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Odor Emissions from Municipal Solid Waste Open Dumps Constituting Health Problems Due to their Composition, Ecological Impacts and Potential Health Risks

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ABSTRACT

The presence of Hydrogen sulfide, Methane, Volatile Organic Compounds (VOCs), and other odorous compounds in the ambient air is the root cause of the offensive odor emitting from the MSW dumping yard. Composition features and health risks associated with odor emissions concentrations in MSW dumping yards. This paper aims to provide an overview of research on health problems due to their composition, ecological impacts, and potential health risks of volatile organic compounds (VOCs) and to examine the relationship between VOC exposure and chronic illnesses in humans and the environment. In this study, a comprehensive investigation of VOC odor emission from an urban MSW dumping site has been performed. The VOC odor sample was analyzed using the GC-MS technique. The maximum VOCs concentration reported is due to tert - butylbenzene at 1.41µg.m^{-3} and the minimum is due to *Sec*-butylbenzene at 0.07 µg.m^{-3}. Scientific databases, including Google Scholar, California Office of Environmental Health Hazard Assessment (OEHHA), and US EPA (Integrated Risk Information System (IRIS), were searched extensively using a bibliographic technique, in addition to a case study on MSW dumping yard workers. The findings of epidemiologic and experimental research, the emission of odors as a result of volatile organic compounds (VOCs) can cause a variety of non-cancerous health effects that are linked to abnormal functioning of the body's vital organs, including the nervous and coronary, and pulmonary systems. It can also have minimal impact on the environment by causing global warming and ozone layer depletion. The odor emissions from the dumpsite pose both carcinogenic and noncarcinogenic risks to the health of the individuals participating in the dumping yard. As a result of these results, it is important to manage odor emissions (VOCs) during composting and take steps to reduce their negative effects on the environment and public health.

INTRODUCTION

The annual production of solid waste (SW) dumping yards is rising due to residents' expansion, urbanization, and worldwide economic development. The World Bank estimates that 2.24 billion tonnes of MSW were created in 2020 and that in a world where nothing changes, 3.88 billion tonnes might have been produced by the year 2050 (Jayasinghe et al. 2023, The World Bank 2023), which will pose great challenges for governments. Odor complaints from locals have increased in recent years, according to many neighborhood organizations. These complaints are typically related to the dumping of municipal solid waste. Commercial and residential waste in a solid or semi-solid state that is produced in a municipal or notified area is referred to as municipal solid waste (MoEF 2022). One of the key concerns is the short- and long-term gaseous emissions that are connected to dangers to human health and the environment, even though MSW dumping sites can be managed or uncontrolled and the type of waste that is disposed of varies from one

country to others (EPA 1997, Young & Parker 1983). All waste management practices, including those at recycling facilities, transfer stations, composting services, and landfills, have the potential to lead to a variety of amenity complaints, such as air and odor emissions. Concerned neighbors are concerned about the odor, which has emerged as the most common complaint in recent years. Mixer of solid waste that can be classified as biodegradable (48.65%), recyclable (37.26%), residual (13.25%), and hazardous (0.84%) characterization of the waste generated at the Ifugao State University Potia Campus. Due to the overall composition of waste on the university campus formation of odor emissions takes place via biological and chemical composition, temperature, and wind speed, which are all the primary causes (Latugan 2024). Odors are a common and unavoidable consequence of the chemical and biological processes that occur when waste breaks down, and they have long been connected to waste disposal methods (Dlamini 2019). Both in landfills and composting yards, organic wastes undergo aerobic and anaerobic processes of decomposition, which are linked to common odors (US-EPA). There are three main types of organic volatility pollutants there are 1) Very volatile organic compounds, 2) Volatile Organic Compounds, and semi-volatile organic compounds. In the GC-MS analysis of collected samples, extremely few samples correspond with the VVOC groups of Methyl Chloride, chloromethane, and chloroform. At very low concentrations, these contaminants show high toxicity, so they are the most causing harm (David & Niculescu 2021). Odor complaints resulting from various household and commercial operations have become more frequent in recent years, especially with connection to waste management facilities and specifically MSW dumping yards. Both organic and inorganic compounds can have odor emissions, such as methane, volatile organic compounds (VOCs), ammonia, hydrogen sulfide, and sulfur-reduced compounds are the typical components of MSW odors (Cai et al. 2007). A dumping yard's odor emissions are typically low concentrations and evenly distributed, unlike industrial emissions (Mahin 2001). People can feel anxious after long-term exposure to such an environment (Jin-Feng Wang & Hu 2012). Determining the ambient concentration of VOCs in urban areas has received increased attention over the past decade due to the open dumping of MSW and the impact of VOCs on human health (IARC 2007). The environment is impacted by volatile organic compounds (VOCs) in addition to human health. When oxidants arise, volatile organic compounds (VOCs) are important. In the troposphere zone, for example, ozone and peroxyacetyl nitrate. In the MSW disposal yard, the majority of odor emission tests are conducted. The most notable odor molecules generated during the biodegradation process are hydrogen sulfide, methyl mercaptan, and methyl sulfide (Wenjing et al. 2015). Odor emissions from the MSW dumping yard create a serious threat to the health of those who work with MSW and the occupants of the surrounding residential areas. They also have an impact on the day-to-day lives of the residents, primarily because of the weather. A modest increase in odor production affects the surrounding area (Liu & Zheng 2020). As per the IARC (2012) study, Groups 1 and 3 are categorized as carcinogenic disorders that primarily impact human health by causing harm to the lymphatic system, central nervous system, and reproductive system. (Demirel et al. 2014). VOCs have been identified as one of the main contributors to odor emissions in the MSW dumping yard. The objective of this paper is to give an in-depth understanding of all the information available regarding the impacts of volatile organic compounds (VOCs) on the environment and public health.

The present experimental study aims to discover the various combinations of odor compounds, their monitored concentrations in the MSW dumping yard, and the health effects that the presence of volatile organic compounds (VOCs) in the MSW dumping yard has on both humans and the environment. The research also attempts to discover the specific compounds, their concentrations, and the health effects that result from their composition. The main objective of this research was:

- To identify the different odor compounds (VOCs) in the MSW dumping yard.
- To provide an overview of research on health impacts due to their composition and ecological impacts.
- To determine the potential health risks of VOCs and to examine the relationship between VOC exposure and chronic illnesses.

Significance of Odor Emission

There have been several attempts to handle MSW segregation, but treating the solid waste in the dumping yard is still not being addressed comprehensively, as is disposing of MSW in the open dumps. It is one of the main reasons for emitting odor emissions from the open dumps as well as in the garbage bins. Both rural and urban areas are still observed gathering all kinds of waste (Ahluwalia & Patel 2018). VOCs are the main odor-emitting compounds in the MSW dumping yard. The main VOC families are sulfur compounds, terpenes, halogenated aromatic hydrocarbons, alkanes, alkenes, and oxygenated compounds. In our monitoring and analyses of VOCs from the MSW dumping yard, five different VOC families are present in the observed samples (Saral et al. 2009, Liu & Zheng 2020). Fikri (2024) has discussed gaseous pollutant formations, their potential health effects, and

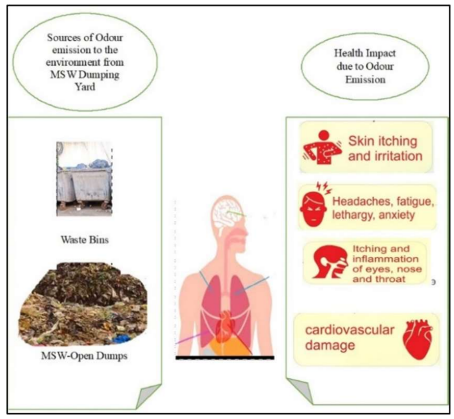

Fig. 1: Routes of MSW dumping yard-released odor compounds into the environment and their harmful effects on human health.

clinical coding to identify gaseous pollutants like methane, carbon dioxide, and non-methane organic compounds at the Piyungan Landfill using the landGEM model. Eventually, there have been issues with odor emissions in both rural and urban regions that have not been successfully managed for the disposal of waste until the present day. Hence, this paper also discusses whether the odor emissions from MSW open dumps constitute health problems due to their composition, ecological impacts, and potential health risks shown in Fig.1

MATERIALS AND METHODS

Field-Based Investigation

Using an ADT probe and a BDX II abatement air sampler for the field-based investigation (shown in Figs. 2a and 2b), it was analyzed with a GC-MS Agilent 6890 N series instrument in the laboratory. The investigation was carried out at an MSW dumping yard adjacent to the one where different kinds of odor were gathered. The ADT probe was used to continuously monitor air quality monitoring inside the MSW over the complete disposal of fresh waste in the dumping yard in the pre-monsoon season of 2023. To track the geographic and seasonal variations in odor in the ambient air, samples are gathered while taking into account the local climatic conditions. Three different locations in the dumping yard were used to collect the samples. The samples were collected and then sent directly to the laboratory for analysis. Air samples containing these compounds will be collected at different distances from the MSW solid waste dumping yard because odors can be observed in ambient air. With a flow rate of 0.5–3.0 LPM, ambient air containing the odor-causing compounds will be collected in the ADT Sampling Probe utilizing a BDX II Abatement Air Sampler pump. The portable BDX II Abatement Air Sampler has an electrical flow control adjustment incorporated right into the

Fig. 2: (a) BDX II Abatement Air Sampler.

Fig. 2: (b) ADT PROBE.

device. The battery pack is rechargeable. VOC samples were obtained using an ADT Probe that works with 9.1cm tubes that are either electronically labeled or untagged. After the sample has been taken, the tube's mouth will be carefully sealed off and labeled with the location, date, and time of the sample. The laboratory will get this sampling tube to find out the odor concentration.

Using GC/MS to Identify the Target VOCs

A gas chromatograph (GC) is used to assess the odor of volatile organic compounds (VOCs). The concentrations were measured using an Agilent 6890 N series GC (Gas Chromatograph system), which included a single Flame Ionization Detector (FID) column. There is one 100 psi EPC Splitless Injection Port used to inject the sample at the designated temperature. An autosampler, 6890 control electronics, 6890 injectors, a Pentium computer, and a 17-inch flat-panel monitor are all included in the GC. ADT probes are used at three sampling locations to take air samples. The solid waste dumping yard's three different locations are where the samples were taken. The ambient air collected from the landfill underwent an analysis of several VOC chemicals. Figs. 3, 4, and 5 depict VOC concentrations according to the solid waste.

RESULTS AND DISCUSSION

VOCs Impact and Concentration from MSW Dumping Yard

It was also found that alkanes, aromatic compounds, chlorofluorocarbons, halogenated compounds, and halogenated aromatic hydrocarbons had been identified, but only in the gaseous samples that were taken from the MSW

dumping yard (Rosa et al. 2005). The most common problems with VOCs are their various direct and indirect effects on people and the environment, Such as the detrimental effects of toxic substances on the environment and the community. An investigation of VOC generation (odor emissions) in MSW dumping yard site. The following information on odor emission concentrations and their health effects provides more information on the three various locations in the MSW dumping yard.

Composition and Chemical Concentration at Station-1

In MSW dumping yards, there are six different types of odor compounds. Fig. 3 shows the six volatile organic compounds, which are part of the aromatic compounds group of volatile organic compounds, were detected at sampling station 1. As a result of the selected temperature program, the peaks appear to separate more precisely. A 1.41 $\mu g.m^{-3}$ t-butylbenzene maximum concentration and a Sec butylbenzene 0.07 $\mu g.m^{-3}$ minimum concentration were found at MSW dumping yard station 1 (Kumarathilaka & Jayawardhana 2016). Two of the Very volatile organic compounds (VVOCs) that are most frequently discovered in landfill dumping yards are *m & p* -xylenes and toluene. According to a study in the pre-monsoon season of 2023, toluene concentrations were 0.195 $\mu g.m^{-3}$, whereas m & p -xylenes concentrations ranged between 0.25 $\mu g.m^{-3}$ (Christensen et al. 1994). O-xylenes and ethylbenzene concentrations ranged between 0.12 and 0.18 $\mu g.m^{-3}$. There was a lower percentage of aromatic hydrocarbons in the other three sampling sites, but they were responsible for 93.7% of the carcinogenic risk associated with odorous chemicals released from MSW dumping grounds (Scaglia et al. 2011). The majority of the BTEX (benzene, toluene, ethylbenzene, and xylene) are discharged from the MSW dumping yard.

BTEX emitted into the environment from MSW dumping yards creates problems for public health and the environment. Toluene is a colorless liquid, and its family of VVOCs can severely harm neurological systems (David & Niculescu 2021).

Composition and Chemical Concentration at Station-2

A total of six odor compounds in landfill dumping yards are shown in Fig. 4. There are six volatile compounds in sampling station 2, of which four belong to the aromatic group, methyl chloride belongs to the halogenated group, and methyl ethyl ketone belongs to the chlorofluorocarbon

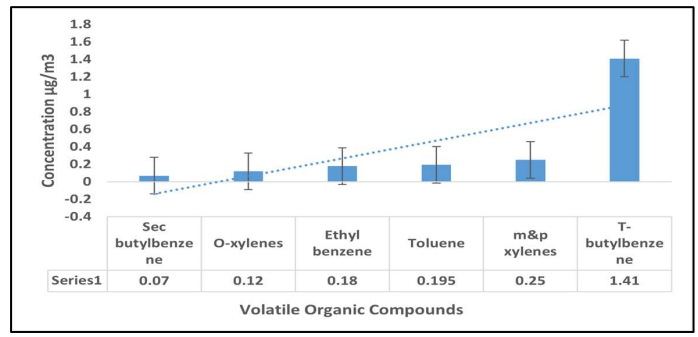

Fig. 3: MSW Dumping yard station-1.

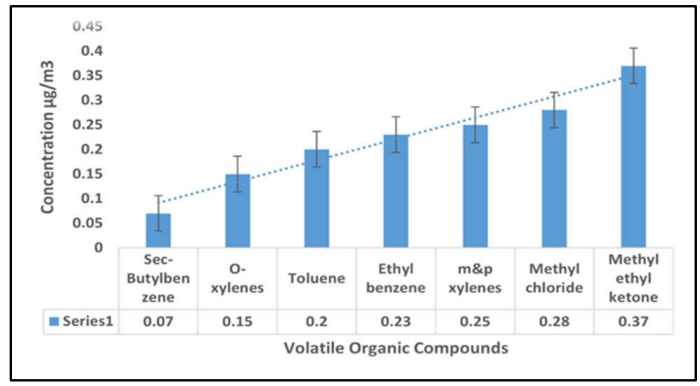

Fig. 4: MSW Dumping yard station-2.

group of Semi volatile organic compounds. As a result of the selected temperature program, the peaks appear to separate more precisely. A 0.37 $\mu g.m^{-3}$ methyl ethyl ketone high concentration and a Sec butylbenzene 0.07 $\mu g.m^{-3}$ low concentration were found at MSW dumping yard station-2 (Kumarathilaka & Jayawardhana 2016). Compared to VOCs, semi-volatile organic compounds. have a greater molecular weight and boiling point. In the MSW disposal yards, the toxicity from broken building debris, e-waste used furniture, and furnishings as additives can cause serious issues.

Methyl chloride is a colorless, explosive, and toxic chemical compound. Depending on the amount and duration of exposure, methyl chloride exposure can cause a variety of side effects, from fatigue and sickness to seizures and unconsciousness. Methyl chloride is also one of the dangerous pollutants that come under the VVOCs (Williams & Koppmann 2007). CFC-related occupational health risks in MSW dumping yards are moderately toxic, but their breakdown products are more dangerous (Hohener et al. 2003).

Composition and Chemical Concentration at Station-3

A total of five odor compounds in landfill dumping yards are shown in Fig. 5. There are five volatile compounds in the sampling station- 3 n-butylbenzene and benzene belong to the aromatic compound group, trichlorofluoromethane, chlorobenzene, and trichloroethane belong to the halogenated compounds of VOCs. As a result of the selected temperature program, the peaks appear to separate more precisely. A 1.02 $\mu g.m^{-3}$ benzene high concentration and a trichloroethylene 0.11 $\mu g.m^{-3}$ low concentration were found at MSW dumping yard station-3 (Kumarathilaka & Jayawardhana 2016).

Long-term skin contact with volatile organic compounds (VOCs) at municipal solid waste (MSW) dumping yards can cause skin irritation. Occupational health risks from VOCs include the potential for cancer through inhalation (Liu et al., 2014). Inhalation is the primary exposure method, with aromatic compounds significantly impacting human health. This includes causing allergic reactions, asthma, and impaired lung function (Pan et al., 2023).

Comparison and Composition of Odor Compounds at Dumping Sites

Throughout monitoring, 18 odor compounds were detected in landfill dumping yards. A comparison and composition of odor compounds at dumping sites is shown in Fig. 6. Based on the temperature program selected, few odor compounds repeat in three stations, but the peaks appear to separate more precisely in all three stations. We analyzed odor samples using GC-MS. According to the analysis, the maximum number of odors reported is due to *T*-butylbenzene at 1.41 $\mu g.m^{-3,}$ and the minimum amount is due to *Sec*-butylbenzene at 0.07 $\mu g.m^{-3}$. Certain compounds found in the MSW dumping yard, such as *sec*-butylbenzene and *tert*-

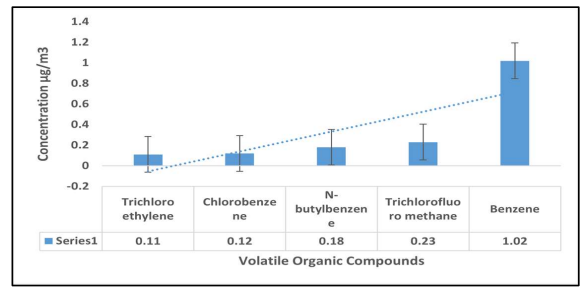

Fig. 5: MSW Dumping yard at station-3.

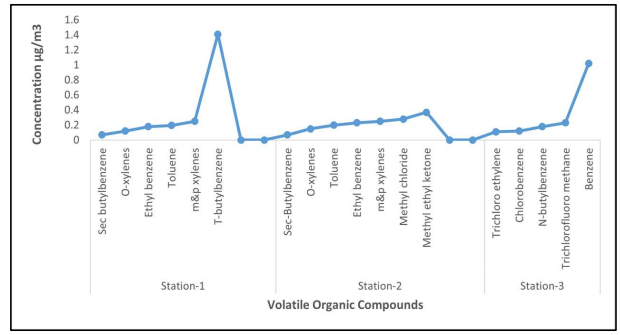

Fig. 6: Comparison and composition of odor compounds.

butylbenzene, can be inhaled or ingested. They are known to cause irritation to the skin, eyes, and respiratory tract. They may also result in lung aspiration (OEHHA 2024b).

Offensive Odors Due to Composition and Chemical Concentrations at Dumping Sites

Small amounts of odor compounds (methane, hydrogen sulfide, Volatile organic compounds, alkylbenzenes, mercaptans, benzene, toluene, and other aromatic hydrocarbons) in landfill dumping yards contribute to odors (Young & Parker 1983).

There is a wide range of odors associated with landfill dumping yard odor compounds, ranging from mildly pleasant to unpleasant and severe. Concentrations are influenced by the kinds of microorganisms found in the waste, as well as by the waste's age, composition, stage of decomposition, and pace of fermentation. Most smelly trace chemicals are considered to be hazards to the environment and workers' health (Young & Parker 1984, Young & Heasman 1985). The wind speed, humidity, and temperature levels in the surrounding air all have a significant impact on the spread of odors from the waste-dumping yard boundaries.

Formation of Odor Emissions (VOCs) and the Impact That They Have on The Environment and Humans

The term "VOCs" refers to organic compounds. VOCs are generated in the MSW dumping yard when various stages of waste and its type both compostable and non-compostable waste -are combined. Depending on the waste and surrounding temperature, VOCs are quickly emitted from the MSW dumping yard under normal pressure. Odor emissions, or volatile organic compounds, have a direct impact on the outdoor environment, cause nuisances to the surrounding area, and have an indirect and direct impact on human health. The detrimental effects of VOCs on the environment and people were the primary subject of discussion in this chapter.

These are the five primary phases in the MSW dumping yard that promote the discharge of odors during the odor emission process. The five phases are as follows: i) the MSW dump yard's size; ii) the landfill cover soil (biodegradation processes will be initiated based on waste type, age, and soil conditions); iii) the atmosphere's ambient temperature; iv) air permeation and oxidizing conditions; and v) biological and chemical activities (Randazzo et al. 2022). Fig. 7 shows the allergy symptoms due to inhalation of Odors at MSW Dumping Yard workers and nearby residents.

Inhaling volatile organic compounds from MSW dumping yards is the main way that humans are exposed to them. People can get a variety of health consequences as a result, such as mild respiratory diseases such as coughs, wheezes, allergies, and asthma (Su et al. 2012). The current study analyzed the impacts of each volatile organic compound (VOC) compound on the environment and MSW dumping yard personnel, as well as the different concentrations and pathways that VOCs emitted from these sites.

Benzene compound: A family of aromatic compounds includes benzene. The primary method of exposure from the MSW dumping yard is inhalation and is non-cariogenic. Health effects due to inhaling benzene from MSW dumping yards are possible to get decreased lymphocyte count (IRIS 2024). Symptoms of infected lymphocytes in human beings like fever, cough, runny nose, nutritional deficiencies, and also autoimmune diseases (NIH 2024). Symptoms due to inhalation of benzene at MSW Dumping Yard are shown in Fig. 1.

Chlorobenzene and ethylbenzene compounds: Chlorobenzene and ethylbenzene are from a family of aromatic compounds. Oral exposure is the main route of exposure from the MSW dumping yard; chlorobenzene

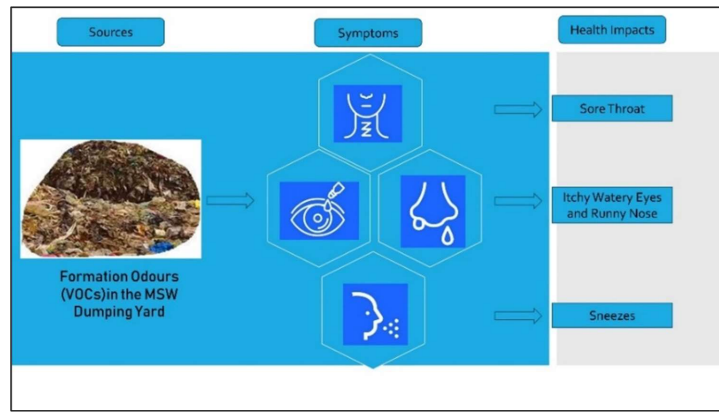

Fig. 7: Allergy Symptoms due to inhalation of Odors at MSW Dumping Yard.

and ethylbenzene can be passed on during communication between the workers in the dumping yard. Due to the presence of chlorobenzene compounds, histopathologic changes in the liver are possible, and ethylbenzene exposure can result in difficulties in the kidney and liver in MSW workers, as Fig. 8 indicates (IRIS 2024).

Methyl chloride compound: In the dumping yard, methanol and hydrogen chloride combine to produce methyl chloride (Holbrook 1992). Methyl chloride can be found in dumping yards indirectly due to burning (Graedel & Keene 1995).

Methyl chloride, also known as chloromethane, is a family of organic compounds. Inhalation is the main route of exposure from the MSW dumping yard. Breathing methyl chloride can irritate the lungs, causing coughing and/or shortness of breath, as shown in Fig. 8 (IRIS 2024).

Methyl ethyl ketone (MEK) compound: In the MSW dumping yard, methyl ethyl ketone (MEK) is frequently found in mixtures with acetone, ethyl acetate, hexane, and toluene. These combinations are composed of chlorofluorocarbons. These VOC compound mixtures are primarily produced in the MSW dumping yard during the biodegradation process (OEHHA 2024a). Inhalation is the main route of exposure from the MSW dumping yard. Low-dose chronic exposure to MEK causes neurological damage, and MEK can be irritating through all modes of exposure. It can be harmful if swallowed, ingested, or come into contact with the skin. In a study involving volunteers, both males and females exposed to 100 ppm (295 $mg.m^{-3}$) reported experiencing nose and throat irritation. (US EPA 2003).

Toluene compounds: Toluene is an aromatic chemical compound that is frequently found in mixtures with benzene. In the MSW dumping yard, toluene is frequently contaminated with other polycyclic aromatic hydrocarbons (PAHs). The primary method of exposure from the MSW disposal yard is inhalation. Fig. 9 shows the symptoms of headache, dizziness, a sense of intoxication, and mild eye and nose irritation brought on by inhaling toluene chemicals released in the MSW dumping yard. (Andersen et al.1983).

Trichlorofluoromethane (TCM) compound: The trichlorofluoromethane compound belongs to the chlorofluorocarbons. TCM is broken down in the presence of oxygen and methane, and the decomposition occurs simultaneously with methane's oxidation (Scheutz et al. 2004). Trichlorofluoromethane has no odor at concentrations lower than 20% (by volume in air); at greater concentrations, it has a faint, ethereal odor (Braker & Mossman 1980). Due to the presence of TCM in the MSW dumping yard, it is possible to get irritation on the skin and eyes and also global warming and ozone depletion potential to the environment (Verschueren 1996). Breathing concentrations in the air that are nearly 0% can cause dizziness and tiredness (USCG 1999). The impact of trichlorofluoromethane on MSW dumping yard workers is shown in Fig. 10.

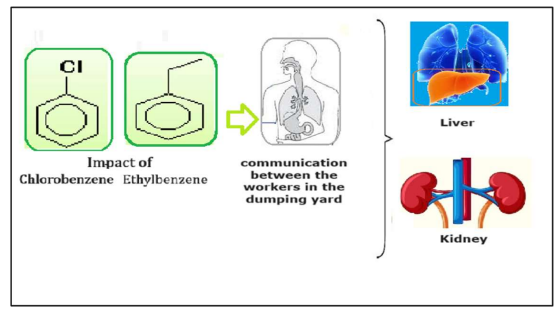

Fig. 8: Exposure of Chlorobenzene and ethylbenzene to MSW Workers.

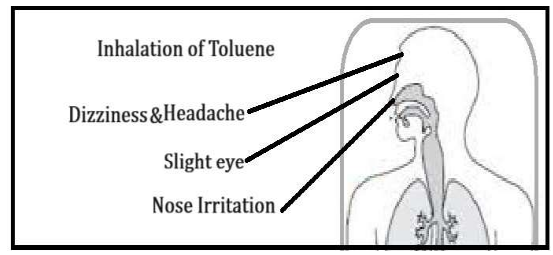

Fig. 9: Symptoms of inhalation of Toluene.

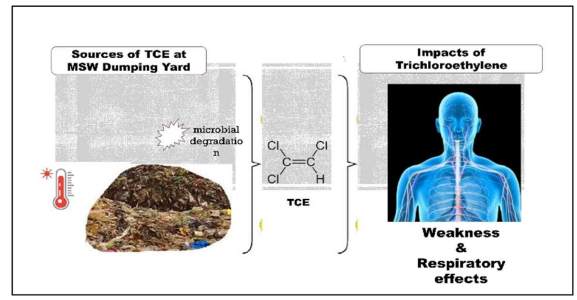

Fig. 10: Formation and impacts of TCE on MSW workers.

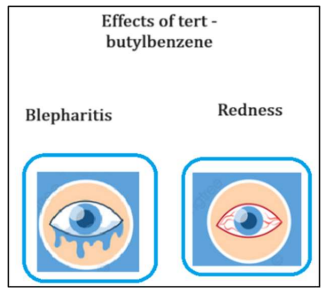

Fig. 11: Impacts of tert-butylbenzene MSW workers.

Trichloroethylene (TCE) compound: The trichloroethylene compound belongs to organic halogen compounds. Vinyl chloride is one of the byproducts of TCE's natural breakdown in the MSW dumping yard. Human health may be adversely affected by TCE across all modes of exposure. Because TCE is present in the MSW dumping yard, dermal and inhalation exposures are the primary routes of exposure. They complement each other regarding strengths and weaknesses. The respiratory effects are attributed to the person working the MSW dumping yard being predisposed to them by inhaling the waste products during the decomposition stage (Blair 1998). Fig. 10 shows the formation and impacts of TCE on MSW workers.

***Tert*-butylbenzene compound:** *Tert*-butylbenzene is an organic chemical compound belonging to the aromatic hydrocarbon family. A carbocation is created when isobutene and a Lewis acid react. Then, benzene and carbohydrate react to form the intermediate product. To allow the tert-butylbenzene to be released into the MSW disposal yard. The MSW Dumping Yard contains tert-butylbenzene, which may cause irritation of the eyes in workers (Blair 1998). Fig. 11 shows the impacts of tert-butylbenzene MSW workers regularly working in dumping yards.

Xylenes (*m,p,o*) compounds: Meta xylenes, para xylenes, and ortho xylenes (m,p,o) are organic chemical compounds that are one of the three isomers of dimethyl benzene. A large number of volatile organic compounds (VOCs), including xylene (m,p,o), present in the MSW dumping yard pose a risk to human health. The substance can get into their eyes, mouths, and skin (Langman 1994). Exposure to low concentrations of xylene (< 200 ppm) can result in temporary adverse effects that do not cause permanent harm. Fig. 12 shows the impacts on xylenes (m,p,o) MSW workers and nearby residents. Continuous exposure can cause nervous problems, headaches, depression, sleeplessness, agitation, and excessive weariness.

CONCLUSIONS

The VOC odor concentration was measured by collecting samples at three different sampling locations selected at the urban municipal solid waste dumping yard. The odor

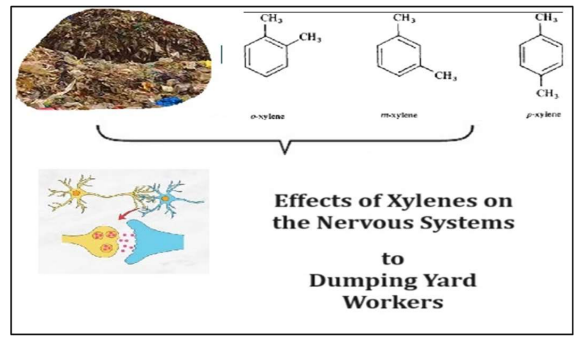

Fig. 12: Effects on MSW workers of xylenes *(m, p, o)*.

emissions were identified in the analysis carried out by the GC-MS 6280N instrument. Three different locations were selected for sampling in the dumping yard. When the dumpsite's total VOC concentrations were monitored in the pre-monsoon, it was discovered that stations 1 and 2 of the dump site, where fresh municipal solid waste is placed, had higher overall VOC concentrations, and more VOCs were detected. The sampling maximum VOC concentration of T-butylbenzene was recorded in the sampling location-1 dumping yard, and the value is 1.41 $\mu g,m^{-3}$. The minimum VOC concentration of 0.07 $\mu g.m^{-3}$ was recorded in sampling station-2 (*sec*-butylbenzene). The MSW fresh waste contains more moisture content, so we only receive a high odor concentration during the disposal of fresh waste. Metrological factors play a major role in the MSW dumping yard. Weather factors like high moisture content or humidity can cause solid waste to hydrate and break down, generating unpleasant odors in the atmosphere. Hence, once the solid waste dumping yard rains during the initial stage of the humidity phase, allergic people may inhale a high concentration of diffused odor emission from the waste material, which can cause an allergic reaction to the surrounding environment, some of which are severe.

Additionally, the odor emissions from the dumpsite pose both carcinogenic and noncarcinogenic risks to the health of the individuals participating in the dumping yard. Thus, it requires adequate management of municipal waste as well as routine health checks for workers at the dumpsite. As a result of these results, it is important to manage odor emissions (VOCs) during composting and take steps to reduce their negative effects on the environment and public health.

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