characterization and assessment of ground water pollution near municipal solid waste landfill site, *Environ. Monit. Assess.*, 118 (1-3): 435-456.
42. Mor, S., De Visscher, A., Ravindra, K., Dahiya, R.P., Chandra, A., and Van Cleemput, O. (2006): Induction of enhanced methane oxidation in compost: temperature and moisture response, *Waste Manage*, 26: 381 – 388.
43. Morris, S.E., Thomson, O.W., Jarup, L., de Hoogh, C., Briggs, D.J. and Elliott, P. (2003): No excess risk of adverse birth outcomes in populations living near special waste landfill sites in Scotland. *Scottish Med. J.*, 48:105-107.
44. Palmer, S.R., Dunstan, F.D.J., Fielder, H., Fone, D.L., Higgs, G. and Senior, M.L. (2005): Risk of congenital anomalies after the opening of landfill sites. *Environ. Health Persp.*, 113:1362-1365.
45. Ponka, A., Pukkala, E., and Hakulinen, T. (1993). lung cancer and ambient air pollution in Helsinki, *Environ. Int.*, 9: 221 – 231.
46. Redfearn, A. and Roberts, D. (2002): Health effects and landfill sites. In *Environmental and Health Impact of Solid Waste Management Activities*. Hester, R.E. and Harrison, R.M., Eds. Royal Society of Chemistry: Cambridge, UK.
47. Rushton, L. (2003): Health hazards and waste management. *Brts. Med. Bul*, 68 (1): 183-197.
48. Schwartz, J., Ballester, F., Saez, M., Perez-Hoyos, S., Bellido, J., Cambra, K., Arribas, F., Canada, A., Perez-Boillos, M., and Sunyer, J. (2001): The concentration response relation between air pollution and daily deaths, *Environ. Health Persp.*, 109 (10): 1001 – 1006.
49. Srivastava, A., Joseph, A.E., and Wachasunder, D. (2004): Qualitative detection of volatile organic compounds in outdoor and indoor air. *Environ. Monit. Assess.*, 96: 263-271.
50. Taleghani, G., and Shabani-Kia, A. (2005): Technical–economical analysis of the Saveh biogas power plant. *Renew. Energ.*, 30: 441–446.

51. Tchobanoglous G., Thiessen H., Vigil S., and McGraw-Hill. (1997): Series in Water resource and environmental engineering", New York. Chapters 3 and 11.
52. United States Environmental Protection Agency (US-EPA), Airborne Particulate Matter (PM) research centers, Deran Pashayan, 1999 – 2004, Website:  
<http://es.epa.gov/ncercq/centres/airpm/>  
(accessed on 10<sup>th</sup> July, 2009)
53. Wahi, S.K., Agnihotri, A.K., and Sharma J.S. (1992): Environmental management, Willey Eastern Ltd., New Delhi.
54. Watanabe, N., Tanikawa, N., Oikawa, T., Inoue, S., and Fukuyama, J. (2003): Improved quartz furnace method for chlorine and sulfur determination in municipal solid waste. *J. Mater. Cycles. Waste. Manage.*, 5: 69-76.
55. West P.W., and Gaeke G.C.(1956): ISC method No. 42401-01-697, *Anal. Chem.*, 28: 1816.
56. Wilkins, K. (1994): Volatile organic compounds from household waste. *Chemos.* 29 (1): 47–53.
57. World Health Organization (WHO) (1987): Air quality guidelines for Europe. European Series No. 23, Geneva.