Overview to Categorization of Emissions from Domestic Sewer Lines & Domestic Sewage Treatment Plant

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Abstract

Since there are many sources of the gaseous emissions and strict rules as well as regulations are being imparted so as to stop this emission from this sources. But seeing apart from them Urban Water Cycle that mainly consists of various water supply, sewer lines, wastewater treatment plants, etc. is also the contributors to these emissions. The emissions given by them are stringent GHG and also highly toxic gases like hydrogen sulphide, VOC. This emission plays vital role as precursors to global warming and climate change. This paper gives review about the process leading to various emissions from sewer lines and sewage treatment plants. When the sewer flows through the sewer lines to the WWTP various gases gets generated and comes in contact to ambient atmosphere leading to their negative long term or short term impact on various surrounding infrastructures, living bodies, non-living bodies etc.

Keyword- Gaseous Emissions, GHG emissions, Formation Processes, Urban Water Cycle

I. INTRODUCTION

India is developing country and along with it, rapid growth is also taking place in its population rate. This is leading the country to experience Urbanization, due to this many large scale urban cities are becoming larger and the small scale towns are getting smaller. Compared to China India is on the second position in world in terms of its population. Currently more than 50% of the world's population resides in urban areas and is expected to increase to 70% by 2050. Greenhouse gas (GHG) emissions coming from urban areas are major topics because of the processes leading to their production. According to the Census of India [2011] population of India was 1.21 billion; from 2001 -2011 the urban growth rate in population was about 31.8% and in rural it was just 12.2%. The augmentation in the urbanization has leaded the country to face abundant environmental issues. Also in this frame work, greenhouse gas emissions from the urban areas are major topic of concern and study. Through rapid population growth, demand for water in urban areas is mounting and as a result wastewater generated from urban areas has also increased.

Mainly in the big cities main concern issue is the generation of the sewage and its management. Numerous research works have studied that the environmental effect due to GHG emission is acute at different scales. Water authorities in many parts of the world are adopting "carbon neutrality" objectives aimed at reduction of the GHG emissions predominantly, by using electricity from renewable sources [02].

II. GREENHOUSE GASES

A. Greenhouse Gases & their Potentials

GHG act as a blanket that retains solar heat in the atmosphere [08]. The gases in the atmosphere that absorb radiation are known as "greenhouse gases" (sometimes abbreviated as GHG) because they are largely responsible for the greenhouse effect. The greenhouse effect, consecutively leads to global warming. Major greenhouse gases are water vapor (H_2O), carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), according to the Environmental Protection Agency (EPA). "Whereas oxygen (O_2) is the second most abundant gas in our atmosphere, O_2 does not absorb thermal infrared radiation," according to Michael Daley, an associate professor of environmental science at Lasell College, told Live Science.

Factors that affect the degree to which any greenhouse gas will influence global warming are as listed below:

- Its load/abundance in the atmosphere
- Duration, for which it stays in the atmosphere
- Global-warming potential

As different GHG gases have different global warming potentials and for this Intergovernmental Panel on Climate Change IPCC have given GWP of different gases, table 1.1 gives the clear idea of it,

GREENHOUSE GAS	FORMULA	SECOND ASSESSMENT REPORT	FOURTH ASSESSMENT REPORT
Carbon dioxide	CO_2	1	1
Methane	CH_4	21	25
Nitrous Oxide	N_2O	310	298
Sulphur hexafluoride	SF_8	23900	22800
Nitrogen triflouride	NF_2	-(not available at that time)	17200

Table 1: Intergovernmental Panel on Climate Change (IPCC) Global Warming Potentials – 100-Year Time Horizon

Source: IPCC's Summary for Policymakers and Technical Summary of Working Group 1 Report (IPCC 1995) & IPCC's Fourth Assessment Report – Errata (IPCC 2012)

B. Urban Water Cycle

Urban water cycle includes water abstraction, water treatment for drinking water, transport and distribution of water, utilization of water, sewerage and rainwater transport and also last but not the least wastewater treatment. Wastewater degradation and energy requirements lead each phase to contribute the urban carbon footprint, but most of the awareness has been placed on direct emissions from wastewater treatment plants (WWTPs). WWTPs are recognized as a major source of gaseous compounds where the biological treatments result in GHG emissions of methane (CH_4), carbon dioxide (CO_2), hydrogen sulphide (H_2S) and nitrous oxide (N_2O) and many others.

1) Municipal Sewage Treatment Plants

STP plays an important role in the abatement of water pollution, but they also generate a huge amount of gaseous emissions to atmosphere. The discharge of hefty volumes of fugitive gases that contains low levels of chemical constituents may still lead to an excessive contribution to air pollution. Most centralized wastewater treatment methods consist of amalgamation of biological processes like activated sludge reactors, trickling filters, anaerobic digesters, etc. that promote biodegradation of organic matters by micro-organism and production of anthropogenic CH_4, and N_2O gaseous emissions [02].

2) Sewers

Open drain [Sewer] networks are a significant constituent of urban wastewater treatment systems that can be seriously embellished by odour complaints and sewer deterioration. Wide variety of volatile organic compounds (VOCs) is formed during sewage transportation due to the biochemical reactions under micro aerobic and anaerobic condition. The gases initiate in sewer drains are oxygen, nitrogen, carbonic dioxide, carbonic oxide, ammonia, carbonate of ammonia, sulphide of ammonium, sulphuretted hydrogen and marsh gas. This mixture is continually changing, according to the degree of putrefaction of the foul matters, which form sediment and a slimy coating of the inner surfaces in sewer pipe [04].

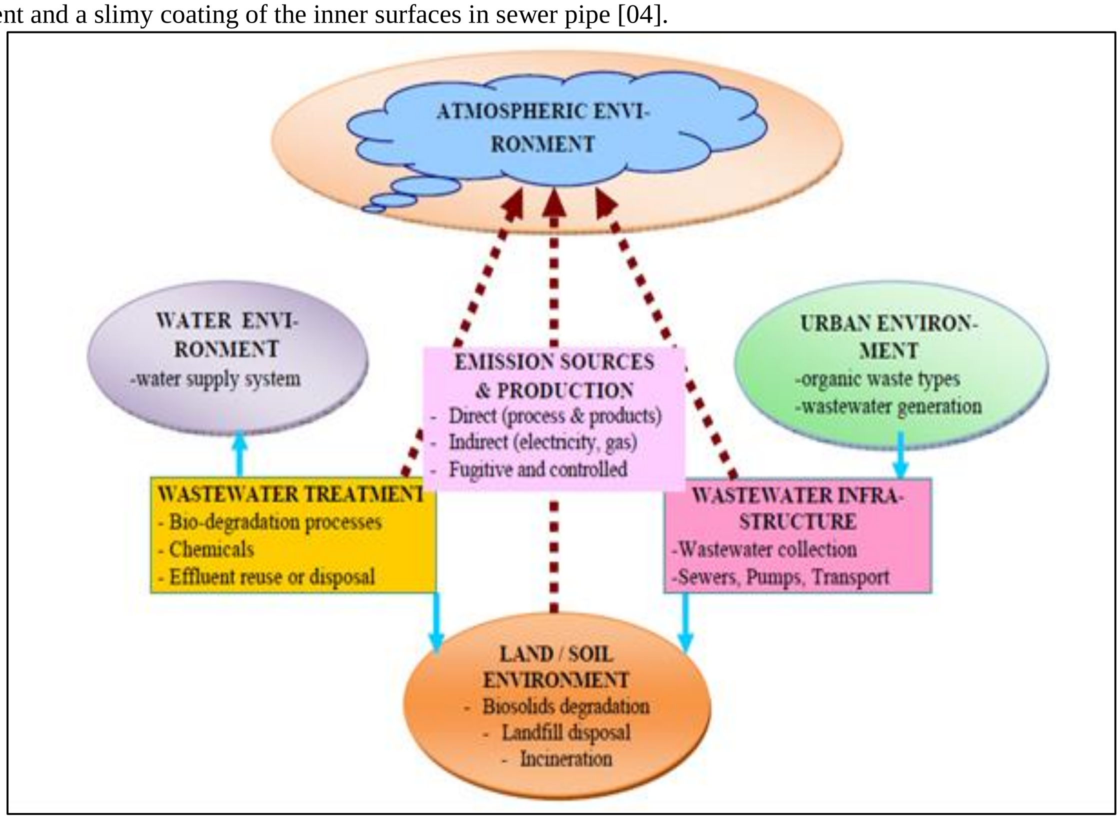

Fig. 1: GHG emission assessment framework from wastewater cycle [02]

III. CATEGORIZATION OF VARIOUS EMISSIONS

A. Volatile Organic Compounds(VOC)

Volatile Organic Compounds (VOCs) emission occurs during complete wastewater cycle. Considerable fraction of VOCs is released to atmosphere by gas-liquid mass transfer [05]. VOCs production during wastewater transportation in sewers occurs during turbulent flow and air exchange between ambient atmosphere and wastewater. Reactions that are biochemical taking place under microaerobic and anaerobic conditions during sewage transportation process may cause the formation and succeeding with release of a wide variety of volatile organic compounds (VOCs) from sewer networks, consequently is potential source for VOC emissions. The occurrence of VOCs in the sewer gas environments, even at trace concentrations, can be toxic, cause corrosion and result in odour annoyance due to the low odour threshold values for many of these compounds. A better understanding of the composition of sewer VOCs emissions is become critical for managing their release into the atmosphere.

The transfer rate of emission is affected by physicochemical properties of chemicals, fluid and flow characteristics. There is a growing concern that several VOCs that are present in wastewaters, especially industrial effluents, find their way to the atmosphere. In particular VOCs such as benzene, chloroform, ethyl benzene, toluene, m-xylene and o-xylene are found in refinery and petrochemical wastewaters in significant amounts as well as in many municipal wastewaters [05].

B. Hydrogen Sulphide [H_2S]:

The odors associated with collection systems and primary treatment facilities are result of an anaerobic or "septic" condition that takes place when oxygen transfer to wastewater is limited. During anaerobic state, the microbes present in wastewater have no dissolved oxygen available for respiration. These allow microbes known as "sulfate-reducing bacteria" to bloom.

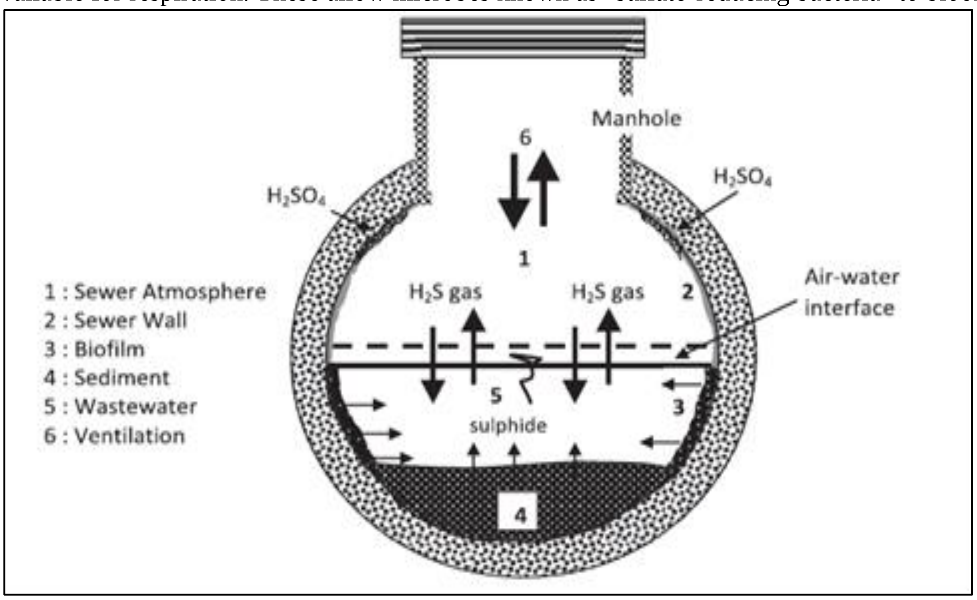

Fig. 2: Illustration of H_2S gas generation process in a partially full sewer [10]

Bacteria are utilized for formation of sulfate ion (SO_4^-) that is naturally copious in most waters as an oxygen source for respiration. The derivative of this activity is hydrogen sulfide (H_2S), which has a little solubility in wastewater and a strong, offensive, rotten-egg odor. In addition to its odor, H_2S can cause severe corrosion problems in the collection system. Due to its low solubility in wastewater, it is released to the atmosphere in areas such as wet wells, head works, grit chambers and primary clarifiers. There are characteristically other "organic" odorous compounds, such as amines and mercaptans , present in these areas, but H_2S is the most prevalent compound[12]

The experimental study carried out on the full scale sewage system [09] confirmed a strong correlation between formation of sulphide and methane gases and the hydraulic retention time. The observed common factors also include:

- Sulphide and methane gasses are generated as a result of bacterial metabolism therefore the time factor plays decisive role.
- Production rate is positively correlated with the hydraulic retention time and the longer the detention time, the higher the gas production rate.
- Production rate of methane in sewers could be correlated with the similar emission corresponding with CO_2 emission from energy usage in the wastewater treatment plant.

C. Carbon Dioxide (CO_2)

Production is endorsed to two main factors; treatment process and electricity consumption. For the period of anaerobic process, the BOD_5 of wastewater is either incorporated into biomass or it is converted to CO_2 and CH_4. A fraction of biomass is further converted to CO_2 and CH_4 via endogenous respiration. Short-cycle or natural sources of atmospheric CO_2 which cycles from plants to animals to humans as part of the natural carbon cycle and food chain do not contribute to global warming. Photosynthesis produced short-cycle CO_2, removes an equal mass of CO_2 from the atmosphere that returns during respiration or wastewater treatment. Digestion processes, either aerobic or anaerobic, also only emit short-cycle CO_2[02].

D. Methane (CH_4)

Breakdown of wastewater organic fraction under aerobic and anaerobic conditions lead sequential formation from complex to simpler product started with hydrolysis of complex particulate matter to simple polymer proteins, carbohydrates, and lipids that are further hydrolyzed to gain bio monomers like amino acids, sugars, and high molecular fatty acids. High molecular fatty acids are oxidized to intermediate by products and hydrogen.

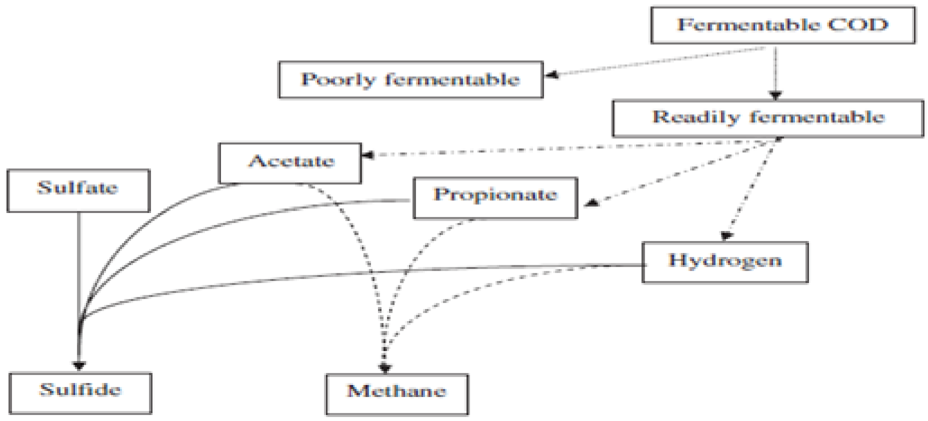

Fig. 3: Schematic representation of biological conversions in a sewer system, SRB(solid), MB(dashed), fermentative bacteria(dash-dotted) [01]

Methane and carbon dioxide production occurs through acetate cleavage. Also methane is produced due to carbon dioxide reduced by hydrogen. The amount of methane production increases due to increase in the BOD or COD content. Factors affecting the methane rate of generation are temperature, hydraulic retention time, pH, degree of wastewater treatment, and toxicants [08].

E. Nitrous Oxide (N_2O):

N_2O production in wastewater treatment systems is generally recognized to nitrification and denitrification processes, with the first one being considered the starting place of the majority of emissions in full-scale plants. Numerous parameters affecting N_2O production and emissions have been identified and evaluated. Low dissolved oxygen (DO) concentrations can lead to N_2O production during nitrification due to the activation of the nitrifier denitrification process. High nitrite (NO^{2-}) concentrations have also been reported to be responsible for N_2O production by ammonia oxidizing bacteria (AOB) in nitrifying systems, In denitrification stages, relatively high NO^{2-} or free nitrous acid concentrations have been reported to lead to N_2O accretion due to the inhibition of the last step of the denitrifying reaction. Likewise, low COD/N ratios and high DO concentrations are known to increase N_2O emissions as a result of impaired denitrification performance Some studies have also shown that transient conditions in terms of DO (oxic/anoxic), ammonium (NH^{4+}) concentration (shock loading) or NO^{2-} concentrations (accumulation) are of great importance and can generally generate N_2O emission events [03].

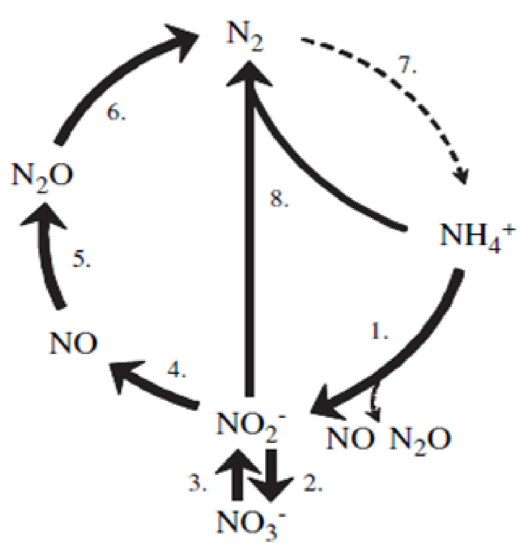

Fig. 4: Biological nitrogen conversions [13]

1) Aerobic ammonia oxidation (autotrophic and heterotrophic AOB and AOA),
2) Aerobic nitrite oxidation (NOB),
3) Nitrate reduction to nitrite (DEN),
4) Nitrite reduction to nitric oxide (AOB and DEN),
5) Nitric oxide reduction to nitrous oxide (AOB and DEN),
6) Nitrous oxide reduction to nitrogen gas (DEN),
7) Nitrogen fixation (not relevant in most WWTPs),
8) Ammonium oxidation with nitrite to dinitrogen gas (Anammox). Complete nitrification comprises step 1 and 2, complete denitrification step 3–6.

IV. Conclusion

– Sewer lines and STP are the contributors to the GHG emissions and also precursors to climate change.
– Need for development of various mitigation strategies that would help out in lower emission rates.
– As process for formation of CH_4, CO_2, and H_2S are all interconnected (acetate cleavage) so efforts must be made to reduce them all through one simple solution.
– Investigation to this emission should be carried out because of this knowledge gap leads to deterioration of atmospheric environment.
– Sustainable developments of water and wastewater cycle will definitely lead towards deciding strategies for climate change.

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