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Greenhouse Gases Emissions from Waste Stabilization Pond (WSP) at Jimma University, Institute of Technology campus, Kitto Furdisa, Jimma, Ethiopia

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Abstract

The most common GHG's emitted from wastewater treatment schemes are Carbon Dioxide, Methane and Nitrous Oxide. Such gasses produce an effect on an environment where we live by producing cover to hold heat of return. Hence, this research paper tries to estimate the emission of such gasses from Kitto Furdissa Campus of Jimma Institute of Technology (JIT) treatment plant for wastewater. The treatment plant has a total area of about 69,236.70 m^2 with two (2) anaerobic pond, one (1) Facultative Pond, and four (4) maturation pond for the whole treatment unit. The pond was sampled twice from each unit and proportionate average was analyzed. The data collection was carried out in March, 2019, in the season of winter to summer in Ethiopia, Jimma and From 10:00 am to 2:50 pm. The greenhouse gas (GHG) estimation was carried out based on the guidelines on IPCC (2006). According t this result the Methane (CH_4) emission was estimated to be 3.86 ktCO_2-eq/year. The main process for emission was the organic decomposition through Methanogenesis. Whereas, the Nitrous Oxide (N_2O) emission was estimated to 0.005 kg CO_2eq which was mainly from nitrification of denitrification-nitrification processes. Hence, we try to recommend the organization has to have the mechanism of control and well management for the Oxidation Pond (OP) to be functional i.e. Denitrification has to be started and Methanogenesis has to be extended.

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First of all, I would like to express my truthful gratitude to my supervisors Dr. Embialle Mengistie and Dr. Gudina Terefe for their motivation, encouragement, inspiration and priceless support throughout my study. I am grateful for the valuable advice, both technical and personal, which they gave me during my study.

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BOD	Biological Oxygen Demand(kg/day)
CH_4	Methane
CO_2	Carbon dioxide
COD	Chemical Oxygen Demand
DO	Dissolved Oxygen (mg/l)
EIA	Environmental Impact Assessment
EPA	Environmental Protection Agency
GC	Gas Chromatograph
GHG	Greenhouse Gas
GWP	Global Warming Potential
IPCC	Intergovernmental Panel on Climate Change
LCA	Life Cycle Analysis
MLVSS	mixed liquor volatile suspended solids
NH_4^+	Ammonium
NO_2	Nitrous oxide
OECD	Organisation for Economic Co-operation and Development
ppmv	parts per million by volume
TKN	Total Kjeldahl Nitrogen
TSS	Total Suspended Solids
WSP	Waste Stabilization Ponds
WWTP	Wastewater Treatment Plant
ASP	Activated Sludge Pond
UASB	**U**pflow Anaerobic Sludge Blanket

1. Introduction

1.1. Background

As a rule Waste Stabilization Ponds (WSPs) are mainly used in most countries of the world because of their less construction costs. Typically, WSPs are shallow water bodies that consist of a series of facultative, maturation and storage ponds, often with two ponds occurring in parallel to increase treatment efficiency. Facultative ponds, receiving raw wastewater, are designed to retain suspended solids and reduce the biological oxygen demand (BOD). Subsequently, maturation ponds are designed to remove pathogens and excessive nutrients, and to lower the BOD (Metcalf and Eddy, 2004). The final treatment phase consists of storage ponds that retain treated water before it is released into the environment or evaporates. All the three futures are visible in our case.

Even though, the purpose of oxidation pond is to treat the waste from its original content like its physical, biological and chemical contents to the acceptable level of pass in the environment it may also createannoyance through producing unwanted gasses. Such gasses include the Greenhouse Gasses (GHG) like; Carbon dioxide (CO_2), Methane (CH_4), and Nitrogen Dioxide (NO_2). According to Jim Shelton (2016) of Yale News, ponds account for 15.1% of carbon dioxide (CO_2) emissions and 40.6% of diffusive methane (CH_4) emissions. Out of these data the Global anthropogenic GHG contribution of waste and wastewater category 2.7% (IPCC, 2007). However, Carbon Dioxide (CO_2) is the most common "greenhouse gas" in the atmosphere along with steam and water vapour. Carbon Dioxide contributes to heating the earth's atmosphere by "trapping" solar energy as heat (UNFCCC p8).

Such treatment plants are so many in types. The centralized wastewater treatment methods can be classified as primary, secondary, and tertiary treatment. In primary treatment, physical barriers remove larger solids from the wastewater. Remaining particulates are then allowed to settle. Secondary treatment consists of a combination of biological processes that promote biodegradation by micro-organisms. These may include aerobic stabilisation ponds, trickling filters, and activated sludge processes, as well as anaerobic reactors and lagoons. Tertiary treatment processes are used to further purify the wastewater of pathogens, contaminants, and remaining nutrients such as nitrogen and phosphorus compounds. This is achieved using one or a combination of processes that can include maturation/polishing ponds, biological processes, advanced filtration, carbon

adsorption, ion exchange, and disinfection (IPCC, 2006). In KittoFurdisa of Jimma University Campus and other campus the previous scenario was septic tank treated waste water was released to the receiving channels of water streaming around. Now all the campus intends to treat in waste stabilization pond by detaining for some period of time (Gloyna, 1971).

In addition to the gasses, sludge is produced in all of the primary, secondary and tertiary stages of treatment. Sludge that is produced inprimary treatment consists of solids that are removed from the wastewater and is not accounted for in thiscategory. Sludge produced in secondary and tertiary treatment results from biological growth in the biomass, aswell as the collection of small particles. This sludge must be treated further before it can be safely disposed of.Methods of sludge treatment include aerobic and anaerobic stabilisation (digestion), conditioning, centrifugation, composting, and drying (IPCC, 2006). This treatment process may also leads to the production of GHGs which was not yet produced enough sludge to treat it separately in the Waste Stabilization Ponds (WSPs) built in Jimma University Ethiopia.

Because of the increasing rate of GHGs emission in the 20th century, UNFCCC2 developed an international agreement to control the release of GHG concentration in the atmosphere. According to this Protocol, all countries should control the amount of GHG production (Bogner et al., 2008). Ethiopia is one of the countries that contribute to the emission of GHGs via numerous sources such as energy production, industrial companies, wastewater treatment plants, etc. Hence, such types of studies would help in decision making towards the level of greenhouse gas emission.

1.2. Statement of the Problem

During the last 200 years the atmospheric concentrations of greenhouse gases (GHGs) have been increasing. Human activities as the agriculture, industry, waste disposal, deforestation, and especially fossil fuel have been producing increasing amounts of GHGs. For example, the concentrations of CO_2 increased from approximately 280 part per million by volume (ppmv) in pre-industrial age to 372.3 ppmv in 2001 and it will continues increase at about 0.5% per year (IPCC, 2001) whereas current CH_4 atmospheric concentration is going up at a rate 0.02 ppmv.yr-1. Furthermore, the annual sources of N_2O have been increased from the surface of the Earth by about 40–50% over pre-industrial levels (Hirsch et al., 2006). As a result, variations in the radiative

forcing of Earth's atmosphere could be being produced, so leading to large and rapid changes in the earth's climate due to global warming produced by these gases.

The most common GHG's emitted from wastewater treatment schemes are Carbon Dioxide, Methane and Nitrous Oxide. Currently Greenhouse Gases (GHGs) are said to be one of the great concerns for the development of better life in the world more than any time ever. It is also said that one of the main contributors for such problem was the anthropogenic activities carried out by far by our activities. The major problems arising from GHG emission was climate change and air pollution. One of the anthropogenic activities which produce GHG is WWTPs, though they are intended for high quality of environment. WWTPs produce carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) during the biological wastewater treatment processes and CO_2 is also emitted during the production of the energy required for the plant operation (Campos et. al, 2016; UNFCCC p8).

According the finding of ZeinandChehayeb, (2015) due to the emission of GHG from such sources there is a global warming which is affecting each and every part of the world. Due to global warming, the glaciers are melting which are causing the rise in the sea level. When the level of the sea rises, it causes danger to the people living in the low lying areas. So, this causes a big problem for people, plants and animals living on the earth or the ecosystem all in all. Pollution whether vehicular, electrical or industrial is the main contributor to the global warming. Everyday billions of vehicles release various gases into the atmosphere. This causes earth to warm up and increase its average temperature. The main purpose of the study is to collect information about a real problem that has negative impact on something in order to be able to reach solution or decrease its impact. This study shows that global warming is the result of many factors including greenhouse gasses which can be reduced if people behave in a responsible way. We can state that pollution is the link between the greenhouse gases released to the air and get trapped in the atmosphere which cause the raise in temperature known as global warming and leading to a huge bulk of negative consequences to all living and non-living creatures on Earth's surface.

Wastewater as well as its sludge components can produce CH_4 if it degrades anaerobically. The extent of CH_4production depends primarily on the quantity of degradable organic material in the wastewater, the temperature,and the type of treatment system. With increases in temperature, the rate of CH_4 production increases. This isespecially important in uncontrolled systems and in warm

climates. Below 15°C, significant CH_4 production isunlikely because methanogens are not active and the lagoon will serve principally as a sedimentation tank.However, when the temperature rises above 15°C, CH_4 production is likely to resume (IPCC, 2006). May be the University of Jimma being situated in tropical areas where it can carry the temperature level the emission of CH_4 might be highly available. Hence the inventory of GHG in an area not protocoled yet like oxidation pond in all Jimma University campus will be really vital.

Inaddition to the technology and unit flair for the increment of greenhouse gases the government none concern towards the issue of GHG emission is another problem for the exacerbation of the current issue arising. Both public and private sector organisations are increasingly being required to report on, manage and (where possible) reduce their greenhouse gas (GHG) emissions. According to (AWT, 2008), the issues around climate change, and the impact of anthropogenic greenhouse gas emissions are increasingly well understood by the scientific community, and this understanding is reflected by efforts to reduce or offset emissions by organisations in both the public and private sector. For most organisations, the first step in managing greenhouse gas emissions is to calculate the organisation or facility's "GHG emissions inventory" is an assessment of the amount of greenhouse gas that is released to the atmosphere on an annual basis as a result of activities attributable to that facility. Hence, the purpose of these studies will be to carry out an inventory as much as possible.

Even one of the most exacerbating factors to the emission of the GHG from such area is there in deficient operation mechanism, in deficientdesign and less management to make it more complicated area for the emission of GHG. Hence, there is potential to reduce GHGs of WWTPs which may happen through different mechanism of energy use. An appropriate and a comprehensive estimation of GHG emissions would be necessary, at the plant level.

Despite several advantages, WSPs are responsible for greenhouse gas (GHG) emissions; mainly methane (CH_4), carbon dioxide (CO_2) and nitrous oxide (N_2O).For instance, according to Huttunen et al. (2002), for WSPs and anaerobic lagoons have an emission for CO_2 and CH_4. These systems emit GHG with a global average of 85 and 86 gm−2 d−1, forCO_2 andCH_4, respectively. In CO_2 equivalent units, this CH4 emission corresponds to 2.1 kg CO_2 eq. m−2 d−1. Hence, the assessment and management of greenhouse gas emissions is of interest for wastewater treatment and

conveyance facilities as these facilities can be relatively energy intensive, and can contribute to the production of greenhouse gasses such as methane, carbon dioxide and nitrous oxide.

Generally, the type and amount of GHG production in WWTPs are highly dependent on the type and amount of degradable organic materials in wastewater. According to international agreements each sector in industry should estimate the generated GHGs and establish reduction strategies. WWTPs should also consider different strategies to reduce GHG emission for the protection of environment while avoiding carbon taxes and reducing energy costs. On the other hand, energy requirement and its price is an important key factor in the design and operation of WWTPs. Energy can be provided from different sources such as electricity or steam, combustion of produced biogas or sludge, while contributing to GHG emission. The estimation of total GHGs produced in Canadian WWTPs in 2005 was based only on on-site GHG generation and did not consider GHG emission due to off-site energy generation or other off-site sources related to the treatment plant. The addition of off-site GHG emissions can increase the contribution of WWTPs to the total GHG emissions of the country. These studies will consider for onsite GHG gas analysis only.

Hence, in most of the areas the main concern is for the treatment of the wastes in the environment where the emission of greenhouse gas is a concern. The focus for the emission of the GHG from such plant is minimal worldwide and not considered yet in Ethiopia either. As a world focus Ethiopia is also focusing on the treatment of wastes from garbage than the consideration of invisible gases like Methane (CH_4) and nitrous oxide (NO_2) where they may create a nuisance of difficulty in an environment more than anything else if proper investigation is not carried out.

The main focus of this study should be on the main difficulty to measure the emission of GHG's from WWTPs of such scale. This may answer the level of difficulty we are in for the activity we carried out for the purpose the improvements of environmental goals. The rare side the measurement this research to undertake was not yet considered in the whole world by large and not yet started in Ethiopia at most. But some countries mainly the most developed once are saying if this is not considered now and not latter the conscience is very bad. Recently the world of countries like us was even starting in to participate in such issues mainly in the major decision area to know whether we are in such scenario, Hence, this research is to support the decision maker as base line date and opportunity for the future generation to follow the same scenario.

The other point is the fear of the visible may lead to the over-care of none polluted environment. This over care may lead to the pollution of the invisible environment. Hence, the gap of such pollution exchange may be minimized by undertaking such major research in the area of universities like ours. Hence, the assessment and management of greenhouse gas emissions is of interest for wastewater treatment and conveyance facilities as these facilities can be relatively energy intensive, and can contribute to the production of greenhouse gasses such as methane, carbon dioxide and nitrous oxide

1.3. Significance of the study

Greenhouse gases (GHGs) are a group of atmospheric gases that are the fundamental reason of greenhouse effect (Ashrafi, 2012;Ehhalt, 2001). There is a broad consensus in a scientific community such gases are responsible for climate change and global warming which has been largely driven by increases in atmospheric GHGs, particularly carbondioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O). GHG emissions have been growing since industrial Revolution and where 60% higher in 2014 than they were in 1990. Since 1880, atmospheric CO_2eq concentrations have risen from around 290 ppm to 430 ppm (Hendersonet, al., 2018).

The anthropogenic sources of such gases are said to be the main causative of a warming to this level than the natural sources. Such sources include; energy, landfills, ruminants, and waste treatment plants (Ehhalt, 2001). Rising of GHG concentration from such sources and different have a wide range of effects including: rising sea Levels because of ice field to melt and ocean surfaces are expanding. Since around 1870, rates of global sea level rise (GSLR) have accelerated and are now about 3.5 mm (0.15 inches) per year. By 2100, sea levels are projected to rise by up to 2 meters (6.6 feet), depending on GHG emissions and the effects of warming air and ocean water on ice. Such increasing of seal levels could submerge the low-lying coastal areas where two third of the world's cities are located.

On the other hand, there might be changing weather patterns and extreme weather. Countries like Somalia, Kenya and other East African countries have experienced below- average rainfall since the late 1990's, contributing a 30% reduction in crop yields and famine in 2010, 2011, and 2016. 2015 was the driest year on record, supplanting 2013; and 2014 had been the third-driest in Western U.S. California (Henderson et, al., 2018). In Flanders, September 2016 was unusual warm, with 32 degrees Celsius on September 13th, an all-time record for that day (Ghent, 2016).

The others include, pressure on water and food, political and security risks, human health risks, and impact on wildlife and ecosystems (Henderson et, al., 2018).

Even though the importance of WWTP like Jimma University has contributes for the improvements of the wastewater clearing for the environments itself it has such impacts to be known. Hence, to undertake such types of studies are valuable for the programme to of the university as whole and the world in particular to take an action which is feasible for the whole process into consideration. Hence, the assessment and management of greenhouse gas emissions is of interest for wastewater treatment and conveyance facilities as these facilities can be relatively energy intensive, and can contribute to the production of greenhouse gasses such as methane, carbon dioxide and nitrous oxide

2. Objectives

2.1. General Objectives

The objective of the present study is to estimate GHG emissions of Waste Stabilization Pond (WSP) at Jimma University KittoFurdissaCampus of Jimma Institute of Technology (JIT). The study estimates GHG emissions from the treatment process only.

2.2. Specific objectives

1. to determine CH_4, CO_2 and N_2O fluxes from a series of WSPs Jimm University, KittoFurdissa Campus in winter to summer climate in Jimma, Ethiopia
2. To link GHG emissions to wastewater characteristics

3. Literature Review

3.1. Global Warming Potential

Greenhouse gases (GHGs) are a group of atmospheric gases that are the fundamental reason of greenhouse effect. The major GHGs are carbon dioxide, methane, nitrous oxide, water vapor,

ozone, CFCs1, and sulphur hexafluoride. Each of these gases has a specific effect on the atmosphere, measured by the Global Warming Potential (GWP) (Mohareb et al., 2004). The GWP relates to the GHG lifetime in the atmosphere and the efficiency of the molecule as a GHG. GWP is measured on a 20-year scale or 100-year scale and relative to the mass of carbon dioxide. The GWP of GHGs is presented in Table 1

Table 1Relative global warming potential and life time of GHGs (IPCC, 2001)

		Global Warming Potential	**Global Warming Potential**
GHG	**Lifetime (years)**	20-year	100-year
CO_2	*	1	1
CH_4	12	72	23
N_2O	114	289	296
CFCs	0.3-50000	5160-11000	140-11700
SF_6	3200	16300	23900

* The atmospheric lifetime for CO_2 is available due to the various rate of its removal **in**

3.2. Greenhouse Gases (GHGs)

Many chemical compounds present in Earth's atmosphere behave as 'greenhouse gases'. These are gases which allow direct sunlight (relative shortwave energy) to reach the Earth's surface unimpeded. As the shortwave energy (that in the visible and ultraviolet portion of the spectra) heats the surface, longer-wave (infrared) energy (heat) is reradiated to the atmosphere. Greenhouse gases absorb this energy, thereby allowing less heat to escape back to space, and 'trapping' it in the lower atmosphere. Many greenhouse gases occur naturally in the atmosphere, such as carbon dioxide, methane, water vapor, and nitrous oxide, while others are synthetic. Those that are man-made include the chlorofluorocarbons (CFCs), hydrofluorocarbons (HFCs) and Perfluorocarbons (PFCs), as well as sulfur hexafluoride (SF6). Atmospheric concentrations of both the natural and man-made gases have been rising over the last few centuries due to the industrial revolution. As the global population has increased and our reliance on fossil fuels (such as coal, oil and natural gas) has been firmly solidified, so emissions of these gases have risen. While gases such as carbon dioxide occur naturally in the atmosphere, through our interference with the carbon cycle (through burning forest lands, or mining and burning coal), we artificially move carbon from solid storage to its gaseous state, thereby increasing atmospheric concentrations (NCEI, 2018).

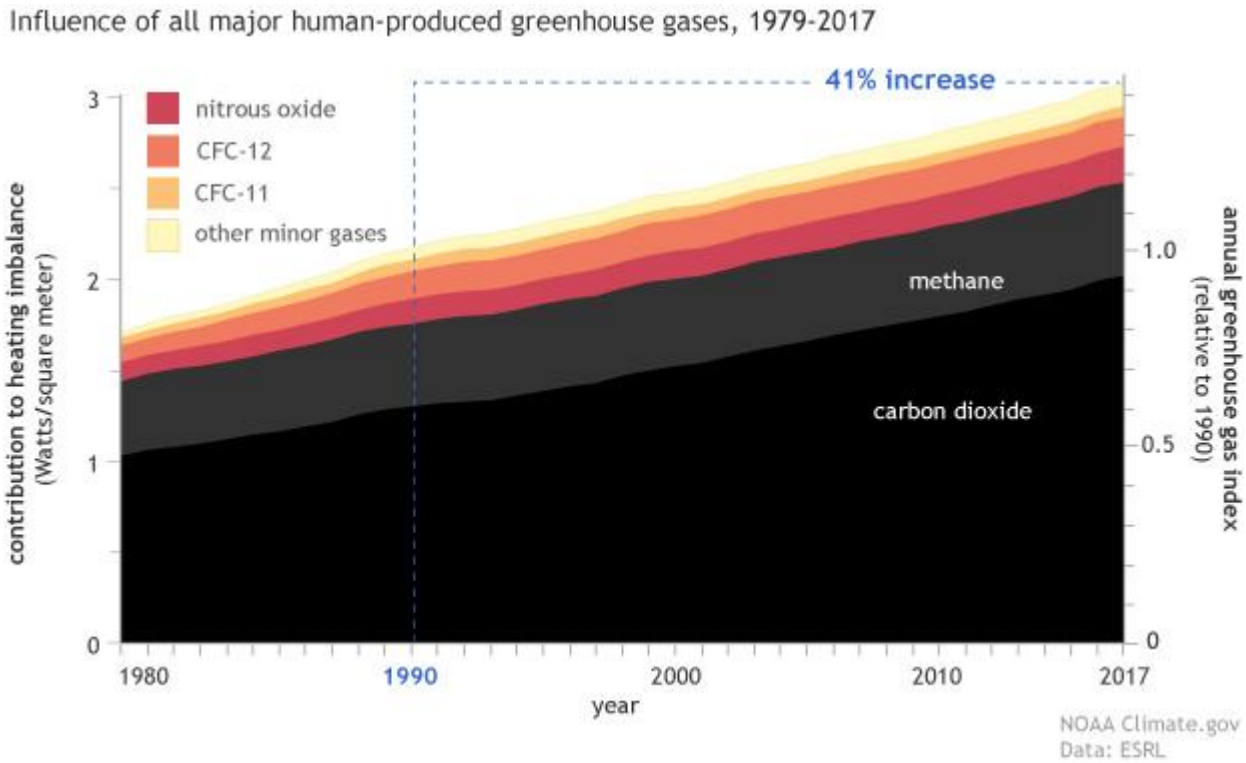


Figure 1 the heating imbalance in watts per square meter relative to the year 1750 caused by all major human-produced greenhouse gases

Monthly concentrations of carbon dioxide in air

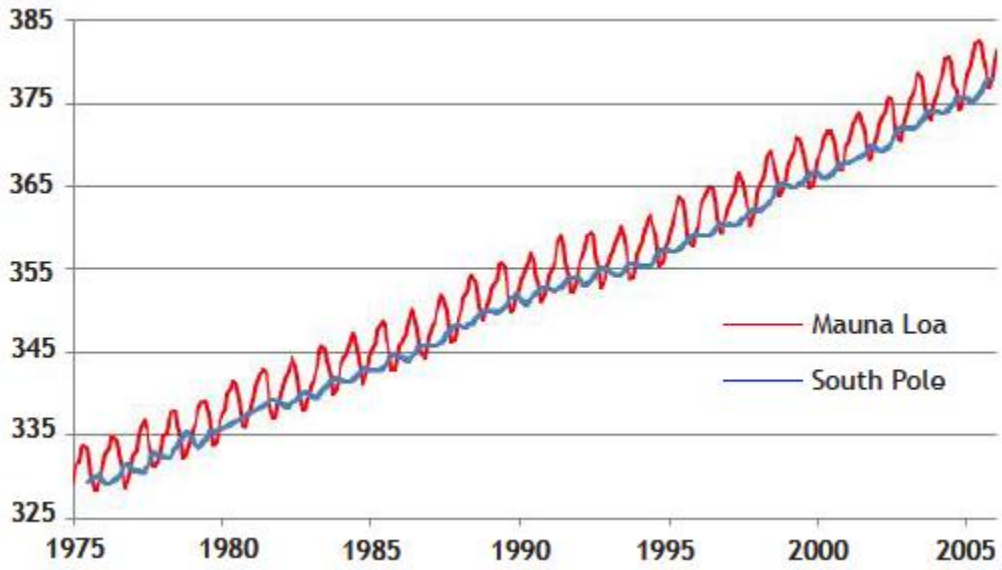


Figure 2 CO_2 concentration monitoring data at Mauna Loa.

The abundance of greenhouse gases in the atmosphere is controlled by biogeochemical cycles that continually move these components between their ocean, land, life, and atmosphere reservoirs. The abundance of carbon in the atmosphere is reduced through seafloor accumulation of marine sediments and accumulation of plant biomass and is increased through deforestation and the burning of fossil fuels as well as through other processes (NOAA, 2014).

Human activities have affected the land, oceans, and atmosphere, and these changes have altered global climate patterns. Burning fossil fuels, releasing chemicals into the atmosphere, reducing the amount of forest cover, and the rapid expansion of farming, development, and industrial activities are releasing carbon dioxide into the atmosphere and changing the balance of the climate system (NOAA, 2014). It is said that, around 1850, the CO_2 level was about 280 ppm, or near the top of a very gradual geological cycle, the level began to shoot upward. It has now reached the unprecedented value of 380 ppm—a 36% increase over the pre-industrial value and is rising at the incredible rate of about 2 ppm per year.In the U.S. the burning of fossil fuels results in the emission of 1.6 billion tons of carbon per year in the form of carbon dioxide. This represents 23% of the world's total CO_2 emissions—a large proportion considering that we have only 5% of the world's population. Electricity production accounts for 42% of our total carbon emissions and the burning of transportation fuels accounts for 32%, so targeting electricity generation and transportation fuels will address about three-quarters of our CO_2 emissions (GSS, 2006).

Global warming refers only to the Earth's rising surface temperature, while climate change includes warming and the "side effects" of warming—like melting glaciers, heavier rainstorms, or more frequent drought. Said another way, global warming is one symptom of the much larger problem of human-caused climate change (NOAA, 2014).Another distinction between global warming and climate change is that when scientists or public leaders talk about global warming these days, they almost always mean human-caused warming—warming due to the rapid increase in carbon dioxide and other greenhouse gases from people burning coal, oil, and gas.

Climate change, on the other hand, can mean human-caused changes or natural ones, such as ice ages. Besides burning fossil fuels, humans can cause climate changes by emitting aerosol pollution—the tiny particles that reflect sunlight and cool the climate— into the atmosphere, or by transforming the Earth's landscape, for instance, from carbon-storing forests to farmland.

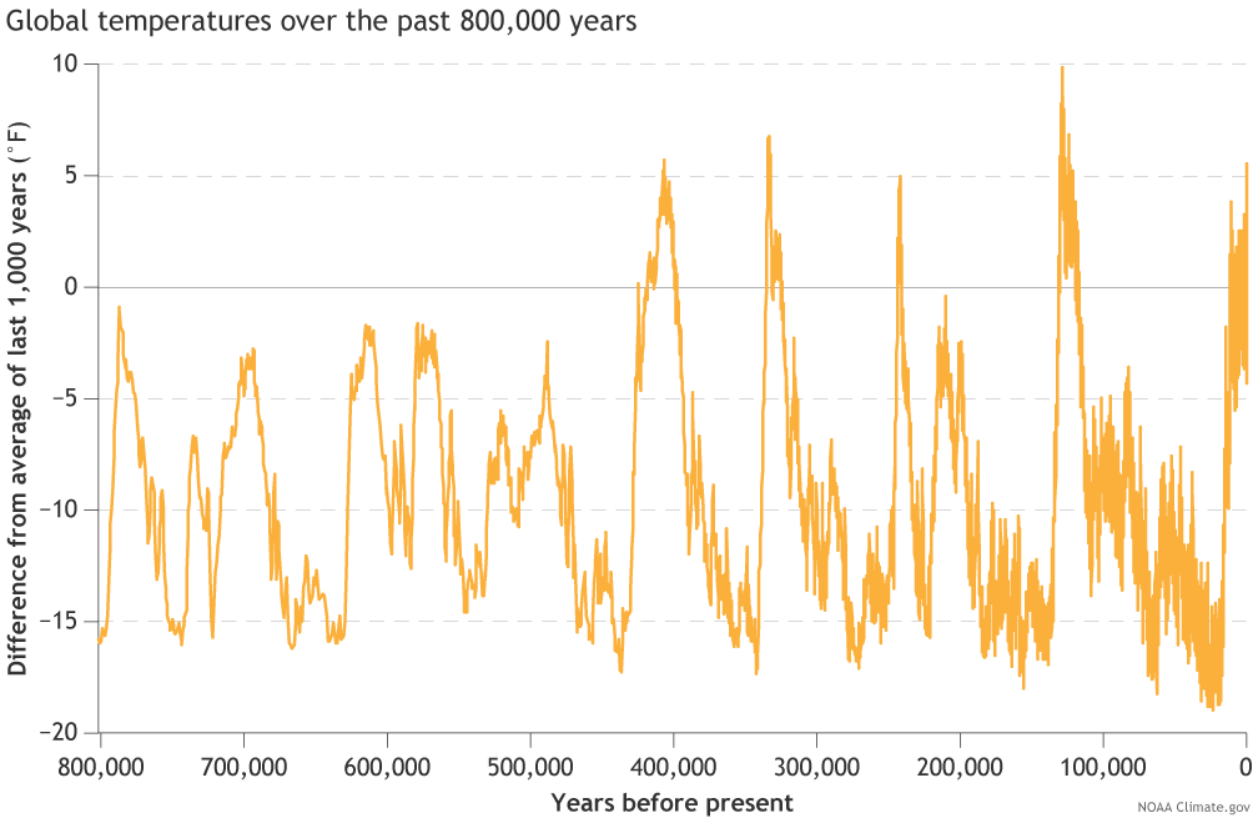


Figure 3 Increases and decreases in global temperature during the naturally occurring ice ages of the past 800,000 years, ending with the early twentieth century.

Today's global warming is overwhelmingly due to the increase in heat-trapping gases that humans are adding to the atmosphere by burning fossil fuels. In fact, over the last five decades, natural factors (solar forcing and volcanoes) would actually have led to a slight cooling of Earth's surface temperature.

Global warming is also different from past warming in its rate. The current increase in global average temperature appears to be occurring much faster than at any point since modern civilization and agriculture developed in the past 11,000 years or so—and probably faster than any interglacial warm periods over the last million years.

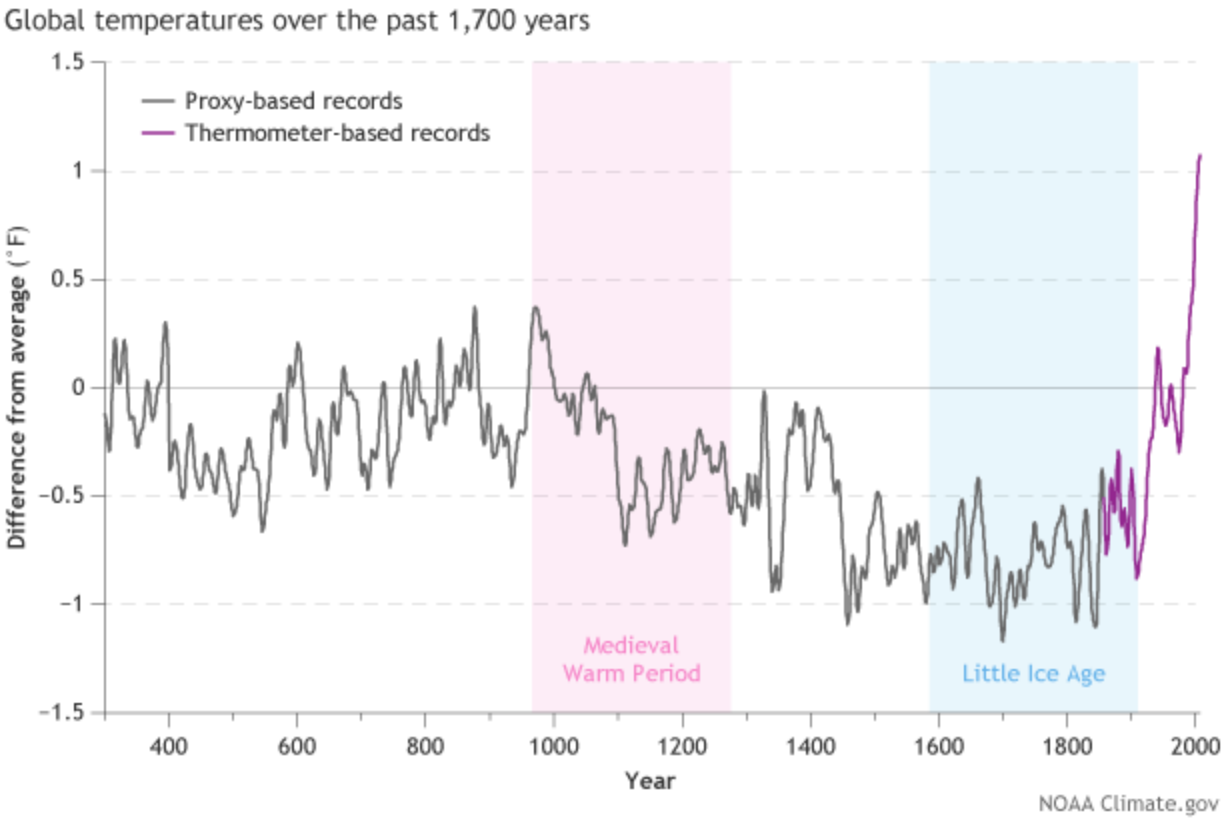


Figure 4 Temperatures over most of the past 2000 years compared to the 1961-1990 average, based on proxy data (tree rings, ice cores, corals) and modern thermometer-based data.

Human activities emit 60 or more times the amount of carbon dioxide released by volcanoes each year. Large, violent eruptions may match the rate of human emissions for the few hours that they last, but they are too rare and fleeting to rival humanity's annual emissions. In fact, several individual U.S. states emit more carbon dioxide in a year than all the volcanoes on the planet combined do (MichonScott&Rebecca Lindsey, 2016).

Figure 5 On the scale of carbon dioxide emissions, human sources far outweigh volcanoes.

Human activities—mostly burning of coal and other fossil fuels, but also cement production, deforestation and other landscape changes—emitted roughly 40 billion metric tons of carbon dioxide in 2015. Since the start of the Industrial Revolution, more than 2,000 billion metric tons of carbon dioxide has been added to the atmosphere by human activities according to the Global Carbon Project.

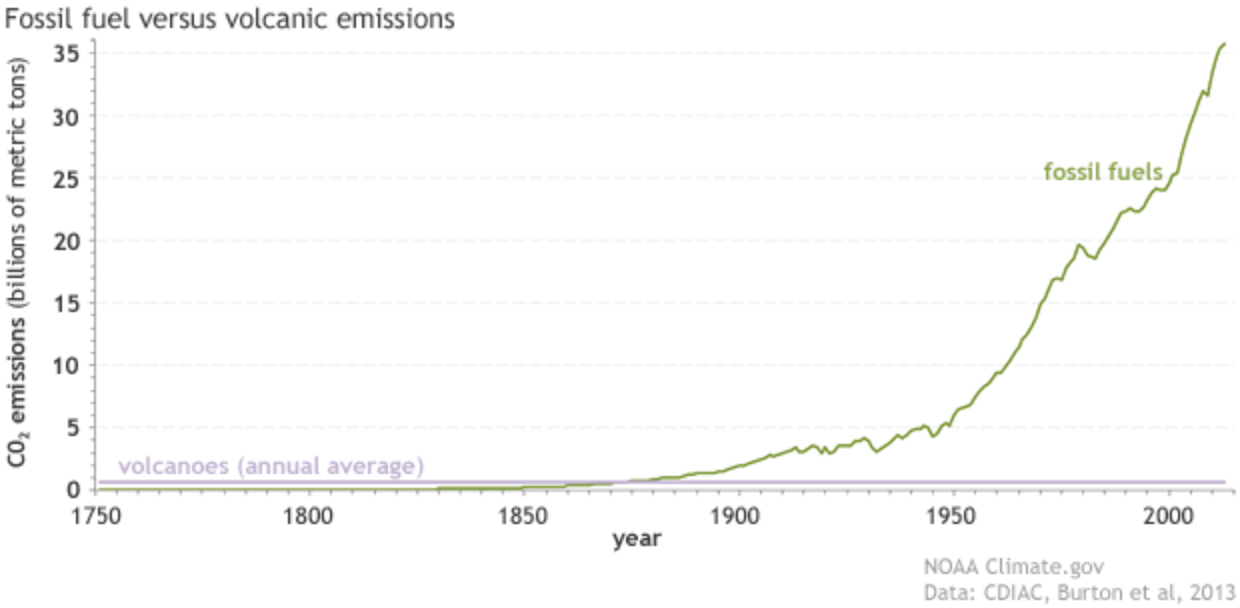


Figure 6 Concentration of Carbondioxide (CO2) from different sources.

3.3. Waste Water Treatment Plants (WWTPs)

Wastewater treatment happens in some infra structures which are called wastewater treatment plant (Hammer, 1986). Generally a wastewater treatment plant consists of Mechanical treatment, Biological treatment and Sludge treatment sections. There are different kinds of pollutants and wastes in the wastewater such as, nutrients, inorganic salts, pathogens, coarse solids etc., which are very dangerous for ecology and human. In order to remove these pollutants different processes have been exposed. There are specific processes and unit operations in wastewater treatment which are chemical, physical or biological. All these processes should be considered before deigning a proper wastewater treatment plant which depends on the characteristics of the wastewater (Kordrostami and Ismail，2015).

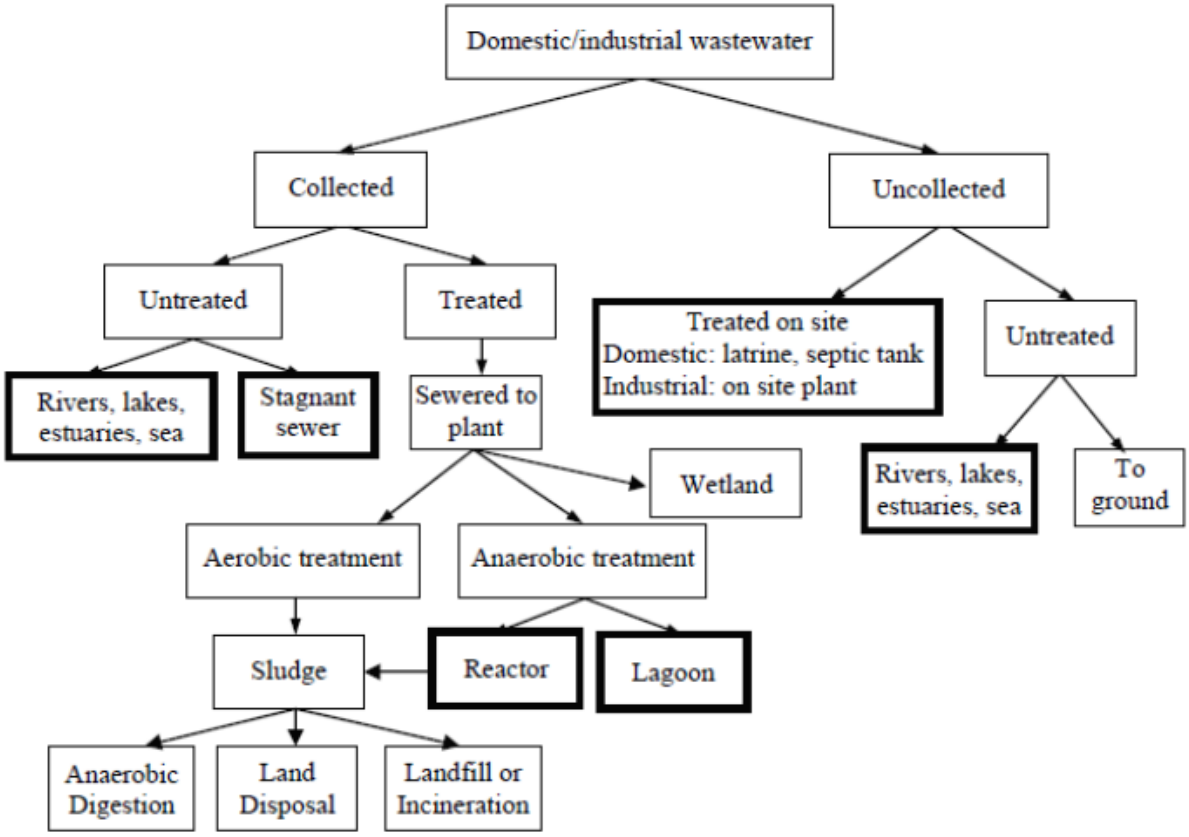


Figure 7 Wastewater treatment systems and discharge pathways IPCC 2006 (Doorn et al, 2006)

Wastewater treatment plants are one of the sources of anthropogenic greenhouse gas emissions (EPA, 1997). Carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O) are the three major greenhouse gases emitted during the wastewater treatment processes. The sources of generation of these gases are aerobic microbial degradation and combustion of organic matter, anaerobic degradation of organics and nitrification and denitrification process for CO_2, CH_4 and N_2O respectively. A set of guidelines was released by Intergovernmental Panel on Climate change (IPCC) to estimate the greenhouse gas (GHG) emissions and to help in formulating an effective mitigation strategies against the global climate change. For the domestic wastewater treatment, the IPCC methodology assumes that mainly methane is a major contributor towards GHGs during the treatment process (Monteith et al. 2005; IPCC 2007).

Jimma University has the WSPs as treatment option for its waste treatment. Oxidation Ponds (OP) and waste stabilisation ponds (WSP) are natural treatment systems while upflow anaerobic sludge

blanket (UASB) and activated sludge process (ASP) are conventional treatment systems. The latter two have working principle is mainly based on bioremediation. The significant removal of BOD was reported by OP And WSP, which is 96 and 87% respectively (Jamwal et al. 2009; Al-Hashimi& Hussain 2013). Other literature has also shown BOD removal efficiency of 6668% and 72610% for OP and WSP. A major limitation of these systems is a high land requirement, 0.8–2.3 hectare/MLD. This is 3–4 times of land required for ASP plant. The capital cost of natural WWTPs is INR (Indian Rupees) 1.5–4.5 million/MLD but operation and maintenance (O&M) cost is much lower than ASP that is, INR 0.06–0.1 million/ year/MLD. The energy requirement for such WWTPs is negligible as compare to ASP (Compendium of sewage treatment technologies 2009).

CO_2 is directly produced in aerobic biological processes by the oxidation of organic compounds accompanied by cell growth. CO_2 derived from wastewater treatment is assumed to originate from short-lived biogenic material (IPCC 2006), however, fossil organic carbon was found in the incoming wastewater of WRRFs and related to direct fossil CO_2 emissions from oxidation by activated sludge (AS), depending in the extent, on wastewater composition and treatment configuration (Law et al. 2013). N_2O is currently the single most important ozone-depleting gas (Ravishankara 2009). N_2O emissions occurring in aerated zones are lined to nitrogen load, volumetric stripping, and the role of ammonia-oxidizing bacteria (Daelman et al. 2015; Guo et al. 2013).cStenström et al. (2014) have found that N_2O formed in liquid phase during denitrification accumulates mainly in the water volume until aeration starts and thereafter it is quickly stripped off to the atmosphere. Similarly, this can happen for CH_4. Although methanogenic activity in AS tanks is deemed to be insignificant (Gray et al. 2002), dissolved CH_4 can enter aerobic AS reactors, where it is stripped or biologically oxidized (Daelman et al. 2012), from sewers (Guisasola et al. 2008) or sections of the WWTPs where anaerobic conditions occur, e.g. in anaerobic selectors (Techobanoglous et al. 2014; Wentzel et al. 2008). Therefore, beside the actual GHG production occurring in aeration tanks, stripping induced by aeration is one of the main causes making this compartment one of the major contributors to WRRF direct emissions.

According to Chris Wells and Suzanne Savanick Hansen, 2008, In total, over the past 18 years Macalester‘s sewage has emitted an estimated 1,576,055 pounds or 788 tons of carbon dioxide which they estimated from water consumption not measured directly. According to the long serving expert in theses area for every one million gallons of sewage that is discharged into the system about 3,000 pounds of CO_2 are emitted to the atmosphere.

According to CH2MHILL, 2007 for CWCCG work, that identified from the previous work WWTPs as one of the top ten emitters of GHG in the state of California. Hence, the assessment and management of greenhouse gas emissions is of interest for wastewater treatment and conveyance facilities as these facilities can be relatively energy intensive, and can contribute to the production of greenhouse gasses such as methane, carbon dioxide and nitrous oxide.

3.4. Emission points

Carbon Dioxide (CO_2) is an odorless, colorless GHG, which has both natural and anthropogenic sources. Natural sources include the following: decomposition of dead organic matter; respiration of bacteria, plants animals, and fungus; evaporation from oceans; and volcanic outgassing. Anthropogenic (human caused) sources of carbon dioxide are burning coal, oil, natural Gas and wood (Eyestone Environmental, 2016).

Methane (CH_4) is a flammable gas and is the main component of natural gas. When one molecule of methane is burned in the presence of oxygen, one molecule of carbon dioxide and two molecules of water are released. A natural source of methane is the anaerobic decay of organic matter. Geological deposits, known as natural gas fields, also contain methane, which is extracted for fuel. Other sources are from landfills, fermentation of manure, and cattle (Eyestone Environmental, 2016).

Nitrous Oxide (N_2O) is a colorless GHG. High concentrations can cause dizziness, euphoria, and sometimes slight hallucinations. Nitrous oxide is produced by microbial processes in soil and water, including those reactions which occur in fertilizer containing nitrogen. In addition to agricultural sources, some industrial processes (fossil fuel-fired power plants, nylon production, nitric acid production, and vehicle emissions) also contribute to its atmospheric load. It is used in rocket engines, race cars, and as an aerosol spray propellant (Eyestone Environmental, 2016).

There are multiple sources of GHG emissions at a WWTP. CCAR, a non-profit voluntary registry for GHG emissions, categorizes emissions types as: direct, indirect, fugitive, and de minimus (CCAR, 2006).

Direct emissions are emissions from sources that are owned or controlled by the reporting organization. Direct emission result from stationary combustion, mobile combustion, and industrial processes. Stationary sources at WWTPs include boilers, emergency generators, and

pumps that emit GHGs such as CO_2, N_2O, and CH_4 as a result of combustion processes. Mobile sources such as automobiles, trucks, of-road vehicles, and construction equipment also release the same type of GHG emission due to combustion processes. Internationally accepted protocols have been established previously to estimate emissions from stationary and mobile combustion sources (CCAR, 2006).

Table 2 presents the main wastewater treatment and discharge systems in developed and developing countries, and their potentials to emit CH_4 and N_2OIPCC 2006 (Doorn et al, 2006).

CH_4 AND N_2O EMISSION POTENTIAL FOR WASTEWATER AND SLUDGE TREATMENT AND DISCHARGE SYSTEMS				
Types of treatment and disposal				**CH_4 and N_2O emission potentials**
Collected	Untreated	River discharge		Stagnant, oxygen –deficient rivers and lakes may allow for anaerobic decomposition to produce CH_4 Rivers, lakes and estuaries are likely sources of N_2O
		Sewers (closed and underground)		Not a source of CH_4/N_2O
		Sewers open		Stagnant, overloaded open collection sewers or ditches/ canals are likely significant sources of CH_4
	Treated	Aerobic treatment	Centralized aerobic waste water treatment plants	May produce limited CH4 from anaerobic pockets. Poorly designed or managed aerobic treatment systems produce CH_4 Advanced plants with nutrient removal (nitrification and denitrification) are small but distinct sources of N_2O
			Sludge anaerobic treatment in centralized aerobic wastewater treatment plant	Sludge may be a significant source of CH_4 if emitted CH_4 is not recovered and flared
			Aerobic shallow ponds	Unlikely source of CH_4/N_2O. Poorly designed or managed aerobic systems produced CH_4
		Anaerobic treatment	Anaerobic lagoons	Likely source of CH_4. Not a source of N_2O.
			Anaerobic reactors	May be significant source of CH_4 off emitted CH_4 is not recovered and flared.
uncollected	Septic tanks			Frequent solids removal reduce CH_4 production
	Open pits/Latrines			Pits/latrines are likely to produce CH_4 when temperature and retention time are favorable.
	River discharge			See above.

Indirect emissions are emissions that are consequence of the actions of a reporting entity but produced by sources owned or controlled by another entity. Indirect emissions result from the purchase of electricity, imported steam, district heating or cooling, and production of electricity from a cogeneration plant. Internationally accepted protocols have been established previously to estimate emissions associated with identified indirect emission sources (CCAR, 2006).

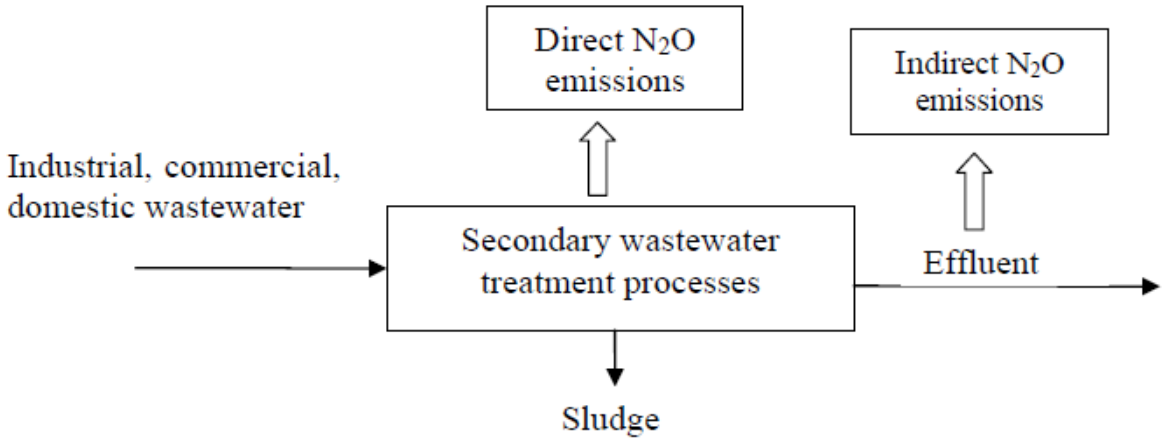


Figure 8 Possible pathways of nitrous oxide sources in conventional wastewater treatment process (adapted from Crawford, 2009) (Das, 2011)

Fugitive emissions as `` intentional and unintentional release of GHG emissions from joints, seals, gaskets, etc. `` Fugitive emissions result from specific industrial processes and can result from WWTP operations. Examples of GHG fugitive emission from WWTP process are CH_4 leaks from digesters and associated equipment for solid handling (e.g., dewatering of anaerobically digested sludge) (CCAR, 2006).

De minimus emission is emission as a quantity of GHG emission from combustion of sources and /or gases which, when summed, are considered insignificant (e.g., equal to less than 5 percent of an organization's total emissions). The category of de minimus emissions was defined to prevent overly burdensome emissions reporting (CCAR, 2006).

In general, plants that achieve high levels of nitrogen removal emit less N_2O, indicating that no compromise is required between high water quality and lower N_2O emissions. N_2O emissions primarily occur in aerated zones/compartments/periods owing to active stripping, and ammonia-

oxidizing bacteria, rather than heterotrophic denitrifiers, are the main contributors. However, the detailed mechanisms remain to be fully elucidated, despite strong evidence suggesting that both nitrifier denitrification and the chemical breakdown of intermediates of hydroxylamine oxidation are probably involved (Law, 2012).

WWTP CO_2 emissions, other than those from stationary and mobile combustion sources, result from combustion of sludge (i.e., incineration) or digester gas (i.e., flares, turbines, boilers, etc.). Both sludge and digester gas are types of biofuels or renewable energy fuel sources, and their resulting CO_2 emissions are generally accepted as ''biogenic'' carbon-neutral emissions or non-fossil fuel emission. The general international practice for CO_2 emission from the combustion of wastewater products such as sludge or digester gas is that these emissions should not be reported as GHG emission and should be kept in a category separate from fossil fuel emission, which are considered anthropogenic emissions. Based on these general practices, CO_2 emissions from WWTPs are no further discussed (CCAR, 2006).

According to (CCAR, 2006) and IPCC, 2006 CH_4 an N_2O are the only recognized GHG emissions from WWTP processes. Based on IPCC, CH_4 emissions from aerobic processes are expected to be limited and are dependent on the design and management of a system. A poorly-managed aerobic system may emit more CH_4 emissions than a well-managed system. The larger source of CH_4 emissions occurs from open anaerobic wastewater treatment processes, when the CH_4 produced is released directly to the atmosphere uncontrolled, and without treatment, such as anaerobic lagoons, anaerobic reactors (e.g., digesters), or septic tanks. While CH_4 emission from septic tanks can be significant, these emissions are not considered in this project for inclusion in a WWTP protocol because septic tanks are not part of municipal WWTP operations. Small amounts of direct CH_4 emissions may also be released as a result of incomplete combustion of digester gas.

In the same finding (CCAR, 2006) N_2O emissions result from nitrification/denitrification (NDN) processes at a WWTP, N_2O, as well as nitric oxide, are normal intermediate byproducts of denitrification, which is a process by which nitrite and nitrate are converted to nitrogen gas. N_2O can also be produced under some nitrifying conditions via nitrifying microorganisms. In addition to the NDN process, N_2O emission can also result from natural denitrification of nitrogen containing compounds in treated wastewater discharged to receiving stream. As wastewater enters

a river or other body of water, the remaining nitrogen species in the effluent can naturally be converted and released as N_2O emission may also come from the combustion of digester gas.

The Global emissions pathway characteristics of different GHG were depicted in different models.General characteristics of the evolution of anthropogenic net emissions of CO_2, and total emissions ofmethane, black carbon, and nitrous oxide in model pathways that limit global warming to 1.5°C with no orlimited overshoot. Net emissions are defined as anthropogenic emissions reduced by anthropogenicremovals. Reductions in net emissions can be achieved through different portfolios of mitigation measuresillustrated in Figure SPM.3b (IPCC, 2018).

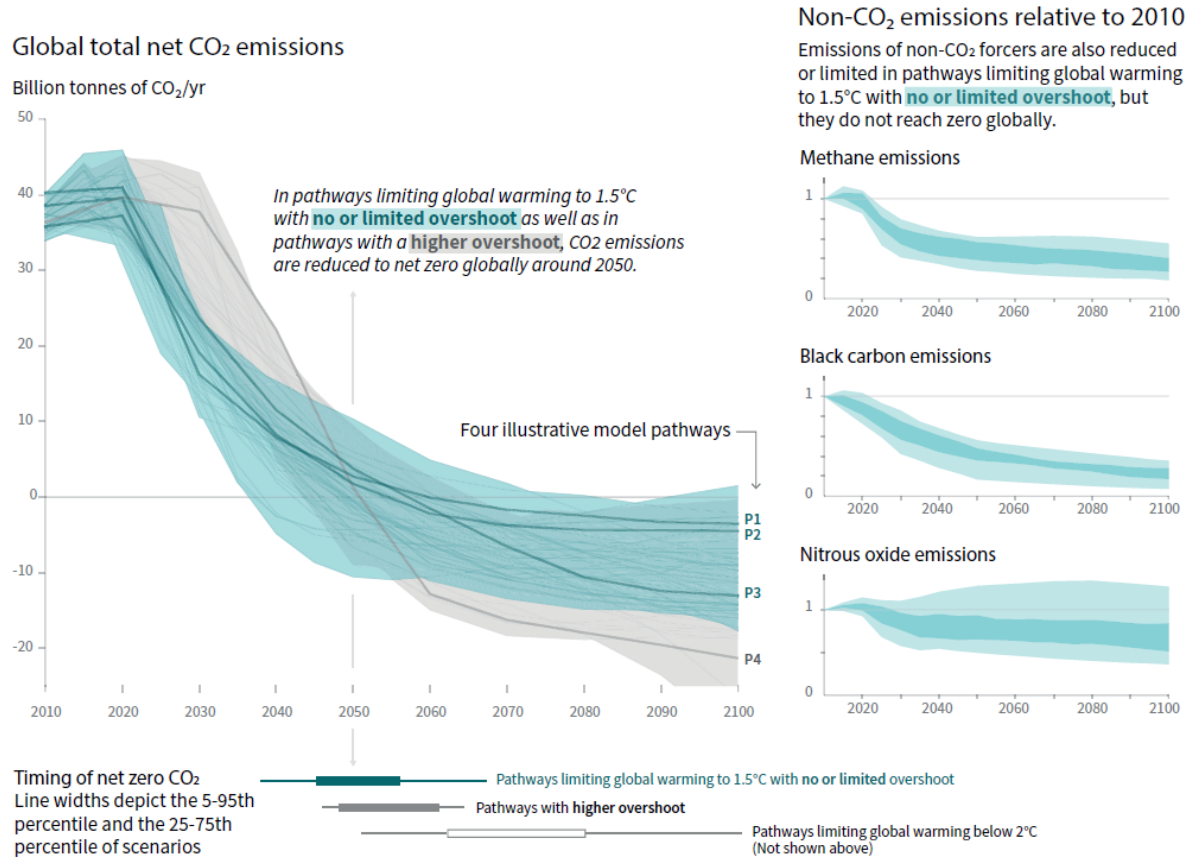


Figure 9 Global emissions pathway characteristics.

3.5. Estimation of greenhouse gas emissions

Most of the researchers in the world use equations and methodologies that are stated on the guidelines of the (IPCC, 2006) for the estimation of GHG emitted from WWTPs. For instance,

Singh, 2017 used the 1996 Guidelines and IPCC Good Practice Guidance for the estimation of greenhouse gas emissions from municipal wastewater treatment systems in India. Thus takes the most common simple methodologicalapproach to combine information on the extent to which a human activity takes place (called activity data orAD) with coefficients which quantify the emissions or removals per unit activity. These are called emissionfactors (EF). The basic equation is therefore:

Equation 1

$$\boldsymbol{Emissions = AD \bullet EF}$$

Where, E, AD and EF are emission, activity data and emission factor respectively. Activity data include the extent to which an activity will take place (e.g. units of electricity consumed, water parameters etc.)

The same finding (Singh, 2017) also used the estimation of methane emission following equation (IPCC 2006):

Equation 2

$$\boldsymbol{E_{CH4} = (kg\ BOD\ X\ EFa\ X\ 365) - S - R}$$

Where ECH_4 is total methane emission from wastewater (kg CH_4); BOD is total organic waste load (kg BOD/year); EFa is emission factor for wastewater type (kg CH_4/kg BOD). The GHG emissions are adjusted for organic component removed as sludge (kg BOD/year) as well as methane recovery (kg CH_4/year). Since the organic sludge removed and methane recovery data are not available for the plants considered in this study, as per the IPCC, the default value of zero is taken. The actual influent BOD data is taken for different WWTPs from the reports as described later. For those plants where data is not available, the weighted average BOD is considered.

They also calculated Emission factor for methane as follows:

Equation 3

$$\boldsymbol{EFa = Bo\ X\ MCF}$$

Where MCF is a methane correction factor and Bo is maximum methane producing capacity of raw sewage (kgCH4/kgBOD). They have used the default value for Bo as 0.6 kgCH4/kgBOD (IPCC, 2006; Gupta & Singh, 2012). MCF is the fraction of BOD that will ultimately degrade in the treatment process. They indicated that MCF values are taken from IPCC for different WWTPs as shown in Table 2 (IPCC 2006; Chang et al. 2014). ASP is considered as aerobic wastewater treatment plant, UASB as an anaerobic reactor, OP as anaerobic deep lagoon and WSP as anaerobic shallow lagoon (Arceivala&Asolekar, 2007). MCF factors for well managed ASP and SBR are taken as 0.05, whereas for others, average MCF factors are taken. The information of well managed and the plants not well managed is obtained from the CPCB database. Also, it is assumed that SBR plants and newly built plants would be well managed. The Methane emissions they have calculated are converted into CO_2 equivalent emissions by considering a time horizon of 100 years depending on (IPCC 2007).

Table 3Includes default maximum CH_4 producing capacity (Bo) for domestic wastewater IPCC 2006 (Doorn et al, 2006).

[illegible]
0.6 kg CH_4/kg BOD
0.25 kg CH_4/kg COD

Similar to the case of CH_4, the other report from Canada by (Lacharity, 2017) used IPCC, 2006 guidelines for the estimation of N_2O emission from the WWTP. Like methane, N_2O emissions from WWTP's are to be reported when a facility meets the reporting threshold. Environment Canada does not require reporting on N_2O resulting from effluent discharge of nitrogen; however, they do require estimates from the treatment process itself and direct the user to IPCC guidelines. In the IPCC guidelines, the N_2O estimate of concern is from the WWTP effluent and a subcategory considers emissions from bioreactors of advanced centralized WWTP's (IPCC, 2006) using the following equation

Table 4 Methane correction factor (MCF) for different municipal wastewater treatment plants.

Type of treatment system	Default MCF value[a]	MCF range[a]
Centralized, aerobic treatment plant	0[b]	0–0.1[b]
	0.3[c]	0.2–0.4[c]
Anaerobic reactor	0.8	0.8–1.0
Anaerobic shallow lagoon	0.2	0–0.3
Anaerobic deep lagoon	0.8	0.8–1.0

[a]Source: IPCC (2006).
[b]Well managed plant.
[c]Plant not well managed.

:

Equation 4

$$N_2O_{PLANTS} = P \; X \; T_{PLANT} \; X \; F_{IND-COM} \; X \; EF_{PLANT}$$

Where:

• N_2O_{PLANTS} = total N_2O emissions from plants in a year (kg N_2O/year)

• P = total serviced population

• T_{PLANT} = degree of utilization of modern, centralized WWTP's (%)

• $F_{IND-COM}$ = Fraction of industrial and commercial co-discharged protein (default = 1.25)

• EF_{PLANT} = emission factor, 3.2 g N2O/person/year

This equation is meant for estimation multiple plants within a geographical area. Since the focus is on individual plants the equation simplifies to:

Equation 5

$$N_2O_{PLANTS} = P \; X \; F_{IND-COM} \; X \; EF_{PLANT}$$

The general equation to estimate CH_4 emissions from domestic wastewater is as follows:

Equation 6

TOTAL CH_4 EMISSIONS FROM DOMESTIC WASTEWATER

$$CH_4\ Emissions = \left[\sum_{i,j}\left(U_i \bullet T_{i,j} \bullet EF_j\right)\right](TOW - S) - R$$

kg

Where:

CH_4 Emissions = CH_4 emissions in inventory year, kg CH_4/yr

TOW = total organics in wastewater in inventory year, kg BOD/yr

S = organic component removed as sludge in inventory year, kg BOD/yr

U_i = fraction of population in income group *i* in inventory year, See Table 6.5.

T_{ij} = degree of utilisation of treatment/discharge pathway or system, *j*, for each income grou fraction *i* in inventory year, See Table 6.5.

i = income group: rural, urban high income and urban low income

j = each treatment/discharge pathway or system

EF_j = emission factor, kg CH_4 / kg BOD

R = amount of CH_4 recovered in inventory year, kg CH_4/yr

Nitrous oxide (N_2O) emissions can occur as direct emissions from treatment plants or from indirect emissions from wastewater after disposal of effluent into waterways, lakes or the sea. Direct emissions from nitrification and denitrification at wastewater treatment plants may be considered as a minor source and guidance is offered in equation 9 to estimate these emissions. Typically, these emissions are much smaller than those from effluent and may only be of interest to countries that predominantly have advanced centralized wastewater treatment plants with nitrification and denitrification steps.

Equation 7

$$N_{EFFLUENT} = (P \bullet Protein \bullet F_{NPR} \bullet F_{NON-CON} \bullet F_{IND-COM}) - N_{SLUDGE}$$

Where:

$N_{EFFLUENT}$ = total annual amount of nitrogen in the wastewater effluent, kg N/yr

P = human population

Protein = annual per capita protein consumption, kg/person/yr

F_{NPR} = fraction of nitrogen in protein, default = 0.16, kg N/kg protein

$F_{NON-CON}$ = factor for non-consumed protein added to the wastewater

$F_{IND-COM}$ = factor for industrial and commercial co-discharged protein into the sewer system

N_{SLUDGE} = nitrogen removed with sludge (default = zero), kg N/yr

Equation 8

N_2O Emissions = $N_{Effluent}$x $E_{FEffluent}$ x 44/28

Where,

$N_{Effluent}$= nitrogen in the effluent discharged toaquatic environments, kg N/yr

$E_{FEffluent}$= emission factor for N_2O emissionsfrom discharged to wastewater-N, kg N_2O -N/kg N; default factor is 0.005.

(IPCC, 2006)

Ammonium (NH_4^+), nitrites (NO_2^-) and nitrates (NO_3^-) are the three soluble forms of Nitrogen susceptible to being transformed into N_2O. In aerobic waters, N_2O is a by-product of the nitrification of NH_4^+. In anaerobic waters, N_2O is a by-product of the denitrification of NO_2^- and NO_3^+ below and the methods used to determine NH_4^+, NO_2^- and NO_3^- (APHA, 2005).

According to APHA-AWWA-WEF (2005) - slandered method 4500-$NO_3^-$is reduced almost quantitatively to nitrite (NO_2^-). The NO_2^- thus produced is determined by the formation of a highly coloured azo dye that is measured colorimetrically (UNESCO, 2010).

The IPCC recommendation of a 3.2 g N_2O/person/year emission factor is based on a single study of one WWTP, with only BOD removal (Czepiel, 1995).They account for this uncertainty by providing ranges for direct WWTP emissions using a range of 2-8 g N_2O/person/year (IPCC, 2006).

According to RTI, 2010 the degradable carbon content determines the CH_4 and/or CO_2 producing potential of a wastewater stream. A common measure of the amount of biologically degradable material in wastewater is the 5-day biochemical oxygen demand (BOD_5) content. The BOD5 determines the amount of dissolved oxygen needed (i.e., oxygen demand) by aerobic biological organisms in a body of water to break down organic material present at a certain temperature (20 °C) over a specific period of time (5 days).The units of measure are commonly milligrams (mg) of oxygen demand per liter (L) of wastewater. BOD_5 is a commonly monitored parameter for all

types of biological wastewater treatment processes (both aerobic and anaerobic units) and used to determine the effectiveness of wastewater treatment processes. A simplified stoichiometric equation for the biochemical oxidation of organic constituents in wastewater is presented in Figure 10.

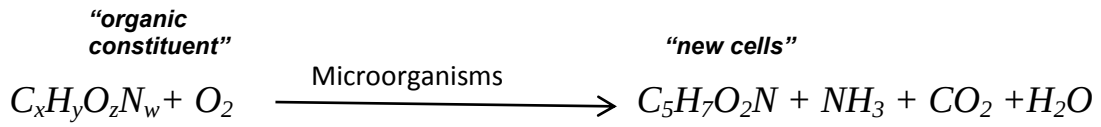


Figure 10Simplified stoichiometric equations for the biochemical oxidation of organic constituents in wastewater.

For each mole of carbon in the organic material in the wastewater influent, one mole of oxygen is needed to convert it to CO_2. While there will be additional oxygen required for converting other molecules contained within the organic material (primarily hydrogen), a reasonable maximum CO_2 generation rate per BOD_5 would be 44 kg CO_2 per 32 kg BOD_5. The BOD_5 test is commonly performed using a series of dilutions to limit the change in biomass population over the test period, so that the BOD_5 provides a reasonable measure of the total degradable organic carbon. Although some organic compounds may be more or less amenable to degradation under aerobic conditions versus anaerobic conditions, the BOD_5 is commonly used to estimate the degradable organic carbon content for either type of treatment system.Depending on the population of microorganisms present in the test inoculum, the BOD_5 test may also measure the oxygen required for nitrification (i.e., oxidation) of some or all of the ammonia present. This "nitrogenous" biochemical oxygen demand (BOD) is considered an interference to the carbonaceous BOD (cBOD) that is most useful in estimating the potential CO_2 or CH_4 emissions from the wastewater. Therefore, for waste streams with high nitrogen loadings or samples seeded with microorganisms from secondary treatment units, it may be necessary to add a chemical nitrification inhibitor, as allowed in the BOD5 test method, to determine cBOD and eliminate a potential bias caused by nitrogenous BOD (RTI, 2010).

Other parameters that may be monitored in the wastewater influent and correlated with the amount of degradable organic content include the chemical oxygen demand (COD) and total organic carbon (TOC). The COD test uses a chemical oxidizing agent to fully oxidize all influent waste constituents. As such, the COD is always larger than the BOD, and includes oxidation of chemicals

that are not easily biodegradable. The unit of measure for COD is the same as that for BOD (i.e., mg oxygen demand/L of wastewater). The TOC test converts carbonaceous materials to CO_2 using high-temperature combustion, chemical oxidation, or ultraviolet oxidation, and then measures the CO_2 produced using a non-dispersive infrared analyzer. The units of measure are typically mg of carbon/L of wastewater. As with COD, TOC may oxidize constituents that are not readily biodegradable, so its use may overestimate the potential CO_2 emissions from biological wastewater treatment systems. On the other hand, TOC provides a more direct measure of the potential CO_2 emissions than BOD by providing a direct measure of carbon content, whereas oxygen demand may be attributed to other elements contained in the wastewater (RTI, 2010).

Many municipal and industrial wastewater treatment systems will have primary clarifiers or other treatment units that can remove organic matter (i.e., BOD_5, COD, and/or TOC) from the wastewater without generating CO_2 or CH_4 emissions. Therefore, in wastewater treatment systems with physical or chemical treatment units upstream of the biological treatment unit, it is important to determine the organic content (either BOD_5, COD, or TOC) at the influent of the biological treatment unit (RTI, 2010).

Aerobic wastewater treatment systems produce primarily CO_2, whereas anaerobic systems produce a mixture of CH_4 and CO_2. Equations 6 and 7 provide a general means of estimating the CO_2 and CH_4 emissions directly from any type of wastewater treatment process assuming all organic carbon removed from the wastewater is converted to either CO_2, CH_4, or new biomass.

Equation 9

$$CO_2 = 10^{-6} \times Qww \times OD \times EFF_{OD} \times CF_{CO2} \times [(1 - MCFWW \times BG_{CH4})\ (1-\lambda)]$$

Equation 10

$$CH_4 = 10^{-6} \times Qww \times OD \times Eff_{OD} \times CF_{CH4} \times [(MCFww \times BG_{CH4})\ (1-\lambda)]$$

Where:

CO_2 = CO_2 emission rate (Mg CO_2/hr)

CH_4 = CH_4 emission rate (Mg CH_4/hr)

10^{-6} = Units conversion factor (Mg/g)

Q_{WW} = Wastewater influent flow rate (m^3/hr)

OD = Oxygen demand of influent wastewater to the biological treatment unit determined as either BOD_5 or COD (mg/L = g/m^3)

Eff_{OD} = Oxygen demand removal efficiency of the biological treatment unit

CF_{CO2} = Conversion factor for maximum CO_2 generation per unit of oxygen demand

= 44/32 = 1.375 g CO2/ g oxygen demand

CF_{CH4} = Conversion factor for maximum CH4 generation per unit of oxygen demand

= 16/32 = 0.5 g CH4/ g oxygen demand

MCFWW = methane correction factor for wastewater treatment unit, indicating the fraction of the influent oxygen demand that is converted anaerobically in the wastewater treatment unit (see Table 6)

BG_{CH4} = Fraction of carbon as CH_4 in generated biogas (default is 0.65)

λ = Biomass yield (g C converted to biomass/g C consumed in the wastewater treatment process).

The biomass yield, λ, in Equations 6 and 7 should be determined based on the net sludge generation from the process. For example, for an activated sludge tank, the sludge wastage rate would be used. Commonly, the mixed liquor volatile suspended solids (MLVSS) value is used as a measure of the biomass concentration. The flow rate of the sludge waste stream multiplied by the MLVSS concentration of the sludge waste stream provides a mass generation rate of biomass. Using the general cell composition from Figure 3-2, carbon accounts for 53% of the biomass weight (dry basis). The carbon consumed in the wastewater treatment process is estimated based on the BOD removal rate. Thus, the biomass yield, λ, can be calculated using Equation 8. When the biomass generation rate cannot be assessed, default values for the biomass yield provided in Table 4 should be used.

Equation 11

$$\lambda = \frac{\text{Qs x MLVSS x CFy}}{Qww\ x\ OD\ x\ EffOD\ x\ CFc}$$

Where:
λ = Biomass yield (g C converted to biomass/g C consumed in the wastewater treatment process)
QS = Waste sludge stream flow rate (m^3/hr)

QWW = Wastewater influent flow rate (m^3/hr)

MLVSSS = Mixed liquor volatile suspended solids concentration of the waste sludge stream (mg/L = g/m^3)

OD = Oxygen demand of influent wastewater to the biological treatment unit determined as either BOD_5 or COD (mg/L = g/m^3)

EffOD= Oxygen demand removal efficiency of the biological treatment unit

CFS = Correction factor for carbon content of the biomass (i.e., MLVSSS)
= 0.53 g C/g MLVSS (default)

CFC = Conversion factor for maximum C consumption per unit of oxygen demand
= 12/32 = 0.375 g C/ g oxygen demand.

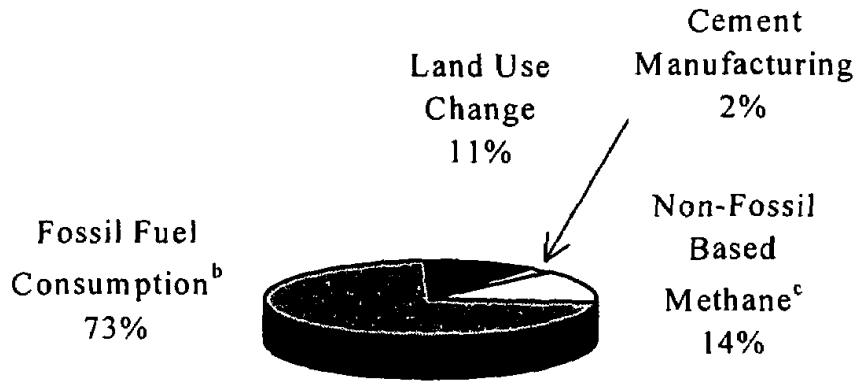
Table 5 Includes default MCF values (adapted from IPCC 2006 (Doorn et al, 2006).

DEFAULT MCF VALUES FOR DOMESTIC WASTEWATER			
Types of treatment plant and discharge pathway or system	Comments	MCF	Range

Untreated system			
Sea, river and lake discharge	Rivers with high organics loading can turn anaerobic	0.1	0-0.2
Stagnant sewer	Open and warm	0.5	0.4-0.8
Flowing river (open or closed)	Fast moving, clean (insignificant amounts of CH_4 from pump station, etc)	0	0
Treated system			
Centralized aerobic treatment plant	Must be well managed some CH_4 can be emitted from settling basins and other pockets	0	0-0.1
Centralized aerobic treatment plant	Not well managed overloaded.	0.3	0.2-0.4
Anaerobic digester for sludge	CH_4 recovery is not considered here.	0.8	0.8-1.0
Anaerobic reactor	CH_4 recovery is not considered here.	0.8	0.8-1.0
Anaerobic shallow lagoon	Depth less than 2 meters, use expert judgment.	0.2	0-0.3
Anaerobic deep lagoon	Depth more than 2 meters	0.8	0.8-1.0
Septic system	Half of BOD settles in anaerobic tank.	0.5	0.5
Latrine	Dry climate, ground water table lower than latrine, small family (3-5 persons)	0.1	0.05-0.15
Latrine	Dry climate, ground water table lower than latrine, communal (many users)	0.5	0.4-0.6
Latrine	Wet climate flush water use, ground water table higher than latrine.	0.7	0.7-1.0
Latrine	Regular sediment removal for fertilizer	0.1	0.1

3.6. Green House Gas emission

The IPCC has identified the emissions of greenhouse gases (GHGs) from human activities as a primary cause for global climate change. The primary sources of anthropogenic GHGs are: Consumption of fossil fuels, Land-Use changes, Agriculture, Cement manufacturing and Landfills and sewage treatment (World Bank, 1998).



Source: Carbon Dioxide Information Analysis Center, 1995.

Figure 11 Sources of Greenhouse Gas Emissions.

The OECD, 2008 also found out that Greenhouse gases are emitted by many economic activities. Quantitatively, the largest share is accounted for by power generation (electricity production and transformation were responsible for 26% of global emissions in 2004), followed by industry generally (about 19%) and transportation (13%). It is important to note that deforestation and forest degradation (about 17%) are estimated to account for more emissions globally than the entire transport sector.

The greenhouse gas emission from waste stabilization ponds (WSPs) in different India WWTPs was minimum for WSPs when compared to the other WWTPs like UASB which has the maximum emission for GHG. UASB has maximum GHG emissions of 1317 $ktCO_2$-eq/year, and the minimum was for WSP, 31.8 $ktCO_2$- eq/year. As compared to other WWTPs, the GHG emissions of ASP were relatively lower than the previous one even, which is _71.6 $ktCO_2$- eq/year. In general, they said that this was due to external use of energies like electricity (Singh et al. 2017).

According to Delre, 2018, Plant-integrated CH_4 emission rates were between 1.1 and 39.5 kg CH_4 h-1,and corresponding CH_4 emission factors were between 1.1% and 21.3% as kgCH_4 (kg CH_4 production)-1 and between 0.2% and 3.2% as kg CH_4 (kg CODinfluent)-1. Plant-integrated N_2O

emission rates were between < 0.1 and 6.4kg N_2O h-1, and corresponding N_2O emission factors were between < 0.1%and 5.2% as kg N_2O-N (kg TN influent)$^{-1}$.

Yerushalmi et al, 2009, said that the in anaerobic and hybrid treatment systems of WWTPs greater emissions result from off-site processes compared to on-site processes. However, in aerobic treatment systems, onsite processes make a higher contribution to the overall GHG emissions. The total GHG emissions were estimated to be 1.6, 3.3 and 3.8 kg CO_2-e/kg BOD in the aerobic, anaerobic and hybrid treatment systems, respectively. In the aerobic treatment system without the recovery and use of the generated biogas, the off-site GHG emissions were 0.65 kg CO_2-e/kg BOD, accounting for 40.2% of the overall GHG emissions. This value changed to 2.3 and 2.6 kg CO_2-e/kg BOD, and accounted for 69.9% and 68.1% of the overall GHG emissions in the anaerobic and hybrid treatment systems, respectively. The increased off-site GHG emissions in the anaerobic and hybrid treatment systems are mainly due to material usage and energy demand in these systems. The anaerobic digester can contribute up to 100%, 55% and 60% of the overall energy needs of plants in the aerobic, anaerobic and hybrid treatment systems, respectively.

In another studies Monteith et al, 2018, found out that the emission rates for methane ranged from 0.005 kg $C0_2$ equivalent/m3 treated for primary treatment facilities to 0.26 kg $C0_2$ equivalent/m3 for conventional activated sludge, with anaerobic sludge digestion to over 0.8 kg C02-equivalent/m3 for extended aeration with aerobic digestion.Of the total C02 equivalents released, approximately 43% (869 Mg/y) was attributed to carbon oxidation in the aeration basin. The GHG emissions were 1.94 kg $C0_2$-equivalent/kg BOD_5 entering the facility. In the same study at Canada country, overall, western provinces emitted more $C0_2$ per volume of wastewater treated than eastern provincesexception of Nova Scotia. The generic estimation procedure for CAS plus anaerobic digestion provided emissions rates ranging from 0.228 to 0.245 kg $C0_2$-equivalent/m3 wastewater treated. The calibration example, Ontario plant A, resulted in a $C0_2$ emission rate of 0.243 kg $C0_2$-equivalent/m^3 wastewater treated. The rangeof $C0_2$ emission rates estimated for the 16 calibration sites was 0.14to 0.63 kg $C0_2$-equivalent/m^3 wastewater treated. This range, however, includes Ontario plants 2 and 3, which incineratesolids and thus have higher emissions than plants without incineration. Incineration is mostly restricted to Ontario, and those treatment works with incineration produce among the highest GHG emission rates per volume of wastewater treated. This is not surprising, however, because, during incineration, all of the carbon in biosolids is

converted to $C0_2$ instead of being moved off-site.Additionally, incineration typically requires additional natural gas,which also contributes to on-site $C0_2$ emissions.

Inaddition, to the above studies the study done in Montreal, Quebec, Canada(Ashrafi, 2012) the overall GHG generation by using the steady-state model was equal to 3152, 6051, and 6541kg CO_2-equivalent/day by the three examined systems. The results showed considerably higher generation of sludge by the aerobic treatment system, amounting to 376 kg/day, compared to that produced by the anaerobic and hybrid treatment systems. The generation of GHGs from aerobic and hybrid processes increased by 27% and 33.2%, respectively, when N_2O emission from nitrogen removal processes was taken into consideration. The results of the dynamic model during 140 days of operation showed that the daily variations of GHG emissions were changed up to ±30%, ±19%, and ±17% in the examined systems. The estimated energy consumption amounted to 4028, 2017 and 3084 MJ/day in the aerobic, anaerobic and hybrid systems. The lowest fluctuations of GHG emission and energy generation were observed in the hybrid system, showing the stability of this particular process design. Parametric studies using the steady-state model indicated that the best strategy to reduce GHG emission and energy consumption would result from a 12% increase in the bioreactor temperature in the aerobic system, a 10% increase of the bioreactor temperature and a 5 days increase of SRT in the anaerobic system, and a 10% increase of temperature and a 5 days reduction of SRT in the anaerobic bioreactor of the hybrid system. Additional reductions in the GHG emission and energy consumption would result from a 50% increase of the primary clarifier underflow rate.

According to the above study, CO_2 emission from biological reactors accounts for 20.9%, 7.7%, and 8.2% of the total GHG emissions in the three treatment systems, while CO2 emission from the anaerobic digester contributes to only 13.0%, 4.5%, and 4.9% of the overall GHG emissions in the aerobic, anaerobic, and hybrid systems, respectively. The major contribution of anaerobic digester to the overall GHG emission is related to methane production in this unit. In the hybrid treatment system, the GHG emissions by anaerobic and aerobic bioreactors amount to 470 and 63 kg CO_2-eq/day. A considerably lower contribution of aerobic reactor to the overall GHG emission, approximately 1%, occurs due to the high BOD removal efficiency of the anaerobic reactor which precedes the aerobic reactor(Ashrafi, 2012).

Das, 2011found out that 0.02 kg CO_2 was released per m3 of wastewater treated in the Biological Aerated Filter (BAF) system, whereas 0.03 kg CO_2 was released per m^3 of wastewater treated in the Activated Sludge System. The amount of on-site GHGs emissions from microbial processes varied with the incoming wastewater characteristics and temperature. The on-site results indicated that plug flow reactors emitted about 45 % higher CO_2 than completely mixed reactors at the Little River Pollution Control Plant (LRPCP). The overall GHGs emissions results showed that off-site emissions were significantly higher than the on-site emissions.The on-site CO_2 emissions from plug flow activated sludge system, Plant 2, were higher than the completely mixed activated sludge system, Plant 1 in the above finding (Das, 2011).

Of the ten countries included in the East Africa Regional mission, GHG emissions data are available for eight countries. Excluding Somalia and South Sudan, for which GHG emissions data are not available, the Democratic Republic of Congo (DRC) has the highest total greenhouse gas (GHG) emissions, followed by Tanzania, Ethiopia, Kenya, Central African (USAID, 2011). For example this study found out that the total GHG emission ($MtCO_2e$) for Ethiopia was found to be 141 $MtCO_2e$.

The above study (USAID, 2011) shows that Republic (CAR), Burundi, Rwanda, and Djibouti. Together, these eight countries in East Africa are responsible for 1.43% of global emissions. On a per capita basis, the region's emissions are 2.5 times below the world average. The exception is the CAR where per capita emissions are more than twice the world average. In all countries, GHG emissions relative to GDP are very high, ranging from 1.5 times the world average in Djibouti and Rwanda to 37.5 times in the CAR. This results in the high regional GDP carbon intensity, which for East Africa is eight times the world average. Within the region, total GHG emissions since 1990 have increased most rapidly in Ethiopia, where emissions have grown 86%, driven by the increase in agriculture sector emissions due to livestock-related activities (Ethiopia's SNC). GHG emissions have decreased in Burundi and Rwanda by 40% and 60% respectively. For both Burundi and Rwanda, WRI CAIT data show that activities in the LUCF sector drive this decrease. According to Burundi's Second National Communication (SNC) to the UNFCCC, the government prohibits bush fires and has begun to implement a national reforestation policy. In Rwanda, according to its SNC, nature reserves and park areas have been preserved and the area of managed forest plantation increased 30% from 2000-2006. Hence, such study in areas like Ethiopia is really vital.

GHG emissions in the East Africa region, from the countries for which data are available, are primarily from the land-use change and forestry (LUCF) and agriculture sectors. Together, regional emissions from these two sectors are responsible for 81% (540 $MtCO_2e$) of total regional GHG emissions (669 $MtCO_2e$), with LUCF responsible for nearly half (324 $MtCO_2e$) and agriculture nearly a third (216 $MtCO_2e$). Energy sector GHG data is not available for the CAR, Djibouti, and Rwanda; excluding their emissions, energy is the region's third highest emitting sector and is the source of 10% of the region's emissions (69 $MtCO_2e$). GHG emissions from the LUCF, agriculture, and the energy sector combined account for 91% of total regional emissions. Emissions from waste and industrial processes (IP) are relatively insignificant (USAID, 2011).

The total GHG emissions of the countries in the East Africa region increased 42% from 1990 to 2011.

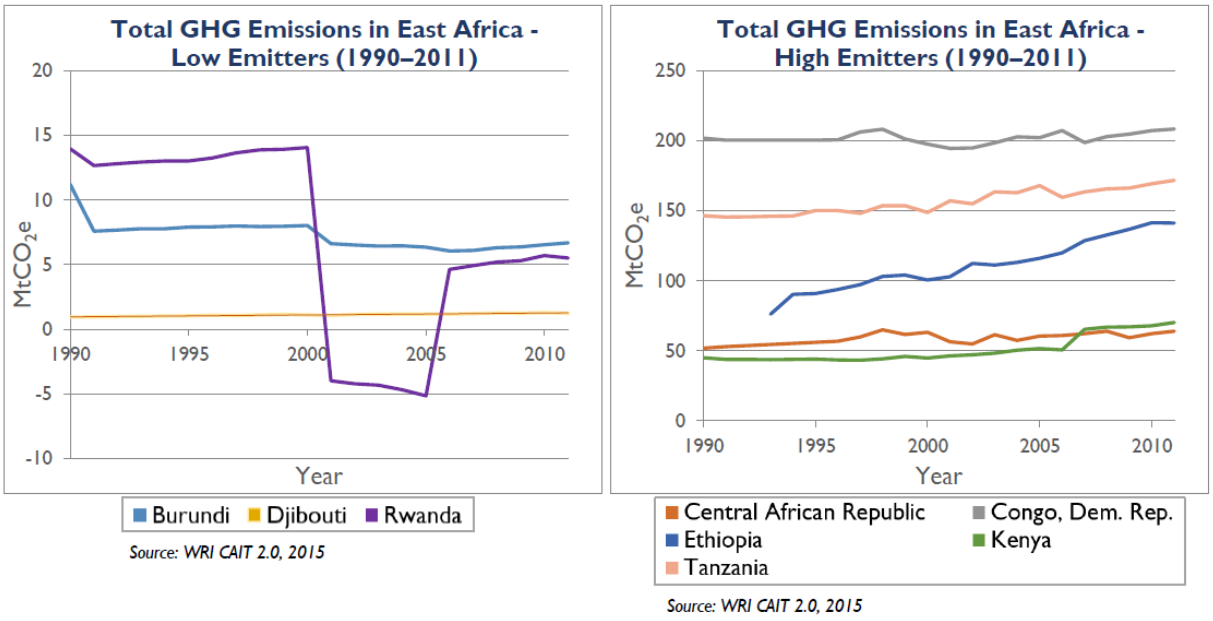


Figure 12Total GHG emission In East Africa Countries

Since all wastewater stabilization ponds (WSP) are common in there nature they may emit the GHG here in the case of Jimma Institute of Technology (JIT). Hence such studies are highly important to quantify the emission level of the GHG from the WWTP of such scale. Then the study was to estimate the level of the emission of such gases from the WWTP by using the data from the IPCC, 2006.

4. Methods and Materials

4.1. Study area

The campus KitoFurdissa of Jimma University has the WSPs for the waste treatment from dormitories, kitchen, Cafeteria, office, Automobile garage, diesel oil area, etc. of its campus. The WSPs has anaerobic, facultative and aerobic units setting in the middle of the wetland area. The area was mainly situated in the bottom of the hill where the campus was built around a military barracked in the nearby. At its out let the pond was connected to the Kitto Stream which flows to the Gilgel-Gibe River to the East. The stream passes to the west side to the near distance before it joins the outlet. Seasonally the area will have muddy soil of water in the rainy season of June, July, and August up to October sometime and otherwise the area was dry land non marshy wet area.

Figure 13Areal Map Jimma University, Kitto Furdissa campus Stabilization Pond Jimma, Ethiopia and April, 2019

Jimma University with its different campuses at different area also tries to use these types of technologies for the treatment of wastes from all departments and unites. Currently, the two campuses namely; College of Agriculture and Veterinary Medicine and Institute of Technology at

two nearest points in area use the Waste Stabilization Ponds (WSPs) for the last five to ten years. The latter, on which my study focuses on contains the three common units; namely Anaerobic Facultative and Aerobic.These ponds have a total of two anaerobic ponds, one facultative pond and four maturation ponds. It was built on an area of 69,236.70 square meters (6.9 hectares). The report shows the Anaerobic pond (2 in number) has a length of 77.94m, 46.49 width and a depth of 4.75 meter; the Facultative pond (1 in number) has a length of 193.83m, a width of 101.53m and the depth of 2.10 meter and Maturation pond (4 in number) has a length of 122.83m, a width of 65.61m and a depth of 2.10meter (EIA,. 2010).

The appropriate pond depth is determined by environmental conditions, by the type of waste to be treated, and by general safety factors desired. If the pond is too shallow (less than 1m), emergent vegetation may destroy it unpleasant odours may develop during the hot season. Depths in excess of 1.5m are for sludge storage or excess capacity during cold weather (Gloyna, 1971). The depth of the pond will differentiates the compartments of the pond as maturation and anaerobic.

Treatment systems or discharge pathways that provide anaerobic environments will generally produce CH_4 whereas systems that provide aerobic environments will normally produce little or no CH_4. For example, for lagoons without mixing or aeration, their depth is a critical factor in CH_4 production. Shallow lagoons, less than 1m in depth, generally provide aerobic conditions and little or no CH4 is likely to be produced. Lagoons deeper than about 2-3 meters will generally provide anaerobic environments and significant CH_4 production can be expected (IPCC, 2006).Hence, the assessment and management of greenhouse gas emissions is of interest for wastewater treatment and conveyance facilities as these facilities can be relatively energy intensive, and can contribute to the production of greenhouse gasses such as methane, carbon dioxide and nitrous oxide

The KittoFurdissa Campus is one of the five Campuses of Jimma University and is located in Jimma city which is by far the largest urban center of the Zone. It has a latitude and longitude of 7°40′N 36°50′E. Jimma has a tropical rainforest climate (Af) under the Köppen climate classification (Kottek et al, 2006). It features a long annual wet season from March to October. Temperatures at Jimma are in a comfortable range, with the daily mean staying between 20 °C and 25 °C year-round. According to wiki data on climate data for Jimma the average high Temperature in ^{0}C from February to May was, 29, 28, 27, and 26^{0}C respectively which will be the time of data collection in the area. In addition the daily mean temperature in ^{O}C in the area was 24, 24, 24 and

23 ^{0}C in the specified months. Similarly the average low temperature in the area was 19, 20, 20, and 20 ^{0}C for those months respectively. The average rainfall in the area during the study time of those months was 55, 95, 140, 160 mm with average rainy days of 10, 14, 15, and 18 days on those months respectively (WC, 2016). The altitude of Jimma town ranges from the lowest 1700m above sea level (around Kitto and air field area) to the highest 2010m above sea level (near Jiren area). The KittoFurdissa Campus and the project site are found on the average elevation of 1726mabove sea level.

Jimma University (JU), located 354km south-west of Addis Ababa, is Ethiopia's first innovative Community Oriented Educational Institution established in December 1999 by the amalgamation of Jimma College of Agriculture (founded in 1952) and Jimma Institute of Health Sciences (established in 1983). This amalgamation resulted in the present Jimma University College of Agriculture and Veterinary Medicine (JUCAVM) being upgraded from a technical college, to a college within a new university, JU.

The study period was in March, 2019 in the season of winter to summer in Ethiopia, Jimma. The data was collected from 10:00 Am to 2:50 PM of the day of data collection. The data was grabbed almost in a sunny day and with little cloud and little rain a day before the data was taken.

4.2. Sampling Points

The sample was taken from all mechanical and biological treatment areas. The sample was taken from two points at each treatment unit of the stabilization ponds except the first sampling points which was taken at one point only. The first sampling point was inside the grit removal (R1). The second sampling point (A1L) was from the anaerobic pond to the top left of the pond around the inlet of the influent from the first anaerobic pond according to the inspection board of the study group. This point was mainly covered with red on top of the green algae and green bottom. The pipe around the sampling point was visible and it was empty except little drop away.

The third sampling points (A2L) was at the bottom side of the same treatment unit to the middle of the bottom right side from the south. In this point the water colour was green the bottom visible was also green. The fourth site which was (A1R) was in the first oxidation pond to the same side of the sampling point stated earlier. At this site the water has similar colour which was the same green top and green scum than the red colour of similar site to the second anaerobic pond which

was to the west of this point. The fifth is now similar to the stated was to the bottom side of the treatment unit of the first anaerobic pond. It has similar green top with green scum in it.

The next two sampling points (F1 and F2) were to the facultative ponds. As usual the facultative pond was sampled one from top side of the right from the north side and bottom side to the left middle to the south sides. Hence it all contain green water on the top except in the second sample point where there is blue green water colour on top than the green. On the other hand the same sampling point was repeated for the next four maturation ponds of the KittoFurdisa Campus of Jimma Institute of Technology (JIT) i.e. top side and bottom side was the same. |For instance the first MU1L point was sampled top side of the left hand side to the south and MU1R was inside a white green algae area which may be high salt area, ML1Lwas inside the high salt area of the maturation pond, MU2L was also in the maturation pond of anoxic behavior, ML1R was in the lower and last maturation pond of similar characteristics, MU2R was in the upper side of the maturation pond, ML2Rwas algae with some clear water and ML2lL has these the same green algae type. But at this point it looks like they like white green than the previous once. In all cases we sample purposefully inside the dying algae of all type.

Beside it will be taken from the inlet and outlet of the compartments (anaerobic, facultative, and aerobic) of the oxidation pond (Vijayan et al, 2017). Thus both the influent and the effluent will be taken at every time of the testing period. Lastly the bottom stream will be sampled at only one place due to the reason stated above.

The last sampling points where the stream sampling of the receiving body of water (S1 and S2). The S1 was before the points of the pipe outlet where as S2 was after the pipe outlet joins the stream. Both of the two were full of vegetation on the top and well covered side wall in the area. Beside they have usual winter water top in Ethiopia highlands. Except in the two streams and inside the grit, at all sampling points there were a duck weeds and other birds. The other two were too small to carry animals whereas, the grit was may be too toxic to carry the animal life. In addition, for all we carried out top sampling method with the same through height of the man.

4.3. Greenhouse gas (GHG) estimation

The greenhouse gas (GHG) was calculated by using the IPCC default values. The default value for BO was taken 0.6 kgCH4/kgBOD. In this study, the maturation pond was taken as centralized aerobic plant, the facultative pond was anaerobic shallow lagoon, anaerobic pond was anaerobic

deep lagoon, grit removal as centralized aerobic treatment and the streams were taken as river. Though, I couldn't find the real data for it from the Jimma University as an owner the WWTP was not well managed and the methane emission was calculated by converting into CO_2 equivalent on 100 year scale bases.

Table 6 The Methane Correction Factor (MCF) for different wastewater treatment plant

Type of treatment and discharge pathway or system	Default MCF value[1]	Range
Anaerobic deep lagoon	1.0	0.8-1
Anaerobic Shallow lagoon	0.2	0-0.3
Centralized, aerobic treatment plant	0.1	0-0.1
Centralized, aerobic treatment plant	0.4	0.2-0.4
Sea, river and lake discharge	0.1	0-0.2

[1]Source IPCC (2006)

The total serviced population for the estimation of Nitrous oxide was 10,426

4.4. Inclusion & exclusion criteria

The criterion for this study mainly depends on the site of the Waste Stabilization Ponds (WSPs) of Jimma University Kittofurdissa Campus.

4.5. Waste water Sampling technique

Emissions and concentrations must be studied along the river course until CO_2 and CH_4 partial pressure reach the natural background levels. The number of sampling stations will depend on the length of the river course affected by the dam (UNESCO, 2010). The sample was taken from at very less rain time of a day before yesterday and some little rain after. The sample was grab sampled at the specified sampling points with bucket at local depth.

However, the sampling of CO_2 and CH_4 will be takes place when there is a low-level outlet, degassing should be followed downstream, with emissions studied along the river course, until CO_2 and CH_4 partial pressure reach the natural background levels. The number of sampling

number of sampling station will depend on the length of the river course affected by the reservoir (UNSCO, 2010).

The sample was taken from the WSP at one time except for the correction of the sample left. Then it was sampled at the months of March, 2019 in the season of winter to summer in Ethiopia Jimma. The time of sampling was from 10:00 Am to 2:50 PM of the day of that day. But the budget constraint, the availability of instrument for measurement and time will determine. According to Czepiel et al. (1995), to determine N_2O, a Weekly grab samples will be taken from WWTPs.

Hence, when there is low-level outlet, Chemical oxygen demand (COD), total suspended solids (TSS), alkalinity, total Kjeldahl nitrogen (TKN), ammonium nitrogen ($N\text{-}NH_4^+$), nitrate nitrogen ($N\text{-}NO_3^-$) were measured according to Standard Methods (APHA, 1999). Conductivity, pH, dissolved oxygen (DO), temperature and oxidation-reduction potential were measured with electrodes.

4.6. Instrument & data collection procedure

Wastewater can be a source of methane (CH4) when treated or disposed anaerobically. It can also be a source of nitrous oxide (N_2O) emissions. Carbon dioxide (CO_2) emissions from wastewater are not considered in the IPCC Guidelines because these are of biogenic origin and should not be included in national total emissions (IPCC, 2006).

Wastewater originates from a variety of domestic, commercial and industrial sources and may be treated on site (uncollected), sewered to a centralized plant (collected) or disposed untreated nearby or via an outfall. Domestic wastewater is defined as wastewater from household water use, while industrial wastewater is from industrial practices only. Treatment and discharge systems can sharply differ between countries. Also, treatment and discharge systems can differ for rural and urban users, and for urban high income and urban low-income users (IPCC, 2006). That of KittoFurdissa in Jimma University Campus is mainly connected to the sewer line till the oxidation pond nearest the main stream leaving the area.

The data was collected short-term variability (day dynamics) due to time and many constraints for N_2O even though, it is shown that short-term sampling is inadequate to accurately estimate the average nitrous oxide emissions from a particular wastewater treatment plant. In this study, the sample collection similarly follows the day dynamics for representation of the data.

The quantity and distribution of GHG produced will depend on the characteristics of the incoming wastewater, the required treated water criteria, and the on-site processes used (Monteit et al, 2018). Determination of the incoming wastewater characteristics can be accomplished using the logic diagram in Figure 16. For an individual facility, flow data and influent characteristics can be obtained, and the BOD, suspended solids, and nitrogen and phosphorus loadings to the liquid treatment train can be determined depending on the flow data. For making broader estimates for regions, however, individual facility data may not be readily available. Hence these will hinder the analysis in the case of our study in Ethiopia. If detailed flow information is not available, flows may be estimated from direct measurement on the site.

4.7. Variables

The principal factor in determining the CH_4 generation potential of wastewater is the amount of degradableorganic material in the wastewater. Common parameters used to measure the organic component of thewastewater are the Biochemical Oxygen Demand (BOD) and Chemical Oxygen Demand (COD). Under thesame conditions, wastewater with higher COD, or BOD concentrations will generally yield more CH_4 thanwastewater with lower COD (or BOD) concentrations (IPCC, 2006).

The BOD concentration indicates only the amount of carbon that is aerobically biodegradable. The standardmeasurement for BOD is a 5-day test, denoted as BOD_5. The term 'BOD' in this chapter refers to BOD_5. The COD measures the total material available for chemical oxidation (both biodegradable and non-biodegradable). Since the BOD is an aerobic parameter, it may be less appropriate for determining the organic components in anaerobic environments. Also, both the type of wastewater and the type of bacteria present in the wastewater influence the BOD concentration of the wastewater. Usually, BOD is more frequently reported for domestic wastewater, while COD is predominantly used for industrial wastewater (IPCC, 2006).

Nitrous oxide (N_2O) is associated with the degradation of nitrogen components in the wastewater, e.g., urea, nitrate and protein. Domestic wastewater includes human sewage mixed with other household wastewater, which can include effluent from shower drains, sink drains, washing machines, etc. Centralized wastewater treatment systems may include a variety of processes, ranging from lagooning to advanced tertiary treatment technology for removing nitrogen compounds. After being processed, treated effluent is typically discharged to a receiving water

environment (e.g., river, lake, estuary, etc.). Direct emissions of N_2O may be generated during both nitrification and denitrification of the nitrogen present. Both processes can occur in the plant and in the water body that is receiving the effluent. Nitrification is an aerobic process converting ammonia and other nitrogen compounds into nitrate (NO_3^-), while denitrification occurs under anoxic conditions (without free oxygen), and involves the biological conversion of nitrate into nitrogen gas (N_2). Nitrous oxide can be an intermediate product of both processes, but is more often associated with denitrification (IPCC, 2006).

4.7.1. Dependent variables

- CO_2
- N_2O
- CH_4

4.7.2. Independent variables

- Temperature
- pH
- TSS
- BOD
- COD
- DO
- P
- Ammonium nitrogen ($N\text{-}NH_4^+$)
- (TKN)Nitrite nitrogen ($N\text{-}NO_2^-$)
- (TKN)Nitrate nitrogen ($N\text{-}NO_3^-$)
- Conductivity

4.8. Operational definition

Anthropogenic: Resulting from or produced by human activities. WGI

Carbon dioxide (CO_2): CO_2 is a naturally occurring gas, also a by-product of burning fossil fuels from fossil carbon deposits, such as oil, gas and coal, of burning biomass and of land use changes and of industrial processes (e.g., cement production). It is the principal anthropogenic greenhouse that affects the Earth's radiative balance. It is the reference gas against which other greenhouse gases are measured and therefore has a Global Warming Potential of 1. WGIII

CO_2 equivalent (CO_2-e): The universal unit of measurement to indicate the global warming potential (GWP) of each of the six greenhouse gases, expressed in terms of the GWP of one unit

of carbon dioxide. It is used to evaluate releasing (or avoiding releasing) different greenhouse gases against a common basis.

Climate Change: Climate change refers to a change in the state of the climate that can be identified (e.g., by using statistical tests) by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcings such as modulations of the solar cycles, volcanic eruptions and persistent anthropogenic changes in the composition of the atmosphere or in land use. Note that the United Nations Framework Convention on Climate Change (UNFCCC), in its Article 1, defines climate change as: 'a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods'. The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition, and climate variability attributable to natural causes. WGIII

Emissions factors: Emission factors are used to calculate greenhouse gas emissions bymultiplying the factor (e.g. kg CO_2-e/GJ energy in petrol) with the activitydata (e.g. kilolitres x energy density of petrol used).

Emission Scenario: A plausible representation of the future development of emissions of substances that are potentially radiatively active (e.g., greenhouse gases, aerosols), based on a coherent and internally consistent set of assumptions about driving forces (such as demographic and socioeconomic development, technological change, energy and land use) and their key relationships. Concentration scenarios, derived from emission scenarios, are used as input to a climate model to compute climate projections. WGIII

Global Mean Surface Temperature: An estimate of the global mean surface air temperature. However, for changes over time, only anomalies, as departures from a climatology, are used, most commonly based on the area-weighted global average of the sea surface temperature anomaly and land surface air temperature anomaly. WGIII

Global Warming Potential (GWP): A factor describing the radiative forcing impact (degree of harm to the atmosphere) of one unit of a given GREENHOUSE GAS relative to one unit of CO_2.

Greenhouse Gas (GHG): Greenhouse gases are those gaseous constituents of the atmosphere, both natural and anthropogenic, that absorb and emit radiation at specific wavelengths within the spectrum of thermal infrared radiation emitted by the Earth's surface, the atmosphere itself, and by clouds. This property causes the greenhouse effect. Water vapour (H_2O), carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4) and ozone (O_3) are the primary greenhouse gases in the Earth's atmosphere. Moreover, there are a number of entirely human-made greenhouse gases in the atmosphere, such as the halocarbons and other chlorine- and bromine-containing substances, dealt with under the Montreal Protocol. Beside CO_2, N_2O and CH_4, the Kyoto Protocol deals with the greenhouse gases sulphur hexafluoride (SF_6), hydrofluorocarbons (HFCs) and perfluorocarbons (PFCs).

Greenhouse gas source: Any physical unit or process which greenhouse gas into the atmosphere.

Methane (CH_4): One of the seven primary GHGs, consisting of a single carbon atom and four hydrogen atoms; a GWP of 25; and produced through the anaerobic decomposition of waste in landfills, animal digestion, decomposition of animal wastes, production and distribution of natural gas and petroleum, coal production, and incomplete fossil fuel combustion.

Nitrous oxide (N_2O): One of the seven primary GHGs, consisting of a two nitrogen atoms and a single oxygen atom; a GWP of 298; and typically generated as a result of soil cultivation practices (particularly the use of commercial and organic fertilizers), fossil fuel combustion, nitric acid production, and biomass burning.

Waste Stabilization Pond: Any pond, natural or artificial, receiving raw or partially treated sewage or waste, in which stabilization occurs through sunlight, air and microorganisms. Waste Stabilization Ponds (WSP), are also known by the name of oxidation ponds or lagoons. They act as holding basins for secondary wastewater treatment, Here organic matter is decomposed naturally, i.e. biologically. In WSP waste is stabilized and pathogens reduced through the action of bacteria and algae. The process aims to convert organic content of the effluent to more stable forms. These ponds are useful in treating variety of wastewater, from domestics wastewater to complex industrial waters.

They can function well in wide range of weather conditions and can be used either alone or integrated with other treatment processes. It utilizes the combination of sedimentation and biological treatment using extensive detention time. These ponds are in fact are large shallow excavation, in which sewage from various sewer systems drain into. The sewage in the pond uses biological process to destroy various disease-causing organisms. The effluent is discharged as treated sewage. However the pond requires regular maintenance to avoid foul odors.

4.9. Data analysis

The respective data from the point of the area will be converted into its own measurement scale. To determine the total CFP, all sources must be converted to CO_2,eq multiplying emission of N_2O and CH_4 times their respective GWP (i.e. 298 end 25 respectively, IPCC 2006). The analysis was carried out depending on the IPCC, 2006 the last pass for the countries GHG emission estimation categories. This is because the limited data to use the other pass.

Wastewater treatment system/pathway usage often differs for rural and urban residents. Also, in developing countries, there are likely to be differences between urban high-income and urban low-income residents. Hence, a factor U is introduced to express each income group fraction. It is good practice to treat the three categories: rural population, urban high income population, and urban low income population separately. It is suggested to use a spreadsheet, as shown in equation 8

Biochemical oxygen demand (BOD) measures the amount of oxygen consumed by microorganisms in decomposing organic matter in stream water. BOD also measures chemical oxidation of inorganic matter. WMO (1994) – NO 168, chapter 17: one of the most commonly used measuring methods is the dilution method; however, manometric techniques may have advantages in some circumstance. BOD is calculated from the measurement of volumetric dilution of the sample and the difference between the dissolved-oxygen concentrations of the sample before and after five-day incubation period. The temperature should be kept at 20^0C during that period, and atmospheric oxygen should be kept away from the sample, should be stored in the dark to minimize the effect of the photosynthetic action by green plants (UNESCO, 2010).

4.10. Data Quality Assurance

These studies was used the IPCC, as the study tool for all its calculation of the GHG emission estimation. Ina addition, we used different equation for the calculation of the presence of the available land for such treatment.

4.11. Dissemination and data use

Dissemination will be takes place through the organization of Jimma University publication and other important line of publication for use in the world. Beside we will tries to disseminate for the Student research Programme (SRP), Community Based Education Programme (CBE), and Jimma Institute of Technology (JIT) for its real change and accomplishment of future survival as important organization in the environment and public health.

5. Result and Discussion

The flow rate of the treatment plant was about $0.023 m^3/s$.The flow was taken in the grit removal. We visited four times of which the grit was zero grit in the first two visit and the grit was with full grit in the second and the last visit. For simplicity we took the maximum grit for all calculation in this study. In general, it was observed that the pond was highly under loaded in its existence and it was implicated in all the findings. The study group couldn't found a measured flow data to the treatment units. Hence, we highly recommend the flow data of the treatment unit has to be there all time.

The high volumetric organic loading rate of the WWTP of KittoFurdisa Campus in Jimma Institute of Technology (JIT) was about 67.22 g BOD_5/m^3d (but we actually done BOD_3in this study which

we think is all similar), which is really lower than the critical value of 100g BOD_5/m^3 d high volumetric organic loading rate in the anaerobic conditions in first-stage stabilization ponds (Gloyna, 1971). As a result the treatment is inside treatment plus it was not anaerobic treatment by nature. That is why it takes place in the treatment plant so that nothing was away from the treatment plant of the area.In addition to this it has one of the longest retention time (8.81 d) in the first treatment plant i.e. anaerobic pond. But the standard shows that (Gloyna, 1971) it shouldn't be more than three hours (3h) in the whole treatment plant. This all leads to the emission of higher greenhouse gas and inorganic salt formation. Hence the organization of Jimma Institute of Technology have to give service to the public nearby so that the volumetric load will be to enough for the treatment plant to be functional or the organization has to late the surface load of the area hence it will be inundated every summer of the season to the next year. Beside the area has covered the large area of the earth it has to be in good function.

Generally speaking the anaerobic pond are classified as biological treatment process that occur in the absence of oxygen (Das, 2011). But in the case of KittoFurdissa campus of Jimma institute of technology (JIT) of Jimma University there were every type of algae are there even in the first anaerobic pond. That means the anaerobic condition was not important and it might be treated in the other methods including the aerobic processes alone or it may be treated in the constructed wetland or grass pass.

It seems from its begging the treatment was highly efficient and the other treatment plant were without load of carbon and other important nutrients so that the microorganisms like bacteria couldn't thrive. Instead there were high growth of all types of algae in the first treatment plant which still anaerobic pond for the area. In other WWTP it was unusual to observe. Some freshwater algae can form harmful algal blooms (HABs), and these specific species create health hazards for humans and animals by producing toxins and bioactive compounds that deteriorate the water quality. Beside, Algae can grow in wastewater whilst its being treated, and decrease the quality of the treated water. This means that treated wastewater will not comply with the waste water quality standards to reenter the environment. (MPC-Grid, 2017). Hence the water we treat has to have proper management in its activities to decrease such harms.

Cyanobacteria or blue-green algae occur worldwide especially in calm, nutrient-rich waters (WHO, 2019). The nutrient-rich in the OP of JIT was the oxic condition it forms in the all treatment

unit of the area. This all due to the less amount of wastewater to it. Such nutrient-rich waters are not allowed in a WWTP though they are mainly found in coastal areas and estuaries. Cyanobacterial toxins in lakes, ponds, and dugouts in various parts of the world have long been known to cause poisoning in animals and humans.The main diseases from such algael bloom (Eutrophication) includes Amnesic Shellfish Poisoning (ASP), Ciguatera Fish Poisoning (CFP), Diarrhetic Shellfish Poisoning (DSP), Neurotoxic Shellfish Poisoning (NSP) and Paralytic Shellfish Poisoning (PSP) which are mainly due to release toxins that may cause illness in humans and other animals, birds, and fish (Bartram and Chorus, 1999).

As stated on the methodology part the sample was taken from two grab points. Except for biochemical oxygen demand (BOD) of the second grab site for the facultative pond and the the second grab site for the last maturation pond the BOD was all available though there is difference (table 6). However for this two sample areas the BOD was not present with in the first three days of our test. This may be due to the fact that the facultative pond sample was taken under the rock filter or bed of the middle of the Dum of light. In general, it is said that the effluent from a facultative pond treating municipal sewage in the tropics will normally have a BOD_5 between 50 and 70 mg/l as a result of the suspended algae(Gloyna, 1971). However in the case of KittoFurdissa campus of Jimma Institute of Technology at the end of the facultative pond it is almost zero BOD.

From the facultative pond data, the surface (or areal) loading for BOD_5 per hectareper day in areas inKittofurdissashould have to be around 1,213.51 kg BOD_5/ha.d. According to this finding the maximum ($\lambda s(max)$ areal load of the WWTP in KittoFurdissa campus of Jimma Institute of Technology was around 8,373.23 kg BOD_5/ha.d. But to a factor of safety of about 1.5 it was assumed to be around 3974.4 kg BOD5/ha.d in total (Gloyna, 1971). From this finding again we calculated that the area of the facultative pond (A_f) was nearest zero. This is because the BOD reached to the pond was minimal to be treated in the pond like we have in KitoFurdissa campus of Jimma Institute of Technology. From the same finding and with the same BOD concentration of the wastewater in the area the flowrate was calculable to the mega scale. Hence, this all indicates it should have been completed in the anaerobic pond.

On the other hand the current water available was mainly from the areal load. If it was from surface loading the treatment plant should have been more lively. Since there is a diversion ditch which prevent to reach it was not usable. The other option to be used is this one.

Biological purification of waste water is generally accompanied by a change in pH. As the table below (table 7) shows the pH of the study area was all in all alkaline. But, according to some literatures, the bacteria and other biological entities which play an active role in wastewater treatment are most effective at a neutral to slightly alkaline pH of 7 to 8. In our case the average pH was about 9.36 including the averages of the stream water (Luklema, 1969). So this indicates the biological activities were hampered by the pH in the treatment process failure even in the natural water. This was mainly due to weakly buffered wastewater to the treatment plant. Hence, the organization has to maintain these optimal pH conditions for biological activity there must be sufficient alkalinity present in the wastewater to neutralize acids generated by the active biomass during waste treatment. This would happen through one, the increment of load to the treatment plant, or there should be the less amount of treatment options to the area. This include, wastewater treatment through grass pass with in the same area or lesser area.

The study shows in the influent the pH was mainly Bicarbonate by nature. Then in the first treatment plant i.e. anaerobic it was increased again to the pH equilibria of the hydroxyl ion and in all in the remaining process. This all damage the biochemical processes of the treatment plus it will damage the plants and animals in the receiving body. In effluent the main factors governing pH will be the equilibria of carbonic acid. Up to pH 8.3 the first ionization step is dominant; at 20°C

$$[H^+] + [HCO_3^-] = 4.15 \text{ X } 10^{-7} [CO_2]$$

In the pH region of 8.3-10.5the equilibrium

$$[H^+] + [CO_3^{2-}] = 4.20 \text{ X } 10^{-11} [HCO_3^-]$$

dominates and above pH 10.5 the concentration of free OH- ions dominate the pH. (Luklema, 1969). In general, the result shows the predominant ions which determine the pH values where carbonate and bicarbonate. In turn this means there is high production of methane (CH_4) in the highly release of hydrogen ion which will react with available carbon. In addition there is high methanogenesis to the area which leads to the production methane to the world. Hence the time of production should be minimized by well-managed due to the high BOD_5 reduction efficiency.

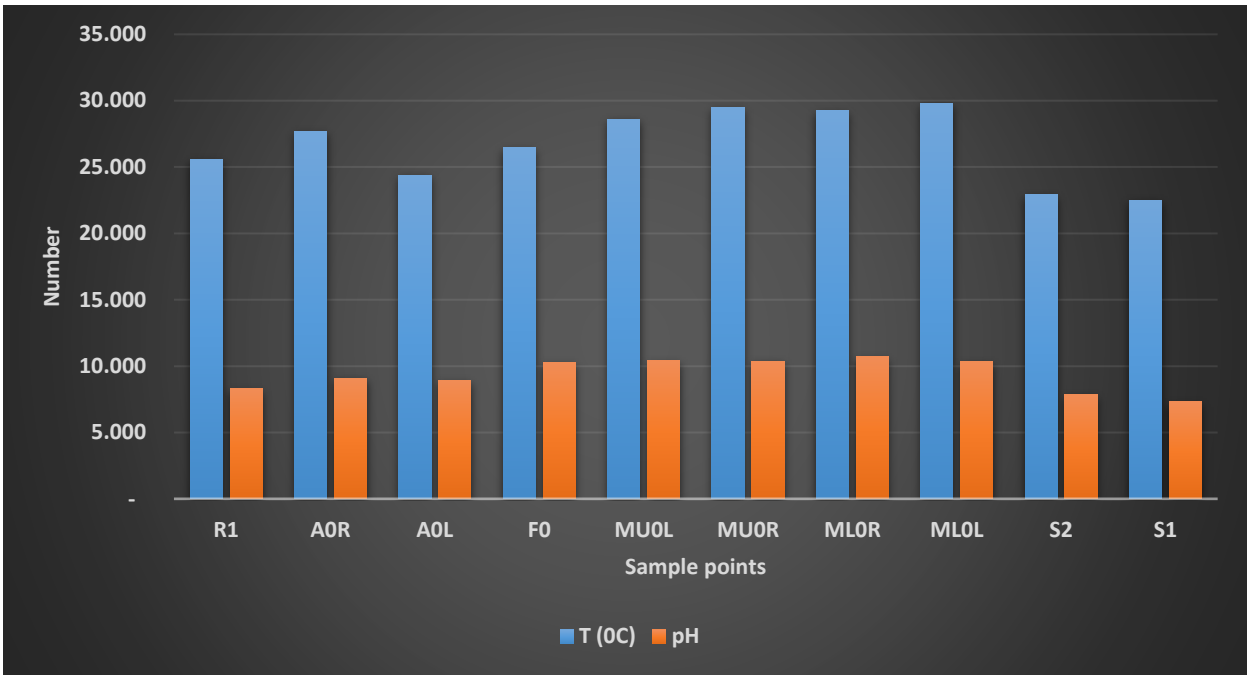


Figure 14 The wastewater temperature (0C) and pH of Waste Stabilization Pond (WSP) at Jimma Institute of Technology (JIT), Jimma, Ethiopia, April 2019

The temperature of the effluent wastewater in this study was also very high when we compare to the influent. The result also shows the pH of the area was in compatible with water temperature. That means the WWTP was too efficient to be released.

Table 7Physicochemical parametersof the Greenhouse Gas (GHG) emission of the Oxidation Pond (OP) at Jimma Institute of Technology (JIT) in Jimma, Ethiopia and April, 2019.

Sample points	**pH**	**Temp. (°C)**	**DO (mg /l)**	**COD (mg/l)**	**P (mg/l)**	**TSS (mg/l)**	**BOD (mg/l)**	**EC(µS/c m)**	NH_3 (mg/l)	NO_3^- (mg/l)	NO_2^- (mg/l)
R1	8.310	25	0.180	270	9.870	9,284.000	592.00	2,300.00	1.6730	5.574	0.364
A0R	9.090	27.700	12.330	356.00	8.025	307.500	176.50	1,863.000	2.2410	5.734	0.325
A0L	8.940	24.400	9.155	285.00	7.875	235.000	52.00	1,154.500	1.4615	4.406	0.341
F0	10.305	26.450	9.725	211.00	5.925	132.000	53.50	642.500	1.5075	2.750	0.043
MU0L	10.395	28.600	16.705	177.00	6.150	67.500	21.50	609.500	0.4915	3.666	0.020

MU0R	10.370	29.500	14.735	120.00	5.640	49.500	19.00	572.500	0.3875	2.803	0.020
ML0R	10.715	29.250	15.285	133.00	4.185	41.000	42.50	565.000	0.1285	2.525	0.048
ML0L	10.350	29.800	9.575	121.00	4.875	30.500	12.00	526.500	0.1170	2.428	0.023
S2	7.830	22.900	0.590	46.40	0.190	92.000	3.00	194.300	-	1.079	0.013
S1	7.300	22.500	0.620	-	0.080	51.000	1.00	175.900	0.0230	0.567	0.013

It is the most important parameter for the operation of wastewater treatment plant next to pH. Hence proper recording of the temperature of the wastewater is highly advisable. However, here in the University of Jimma such practice was not usual to measure the effluent and influent parameter for its proper management.

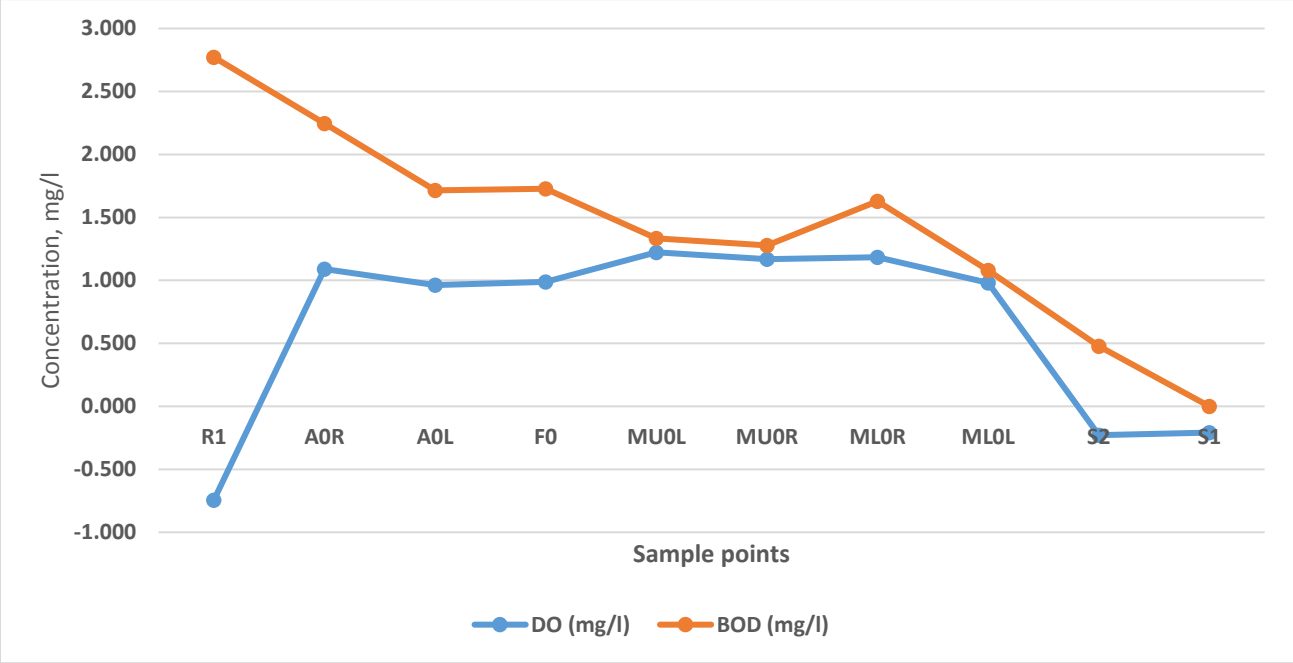


Figure 15 The Dissolved oxygen (DO) and Biochemical oxygen demand (BOD) concentration of Waste Stabilization Pond (WSP) at Jimma Institute of Technology (JIT), Jimma, Ethiopia, and April 2019

The result shows in the first place there was less chemical reaction in the grit. Hence the dissolved oxygen (DO) was very minimal. At low dissolved oxygen (DO) there is high production of greenhouse gases including N_2O. The DO was shout to higher level in the next treatment unit i.e. first anaerobic pond and then it calm down. In this case it was may be due to high BOD removal

Then all of a sudden it rise in the last three maturation ponds due to high chemical reaction. It seems the last treatment plant forms difference i.e. from oxic to anoxic. However, the Oxic–anoxic interface will never be allowed in the treatment plant. Hence, the treatment plant have to plug flow or continues type. In the case of KittoFurdisa Campus of JIT it was no flow type during our visit.

Except for the sample point S1 which is the upper stream before it joins the effluent of the oxidation pond the COD analysis was carried out for the other. This is because there is no COD flasks (kit) at that time. Phosphorus was highly represented in the anaerobic and facultative ponds than in the maturation ponds. Incredibly we highly found the conductivity in the all the ponds. The dissolved oxygen (DO) of the area was also high in both anaerobic and facultative ponds means less load to the pond. Ammonium was not available in the last sample site which is in S2 of the stream after he junction. The first anaerobic pond high ammonia presence shows there is an inside or back treatment of the WWTP in JIT of KittoFurdissa. Such treatment option was backward and time consuming in addition to its environmental disaster.

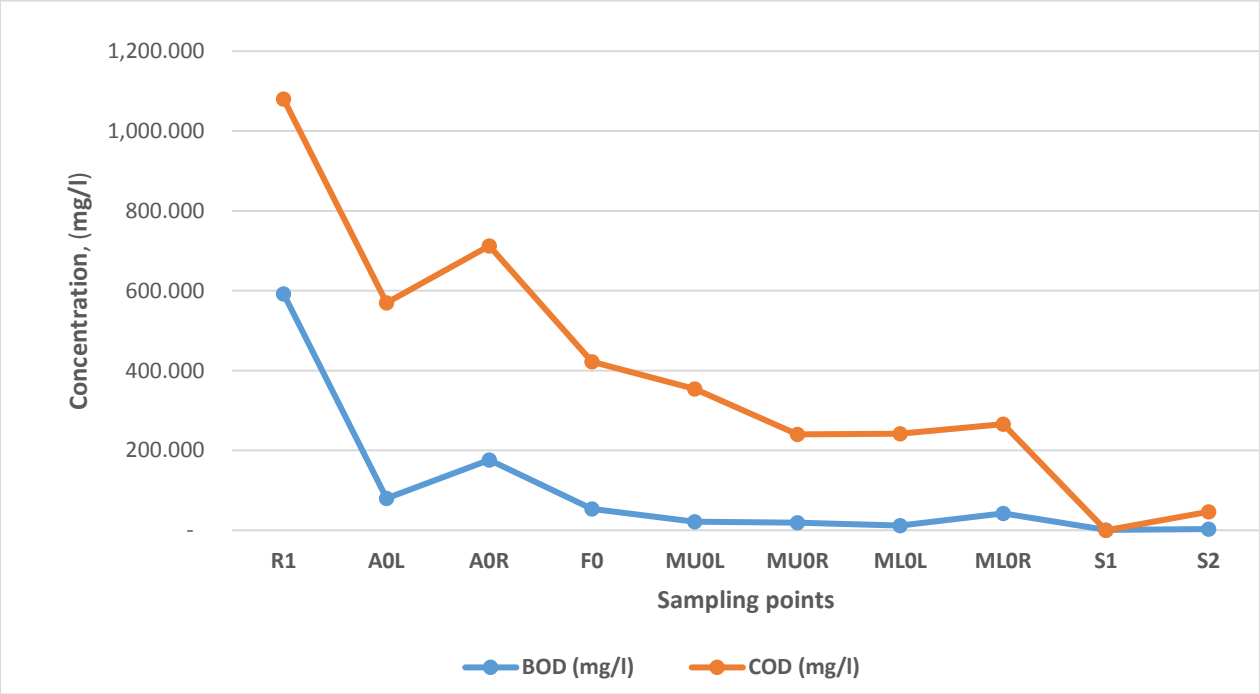


Figure 16 The Biochemical oxygen demand (BOD) and chemical oxidation demand (COD) concentration of Waste Stabilization Pond (WSP) at Jimma Institute of Technology (JIT), Jimma, Ethiopia, and April 2019

The electron conductivity (EC) of the study area also shows the plant only produce large amount of inorganic salt and unwanted gases. The EC graph is always on the top of the COD graph means there is high chemical reaction even in the last anoxic plant.

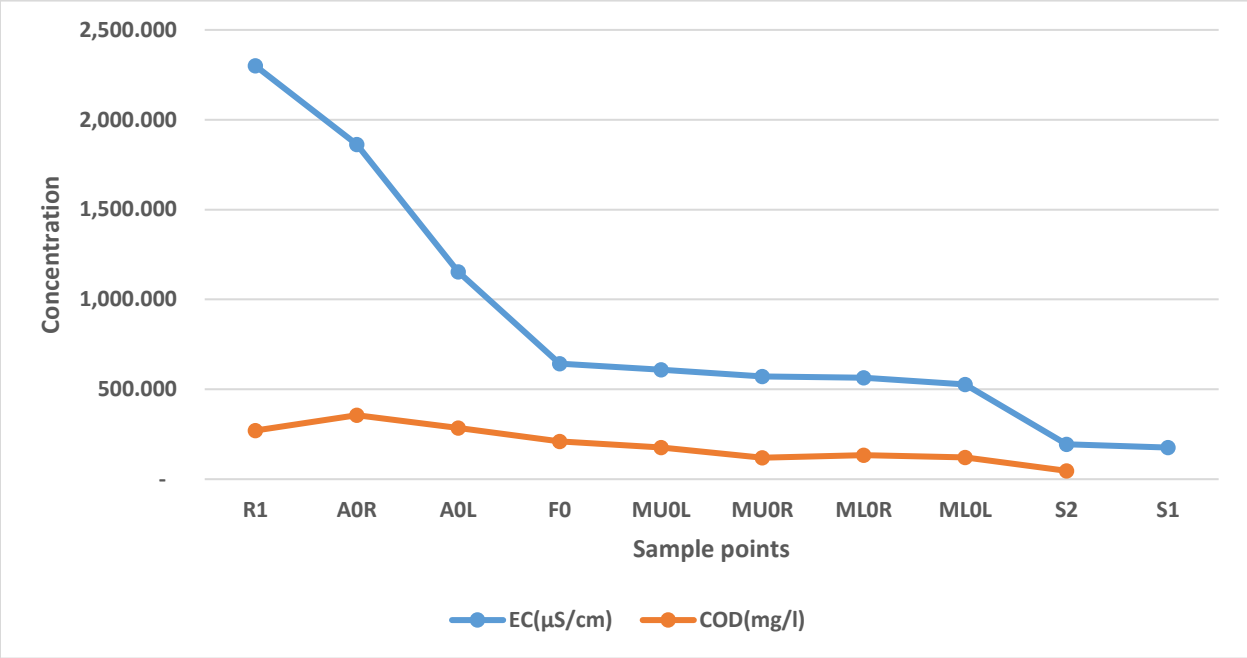


Figure 17 The electron conductivity (EC) and chemical oxidation demand (COD) concentration of Waste Stabilization Pond (WSP) at Jimma Institute of Technology (JIT), Jimma, Ethiopia, and April 2019

The graph (fig. 16) shows it was highly efficient in treatment which was not that necessary. This because a treatment plant have to have a nutrient for the natural water course. The COD/BOD of the waste water shows that it low strength of wastewater (1.82). According to Das, 2011, the typical ration for the in between the COD/BOD in municipal wastewater is from 1.5-2.0. According to this standard the treatment plant in KittoFurdissa was too big to be treated in the operating plant.

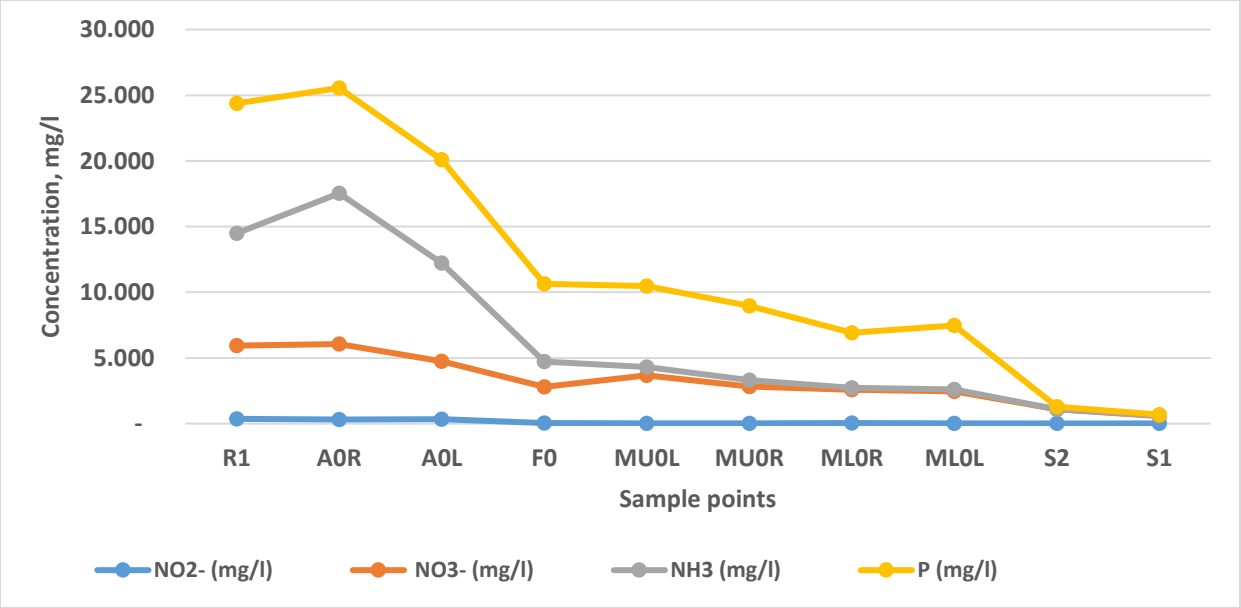


Figure 18The nitrogen and phosphorus concentration of Waste Stabilization Pond (WSP) at Jimma Institute of Technology (JIT), Jimma, Ethiopia, and April 2019

The graph also shows that there is a complete depletion of the phosphate and the nitrogen group from the waste water. This again was unnecessary for that it contribute for the production in a water course. For instance, European Standards for wastewater discharge in water bodies for BOD of max concentration of 125 mg/l O_2 (75% minimum reduction), COD of maximum concentration 25 mg/l O_2 (70-90 % minimum reduction, nitrogen will be 15mg/lN (70-80% minimum reduction), and total phosphorus 2mg/l P (80% minimum reduction (Villafañe, 2013). But in the case of our study eutrophication was happened inside the treatment plant itself. But nobody needs this to happen and in some countries it is highly punishable.

From the phosphate data the WWTP produces a phosphate of 0.365674 kg/m2. This means there is high salt production in a treatment plant itself which makes it oxic anoxic formation. This will form the high application of salt to the environment.In European standard the wastewater discharge to the water bodies has to have a phosphate of Total Phosphorus 2 mg/l P. However, in the case of our study it is much bigger than this number and the phosphate was orthophosphate only in contrast to the European standard. .

The operation of wastewater treatment plants results in direct emissions, from the biological processes, of greenhouse gases (GHG) such as carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O), as well as indirect emissions resulting from energy generation. The methane (CH_4)

emission of the WWTP at KittoFurdisa campus of Jimma University Institute of Technology was about 3.86 ktCO2-eq/year. The emission of CH_4 was higher inside the grit removal which was the first sampling points (R1). The CH_4emission was also higher in the first treatment unit which was anaerobic according to the report on the depth. The main sources of methane detected by these authors were related to the sludge line units where anaerobic digestion is carried out: These units contribute to around89.03% in the KittoFurdissa of JIT of methane emissions of the WWTPs while the remaining emissions come from the biological reactors and can be mainly attributed to the CH_4 dissolved in the wastewater which is not totally removed by the biological system. It also showed that most of the methane emissions from WWTPs are closely related to processes involved in the sludge line (even though these is for further study). But as it moves to the next facultative pond then it fall down to the emission of about zero. This implies the first treatment plant in the first compartment which is the anaerobic pond was extremely efficient for the treatment of a BOD load of these much. As a result of this we didn't considered the maturation pond for the emission of methane (CH_4) since it has less than zero emission factor (MCF). This zero emission was due to there is no load compared to the area of the wastewater treatment plant (WWTP) in KittoFurdisa campus Jimma University Ethiopia.

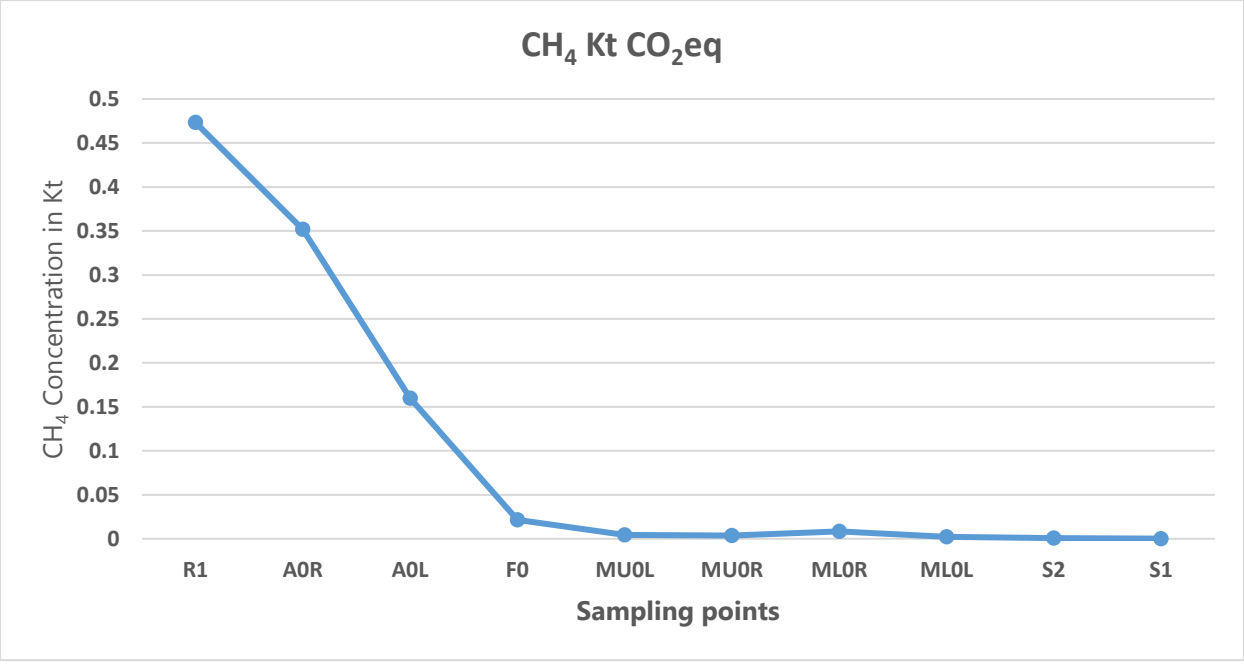


Figure 19 Methane (CH4) emission level of Waste Stabilization Pond (WSP) at Jimma Institute of Technology (JIT), Jimma, Ethiopia, and April 2019

Methane was said to be never to come from the influent. It is said that the with regard to CH4 emissions, found out that about 1% of the incoming chemical oxygen demand (COD) to the WWTPs was emitted as methane. So, it mainly comes from biological processing the anaerobic environment. Methane emissions (kt of CO_2 equivalent per capita) in Ethiopia was reported at 0.00148 in 2000, according to the World Bank collection of development indicators, compiled from officially recognized sources (WDI, 2000). Except the facultative pond the anaerobic pond has more emission when we compare with this data. The first now shows lesser emission than this data. Theoretically, removal of 1 kg of COD from the wastewater will result in the production of 0.35 m3 of methane (at STP, standard temperature and pressure). In the case of KittoFurdissaCampuse of JIT, it shouldn't be more than this at least. However, in actual practice, the process generates 0.27-0.30 m^3 methane per kg COD removed.

The production of methane mainly from the organic degradable, temperature (where the tropics like Jimma has high importance because of active methanogens) and the type of the treatment plant (IPCC, 2006). The first treatment plant i.e. anaerobic pond has long duration for methanogensis. Hence it has to be functional for at least three hour (3 hr.) of the treatment unit rule. According to these estimation the emission GHG the treatment plant was not well designed and was not managed properly of the green house. The other is the organization of JimmaInstitue of Technology has made no observable strategies for the reduction of such unwanted gases.

N_2O emission of the wastewater treatment plant (WWTP) in JIT of KittoFurdisa was on average 0.018 g/y. this is equal to0.005 kg CO_2eq. The biggest emission again was from the first anaerobic pond which is about 0.015 kg CO_2eq and the last emission to the water bodies even though there was a little drop or no pass to the water bodies was0.002 kg CO_2eq.

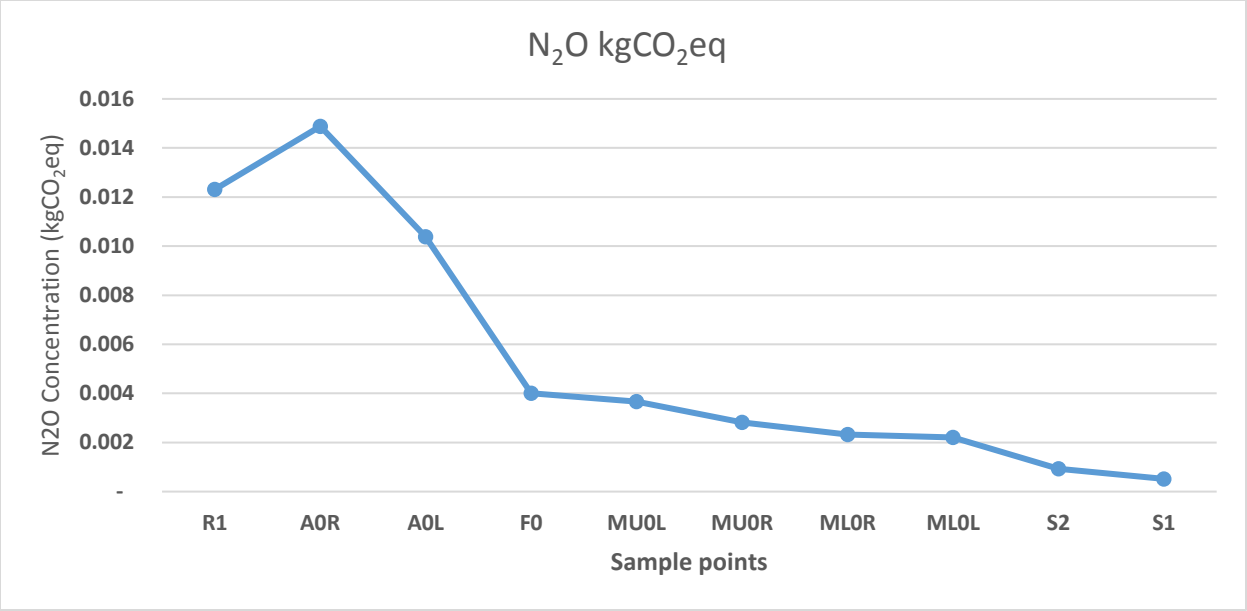


Figure 20 Nitrous oxide (N2O) emission level of Waste Stabilization Pond (WSP) at Jimma Institute of Technology (JIT), Jimma, Ethiopia, and April 2019

The emission of nitrous oxide was mainly from the nitrification denitrification process. The nitrification was mainly due to the algal growth and death in the WWTP. It is mainly due to, less nitrogen load, uncontrolled volumetric stripping and high ammonia-oxidizing bacteria death because of anoxic- oxic pattern. The nitrification was mainly due to the respiration of the algae instead of bacteria which day time unavailable and the study has to continue for the night time Nitrous oxide (N_2O) emission.

Denitrification is an anaerobic process which converts nitrate to dinitrogen in the following sequence: $NO_3^- \rightarrow NO_2^- \rightarrow NO \rightarrow N_2O \rightarrow N_2$.Wheras, Nitrification is a microbial process by which reduced nitrogen compounds (primarily ammonia) are sequentially oxidized to nitrite and

$$\begin{array}{l} NH_4^+ \rightarrow NO_2^- \rightarrow NO_3^- \\ \qquad\quad \downarrow \\ \qquad\quad NO \rightarrow N_2O \rightarrow N_2 \end{array}$$

nitrate (EPA, 2002).

The WWTP currently use the whole treatment units. Instead of the other options we listed above the plant may use the three system only i.e. one anaerobic pond instead of two; little facultative pond instead of the large once and only one maturation pond instead of four. In these form we can alleviate all the problems of unwanted gases emission and salt accumulation to the area.

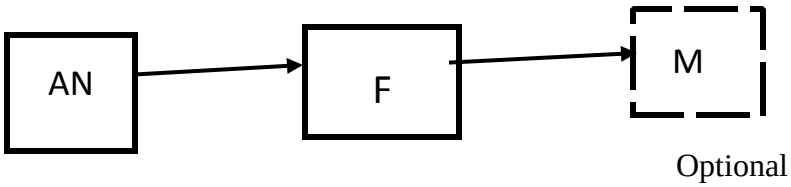


Figure 21 The optional management for the WWTP in the Jimma Institute of Technology (JIT), Jimma, Ethiopia, and April, 2019

The public services to increase the volumetric load to the treatment plant will be possible as to my assumption through three direction of line for the sear to the area.

The GHG emissions accountable to a particular project are those that fall within that project's boundaries. A variety of different terms and conventions may be used to define these boundaries. One approach is to categorize emissions as either on-site or off-site. The essence of this approach is geography. Emissions that take place at a project site are of course considered on- site, while those that result from activity elsewhere are considered off-site. Classifying emissions in this way is simple but not complete ((World Bank, 1998). Hence this study also considers the emission of GHG which are on-site.

As the figure above indicates the nitrous oxide (N_2O) is still rising to form a GHG problem than the methane gas (CH_4) from the area because of oxic anoxic formation in the treatment plant. This indicates the GWP (296 times more than the other) of nitrous oxide is by far greater than the other two means this GHG has to be in controlled condition. These should averted 1) by decreasing the nitrification process and increasing denitrification process 2) the other is may the load of the carbon compound has to be increased to start the methane forming compound 3) there should an additional mechanism to control the growth of algae or the removal of algae has to undertake even though it cost additional and has other GHG effect because it needs machinery to clean algae every time means it produces GHG offsite. This is again rely dangerous than the other two.

The boundary system shows that all the greenhouse gas trend was changed to the first thought of the production of the project i.e. the first anaerobic and the next two compartments produced the gasses. But, according to different literatures the production of GHG was distributed as, CH_4 was mainly from the anaerobic decomposition of organic matter whereas, the N_2O was mainly from aerobic area.

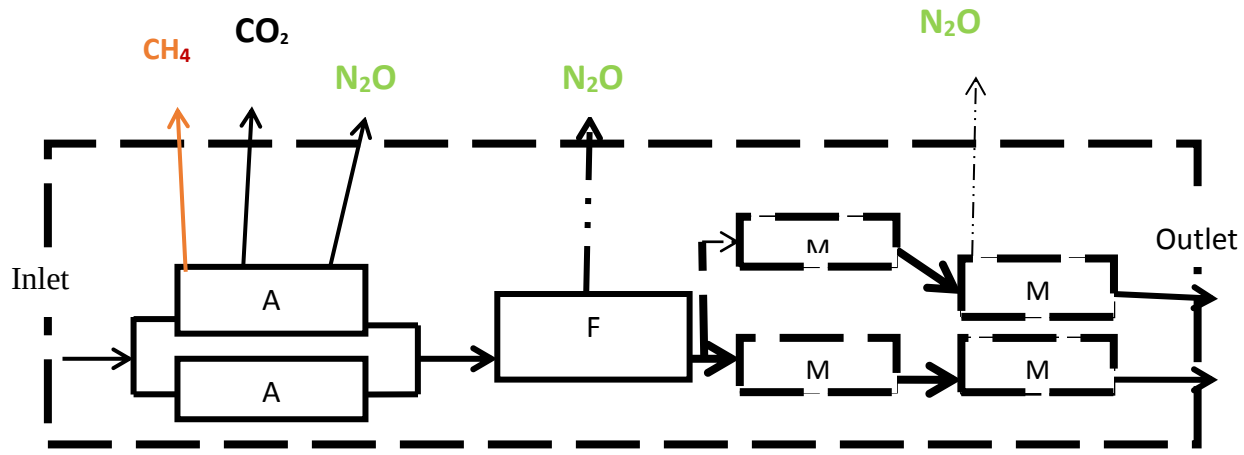


Figure 22Boundry system

A = Anaerobic F = Facultative M = Maturation

From the characteristics of the gases production and the WWTP itself we can conclude that it is too many treatment unit for the specified wastewater. Hence, the organization has to find some solution like we stated above i.e. they have to increase the load or the have to use surface loading.

In general, the WWTP in JIT of KittoFurdissa has so many GWP (Global Warming Potential) as compared to the other environmental compartment near Jimma, Ethiopia. First it high Methane (CH_4) and Nitrous Oxide (N_2O) release to the environment. Second the inorganic salts are the main sources for the development of algae of different type. This has different health and environmental effect of unprecedented scale to the knowledge of mankind. In addition, due to reluctant control and unwell management there is even a report of three (3) human death to the area. Such deathes were may be caused by the algal bloom may deplete oxygen in the waters and they were asphyxiated in the passing road or drawn to it. Hence, we highly recommend that there should be well management to the Wastewater Treatment Plant (WWTP) namely Oxidation Pond (OP) and has to be controlled both for human health and to our environment.

6. Conclusion and recommendation

6.1. Conclusion

In general,

- The GHG emission of the WWTP was so high to cause the global threat.
- There was less or no load to the WWTP (BOD, COD and water).
- There was high variation in Temperature and pH.
- There is high EC which indicates high organic salt deposit (high phosphorous release to the area).
- The nitrogen (N) was also too high in the treatment plant itself because of anoxic and oxic formation

6.2. Recommendation

The study group will tries to recommend the following steps

- There should be an office, laboratories, special compound and an operator to the area so that the problem of GHG emission, inorganic salt deposition and physical death will be alleviated. As to my recommendation there should be more than 15 professionals which has to be enrolled to the area as an operator of Oxidation pond (OP) of that scale.
- The area has to be controlled at least to prevent physical death.
- The Department of Environmental Health Sciences and Technology has under take the course Global Warming (GW) and Greenhouse gas (GHG) for its students so that there should be high awareness to the area of concern.
- The organization has to give public services so that big organization will benefit from carbon offset and the OP will be functional to the area than its dangerous release of unwanted gases and inorganic salt will be decreased.

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