*International Research Journal of Environmental Sciences*_____ ISSN 2319–1414
Vol. **7(2),** 74-77, February **(2018)** *Int. Res. J. Environmental Sci.*

Short Review Paper

Emission of various contaminants into ambient air from wastewater treatment plant

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Available online at: www.isca.in, www.isca.me
Received 14th November 2017, revised 3rd February 2018, accepted 17th February 2018

Abstract

Volatile organic compounds (VOCs) and odorous compounds released into atmosphere causes ecological and health hazards. In this paper, emissions from wastewater treatment plant has been categorised into greenhouse gases and odorous compounds. Methane is produced in abundance due to anaerobic decomposition of organic waste along with carbon dioxide, nitrous oxide and other chemical compounds. They pose various health problems in terms of health and economy. Odorous compounds are the mixture of number of chemical species like hydrogen sulphide, ammonia and acetic acid etc. They create problems of headache and neuropsychology. Along with the production of these chemical species of different categories, process of their control and regulations has also been discussed.

Keywords: Emission of contaminants, greenhouse gases, volatile organic compounds, biofiltration, wastewater treatment plant.

Introduction

The stricter environmental regulations, rapid growth of residential areas and its burden on wastewater treatment plants (WWTPs), and increase in public demands on different privatized water companies have resulted in an increase in the number of public odor complaints during the recent decade. They may not be a direct cause of disease but their long-term exposure to high-strength odorant emissions actually does have negative effect on human health[1]. Air emissions are caused by point, area and volume sources of wastewater treatment facility[2]. During the process of waste water treatment, various types of contaminants are released into the atmosphere in contact with. These elements pollute the environment in numerous ways. Processing of waste water can produce odors problem as well as production of greenhouse gases. Waste water treatment emissions are generally volatile organic compounds which are present in the influent waste water and released from liquid or sludge in the treatment process. Volatile organic compounds vary in their concentrations depending upon their source like whether they are from sewers or primary and secondary clarifiers etc[3]. In a waste water treatment plant, gas-liquid partitioning occurs at the surface of channel, to/from bubbles used in processes with aeration and over weirs and drops. Production of the emissions will depend on the nature of waste water, method of treatment adopted and meteorological conditions. They emissions can be harmful to human health and resulting in headaches, nausea, eye problems, respiratory and even cause neuropsychological symptoms. If hydrogen di-sulphide is present in a concentration of more that 50 parts per million, it can cause unconsciousness and even death also. They adversely affect neurophysiologic functions[4]. These emitted contaminants can be analysed by different scientific methods i.e., physical, chemical and biological methods and once they are determined, preventive measures can be taken to counter their effects.

Theory and chemical equations

Emission of Greenhouse Gases (GHG): Greenhouse gases are mainly carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (NO_2) which are produced during anaerobic treatment of waste water[5]. Methane is produced by decomposition of a wide range of organic matter by microbial activities in the absence of oxygen, known as anaerobic decomposition. Fermentative bacteria break down the bigger organic molecules into smaller ones such as alcohols and fatty acids. These smaller compounds are further converted into methane and carbon dioxide. In general, around 40-45% of volatile matter present in feed sludge is converted into methane and carbon dioxide[6]. Methane emission is negligible during primary treatment of wastewater. But its production is very high in secondary treatment and it is proved by the fact that air collected from surface of activated sludge process has similar composition obtained from sewers. It is observed that in a volume of 1 m^3 of gas which consists 65 percent methane and 35 percent carbon dioxide are produced for every 1 kg of volatile matter microbially converted[7]. Capacity of waste water for methane production can be determined in terms of Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD). Methane gas can be measured by gas chromatography with fame ionisation detectors (FID) or thermal conductivity detectors, by IR spectroscopy, with or without

chromatographic separation and very conveniently by hand held detectors.

Nitrous oxide is obtained from biochemical oxidation of ammonia to nitrate[8]. This conversion occurs in two steps. In first step, ammonia is oxidised to nitrite by nitromonas bacteria and in second step, nitrite obtained is converted to nitrate by nitrobacter. Emissions of Nitrous oxide are associated with first stage of oxidation. It is also observed that when denitrification occurs under strong reducing conditions i.e. with zero concentration of dissolved oxygen will mainly produce gaseous nitrogen and when it is carried in the presence of low concentration of dissolved oxygen, it produces nitrous oxide. But still denitrification contributes more for the nitrous oxide emissions. Nitrous oxide generated within an anoxic zone i.e., oxygen depleted zone of an activated sludge plant is mostly emitted in subsequent aeration zone.

$NH_4^+ + NO_2^- \longrightarrow N_2O$

$NO_3^- \longrightarrow NO_2^- \longrightarrow NO + N_2O \longrightarrow N_2\,(g)$

Different wastewater treatment and storage facilities are producing huge emission quantity of volatile organic compounds. There quantity varies between 1600000 to 5000000[9]. Global emission of nitrous oxide is expected to increase at the rate of 13% with respect to present scenario from 2005 to 2020[10]. Several models have also been made to estimate the concentration of Volatile Organic Hazardous Air Pollutants in US based upon sewer emissions[11].

Emission of carbon dioxide from biological treatment of waste water is not considered in Green House Gas emission because it will be used up into the system by photosynthesis and finally re-enters the treatment process again. Contribution of carbon dioxide in GHG emission can be counted as an indirect emission which is produced by utilization of electricity and fossil fuels etc.

Emission of odours: Odors are sensations which are the result of reception of a stimulus our olfactory system[12]. Waste water collection system and various treatment units have the capacity to produce unpleasant odours. Odours are produced in waste water treatment plant in not only in liquid processes like primary treatment, secondary treatment and disinfection but also in solids processing which involves thickening of primary and secondary sludge and hauling of biosolids offsite for reuse. Headworks and preliminary treatment operations at waste water treatment plant have highest capacity to release odours and this condition is more deteriorated in situations like long collection systems. The most important sources of odours are sludge thickening processes, sludge digestion units and sludge load-out systems[13]. Odour threshold is technically defined as that concentration at which odour is observable by 50 percent of the available subjects. Odours are a very complex mixture of number of different substances and produced by different process conditions. In Table-1 given below, there is list of most commonly found odorous substances in waste water emissions along with their categorised smell and boiling point.

Table-1: Odorous chemical compounds with their specifications.

	Chemical species	Chemical formula	Natural smell	Boiling point (in ^{0}C)
Volatile sulphur compounds	Hydrogen sulphide	H_2S	Rotten egg	-60
	Methyl mercaptan	CH_3SH	Decayed cabbage, garlic	6
	Dimethyl disulphide	$CH_3S_2CH_3$	Putrefaction, Rotting vegetable	37-38
	Ethylmethyl sulphide	$C_2H_5SCH_3$		66-67
	Carbon disulphide	CS_2	Rotting radishes	46
	Sulphur dioxide	SO_2	Pungent, irritating, acidic	-10
Nitrogenous compounds	Ammonia	NH_3	Sharp, pungent, irritating	-33.40
	Methylamine	CH_3NH_2	Fishy, rotten	-6.4
	Ethylamine	$C_2H_5NH_2$	Ammonical	17
	Pyridine	C_6H_6N	Irritating	115
Acids	Acetic acid	CH_3COOH	Vinegar, sour	118
	Valeric acid	C_3H_7COOH	Sweat	185
Aldehydes and ketones	Formaldehyde	HCHO	Suffocating	-19
	Acetone	CH_3COCH_3	Fruit, sweet, mint	56
	Phenol	C_6H_5OH	Tar	79
Chlorine compounds	Chlorine	Cl_2	Pungent, suffocating	-34

These substances are not only malodourous but also the pose problems in terms of corrosion and health risk. Even their concentration in very small amounts (ppb level) can cause problems like headaches or even neuropsychological problems. These gases also undergo photochemical reactions and form the photochemical oxidants, primarily ozone. It is not easy to determine emission concentration of different chemical species in odour. Very lesser number of studies till date have measured specific odorous compounds as there is large variations are involved within the system itself. Hydrogen sulphide is more prevalent among all gases and they are found in influent pumping station, headworks and primary clarifiers than in downstream processing units. Apart from all variables discussed, meteorology of specific location will also affect odour release. Further, dispersion of these emissions will depend on the height of emission, topography, wind direction, temperature etc.

There are different physical, chemical and biological methods to control odour from waste water treatment plant like scrubbing, adsorption, condensation and oxidation etc[14]. Physical method includes proper ventilation and high emission point to increase dispersion. Oxygen and air can also be directly fed into the system to prevent anaerobic conditions. Adsorbent systems made up of activated carbon in the form of static beds can be effectively used for odour control. These adsorbent beds are used as a media for removing odorous contaminants by keep backing and concentrating on them. But it is somewhat uneconomical because cost of replacement and disposal of absorbent is fairly high. Chemical method includes ozonisation or by the addition of strong acidic and alkaline agent which increases the performance level of scrubbing tower. Now it will further depend upon complex airstreams and odour causing compounds that how many units with different chemicals is required for controlling of odours. Few drawbacks of chemical scrubbing are that it is uneconomical, chemical storage issues and handling requirements. There are many chemical compounds which can be used to prevent anaerobic conditions because of their oxidising capacity like hydrogen peroxide, ozone, potassium permanganate, chlorine dioxide and sodium hypochlorite in collection system along with waste water treatment plant[15]. Problem in this case is that it adds additional cost of treatment and problem of disposing residual products. Biological method includes biofiltration technique which is now a day more popular due to its high efficiency in removing complex odour emissions and more importantly its low capital and operational cost[16]. It is recent technology for air pollution control in which gases produced as a by product and containing volatile organic compounds or inorganic air toxics are passed through a material which are biologically active. It consists at least one bed of biologically active material. Filter beds are 1m high. Contaminated gas from source is passed through the filter. When sufficient removal time is given, then contaminants present in off-air will diffuse into a biologically active and wet layer surrounding the filter particle[17]. Aerobic degradation of all diffused contaminants will occur in biofilm using microorganisms and end products from complete biodegradation of air contaminants are water, carbon dioxide and stabilised microbial mass[18]. An experiment was conducted using bench- and pilot-scale reactors for the purpose of establishment of optimal operating conditions for a full-scale conceptual design. As a possible biofilter media, granular activated carbon (GAC) and yard waste compost (YWC) were tested with and without pH control. The sixteen month field study resulted in 99% removal of hydrogen sulfide, 53 to 98% removal of aromatic hydrocarbons, 37 to 95% removal of aldehydes and ketones, and 0 to 85% removal of chlorinated compounds.

Conclusion

Air emissions from wastewater consist of a very complex mixture that contains a number of different substances which are generated under different process situations. The most commonly found compounds are fatty acids, aldehydes, volatile sulphur and volatile nitrogenous compounds and chlorinated compounds. At present, available air treatment methods can be classified into biological, physical and chemical and methods i.e., scrubbers, adsorption and biofilters. Among all the greenhouse gases released, methane was most important chemical species to be released. Methane constitutes almost 65 percent of gases produced and 35 percent was carbon dioxide. Nitrous oxide was produced during both the process of nitrification and denitrification in which, denitrification was producing majority of nitrous oxide. Their production directly depends upon availability of nitrogenous compound in waste water. Associated health impacts are headache and nausea etc. Methane being highly flammable in nature, it may cause in burning in the system if present in excess. These gases also cause suffocation if their concentration exceeds their permissible limit in ambient air. Air Pollution Prevention and Control Division of EPAs started a field test program to develop a Green House Gas emission factors on the basis of actual emission measurement. This field test program involves the use of open path monitoring/transect method technique with Fourier Transform Infrared spectroscopy to measure emissions from wastewater treatment plant. Odorous compounds are produced during anaerobic decomposition of organic matter. They are primarily released during pumping and primary treatment of waste water. Numbers of chemical species are responsible for odour production. Some of them are hydrogen sulphide, ammonia, acetic acid and chlorine etc. They are detrimental to human health. Various steps can be taken to prevent them which involve covering of them and providing vent system to release them at suitable height for adequate dispersion in atmosphere. Latest technology in use is Biofiltration which is effective and economical. Emissions from waste water treatment plant should be analysed using suitable tools and proper emission factors. Several air regulations have been applied by government to control and reduce emission from waste water treatment plant. There is need of more researches in this regard so that effective control can be provided at the most economical rate. And their implementation should not be limited to only large waste water

treatment plant. To calculate emissions from wastewater treatment plant, different computer based emission models can be used which are based on the types of collection and treatment system, level of specific site data accepted and default data provided[19].

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