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# Evaluation of Waste Stabilization Ponds Performance Efficiency in Bahir Dar University Peda Campus, Bahir Dar, Ethiopia

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**BAHIR DAR UNIVERSITY**

**COLLEGE OF SCIENCE**

**DEPARTMENT OF BIOLOGY**

# EVALUATION OF WASTE STABILIZATION PONDS PERFORMANCE EFFICIENCY IN BAHIR DAR UNIVERSITY PEDA CAMPUS, BAHIR DAR, ETHIOPIA

**BY**

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**JUNE 2023**

**BAHIR DAR, ETHIOPIA**

**BAHIR DAR UNIVERSITY**

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B Y

SIFRASH ADANE

A THESIS SUBMITTED TO THE DEPARTMENT OF BIOLOGY OF BAHIR DAR UNIVERSITY IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTERS IN BIOLOGY (APPLIED MICROBIOLOGY)

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COLLEGE OF SCIENCE

DEPARTMENT OF BIOLOGY

Approval Sheet of Research Advisor

As a thesis advisor, I certify that I have read and evaluated this thesis prepared under my guidance by Sifrash Adane entitled **“Evaluation of Waste Stabilization Ponds Performance Efficiency in Bahir Dar University Peda Campus, Bahir Dar, Ethiopia**” and I recommended the thesis paper to be submitted as fulfilling the requirements for the degree of master in Applied Microbiology.

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Approval Sheet of Thesis Examiner

As members of the board of examiners, we examined this thesis entitled "**Evaluation of Waste Stabilization Ponds Performance Efficiency in Bahir Dar University Peda Campus, Bahir Dar, Ethiopia**" by Sifrash Adane. We hereby certify that the thesis is accepted for fulfilling the requirements of a master's degree in Applied Microbiology

**Board of Examiners**

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**DECLARATION**

I, the undersigned, declare that this MSc thesis is my original work and has not been presented for a degree in any other University and all sources of materials used for the thesis have been dully acknowledged.

Sifrash Adane

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| Name of Student | Signature | Date |

TABLE OF CONTENTS

**LIST OF TABLES**

## LISTS OF FIGURES

## LIST OF APPENDIX

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## LIST OF ABBREVIATIONS

| | |
|---|---|
| ANOVA | Analysis of Variance |
| APHA | American Public Health Association |
| BDU | Bahir Dar University |
| DO | Dissolved Oxygen |
| EC | Electrical Conductivity |
| EEPA | Ethiopian Environmental Protection Authority |
| FAO | Food And Agriculture Organization |
| FC | Fecal Coliform |
| MPN | Most Probable Number |
| NTU | Nephelometric Turbidity Unit |
| TC | Fecal Coliform |
| TSS | Total Suspended Solids |
| USEPA | United State Environmental Agency |
| WHO | World Health Organization |
| WSP | Waste Stabilization Pond |

## ABSTRACT

*A waste stabilization pond system (WSPs) is one of the most promising wastewater treatment methods in the world. Bahir Dar university Peda campus constructed waste stabilization ponds and the effluent is discharged into the environment without evaluating its performance and determining its quality. The present study aimed to evaluate the WSP removal efficiency in terms of TC, FC, nitrate, and phosphate, and assess water quality parameters like temperature, pH, dissolved oxygen, conductivity, turbidity, and chlorophyll-a. A laboratory-based seasonal study was conducted in dry, wet, and semi-wet seasons from April 2022 to January 2023. The water sample was taken three times per each season. A total of 45 samples were analyzed from five sampling sites in the three seasons. A standard APHA method of procedure was used to collect and analyze bacteriological and physicochemical parameters of the sample. MINITAB version-18 was used for statistical analysis. Multiple tube fermentation technique use used for coliform enumeration. The removal efficiency of total* coliform was 93.7%, 91.9 %, and 76.9% in dry, wet, and semi-wet seasons respectively. *Whereas removal efficiency of fecal coliforms was 99.2%, 73.9%, and 77.7% in dry, wet, and semi-wet seasons, respectively. But the effluent coliform in all seasons was above the national standard. Although the WSP removes nitrate up to 45% (0.85 mg/L effluent), 70.2% (0.56 mg/L effluent), and 40 % (1.50 mg/L effluent) was in dry, wet, and semi-wet seasons respectively. The removal efficiency of the stabilization pond for Phosphate was 78.5% (5.51 mg/L effluent), 56.3% (5.1 mg/L effluent), and 37.2% (20.5 mg/L effluent) in dry, wet, and semi-wet seasons, respectively. Most of the physicochemical parameters were in line with Ethiopian Environmental Protection Authority guidelines except phosphate. However Bahir dar university peda campus WSP showed above up to 99% coliform and up to 78% nutrient removal, the effluent water quality of WSP is not suitable for drinking, recreation, and agriculture. Therefore, to improve the efficiency of the WSP and to produce adequately treated water; frequent monitoring and maintenance of the pond are needed. Further research should be conducted in the BDU Peda Campus waste stabilization pond to investigate other performance indicator parameters of waste stabilization pond like biological oxygen demand and total suspended solid.*

*Keywords: coliforms, nutrient, wastewater, waste stabilization pond, removal efficiency*

# 1. INTRODUCTION

## 1.1. Background of the study

Water is the most important natural resource for all types of life on Earth. It is mostly sourced from rivers, lakes, streams, and groundwater, all of which are easily exposed to pollution from industries, agriculture, and institutional and residential use, and turn into wastewater (Sukumaran *et al*., 2015). Both developed and developing countries suffer from the issue of water pollution. Human activities that produce water also introduce numerous sorts of pollutants (Ali *et al*., 2018). Water quality is mostly affected by the discharge of poorly treated effluents into surface and groundwater sources. The wastewater contains organic and inorganic chemicals, biodegradable organic substances, nutrients, pathogens and toxic materials (Haddis *et al*., 2014; Edokpayi *et al*., 2020).

Many institutions, industries, agricultural activities, and households discharge their wastewater into receiving water bodies like rivers, streams, lakes, and wetlands without any treatment, which may cause ecological damage and constitute a public health risk that requires proper waste management to mitigate the effects caused by the pollutants (De-Troyer *et al*., 2016). More than 50% of the population in poor nations lacks access to sanitation, and as a result, more than 80% of the wastewater produced is directly released into water bodies(Gad *et al*., 2022).

Wastewater treatment contributes to the reduction of contamination and pollution of natural waters and the improvement of aquatic ecosystem health. It reducing contamination by microorganisms including coliform bacteria, suspended particles, nutrients, and organic loads is the primary goal of wastewater treatment (Ali *et al*., 2020). Sourced wastewater must be collected, treated, and disposed of without altering the ecosystem of the receiving environment to provide a healthy and pollution-free environment. Inadequate wastewater treatment frequently results in environmental degradation and human sickness because it contains harmful microorganisms and high loads of nutrients are the primary problems of improperly treated wastewater (Kokkinos *et al*., 2015).

The wastewater treatment system can remove contaminants such as pathogens, organic matter, and microbial to be effective (Verbyla et al., 2016). The nature of the wastewater entering the wastewater treatment plant and the expected use and quality of the effluent significantly impacts the treatment system's type (Ahmadi et al., 2020). Wastewater treatment techniques are classified into two groups: conventional and non-conventional treatment plants. Conventional sewage treatment systems (sometimes referred to as mechanical systems) are used where space is very limited. Because they are mechanized, they are more expensive to build and operate compared to natural treatment systems that require more space, such as lagoons. Non-conventional technologies have lower environmental impacts and reduce contaminant loads at lower costs than conventional treatments. Compared to the conventional method, the non-conventional method uses more advance equipment and technology (Rajasulochana and Preethy, 2016).

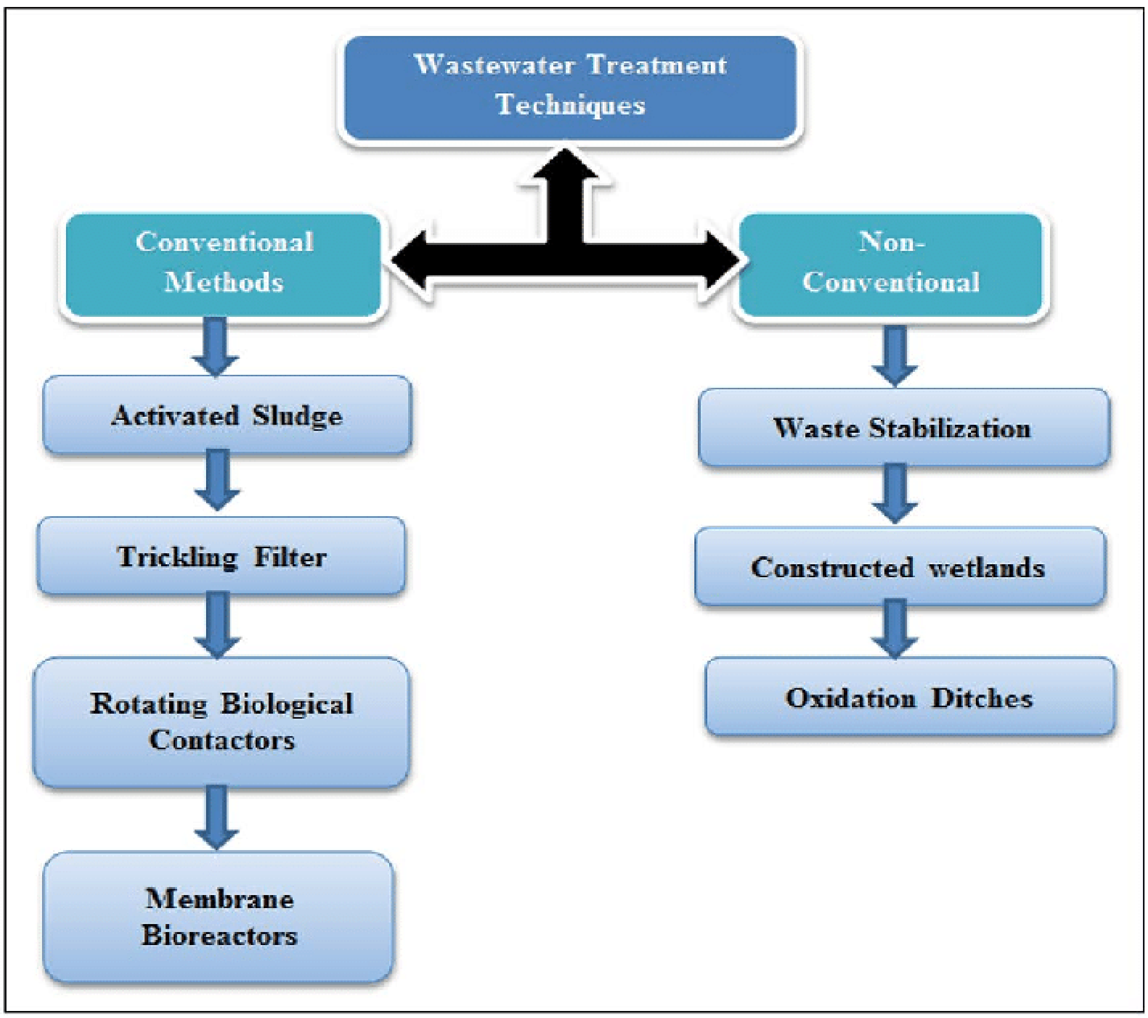



**Figure 1:waste water treatment techniques (Source :Fahad *et al*., 2019)**

The most suitable wastewater treatment is one that, at a reasonable cost, and with the fewest operating and maintenance requirements, results in an effluent that satisfies the recommended microbiological and chemical quality parameters. In many cases, it will be preferable to build a reuse system to take low-grade wastewater rather than relying on sophisticated treatment procedures to produce recovered effluent that consistently reaches a high standard of quality (Al-Hashimi and Hussain, 2013).

A waste stabilization pond system (WSP) is one of the most promising wastewater treatment methods in the world. It is suitable for domestic, animal, and industrial wastew ater treatment. WSP is natural, and self sufficient, it has a simple design, reduces the oper ator's responsibility to manage the system, and a reduction in labor costs (Al-Ajalin *et al.*, 2020). WSPs provide wastewater treatment capacities for countless farms and rural communities. While cost-efficient organic carbon and pathogen removal can be achieved in WSPs, these systems seldom provide the levels of inorganic nutrient removal efficiency that are now increasingly required (Gruchlik *et al*., 2018)). WSP is used around the world, specially where treating wastewater using conventional treatment methods is costly and in places with year-round mild to warm climate conditions (Edokpayi *et al*., 2021).
Based on to the availability of oxygen for the stabilization process, WSP has been classified as anaerobic, facultative, and maturation ponds to achieve effective treatment. Anaerobic and facultative ponds are used for primary and secondary treatment, respectively. They are both designed for the removal of organic matter. The maturation ponds are used for the tertiary treatment of wastewater effluent and are designed for pathogens and nutrient removal (Chambonniere *et al.*, 2021). In both tropical and subtropical areas of the world, the use of waste stabilization ponds is seen to be one of the most effective systems for treating the world's rising urban wastewater flows (Kayira and Wanda, 2021). It provides a straightforward but economically advantageous technology for treating wastewater before releasing it into an aquatic ecosystem. For many years, wastewater oxidation ponds have been evaluated for their low hydraulic loads and low capital costs in various regions of the world, including developing nations and places where adequate land is inexpensively accessible (Cao *et al*., 2022). WSPs have the capability to effectively attenuate organic and nutrient concentrations, as well as and pathogen present in municipal wastewater. The

removal of a wide range of pathogenic organisms, such as bacterial, viral, protozoan and helminthic pathogens, is commonly achieved in WSP systems (Reinoso *et al*., 2008).

However there are studies conducted in many industries and educational institutions in Ethiopia about waste stabilization ponds performance (Desye *et al*., 2022b; Flipos Engdaw, 2014; Gizachew Teshome *et al*., 2019; Dejene and Prasada 2012; Sintayehu Kebede, 2017), their study were not seasonal. In addition to this, there is no previous study on the performance of waste stabilization ponds on Bahir Dar University peda campus. Therefore this study will fill the gap by evaluating the removal efficiency of the constructed waste stabilization pond by assessing the physicochemical and bacteriologica l characteristics of effluent wastewater from Bahir Dar University in dry, wet, and semi-wet seasons.

## 1.2. Statement of the problem

The majority of developing nations currently release a variety of waste sources, including domestic and organizational garbage from universities, hotels, hospitals, and industries, into the environment without proper treatment. Three-fourths of Ethiopia's children's health issues are communicable diseases brought on by contaminated water and poor sanitation, according to the annual report of the country's health minister. More than 60% of communicable diseases in Ethiopia are due to poor environmental health condition arising from unsafe and inadequate water supply and poor protection of water supply from contamination and regular surveillance of water sources (WHO, 2010).

Bahir Dar University has built oxidation ponds to enhance the pleasantness of discharged wastewater from the student cafeteria, bathroom, and toilet, from staff, laboratories, and residents to keep the surroundings free from pollution. There are different source of waste effluents from the university which are harmful for downstream communities. Wastes released from student dormitory, different chemicals in laboratory, organic wastes from student cafe, and waste from construction raw material disposal and wastes in each office. All of these wastes directly released in to the prepared waste stabilization pond which is used as a treatment plant. The principal objective of wastewater treatment is generally to allow human and organizational effluents to be disposed of without danger to human health or unacceptable damage to the natural environment. Unfortunately, the ponds are still being used regardless of the increase in population from the initial design up to now without determining the water quality and removal efficiency of the waste stabilization pond as I got information from Personal Communication with the Physical Project Officer of BDU. Therefore, the research project presented here is aimed to evaluate the performance of the waste stabilization pond at Bahr Dar University Peda Campus in terms of physicochemical and microbiological performance indicators and assess water quality parameters like temperature, pH, turbidity, chlorophyll-a, conductivity, and dissolved oxygen and compare them with the national standard of wastewater to discharge into environment and reuse for agriculture and aquatic life.

## 1.3. Objectives of the study

### 1.3.1 General objective

The general objective of the study is Evaluation of Waste Stabilization Ponds Performance Efficiency in Bahir Dar University Peda Campus, Bahir Dar, Ethiopia in dry, wet, and semi-wet seasons

### 1.3.2 Specific objectives

To enumerate total and fecal coliforms in the waste stabilization ponds in dry, wet and semi-wet seasons

To determine the physicochemical parameters of the waste stabilization pond in dry, wet and semi-wet seasons

To assess the removal efficiency of the waste stabilization ponds in dry, wet and semi-wet seasons

## 1.4. Significance of the study

The fundamental intention of wastewater treatment is to decrease contamination of pathogenic bacteria, physical and chemical components. To avoid or minimize pollution of soils, receiving water bodies, and endangering human health, it is necessary to monitor water quality in the treated domestic wastewater before it is discharged This study helps to obtain necessary data on the pollution load of wastes from Bahir Dar University Peda campus and to recommend frequent monitoring and maintenance of the waste stabilization pond if not effective. Performance evaluation is vital to estimate the water quality status of the waste stabilization pond and recognize the current effluent level. This research title is recommended by the institution to do this so, Knowing the performance of each pond will also speed up targeted intervention to improve performance. The results obtained from the study will serve to identify areas where prevention and control measures are necessary, enhance decision-making tools for waste management and identify which season needs additional treatment. In addition, the study initiated other researchers to apply to other campuses in the university and other institutions. It also serves as a baseline for a further similar study.

# 2. LITERATURE REVIEW

## 2.1. Wastewater Characteristics and the Rationales for wastewater treatment

Water is the most important natural resource for all types of life on Earth. This water is mostly sourced from rivers, lakes, streams, and groundwater, all of which are strongly exposed to pollution from industries, agriculture, and institutional and residential use, and turns into wastewater (Sukumaran *et al*., 2015). Wastewater typically has a grey color, a musty smell, and a solids concentration of 0.1%. A mixture of feces, food scraps, toilet paper, grease, oil, soap, salts, metals, detergents, sand, and grit makes up the solid substance. Pathogens, organic substances, synthetic chemicals, nutrients and heavy metals made up the various components found in wastewater. When discharged into the receiving environment, the suspended solids may result in the formation of sludge deposits and anaerobic conditions. These elements may be bioaccumulative, persistent, and synergistic, compromising human security and impacting ecology, food production, and human health (Sintayehu Kebede, 2017).

Wastewater contains wastes from domestic, commercial, or industrial facilities. High concentrations of organic and inorganic matter, pathogenic organisms, nutrients, and numerous hazardous substances, including heavy metals, may be present in untreated water from domestic sewage and industrial activity (Sperling, 2015). This turns wastewater into a risk to the environment and human health that needs to be properly treated before disposal. Due to differences in the wastewater composition and the ambient temperature at different periods of the year, many wastewater treatment processes also cannot be work effectively. This implies that a certain treatment approach can be effective at some points but not at others (Bwapwa and Jaiyeola, 2016).

The wastewater is characterized by physical, chemical, and biological constituents. Domestic wastewater is discharged from commercial, institutional, and residential buildings. Chemical compositions in domestic wastewater are highly diverse substances from simple compounds to complex polymers. Types and amounts of substances show the characteristic of domestic wastewater (Widyarani *et al*., 2022). Characterization of the overall substances is important to expand the knowledge in selecting appropriate wastewater treatment processes or models. Determination of characteristics of domestic wastewater is also important to evaluate the existing treatment plants and the selection of appropriate treatment plants. Besides that, it is also necessary to determine the utilization of treated or untreated wastewater based on its contents (Choi *et al*., 2017).

The concentrations and ratios between various parameters in wastewater influent can influence the selection and function of treatment processes. Wastewater characteristic is related to water quality standard that is aimed to protect the designated use of water body ( Pierce and Rhoads, 2016).

Generally, the characteristics of domestic wastewater are specifically represented by physicochemical parameters, such as pH, total suspended solids, dissolved oxygen (DO), BOD5, COD, nitrate, phosphate, and potassium and bacteriological parameters like total and fecal coliforms. Other, minority components include metal, toxins, detergent, and germs. The color of wastewater may be grey or black regarding the sources. Grey wastewater is wastewater that originates from bathtubs, showers, hand basins, laundry machines, and kitchen sinks, and other fixtures found in homes, offices, and schools. Compared to black wastewater, which is contaminated with fecal matter like feces and urine, it is less polluted (Wijaya and Soedjono, 2018).

## 2.2. Effect of waste on public health

Wastewater with organic pollutants contains great quantities of suspended solids which decrease the light offered to photosynthetic organisms. Organic pollutants include hydrocarbons, phenols, plasticizers, pesticides, fertilizers, detergents, oils, pharmaceutical s, carbohydrates and protein. Effluents also contain heavy metals which are harmful to human health either through direct ingestion or from fish and other animals or plants. Heavy metals particularly arsenic, mercury and lead are environmental pollutants threatening the health of human population and natural ecosystem (Abdelhafeez *et al*., 2022).

As it has been found in other developing countries, the infectious diarrhea was significantly related with contamination of fecal coliform bacteria in drinking waters(Gruber *et al*., 2014).According to world health organization (WHO) 80% diseases are water borne. Drinking water in various countries does not meet WHO standards( Khan *et al*., 2013). 3.1% deaths occur due to the unhygienic and poor quality of water (Pawari and Gawande, 2015). Water pollutants are killing sea weeds, mollusks, marine birds, fishes, crustaceans and other sea organisms that serve as food for human. Insecticides like DDT concentration is increasing along the food chain. These insecticides are harmful for humans (Owa, 2013). Waste from the industries like, sugar, textile, electroplating, pesticides, pulp and paper are polluting the water (Kamble, 2014). Polluted river have intolerable smell and contains less flora and fauna. 80% of the world's population is facing threats to water security (Owa, 2013).

## 2.3. Wastewater treatment systems

Treatment of wastewater involves physical, chemical, and biological processes. In comparison to the biological process, where microbes are crucial to the breakdown of biodegradable organic matter, the physical process entails the removal of coarse and suspended matter. The chemical procedure further improves the treatment quality (Sintayrhu Kebede, 2017). The purpose of wastewater treatment plants is to remove or reduce contaminants in water that impose threats to humans and the environment if discharged to the surface and/or ground waters without proper treatment (Bhave, 2020). As developed countries continue to work on more efficient treatment processes in the sewage treatment plant and establish new technologies to meet the growing water demand, undeveloped countries are still struggling to establish the required infrastructure for the treatment (Achag *et al*., 2021). Untreated industrial, university, hospital and other municipal wastewater contain non-biodegradable organic matter, heavy metals, and other toxicants that deteriorate the receiving stream. Due to the large palette of inputs in the sewers, contains certain undesirable components including organic, inorganic, and toxic substances, large amounts of potentially toxic elements as well as pathogenic or disease-causing micro-organisms (Gizachew Teshome *et al*., 2019).

Wastewater treatment and reuse are not new, and knowledge on this topic has evolved and advanced throughout human history. Reuse of untreated municipal wastewater has been practiced for many centuries to divert human waste outside of urban settlements. Likewise, land application of domestic wastewater is an old and common practice, which has gone through different stages of development. This has led to a better understanding of process and treatment technology and the eventual development of water quality standards (Paranychianakis *et al*., 2015). Today, the planning of projects for the wastewater treatment and reuse of effluents is significantly increasing in several countries. The main reuses of treated wastewater are irrigation, recharge of aquifers, seawater barriers, industrial applications, dual-distribution systems for toilet flushing, and other urban uses. International organizations, such as the World Bank, the Food and Agriculture Organization (FAO) of the United Nations, and the World Health Organization (WHO) estimate that the average annual increase in the reused volume of such water in the USA, China, Japan, Spain, Israel, and Australia ranges from up to 25 (Angelakis and Snyder, 2015).

## 2.4. Waste stabilization ponds

Waste Stabilization Ponds (WSPs) are large, shallow basins in which raw sewage is treated entirely by natural processes involving both algae and bacteria (Mahapatra *et al*., 2022). They are used for sewage treatment in temperate and tropical climates and represent one of the most cost-effective, reliable, and easily-operated methods for treating domestic and industrial wastewater. It is very effective in the removal of fecal coliform bacteria (Verbyla *et al*., 2016). Energy from sunlight is the only requirement for its operation. Further, it requires minimum supervision for daily operation by simply cleaning the outlets and inlet works. The temperature and duration of sunlight in tropical countries offer an excellent opportunity for this high-efficiency water cleaning system. They are well-suited for low-income tropical countries where conventional wastewater treatment cannot be achieved due to the lack of a reliable energy source. Further, the advantage of these systems, in terms of the removal of pathogens, is one of the most important reasons for their use (Ghalhari *et al*., 2021). Waste stabilization ponds (WSPs) provide wastewater treatment capacities for countless farms and rural communities. While cost-efficient organic carbon and pathogen removal can be achieved in WSPs, these systems seldom provide the levels of inorganic nutrient removal efficiency (or consistency) that are now increasingly required (Chambonniere, 2021).

The activity in the WSP is a complex symbiosis of bacteria and algae, which stabilizes waste and reduces pathogens. The result of this biological process is to convert the organic content of the effluent to more stable and less offensive forms. WSPs are used to treat a variety of wastewaters, from domestic’s wastewaters to complex industrial waters, and they function under a wide range of weather conditions, i.e. tropical to arctic. They can be used alone or in combination with treatment processes (Surampall, 2020).

The fundamental principles of wastewater treatment include Preliminary treatment that removes large objects, rags, and grit. In primary treatment, floating particles are skimmed from the surface and heavy particles are removed by quiescent settling or sedimentation. In advanced primary treatment, chemicals may be added to enhance the sedimentation and removal of lighter suspended solids and, to a lesser extent dissolved solids. Primary treatment is carried out in anaerobic ponds, secondary treatment in facultative ponds, and tertiary treatment in maturation ponds. Anaerobic and facultative ponds are for the removal of organic matter (normally expressed as BOD) and maturation ponds are for the removal of fecal viruses, fecal bacteria (for example, *Salmonella*, *Shigella*, *Campylobacter*, and pathogenic strains of *Escherichia coli*, nitrogen, and phosphorus (Ali and Hashimi, 2014). The oxidation pond comprises different groups of organisms such as bacteria, algae, protozoa, fungi, viruses, rotifers, nematodes, insects, and crustacean larvae. These organisms coexist and compete with each other. The bacteria present in the pond decompose the biodegradable organic matter and release carbon dioxide, ammonia, and nitrates (Alamgir *et al*., 2016). These compounds are utilized by the algae, which together with sunlight and the photosynthetic process releases oxygen, enabling the bacteria to break down more waste and accomplish a reduction in BOD levels. The nutritional aspects of bacteria, algae and fungi are interrelated. These ponds often harbor aquatic weeds and are termed macrophyte ponds. Initial research on oxidation ponds (1946 to 1960) describes pond activity in terms of the mutualistic behavior of algae and protozoa through photosynthesis (Tharavathy *et al*., 2014).

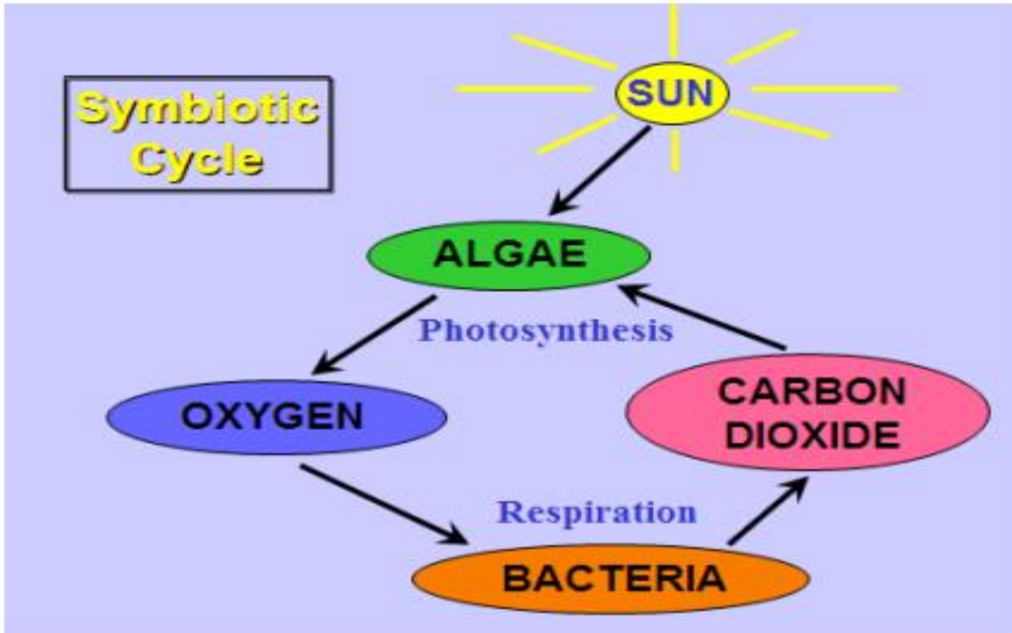



**Figure 2:Symbiotic cycles in stabilization pond (Alamgir *et al.*, 2016)**

Depending on the design requirements and operating conditions of each kind, WSP systems comprise a single string of anaerobic, facultative, and maturation ponds in series, in which there is a continuous in and outflow of wastewater. The best pond structure for purification varies greatly depending on several factors, including the organic loading rate, the amount of available land, the climate information, the characteristics of the influent, and the desired effluent values (Achag *et al*., 2021). Regarding how they contribute to the overall wastewater treatment system, these ponds have different purposes. Anaerobic, facultative, and aerated ponds' main goal is to eliminate carbon-containing organic debris, whereas maturation ponds' primary purpose is to remove pathogens (Verbyla *et al*., 2017). Maturation ponds like facultative ponds use algae as the major driving force for the treatment of wastewater. Maturation ponds are used to remove fecal coli form, pathogens, and nutrients, whereas facultative ponds often treat BOD (Butler *et al*., 2017).

Anaerobic ponds are commonly 2 – 5 m deep and receive wastewater with high organic loads (i.e., usually greater than 100 g BOD/$m^3$ day), and rely totally on anaerobic digestion to achieve organic removal. The process of anaerobic digestion is more intense at temperatures above 15$^o$C(Mara and Pearson, 1998). The anaerobic bacteria are usually sensitive to pH <6.2. A shorter retention time of 1.0 - 1.5 days is commonly used (Abdullahi *et al*., 2014).

A facultative pond relies on naturally-growing algae, and BOD removal by the pond bacteria is generated primarily via algal photosynthesis. Facultative ponds are usually 1.5-2.5 m deep. The Hydraulic Retention Time (HRT) for ponds treating anaerobic effluent varies between 5 and 30 days. The maturation ponds (1 to 1.5 m deep) receive effluent from the facultative ponds and are required only when stronger wastewaters are to be treated before surface water discharge. The primary function of maturation ponds is the removal of excreted pathogens (Amoo and Aremu, 2012; Oberlin, 2018).

## 2.5. Factors affecting performance of waste stabilization ponds

Physicochemical factors affect the habitat of microorganisms and consequently the wastewater treatment process. The most important environmental factors to take into consideration are temperature, pH, conductivity, turbidity, and nutrient requirements.

### 2.5.1. Temperature

The performance of waste stabilization ponds is significantly influenced by temperature. The temperature has an impact on the metabolism of bacteria and algae, the amount of organic matter destroyed, and the stabilization of inorganic nutrients (Ali *et al.*, 2020). The temperature of wastewater is commonly higher than that of the local water supply, because of the addition of warm water from households and industrial activities. Depending on the location and the time of the year, the effluent temperatures can be either higher or lower than the corresponding influent values. (Ho and Goethals, 2020). Oxygen is less soluble in warm wastewater than in cold wastewater. In addition, abnormally high temperatures can promote the growth of undesirable water plants and wastewater fungi. Also, optimum temperatures for bacterial activity are in the range of 25 to 35°C. It is important to take note that as the temperature of wastewater rises, its ability to hold dissolved oxygen decreases (Rukoro, 2018).

In the summer and winter, when the surface water heated by the sun remains at the top of the pond and the cooler, denser water is at the bottom, the temperature has a significant impact on the productivity of the pond (Ghalhari *et al.*, 2021). Stratification is the process of creating layers or strata as a result of the detectable temperature shift that occurs as depth increases. Winter months see an increase in stratification as sheets of ice can form inside the pond layers, blocking light and preventing the production of additional water layers (Butler *et al*., 2017).

### 2.5.2. pH

The hydrogen-ion concentration is an important quality parameter of wastewater indicating how acidic or alkaline the wastewater (Mandal, 2014). It is measured on a scale from zero to 14, and 7 being neutral meaning neither acidic nor alkaline. The concentration suitable for the existence of biological life is pH 6 to 9 (Posadas *et al*., 2015). The pH of water varies greatly with time due to interaction with biological activity, air, and temperature changes. Important pH changes occur as a result of waste disposal. The pH specifically influences the effectiveness of the secondary treatment process since the survival of most biological life depends on essential and slight pH extent (Rukoro, 2018).
The pH of the wastewater decides its functionality for many purposes. As a very high or low pH, it is toxic to marine organisms as well as affects the solubility of basic elemental and chemical contaminants (Boczkaj and Fernandes, 2017). The optimum pH range for all methanogenic bacteria is between 6 and 8, but the optimum value for the group as a whole is close to 7. High or low pH values in a river have been reported to affect aquatic life and alter the toxicity of other pollutants in one form or the other. At high pH values ($pH>8.5$) free ammonia is more toxic to aquatic biota than when it is in the oxidized form of ammonium ions (Singh, 2021). Wastewater with a high pH is difficult to treat by biological means. Both anaerobic and facultative ponds operate most efficiently under slightly alkaline conditions (Beyene and Redaie, 2011).

### 2.5.3. Turbidity

Turbidity is a measure of the light-transmitting properties of wastewater and is a test used to indicate the quality of wastewater for colloidal and residual suspended matter NTU (Nephelometric Turbidity Unit) is used for water turbidity. FNU (Formazin Nephelometric Unit) is equal to NTU; however, there is a difference in the way FNU and NTU are measured. The instrument used for measuring it is called a turbid meter, which measures the intensity of light scattered at 90 degrees as a beam of light passes through a water sample (Tu *et al*., 2021). Wastewater contains suspended solid matter consisting of particles of many different sizes. While some suspended material will be large enough and heavy enough to settle rapidly to the bottom of the container if a liquid sample is left to stand (the settable solids), very small particles will settle only very slowly or not at all if the sample is regularly agitated or the particles are colloidal (Mucha and Kułakowski, 2016).

### 2.5.4. Electrical conductivity

The electrical conductivity (EC) of wastewater is a measure of the ability of a solution to conduct an electrical current. Because the electrical current is transported by the ions in the wastewater, the conductivity increases as the concentration of ions increases. Wastewater effluents often contain high amounts of dissolved salts from domestic sewage. EC is therefore a useful indicator of its salinity or total salt content. The electrical conductivity in SI units is expressed as millisiemens per meter (mS/m) (Riffat and Husnain, 2022). Conductivity itself is not a human or aquatic health concern, but because it is easily measured, it can serve as an indicator of other water quality problems. If the conductivity of an environment (stream) suddenly increases, it indicates that there is a source of dissolved ions in the vicinity. Therefore, conductivity measurements can be used as a quick way to indicate potential water quality problems (Juanarena *et al*., 2020).

### 2.5.5 Dissolved Oxygen

Water DO is a reliable indicator of the pollution situation of water systems. Lack of oxygen in water protects anaerobic bacteria and other pathogens harmful to human health by stimulating bioaccumulation and biomagnifications (Hacioglu and Dulger, 2010). Dissolved oxygen (DO) is oxygen that is dissolved in wastewater. DO is necessary for the respiration of all aerobic life forms as well as aerobic microorganisms. However, oxygen is only slightly soluble in water. The amount of oxygen present in wastewater is determined by the factors of the solubility of the gas, the partial pressure of oxygen in the air, the temperature, and the concentration of impurities such as salinity, suspended solids (Riffat and Husnain, 2022). As the temperature of wastewater rises, the amount of dissolved oxygen decreases. At 0°C and sea level, the most oxygen that will dissolve in wastewater is 14.6 mg/L. At 20°C, the most oxygen is about 9 mg/L. However, because of excessive algal activity, stabilization ponds are known to hold more than 14.6 mg/L (often as high as 25-30 mg/L) (Rukoro, 2018)**.**

## 2.6. Nutrient Removal in Oxidation Ponds

The nutrients found in the residence, agricultural, and industrial wastewater that enter natural waters cause eutrophication, which accelerates the growth of algae and reduces the amount of dissolved oxygen in the water. These nutrients are toxic to fish and hazardous to human health (Novikova *et al.*, 2019). The degradation is a result of the effluent produced from wastewater treatment plants (WWTPs), which can be a significant source of nutrient loading to aquatic habitats. higher nitrogen and in environmentally vulnerable locations, wastewater treatment facilities have imposed phosphorus discharge limits(Qin *et al*., 2015). Increased nitrogen and phosphorus flow to the water system is caused by municipal services, agricultural activity, and urbanization. The primary cause of eutrophication, which results in oxygen depletion, biodiversity loss, fish deaths, stench, and increased toxicity, is an excess of nutrients, primarily N and P. The effluents from municipal wastewater treatment plants frequently fall short of the required level of effluent quality (Wijaya and Soedjono, 2018).

Nutrients such as phosphorous and nitrogen are essential for the growth of algae and other plants. But excessive concentrations of nutrients, however, can over stimulate aquatic plant and algae growth. According to (Ge *et al.*, 2015), in untreated wastewater, nitrogen exists in the forms of ammonia, nitrite, nitrate, and organic nitrogen. Urea, protein, and amino acids are the major forms of organic nitrogen along with the discharge of these nitrogen compounds into the receiving environment would lead to several environmental and health risks (Holmes *et al*.,2019). Therefore, nitrogen compounds must be removed from the wastewater. For the removal of nitrogen, the biological nitrogen removal system is superior to other systems with three successive processes: ammonification, nitrification, and denitrification (Wang *et al*., 2016).

In WSP significant reduction of nitrogenous oxygen demand is possible in the form of a reduction of amino groups, ammonia, and total nitrogen concentration of wastewater (Ma *et al*., 2021). Nitrification of ammonium occurs in the oxidized root zone of the macrophyte. This process is enhanced beneath stands of plants that transport large quantities of oxygen, such as pennywort. Nitrate-N thus formed diffuses into reduced microenvironments in the pond system, where it is utilized as an electron acceptor by facultative anaerobic bacteria and is lost from the system as N gas. It is possible to achieve greater reductions in total nitrogen concentrations in summer (Wang *et al*., 2016). Contrary to popular belief, this is achieved not by harvesting the plants (which could have had the luxury uptake of nitrogen) but by other mechanisms, principally nitrification and denitrification (Rahimi *et al*., 2020).

In anaerobic ponds, organic nitrogen is hydrolyzed to ammonia. Thus, the effluents from anaerobic ponds usually have higher concentrations of ammonia than raw sewage. In facultative and maturation ponds, ammonia is incorporated into algal biomass. At high pH values, ammonia leaves the pond through volatilization. There is little evidence for nitrification (hence denitrification, unless the wastewater has high nitrate content). This is because the population of nitrifying bacteria is low because of the lack of physical attachment sites in the aerobic zone. Total nitrogen and ammonia removal from WSP can reach 80 and 95%, respectively (Hauck *et al*., 2016).

Phosphorus occurs naturally in low concentrations and is essential for all forms of life. It comes from processes such as weathering of rocks and the decomposition of organic matter. Phosphorus indicates nutrient status, organic enrichment, and the consequent health of the environment. Increased levels may result from erosion, discharge of sewage or detergents, urban runoff, rural runoff containing fertilizers, and animal and plant matter (Sarvajayakesavalu *et al*., 2018). When concentrations are too high, problems such as algal blooms, foul smells, excessive weed growth, and the loss of species diversity can occur ( Pirsaheb *et al.*, 2014).

Phosphorus removal in WSP is associated with its uptake by algal biomass, precipitation, and sedimentation. The best way to remove much of the phosphorus in the wastewater by WSP is to increase the number of maturation ponds (Mirquez *et al*., 2016). It becomes bound chemically to other elements in the sediments. When the bound phosphorus is less available to the microbes than phosphate in solution, the sediment/microbe complex becomes a significant sink for phosphorus. The cause and magnitude of winter releases of sediment-stored phosphorus are related to changes in the chemistry of the sediment environment brought about by a combination of climatic and biological factors (Vymazal and Kröpfelová, 2008).

## 2.7. Pathogen removal in waste stabilization ponds

The principal mechanisms for fecal bacteria removal in facultative and maturation ponds are retention time, temperature, high pH (>9), and high light intensity together with high dissolved oxygen concentration (Beyene and Redaie, 2011). The term ‘pathogen removal’ is preferred over ‘disinfection’ because it is unclear if the pathogen(s) targeted is (are) indeed killed (or at least de-activated) and not merely removed from the wastewater. The lack of knowledge of the actual mechanisms involved means true disinfection is often hard to establish in real systems, especially when considering that only indicator organisms are routinely monitored during wastewater treatment. Indeed, although the removal of fecal indicators is used as evidence of pathogen removal in practice (WHO, 2012), there are no truly universal indicators (Chambonniere *et al*., 2021).

Pathogens in wastewater can be removed or inactivated using a variety of different processes that operate at various levels and speeds. These systems' effectiveness is influenced by a variety of operational, environmental, and design factors. Although other parameters like temperature, dissolved oxygen, sunlight exposure, and pH have a significant effect on the elimination of viral and bacterial infections. The elimination of protozoan pathogens depends on several essential elements, including sedimentation, hydraulic efficiency, sunlight exposure, and physicochemical variables (Shingare *et al*., 2019).

Different pathogen types that are removed by the same mechanism are not necessarily removed at the same rate by that mechanism. For example, viruses and bacteria are both damaged by sunlight in WSPs, but viruses are generally more resistant than bacteria (Verbyla and Mihelcic, 2015). Although some fecal bacteria are removed in anaerobic ponds, mostly through the sedimentation of solids-associated bacteria, fecal bacteria are mostly eliminated in facultative and especially maturation ponds whose size and number dictate the quantities of fecal bacteria in the final effluent. We now understand that time (retention time as pathogen attenuation occurs over time), temperature (fecal bacteria die off increases with temperature), pH (> 9), and high light intensity combined with high dissolved oxygen concentration are the main mechanisms for fecal bacteria removal in facultative and maturation ponds (Kaseva *et al*., 2008).

As predictors of the presence of harmful microorganisms microbiological indicators are u tilized (Mouheb *et al*., 2022). Fecal coliforms and total coliforms are frequently used as indicator organisms to assess the efficacy of treated wastewater and recognize potentially hazardous germs. The fact that they exist may be an accurate indication of fecal contamination (Liu *et al*., 2020).

Waste stabilization ponds are capable of eliminating 100% of helminths and reducing fecal coliform by 99.9%, making it easier to collect wastewater for irrigation of agricultural land under both restricted and unregulated conditions. The time when irrigation is most common, the warm months, sees the highest pathogen decreases. During these seasons, it is simple to achieve effluent standards (Mara and Pearson, 1998; Younos *et al*., 2007).

## 2.8. Environmental Protection Agency Effluent Discharge Criteria of wastewater

The effluent standard implemented in domestic wastewater treatment plants (WWTPs) depends on the classification of the receiving water environment and the design age of the WWTP(Wang *et al*., 2015). Upgrading WWTPs will give rise to other adverse environmental effects owning to energy and chemicals consumptions, waste activated sludge (WAS) production, and greenhouse gas emission, representing a clear example of problem-shifting (Li and Achal, 2020). If WWTPs are designed and operated to solve local-scale environmental problems without taking into account the global nature of the environment, it is possible that no net environmental improvement will be gained. On this respect, all environmental consequences throughout the life cycle of a WWTP should be considered recommendable (Corominas *et al*., 2013).

# 3. MATERIALS AND METHODS

## 3.1 Description of the location of the waste stabilization ponds

The study will be conducted in Bahir Dar University, Bahir Dar, Ethiopia. The distance from the capital city Addis Ababa to Bahir Dar is 552 kilometers. It is located at 11°35'29.99" N 37°23'26.99" E on end of Lake Tina. It is found on an average altitude of 1830 m above sea level and characterized by hot and humid weather with an average annual temperature of 20.1$^0$C. It receives 1416 mm annual rainfall from June to September and has distinct dry and wet seasons (CSA, 2010). In Bahir Dar, the wet season is overcast, the dry season is partly cloudy, and it is warm year round. Over the course of the year, the temperature typically varies from *56°F* to *87°F* and is rarely below *52°F* or above *92°F*.The waste stabilization pond is located in the Southeastern corner of Bahir Dar University's main campus. It is located at 11°34'3" N 37°24'3" E. According to the recorded information from the University Registrar and Human resource directorate, the ponds serve 1389 employees and 10574 students (2816 regular and 7758 distance, summer, and extension students). The sewage from the cafeteria, student dormitory, toilet and bathroom, laboratories, academic area, and residences is collected and treated on it. There are two waste stabilization ponds constructed in parallel and have the same inlet and outlet. As shown in Figure 4, the types of oxidation ponds in Bahir Dar University Peda Campus are anaerobic (AP), facultative (FP), and maturation (MP) laying in series with common inlet and outlet. The depth of anaerobic, facultative, and maturation ponds are 1.75 m, 1.20 m, and 1.50 m (Personal Communication with the Physical Project Officer of BDU). The wastes are conveyed to the ponds through sewers made of concrete pipes.

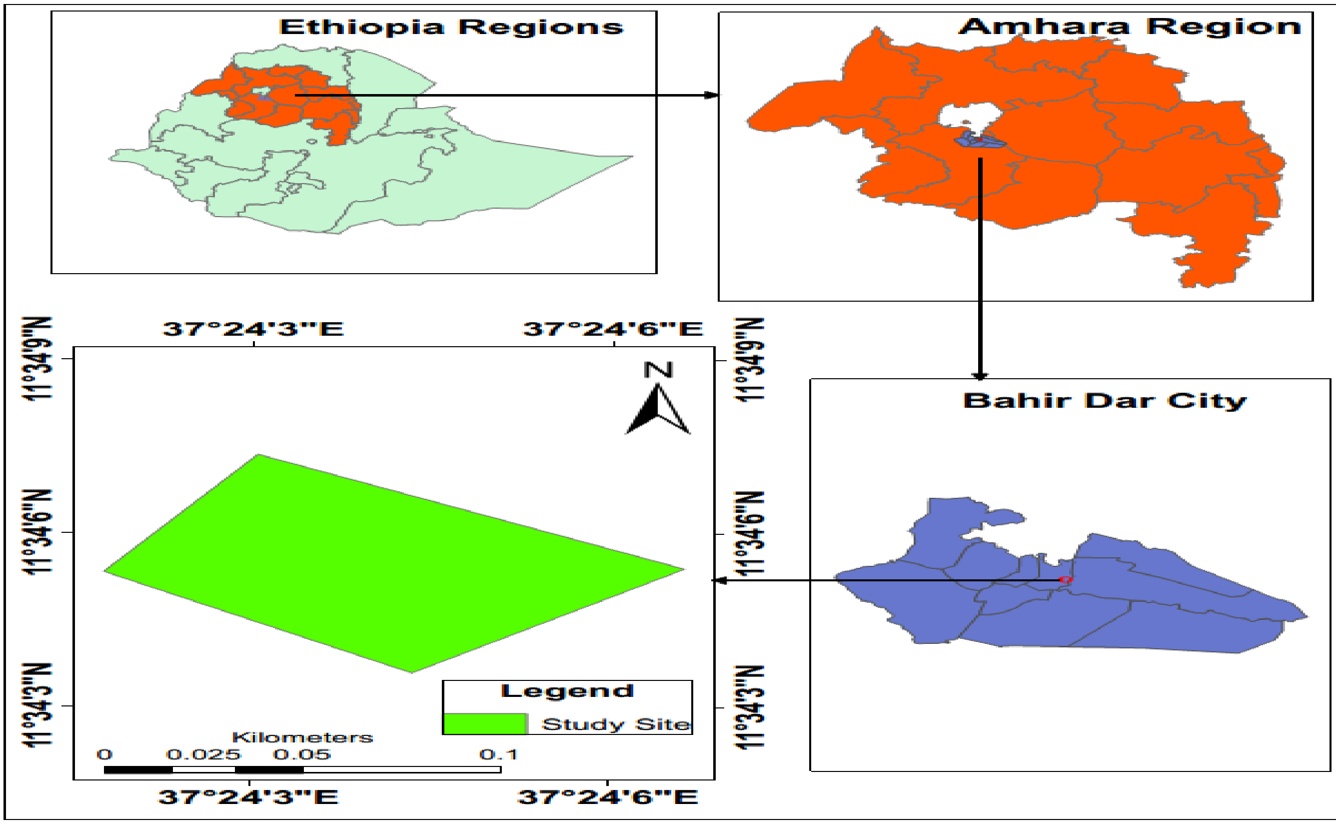



Figure 3: Maps of the study area

### 3.2. Study Design and Period

A laboratory-based seasonal study was conducted at Peda Campus, Bahir Dar University, Ethiopia, from April 2022 to January 2023 in dry, wet, and semi-wet seasons. The classification of seasons based on the warm, cold and intermediate months of the year were determined through the weather data of the previous years.

### 3.3. Wastewater Sample Collection and Transportation

The sample sites are represented by P1, P2, P3, P4, and p5. P2, P3, and P4 represent anaerobic, facultative, and maturation ponds respectively, whereas P1 represents the inlet pond and P5 represents the outlet pond in the wet and semi-wet seasons, but in the case of the dry season, P4 is used as an outlet because of no flow of water in the outlet. Wastewater samples were collected from the influent (inlet), anaerobic pond (P2), facultative pond (P3), maturation pond (P4), and effluent (outlet) of the waste stabilization pond in dry, wet, and semi-wet seasons during the study period. The wastewater samples were taken at two o'clock three times per season from each sampling site. A total of 45 samples were taken in one point (15 from each season).

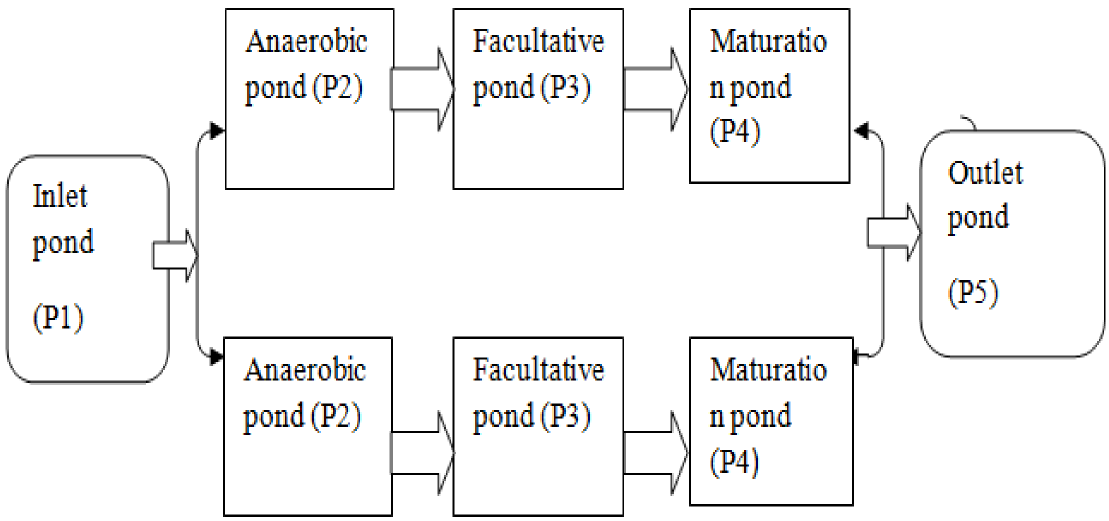



**Figure 4: The layout of Bahir Dar University Peda Campus waste stabilization pond (Reconstructed from the site plan)**

A 100ml and 500ml of wastewater samples were collected aseptically using 100 ml of sterile glass bottles for bacteriological analysis and 500 milliliters of plastic bottles for measuring turbidity and nutrient analysis. Before sampling, the glass bottles were sterilized in an autoclave for 15–20 minutes at 120°C, and plastic bottles were rinsed with distilled water. The samples were sealed, labeled, and transported in an icebox to Microbiology Laboratory, at Bahir Dar University Peda Campus. The sampling protocol was carried out by following the standard methods of the American Public Health Association (APHA, 2012).

### 3.4. Wastewater Analysis for Physicochemical Parameters

To determine the efficiency of WSP operation, physicochemical parameters were measured. The temperature, pH, electrical conductivity (EC), and dissolved oxygen (DO), were measured onsite immediately after sampling using a pri-calibrated Multi-probe meter (YSI 556 MPS). Chlorophyll-a was measured by using a handheld fluorometer (aqua fluor™) onsite by inserting the instrument in the wastewater and the press on and then read and turbidity was measured in the laboratory by turbidity meter (AL250T-IR). Wastewater samples for nitrate and phosphate analysis were filtered using a 0.45 µm pore size, 47 mm diameter Millipore filter membrane, and preserved using a 50 ml centrifuge tube and stored at 4oC until analysis was carried out. The determination of the concentration of nitrate and phosphate was carried out using a spectrophotometer (DR/2010 HACH, Loveland, USA) according to HACH instructions (APHA, 2012). For phosphate analysis 10ml of the sample was taken and then add number 1 and number 2 plain test tablets and crashed after that wait for 10 minutes until the color changed. Finally put into the photometer and read the value. Similarly, for nitrates 20ml of the sample was taken, and add one spun powder and nitracol tablet and shake. After that wait for 5 minutes until settling and then take 10ml of it and add nitrate test table and crash. Finally put into the photometer and read the value.

## 3.5. Wastewater Analysis for a total and fecal coliform count

The coliform analysis was performed using the most probable number (MPN) method in three portions of five test tubes (15 test tubes for each sample), five undiluted (1ml), five 10 X dilution (0.1ml), and five 100X dilution (0.01ml) in 10ml single strength MacConkey broth with inverted Durham tube, and then incubated at 37°C and 44°C for 24-48hr for TC and FC respectively. Tubes showing both color change and gas formation were considered coliform positive for both total and fecal coliform. The total coliform (TC) and fecal coliform (FC) were enumerated using the most probable number (MPN) method as explained in standard methods (APHA, 2012). The total and fecal coliform value was read from the MPN table (APHA, 1992).

## 3.6. Assessment of the removal efficiency of the wastewater oxidation ponds

The removal efficiency of the wastewater oxidation ponds for some parameters (total coliform, fecal coliform, nitrate, and phosphate) concentration in the influent and corresponding levels in the effluent was calculated by using the equation

$$\text{Removal efficiency (\%)} = \frac{\text{level of a parameter in the influent} - \text{level of a parameter in the effluent}}{\text{level of the parameter in the influent}} \times 100$$

(Valipour *et al*., 2015)

### 3.7. Data analysis

The raw data were coded and entered into a Microsoft Excel spreadsheet. After that, the data were exported to MINITAB for statistical analysis. Descriptive statistics were used for the mean value of bacteriological and physicochemical parameters at each site. Graphs and tables were used to interpret the data. One way ANOVA is used to assess the bacteriological and physicochemical quality analysis among the five sampling sites. The data was analyzed using person correlation to check the significant positive or negative relation among bacteriological and physicochemical parameters. The results of bacteriological and physicochemical analyses were compared with EPA guidelines for different uses and discharge into the environment.

# 4. RESULTS

## 4.1. Microbiological characteristics

### 4.1.1 The total and fecal coliform removal efficiency

The results of total and fecal coliform counts of the wastewater samples indicate that their number decreased from the inlet to the outlet pond. There was also a decrease in coliforms from P1 to P2, P2 to P3, and P3 to P4. The value of total coliforms in the dry season was (10846.7 MPN/100 ml) inlet and outlet (686.7 MPN/100 ml) with an efficiency of 93.7% and inlet 8066.7 MPN/100 ml and outlet 650 MPN/100 ml total coliform with an efficiency of 91.9% in the wet season and inlet 3266.7 MPN/100 ml and outlet 756 MPN/100 ml total coliform with an efficiency of 76.9% in semi-wet season. There was a statically significant difference of $p<0.05$ between sample sites in wet and semi-wet seasons but not in the dry season p-value >0.05.

The mean value of inlet for fecal coliform was 6490 MPN/100 ml, 76.7 MPN/100 ml, and 343.3 MPN/100 ml in dry, wet, and semi-wet seasons respectively. The mean value of the outlet fecal coliform was 50 MPN/100 ml, 20 MPN/100 ml, and 56.7 MPN/100 ml (Table 1) with a removal efficiency of 99.2%, 73.9% and 77.7% in dry, wet, and semi-wet seasons respectively (Figure 4). There was a statistical significance difference among sample sites in wet and semi-wet seasons but not in the dry season, where the p-value was greater than 0.05. Both total and fecal coliform counts in all three seasons of the effluent are above the national permissible discharge limit, which is <10 for fecal coliforms and <50 for total coliforms (Table 1).

**Table1: Average total and fecal coliform analysis result of the waste stabilization pond within three seasons (n=3)**

| Season | Sample points | TC (MPN/100 ml) | FC (MPN/100ml) |
|---|---|---|---|
| Dry season | P1 | 10846.7±8926[ns] | 6490.0±8413[ns] |
| | P2 | 10793.3±9018[ns] | 1406.7±1807[ns] |
| | P3 | 2013.3±1539 [ns] | 216.7±170.4[ns] |
| | P4 | 686.7±887[ns] | 50.0±52.0 [ns] |
| Wet season | P1 | 8066.7±2194[a] | 76.7±30.6 [a] |
| | P2 | 3900.0±1345[b] | 46.7±25.2 [ab] |
| | P3 | 3250.0±391 [bc] | 40.0±00.0 [ab] |
| | P4 | 2450.0±606 [bc] | 33.3±11.5 [ab] |
| | P5 | 650.0±40 6 [c] | 20.0±00.0 [b] |
| Semi-wet season | P1 | 3266.7±404 [a] | 343.3±116.8 [a] |
| | P2 | 2600.0±346 [ab] | 336.7±46.2 [a] |
| | P3 | 2250.0±527 [ab] | 220.0±106.0 [ab] |
| | P4 | 1700.0±557 [bc] | 153.3±140.1 [ab] |
| | P5 | 757.0±319 [c] | 56.7±47.3 [b] |
| EEPA gridline | | <50 | <10 |

Note: P1=Inlet Pond, P2=Anaerobic Pond, P3=Facultative Pond, P4=Maturation Pond, P5=Outlet Pond, and EEPA =Ethiopian environmental protection agency, ns = no significant difference. The different superscripts in the same column indicate a significant difference at $p<0.05$

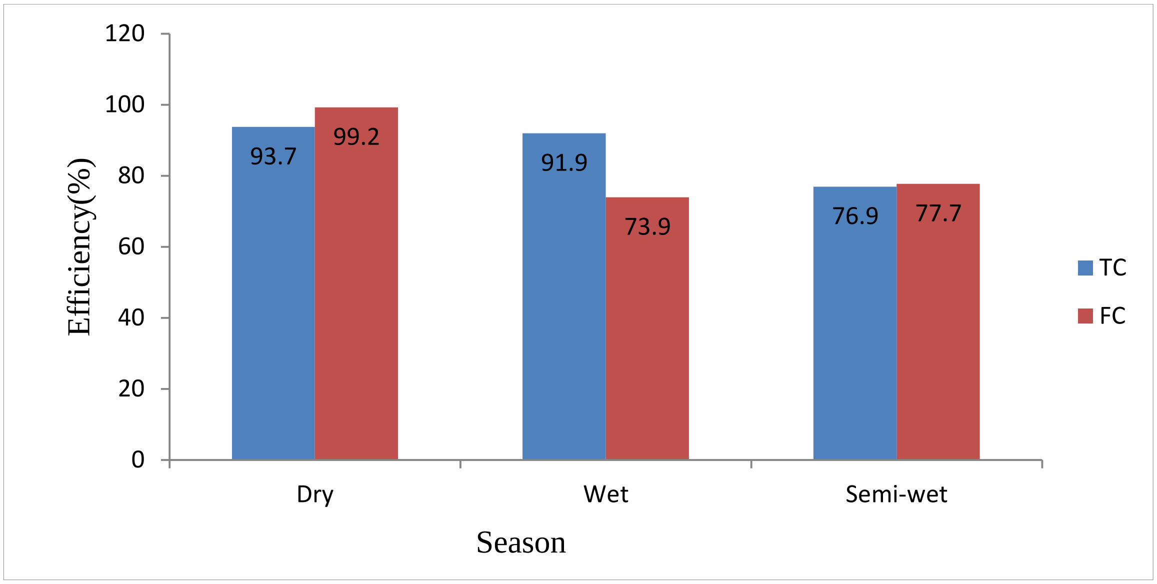



**Figure 5: Removal efficiency of wastewater treatment oxidation pond for total and fecal coliform within three seasons.**

## 4.2. The physicochemical characteristics of the samples

The mean values of pH and DO values increased from influent to effluent of the pond, while turbidity and EC decreased. This indicates the effectiveness of the WSP in removing suspended substances and salts. The overall physical parameters in the influent of the treatment plant were pH (7.7), DO (5.8 mg/L), temperature (22.7°C), turbidity (31 NTU), chlorophyll–a (4.7 µg/l), and EC (1077.7 $\mu$S/cm). The effluent of the treatment plant pH (10.2), DO (5.9 mg/L), temperature (23.2°C), turbidity (21.5 NTU), chlorophyll –a (80.3), and EC (618.2 $\mu$S/cm) in the dry season.

The mean value of influent temperature, DO, EC, and pH in the wet season was less than the value in the dry season but turbidity and chlorophyll-a were higher than in the dry season. The overall physical parameters in the influent of the treatment plant were pH (6.8), DO (2.2 mg/L), temperature (18.9°C), turbidity (78.6 NTU), chlorophyll-a (5.3) and EC (944.4 $\mu$S/cm) in the influent and pH (7.1), DO (6.7 mg/L), temperature (18.4°C), turbidity (18.9 NTU), chlorophyll (15) and EC (662.9 $\mu$S/cm) in the effluent of the waste stabilization pond.

The mean value of physical parameters in the influent of the treatment plant was pH (7.7), DO (2.3 mg/L), temperature (19°C), turbidity (47.3 NTU), chlorophyll (7.7) and EC (1212.7 $\mu$S/cm). Whereas, the effluent physical parameters of the treatment plant were pH

(9.1), DO (5.1 mg/L), temperature (18.5°C), turbidity (20.6 NTU), chlorophyll-a (163 µg/l), and EC (1097 $\mu$S/cm) in semi-wet season, as depicted in Table 2.

**Table 2: Mean value of physicochemical parameters of the wastewater treatment oxidation ponds within three seasons (n=3)**

| Season | Sampling point | Parameters | | | | | |
|---|---|---|---|---|---|---|---|
| | | Temperature ($^{O}$C) | Ph | DO (mg/l) | EC ($\mu$S/cm) | Chlorophyll (µg/l) | Turbidity (NTU) |
| | P1 | 22.7 | 7.7$^{b}$ | 5.8 | 1077.7 | 4.7 $^{c}$ | 31.0 |
| | P2 | 24.5 | 8.0$^{b}$ | 9.2 | 967.0 | 199.0 $^{a}$ | 29.5 |
| | P3 | 22.9 | 9.0$^{ab}$ | 8.7 | 690.3 | 199.0 $^{a}$ | 26.7 |
| Dry | P4 | 23.2 | 10.2$^{a}$ | 5.9 | 618.2 | 80.3 $^{b}$ | 21.5 |
| | P1 | 18.9 | 6.8a$^{b}$ | 2.2 $^{b}$ | 944.3 | 5.3 $^{c}$ | 78.6 $^{a}$ |
| | P2 | 19.4 | 6.7$^{b}$ | 3.9 $^{b}$ | 826.0 | 55.3$^{ab}$ | 53.7 $^{ab}$ |
| | P3 | 19.0 | 6.9$^{ab}$ | 3.9 $^{b}$ | 684.0 | 70.0 $^{a}$ | 41.9$^{bc}$ |
| | P4 | 18.8 | 6.9$^{ab}$ | 4.6 $^{ab}$ | 652.7 | 59.7 $^{a}$ | 35.9b $^{c}$ |
| Wet | P5 | 18.4 | 7.1$^{a}$ | 6.7 $^{a}$ | 662.9 | 15.0 $^{bc}$** | 18.9 $^{c}$ |
| | P1 | 19.0 | 7.7$^{b}$ | 2.3 | 1212.7 | 7.7 $^{b}$ | 47.3 |
| | P2 | 18.4 | 7.9$^{b}$ | 3.1 | 1093.3 | 30.3 $^{b}$ | 41.5 |
| | P3 | 18.7 | 8.1a$^{b}$ | 3.0 | 1220.7 | 48.3 $^{b}$ | 35.4 |
| | P4 | 18.9 | 8.4a$^{b}$ | 5.3 | 1188.7 | 86.3 $^{ab}$ | 29.9 |
| Semi wet | P5 | 18.5 | 8.9$^{a}$ | 5.1 | 1097.0* | 163.0 $^{a}$ | 20.6 |
| EPA(2003) | | <40 | 6-9 | >5 | <1000 | - | <300 |
| WHO | | 25-40 | 6.5-8.5 | - | <1500 | 30-3000 | - |

Note: EPA=Ethiopian environmental protection authority,*=mean of effluent above the standard and** =below the standard, Means that do not share a letter are significantly different *and means that do not contain a letter are not significant (p value>0.05).*

## 4.3 Nitrate and phosphate removal efficiency

The value of phosphate in the dry season dropped from the inlet (25.67mg/L) to the outlet (5.51mg/L) with a removal efficiency of 78.5% in the dry season, from 11.67mg/l to 5.1mg/l with a removal efficiency of 56.3% in the wet season and 32.67mg/l to15.5mg/l with a removal efficiency of 53% in the semi-wet season. The value of nitrate at the inlet was 1.57 mg/L and decrease to 0.85 mg/L in the outlet with a removal efficiency of 45.9% in the dry season, from 1.88mg/l to 0.56mg/l with a removal efficiency of 70.2% in the wet season and decrease from 2.5 mg/l to1.5 mg/l with a removal efficiency of 40% in the semi-wet season as depicted in Table 3 and figure 6. There was a statistical difference in nitrate among sample sites in the wet season and phosphate in the dry and semi-wet seasons.

**Table 3: Mean +standard deviation value of nitrate and phosphate of the waste stabilization ponds within three seasons (n=3)**

| Season | Sampling point | Parameters | | EEPA(2003) |
|---|---|---|---|---|
| | | Nitrate (mg/l ) | Phosphate (mg/l) | |
| Dry | p1 | 1.57±1.67 | 25.67±10.69[a] | Nitrate <45<br><br>Phosphate <0.02 |
| | p2 | 0.91±0.36 | 30.33±4.51[a] | |
| | p3 | 0.87±0.27 | 7.67±2.84[b] | |
| | p4 | 0.85±0.32 | 5.51±0.91[b] | |
| Wet | P1 | 1.88±1.01[a] | 11.67±4.86 | |
| | P2 | 0.43±0.14[b] | 8.33±4.07 | |
| | P3 | 0.54±0.03[b] | 9.00±5.29 | |
| | P4 | 0.34±0.08[b] | 6.88±3.27 | |
| | P5 | 0.56±0.20[b] | 5.10±3.91 | |
| Semi wet | P1 | 2.50±0.56 | 32.67±0.57[a] | |
| | P2 | 1.35±0.71 | 31.67±1.52[bc] | |
| | P3 | 1.64±0.45 | 30.33±10.2[ab] | |
| | P4 | 1.71±0.13 | 16.33±4.04[a] | |
| | P5 | 1.50±0.30 | 15.50±5.22[c] | |

EEPA=Ethiopian environmental protection agency, Means *that do not share a letter are significantly different, means that do not contain a letter are not significant (p value>0.05).*

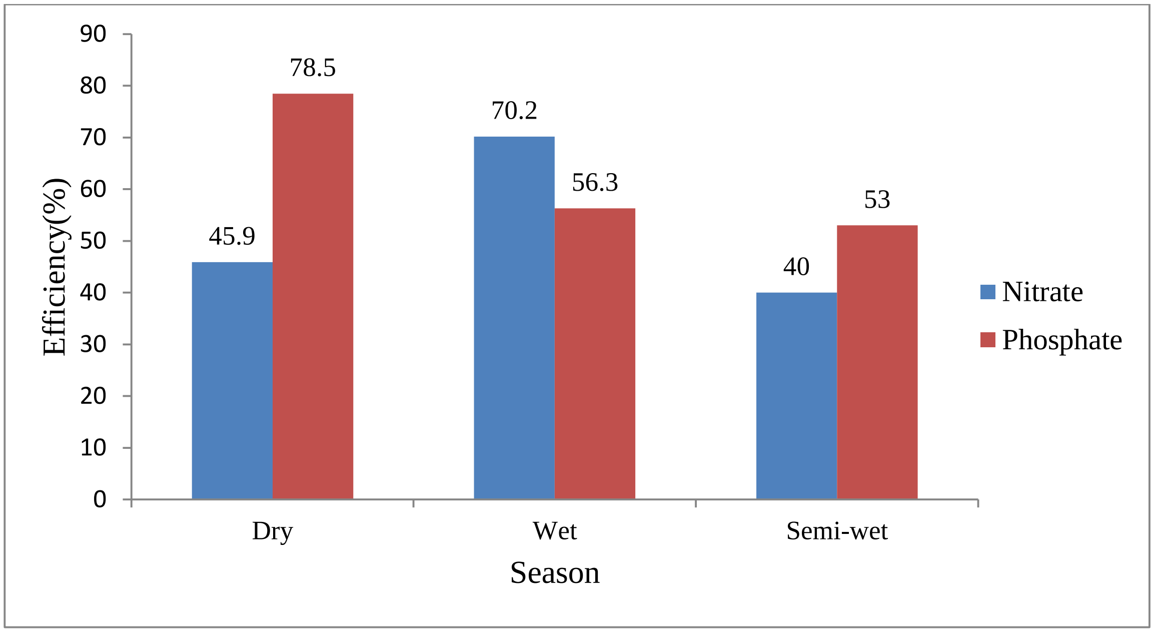
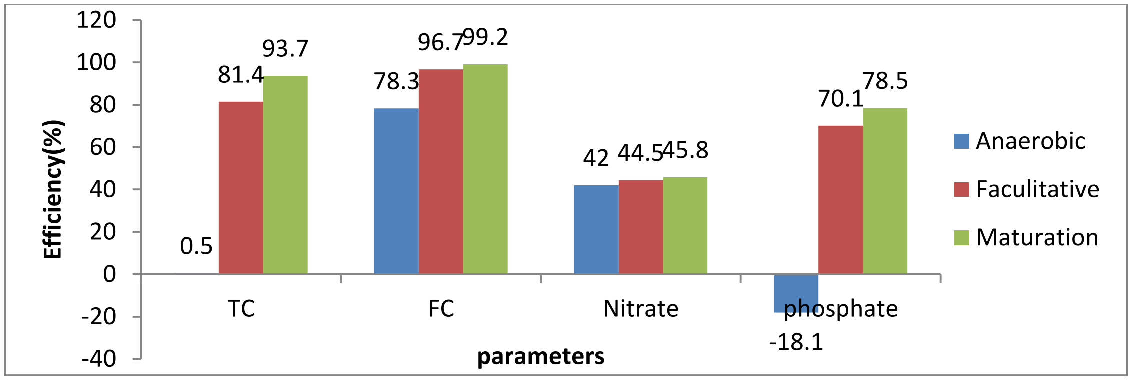


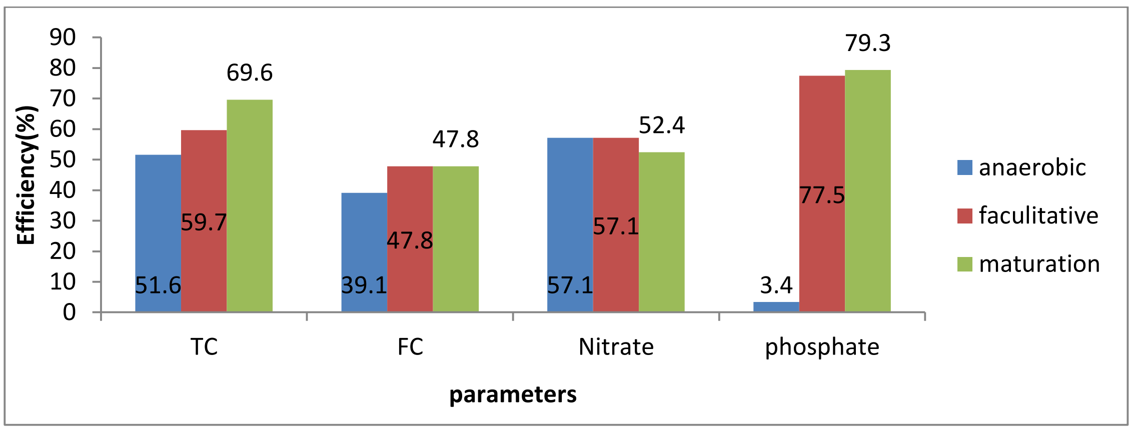

**Figure 6: Removal efficiency of treatment oxidation pond for chemical (nitrate and phosphate) parameters within three seasons.**

## 4.4 Removal efficiency of anaerobic, facultative, and maturation ponds

The removal efficiencies of anaerobic, facultative, and maturation ponds in the dry season were 0.5, 81.4, and 93.7%, respectively for TC and 78.3, 96.7, and 99.2% for FC. Nitrate and phosphate were found to be 42 and -18.1%, 44.5 and 70.1%, and 45.8 and 78.5% in anaerobic, facultative, and maturation ponds respectively. The removal efficiencies of anaerobic, facultative, and maturation ponds for TC, FC, nitrate, and phosphate were listed in Figure 7 (b and c). TC and FC are highly removed in maturation ponds especially in dry (93.7 and 99.2%), 69.6 and 47.8% in wet and, 47.9 and 55.4%, in semi-wet seasons. Nitrate and phosphate were highly removed in facultative and maturation ponds in dry and wet seasons. The removal efficiencies for nitrate in a semi-wet season were 46%, 34.4%, and 32% in anaerobic, facultative and maturation ponds. Although, an Anaerobic pond in the dry season has negative removal (-18.1 %) as depicted in Figure 6.




A

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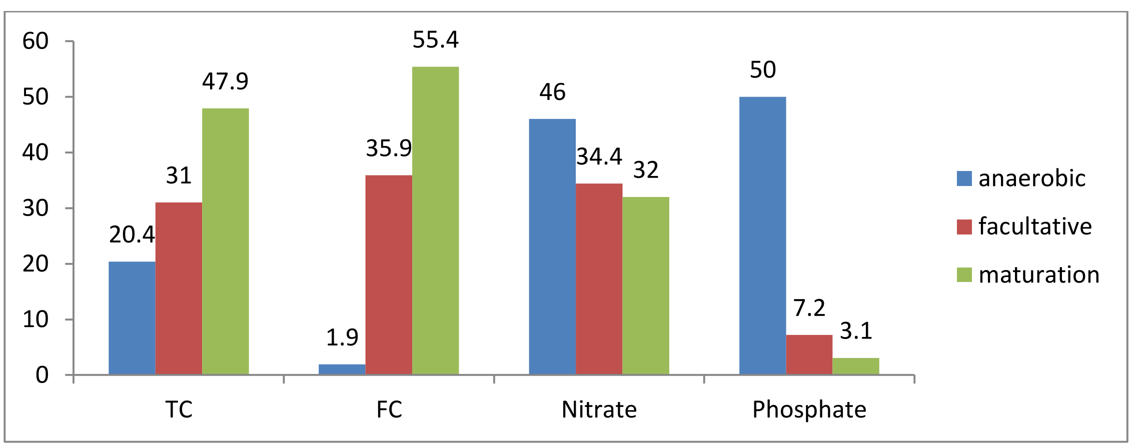


C.

**Figure 7: Removal efficiency of anaerobic, facultative, and maturation ponds in dry (A), wet (B), and semi-wet (C) seasons using some selected parameters**

## 4.5 Correlation analysis among bacteriological and physicochemical parameters

Analysis of the correlation between coliform bacteria and water quality factors in the influent and effluent can be seen in Tables 4 and 5 respectively. Total and fecal coliforms of the influent showed that positive correlation with temperature, pH, EC, chlorophyll-a, nitrate, and phosphate and a negative correlation with DO and turbidity. Total and fecal coliforms of the effluent showed significant positive correlations with temperature, pH, DO, EC, nitrate, and phosphate and a negative correlation with chlorophyll-a and turbidity. In wet and semi-wet seasons most of the physicochemical parameters were correlated negatively with coliforms.

The correlation coefficients between TC, FC, and temperature were 0.93 and 0.36, -0.93 and 0.80, and -0.81 and -0.71 in dry, wet, and semi-wet seasons respectively. The correlation coefficient between TC, FC, and DO were 0.78 and 0.99in dry, 1.0 and 0.5 in wet, and 0.38 and 0.96 in semi-wet seasons. Correlation coefficients between TC, FC, and pH were 0.61 and -0.2, -0.25 and 0.96 and -0.12, and 0.98 in dry, wet, and semi-wet seasons respectively. The corresponding coefficients between coliforms and other parameters like chlorophyll-a, turbidity, nitrate, and phosphate in influent and effluent are listed in Tables 5 and 6.

**Table 4: Correlation among bacteriological and physicochemical parameters in the influent of oxidation pond in dry, wet, and semi-wet seasons (n=3).**

| Parameters | Seasons | | | | | |
|---|---|---|---|---|---|---|
| | Dry | | Wet | | Semi-wet | |
| | TC(MPN/100ml) | FC(MPN/100ml) | TC(MPN/100ml) | FC(MPN/100ml) | TC(MPN/100ml) | FC(MPN/100ml) |
| FC | 0.67 | 1.00 | 0.93 | 1.00 | 0.17 | 1.00 |
| Temperature | 0.93 | 0.36 | 0.93 | 0.80 | -0.81 | -0.71 |
| pH | 0.61 | -0.20 | -0.25 | -0.96 | -0.12 | 0.98 |
| DO | -0.78 | 0.99 | 1.00 | 0.50 | 0.38 | 0.96 |
| Chlorophyll-a | 0.95 | 0.87 | -0.56 | 0.37 | 0.06 | 0.77 |
| EC | 0.99 | 0.54 | -0.55 | 0.76 | -0.50 | -0.97 |
| Turbidity | -0.97 | -0.47 | -0.99 | 0.97 | -0.11 | -0.99 |
| Nitrate | 0.53 | 0.99 | 0.64 | -0.42 | -0.33 | -0.98 |
| Phosphate | 0.54 | -0.27 | -0.13 | -0.12 | -0.50 | 0.77 |

**Table 5: Correlation among bacteriological and physicochemical parameters in the effluent of waste stabilization pond in dry, wet, and semi-wet seasons (n=3).**

| Parameters | Seasons | | | | | |
|---|---|---|---|---|---|---|
| | Dry | | Wet | | Semi-wet | |
| | TC(MPN/100ml) | FC(MPN/100ml) | TC(MPN/100ml) | FC(MPN/100ml) | TC(MPN/100ml) | FC(MPN/100ml) |
| FC | 0.99 | 1.00 | 0.99 | 1.00 | -0.36 | 1.00 |
| Temperature | 0.84 | 0.75 | -0.97 | -0.99 | -0.85 | -0.20 |
| Ph | 0.76 | 0.66 | -0.15 | 0.00 | -0.25 | 0.99 |
| DO | 0.73 | 0.82 | -0.30 | -0.14 | -0.85 | -0.19 |
| Chlorophyll-a | -0.60 | -0.48 | -0.78 | -0.87 | -0.65 | 0.95 |
| EC | 0.64 | 0.52 | -0.92 | -0.98 | 0.96 | -0.09 |
| Turbidity | -0.80 | -0.88 | -0.09 | -0.24 | 0.77 | -0.87 |
| Nitrate | 0.96 | 0.90 | -0.78 | -0.87 | 0.98 | -0.52 |
| Phosphate | 0.81 | 0.72 | -0.24 | -0.39 | -0.95 | 0.63 |

# 5. DISCUSSION

Wastewater treatment plant plays an important role in the remediation of polluted water. The result of the present study demonstrates the current condition of the oxidation ponds of Bahir Dar University Peda campus. Measurements of physicochemical and bacteriological parameters provide information about the efficiency of the WSP.

## 5.1. Removal efficiency of total and fecal coliforms

The influences of pond types on the numbers of bacterial indicators and their final removal efficiency in the wastewater samples are shown in Table1 and figure4. The treatment plant reduced the number of total coliforms by 93.7% and fecal coliforms by 99.2% in dry, 91.9 % of total coliform and 73.9% fecal coliform in wet, and 76.9% total coliform and 77.7% fecal coliform in the semi-wet seasons, the effluent in all seasons contains a large number of total and fecal coliform, above the permissible limit of the Ethiopian environmental protection agency (EPA, 2003) for the restricted and unrestricted irrigation systems is to be <50 MPN/100 mL for total and <10MPN/mL for fecal coliforms. The removal efficiency of the findings in the dry season was somewhat consistent with fecal coliforms (99.36%) in Hawassa, Ethiopia (Desye *et al.*, 2022b). The reason for higher FC removal efficiency in the dry season of the WSP systems may be due to high temperature and algal growth (chlorophyll-a). Amongst the ponds, the average chlorophyll *a* concentration ranged from 4 µg/l to 199 µg/l and the highest value of chlorophyll *a* was in dry season in the P2 pond (Table 2). Therefore the highest removal efficiency was generated by microbial photosynthesis (chlorophyll *a*: 199 µg/L) and their abundant growth in the anaerobic pond dry season colored the water dark green. Minimum removal rates of fecal coliforms were found during semi-wet seasons. A similar result was reported by (Goyal and Mohan, 2013). Reduction of microbial parameters was found throughout the system but maximum reduction was found in maturation ponds.

The mean levels of effluent fecal coliform in all dry, wet, and semi-wet seasons exceeded the recommended specifications, thereby posing serious risks to receiving environment. High levels of fecal coliform are indicators of the presence of pathogens in treated wastewater so it must be considered from the perspective of public health. Several dangerous bacteria like cholera, typhoid fever, gastroenteritis, and dysentery can lead to illnesses may lead to incidences of typhoid fever, hepatitis, gastroenteritis, dysentery, and ear infections in animals and humans (Butler *et al*., 2017). Settled sludge and the availability of nutrients might have contributed to the increase of microorganisms in the ponds. High phosphorus concentration in the WSP might have contributed to the multiplication of bacteriological indicators. Birds were also observed around the ponds which might have increased the bacteria counts through their droppings as previously reported by (Wu *et al*., 2016).

## 5.2 Physicochemical characteristics of the stabilization pond

The pH value is extremely important since most of the chemical reactions in the aquatic environment are controlled by any change in its value (Himmel *et al*., 2018). In the current study, the pH value was increased from the inlet pond to the outlet pond. The effluent pH value in the dry season (10.2) was much higher than those of the wet and semi-wet seasons. This might be due to high temperatures and increased algal activity in facultative and maturation ponds as $CO_2$ is consumed during photosynthesis by algae. The increase in pH has been attributed to biological activities since carbonate-bicarbonate equilibrium is affected by phytoplankton using carbon dioxide (Ragush *et al.*, 2015). Since algae were observed in the facultative and maturation ponds, these might have elevated the pH through photosynthesis, which consumed more carbon dioxide than the bacteria could restore through respiration. Similar findings were reported in Hawasa, Ethiopia (Sintayehu Kebede, 2017) and Jima, Ethiopia (Desye *et al*., 2022). The pH value in the effluent of the treatment plant was within the permissible range of EEPA (6 - 9) (EPA, 2003) in wet and semi-wet seasons but there was above the permissible range in the dry season (10.2). This may be the high temperature during this period because temperature and pH have a positive correlation

In wastewater treatment, the temperature of the water treatment plant plays a role in the completion of physical, chemical, and biological processes. The range of temperatures in the treatment plant was appropriate for the treatment plant's efficient operation, All ponds work well between 15 to 35 °C, and the range of temperature in the treatment plant was suitable for the proper functioning of the treatment plant (Goyal and Mohan, 2013). In this study, the mean value of temperature in the dry season was higher than that of wet and semi-wet seasons at each sampling point. The mean temperature was slightly dropped from the inlet to the outlet in the wet and semi-wet seasons. The influent (P1) temperature averaged 22.7˚C, 18.9˚C, and 19˚C in dry, wet, and semi-wet seasons respectively. Among the ponds, the temperature was higher in an anaerobic pond (P2) it could be due to its highest bacterial loading speed up reaction and produce heat.

The sample points P1(inlet) and P5 (outlet) had not been directly exposed to sunlight but the other sampling points were directly exposed to sunlight, due to this reason the temperature at the inlet and outlet was decreased as compared to the other sample points (P2, P3, and P4) in the three seasons. The final effluent temperature of 23.2°C, 18.4°C, and 18.5 in dry, wet, and semi-wet seasons respectively was within the limit of the Ethiopian Environmental protection agency Standard <40$^{c}$C (EPA, 2003). The finding was similar to Iram *et al*., 2013. It is also in line with the report of (Gizachew Teshome *et al*., 2019). Chemical and biological activities are strongly influenced by temperature and below 10˚C biological activities are reduced (Ragush *et al*., 2015). The results suggest that the biological activities were not negatively affected since the average temperatures in all the ponds were higher than 10˚C.

Dissolved oxygen plays an important role as a regulator of the metabolic activities of organisms and thus governs the metabolism of the biological community as a whole and is used as an indicator of the trophic status of the water (Khan *et al*., 2012). The lowest values were recorded at P1 (2.2, and 2.3 mg /L) in wet and semi-wet seasons whereas the highest values were recorded at P2 (9.2 mg/ L) in dry, P5 (6.7 mg/ L) in wet seasons, respectively. The high value of DO may be due to the presence of high algal growth (199 µg/L of chlorophyll-a) taking place photosynthesis and releasing oxygen.

The mean dissolved oxygen concentration present in the effluent of WSP was greater than the influent in all three seasons, which means the consumption of oxygen by organic matter was became decreased from inlet to outlet. The mean obtained result in the outlet (effluent) was 5.9 mg/L, 6.7 mg/L, and 5.1 mg/L in dry, wet, and semi-wet seasons respectively. Maximum effluent DO was found during the dry season whereas the minimum was in the semi-wet season. The DO concentration of effluent wastewater was in line with the recommended value for aquatic species to respire and perform metabolic activities (≥5 mg/L). USEPA (1998) defined the healthy water value of DO within the range of 5−14.6 mg/L and less than 5 or greater than 14.6 indicate the impairment of the water body. The result obtained from the current study indicated that the treatment system is enough to remove the rate of organic matter that decomposes in the waste stabilization pond. The finding was higher than (4.86 mg/L) reported in Hawasa, Ethiopia (Sintayehu Kebede, 2017) and (2.12 mg/L) reported in Jimma, Ethiopia (Desye *et al*., 2022).

The electrical conductivity of water is a useful indicator of its salinity or total salt content. The results of EC in Table 2 show a general removal of salts contributing to conductivity from the influent (1077.7 µS/ cm*)* to the effluent sample (618.2 µS /cm*)*, influent (944.3 µS/ cm) to effluent (662.9 µS/ cm) and influent (1212.7 µS/ cm) to effluent (1097 µS/ cm) in dry wet and semi-wet seasons, respectively. The mean conductivity value decreased from the influent to values recorded from the effluent of the oxidation pond. The EC value in the semi-wet season was higher than EC in dry and wet seasons. This might be due to the high rain during sampling day and there was flow water from the surrounding to the pond by flood and mixed the settled contents inside the pond. A decrease in EC from influent to effluent is an indication of the effectiveness of the oxidation pond in removing dissolved salts from the pond. The effluent concentration was within the recommended limit of EEPA 1000 µS/cm. Therefore, the effluent water has no adverse effect on the environment and is suitable for irrigation and it would pose a low salinity hazard in the soil.

Turbidity refers to the cloudiness of water caused by a variety of particles. The raw wastewater (influent) held a mean value of 31, 78.6, and 47.3 NTU in dry, wet, and semi-wet seasons respectively while the final effluent was decreased to 21.5, 18.9, and 20.6 NTU. The least turbidity recorded in the outlet pond may be due to the efficiency of microorganisms in the decomposition process. There was also a decreasing pattern among all sampling points (P1 to P2, P2 to P3, P3 to P4, and P4 to P5) in all three seasons. A slight increase was seen in the wet season and later decrease again in the semi-wet season. A sudden increase of turbidity in the wet season might be due to runoff water and flood wash soil and other materials into the treatment ponds. The effluent concentration was within the recommended limit of EEPA <300 µg/L. The efficiency of turbidity obtained from the current study is (32.3%, 75.9%, and 56.4%) in dry, wet, and semi-wet seasons respectively. Turbidity obtained from the current study in wet and semi-wet seasons was higher than the study obtained by (Dejene and Prasada 2012) in Sebeta with an efficiency of 31.47 % and (Sintayehu Kebede, 2017) in Hawasa with an efficiency of 31.74 %, but the result obtained in the dry season (32.3%) was comparable.

A high concentration of chlorophyll-a in the effluent indicates that the system releases water with a very high concentration of phytoplankton. High phytoplankton concentration impacts the river system to which this water is discharged in terms of oxygen demand, nutrient enrichment, and light. It also renders the water not suitable for many domestic uses since the green color; odor and turbidity that come with a high concentration of algae become a nuisance. The least chlorophyll-a value recorded in the inlet pond in the three seasons may be due to the high concentration of microorganisms and nutrients that decreased the growth of algae and consequently the photosynthetic activity. There was high chlorophyll-a value in an anaerobic pond in the dry season but the chlorophyll content decreased in the wet season. These may be due to high temperature in dry season and increase of pond water in wet season. The effluent concentration of chlorophyll was within the recommended limit of WHO 30-30000 µg/L.

Nutrients could be from the sewage system or from birds that were always found in the maturation ponds eating algae and insects. In this study, the level of phosphate and nitrate decreased from inlet to outlet except nitrate in the semi-wet season due to the removal of inorganic and organic matter.

The mean levels of nitrates ranged from 0.34 to 2.57 mg/L and phosphate ranged from 5.1mg/L to 32.67 mg/L (Table 3). Excess amount of nitrate in the water not only causes the depletion of oxygen and the formation of eutrophication in the water body but also causes adverse effects if it is used for drinking purposes. Nitrate is a product of organic nitrogen by the bacteria present in soil and water where sufficient oxygen is present. High concentration of nitrates is useful in irrigation but their entry into water resources increase the growth of nuisance algae, and macrophytes and trigger eutrophication and pollution (Mezgebe *et al*., 2015). From the three seasons, the efficiency of Nitrate obtained in the wet season was good in all pond types followed by the dry season but, the removal efficiency of nitrate in a semi-wet season was negative in all three pond types. There was also a negative and less 3.4 removal efficiency of phosphate in an anaerobic pond in the dry and wet seasons so, additional treatment of the ponds is needed. In the current study

(70.2%) removal efficiency nitrate is comparable with the finding of Jima, Ethiopia 70.7% (Desye *et al*., 2022), greater than the report of Sebeta, Ethiopia WSP (68.58 %) by Dejene and Prasada (2012), and lower than the finding of Hawasa main campus 73.77% by Sintayehu Kebede (2017). The concentration of nitrate in the effluent of the pond was found within the permissible limit of EEPA <50mg/L (EPA, 2003).

The high value of phosphate in an anaerobic pond (P2) is expected, as there was a prolific algal growth on the oxidation pond during sampling in the dry season. During wet and semi-wet seasons Level of phosphate in the influent (P1) was 11.67mg/ L and 32.67mg/L. unlike to dry season, the value of phosphate decreases slightly from inlet to P2 (8.33 and 30.33 mg/L) in wet and semi-wet seasons because of less algal growth on the oxidation pond during the sampling period. During the sampling period, the value of phosphate in wet seasons was relatively small as compared to dry and semi-wet seasons. This might be the rainy season of the sampling period diluting its concentration. The present study's 78.5% in the dry season is higher than the finding of Sintayehu Kebede (2017) Hawasa University main campus (73.7%) and Hunachew and Redaie (2011) Hawasa Referral Hospital WSP (59.64%) but the efficiency of the pond in a semi-wet season was lower than the above reports. This discrepancy might be due to the surrounding environmental conditions, and the decrease of graduated students. However, the concentration of phosphate in the effluent of the pond was found above the permissible limit of EEPA <0.02mg/L (EPA, 2003). This may be due to the release of detergents and soaps from the students and residents to wash their clothes and for bathing as well as discharges of storm water. Therefore, these high values of phosphate in the effluent of the pond may cause significant pollution in receiving water bodies and the environment. This value might be due to the design nature of the pond, the surrounding environmental conditions, and the nature of the raw wastewater (Bellinger and Sigee 2015; Butler *et al.* 2017).

## 5.3 Effect of physicochemical factors on Coliform Bacteria

The physicochemical properties of water influence the survival, decomposition, and growth rates of coliform bacteria (Niu *et al*., 2019). In the case of Bahir dar university peda campus waste stabilization pond total coliforms of the influent in the dry season showed a significant positive correlation with temperature, pH, chlorophyll-a, electric conductivity, nitrate, and phosphate and a significant negative correlation with DO and turbidity. Whereas fecal coliform had a positive correlation with DO, chlorophyll-a, electric conductivity, and nitrate and a negative correlation with turbidity but did not correlate with temperature, pH, and phosphate. A similar result was reported by(Guemmaz and Neffar, 2019).

In the wet season influent total coliforms showed a significant positive correlation with fecal coliform, DO, and nitrate and a negative correlation with temperature, chlorophyll-a, electric conductivity, turbidity, and nitrate but pH and phosphate had weak or no correlation with total coliform. Although Fecal coliform in the wet season showed a positive correlation with temperature, DO, chlorophyll-a, electric conductivity, and turbidity and a negative correlation with pH and nitrate, but did not correlate with phosphate. The same result was reported by Pearson *et al.* (1987) who observed significant negative correlations between FC counts and pH. In the semi-wet season of the influent total coliform showed a negative correlation with temperature, electric conductivity, phosphate, and nitrate and a positive correlation with only DO but had weak or no correlation with fecal coliform, chlorophyll-a, pH, and turbidity. The influent fecal coliform showed a significant positive correlation with pH, DO, chlorophyll-a, and phosphate. And negative correlation with temperature, electric conductivity, turbidity, and nitrate.

Total and fecal coliforms in the effluent showed a significant positive correlation with temperature, pH, DO, electric conductivity, nitrate, and phosphate and a significant negative correlation with chlorophyll-a and turbidity in the dry season. While in the wet season, total and fecal coliforms showed a significant negative correlation with temperature, chlorophyll-a, electric conductivity, and nitrate but pH, DO, turbidity and phosphate had weak or no correlation with total and fecal coliform. This may be due to an increment of pond water and a temperature decrease. In the semi-wet season of the effluent total coliform showed a positive correlation with electric conductivity, turbidity, and nitrate and a negative correlation with temperature, DO, chlorophyll-a, and phosphate, but had weak or no correlation with fecal coliform and pH. The effluent fecal coliform showed a significant positive correlation with pH, chlorophyll-a, and phosphate and a negative correlation with turbidity and nitrate but had no correlation with temperature and DO.

# 6. CONCLUSION AND RECOMMENDATIONS

## 6.1. Conclusion

This study determined the water quality of stabilization pond receiving wastewater in BDU Peda Campus. The results of coliform analyses revealed that the values exceed the standards established by EPA and WHO in all three seasons which indicates large fecal pollution. In effect, the high level of bacterial loads indicates fecal pollution in the study area. The findings showed that wastewater effluents pose serious environmental contamination issues and health risks that can affect communities, agricultural lands, crop products, and aquatic life forms that rely on water from stabilization ponds. The presence of fecal coliform in levels above the EPA permissible levels does not give a good picture of the performance, despite registering a substantial reduction in levels of fecal coliform.

The WSP discharges effluent wastewater with a high effluent concentration of phosphate in all three seasons which exceeded the national limit.

Generally, the treatment plant is still capable of treating wastewater, but it needs frequent monitoring and maintenance of the pond system to meet the discharge standard limit requirements of treated effluent and to make it suitable for drinking, irrigation, recreational purpose, and aquaculture.

## 6.2. Recommendation

The removal efficiency of the treatment plant was higher in the dry season than wet and semi-wet seasons therefore; it needs special monitoring and maintenance in wet and semi-wet seasons. To adequately treat wastewater and make it suitable for disposal in the environment, it requires adequate preliminary treatment like septic tank to reduce the incoming organic loading, modification of the design, desludging of the pond, additional treatment, Further research should be conducted in the BDU Peda Campus waste stabilization pond to investigate other performance indicator parameters of waste stabilization pond like BOD5, COD and TSS

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# APPENDIX

Appendix 1: photo graph showing sampling area (waste stabilization pond



**Appendix 2: photo graph showing sampling,**

**laboratory work and Coliform result photo**

  

Test tube that contains both color change and gas formation was coliform positive for both total and fecal coliforms

## Appendix 3: MPN table for coliform enumeration

**Table 10.5** MPN index and 95 per cent confidence limits for various combinations of positive results when five tubes are used per dilution (10 ml, 1.0 ml, 0.1 ml portions of sample)

| Combination of positives | MPN index per 100 ml | 95 % confidence limits | | Combination of positives | MPN index per 100 ml | 95 % confidence limits | |
|---|---|---|---|---|---|---|---|
| | | Upper | Lower | | | Upper | Lower |
| 0-0-0 | <2 | - | - | 4-2-0 | 22 | 9.0 | 56 |
| 0-0-1 | 2 | 1.0 | 10 | 4-2-1 | 26 | 12 | 65 |
| 0-1-0 | 2 | 1.0 | 10 | 4-3-0 | 27 | 12 | 67 |
| 0-2-0 | 4 | 1.0 | 13 | 4-3-1<br>4-4-0 | 33<br>34 | 15<br>16 | 77<br>80 |
| 1-0-0 | 2 | 1.0 | 11 | 5-0-0 | 23 | 9.0 | 86 |
| 1-0-1 | 4 | 1.0 | 15 | 5-0-1 | 30 | 10 | 110 |
| 1-1-0 | 4 | 1.0 | 15 | 5-0-2 | 40 | 20 | 140 |
| 1-1-1 | 6 | 2.0 | 18 | 5-1-0 | 30 | 10 | 120 |
| 1-2-0 | 6 | 2.0 | 18 | 5-1-1<br>5-1-2 | 50<br>60 | 20<br>30 | 150<br>180 |
| 2-0-0 | 4 | 1.0 | 17 | 5-2-0 | 50 | 20 | 170 |
| 2-0-1 | 7 | 2.0 | 20 | 5-2-1 | 70 | 30 | 210 |
| 2-1-0 | 7 | 2.0 | 21 | 5-2-2 | 90 | 40 | 250 |
| 2-1-1 | 9 | 3.0 | 24 | 5-3-0 | 80 | 30 | 250 |
| 2-2-0 | 9 | 3.0 | 25 | 5-3-1 | 110 | 40 | 300 |
| 2-3-0 | 12 | 5.0 | 29 | 5-3-2 | 140 | 60 | 360 |
| 3-0-0 | 8 | 3.0 | 24 | 5-3-3 | 170 | 80 | 410 |
| 3-0-1 | 11 | 4.0 | 29 | 5-4-0 | 130 | 50 | 390 |
| 3-1-0 | 11 | 4.0 | 29 | 5-4-1 | 170 | 70 | 480 |
| 3-1-1 | 14 | 6.0 | 35 | 5-4-2 | 220 | 100 | 580 |
| 3-2-0 | 14 | 6.0 | 35 | 5-4-3 | 280 | 120 | 690 |
| 3-2-1 | 17 | 7.0 | 40 | 5-4-4 | 350 | 160 | 820 |
| 4-0-0 | 13 | 5.0 | 38 | 5-5-0 | 240 | 100 | 940 |
| 4-0-1 | 17 | 7.0 | 45 | 5-5-1 | 300 | 100 | 1,300 |
| 4-1-0 | 17 | 7.0 | 46 | 5-5-2 | 500 | 200 | 2,000 |
| 4-1-1 | 21 | 9.0 | 55 | 5-5-3 | 900 | 300 | 2,900 |
| 4-1-2 | 26 | 12.0 | 63 | 5-5-4<br>5-5-5 | 1,600<br>>1,600 | 600<br>- | 5,300<br>- |

Source: After APHA, 1992

**Note: MPN for dilution 1, 0.1 and 0.01 the MPN value must be multiplied by 10**

**Appendix 4: Correlation and ANOVA analysis result out put**

Dry season inlet correlation

| | TC | FC | temp | pH | DO | EC | chlo | nitrate | Phosphate |
|---|---|---|---|---|---|---|---|---|---|
| FC | 0.666 | | | | | | | | |
| | 0.536 | | | | | | | | |
| Temperature | 0.935 | 0.359 | | | | | | | |
| | 0.230 | 0.766 | | | | | | | |
| PH | 0.596 | -0.202 | 0.842 | | | | | | |
| | 0.593 | 0.871 | 0.363 | | | | | | |
| Do | -0.775 | -0.988 | -0.501 | 0.045 | | | | | |
| | 0.435 | 0.101 | 0.666 | 0.971 | | | | | |
| EC | 0.988 | 0.543 | 0.979 | 0.712 | -0.669 | | | | |
| | 0.098 | 0.634 | 0.132 | 0.495 | 0.534 | | | | |
| chlorophyll | 0.945 | 0.874 | 0.768 | 0.300 | -0.939 | 0.883 | | | |
| | 0.212 | 0.324 | 0.443 | 0.806 | 0.223 | 0.311 | | | |
| Nitrate | 0.528 | 0.985 | 0.194 | -0.367 | -0.946 | 0.391 | 0.777 | | |
| | 0.646 | 0.110 | 0.876 | 0.761 | 0.210 | 0.744 | 0.433 | | |
| phosphate | 0.540 | -0.268 | 0.803 | 0.998 | 0.113 | 0.663 | 0.235 | -0.429 | |
| | 0.637 | 0.827 | 0.407 | 0.043 | 0.928 | 0.539 | 0.849 | 0.717 | |
| Turbidity | -0.970 | -0.465 | -0.993 | -0.773 | 0.598 | -0.996 | -0.837 | -0.306 | -0.728 |
| | 0.156 | 0.692 | 0.074 | 0.437 | 0.592 | 0.058 | 0.369 | 0.802 | 0.481 |

Dry season outlet correlation

| | TC | FC | TEMP | DO | PH | EC | CHLOR | TURB | NITR |
|---|---|---|---|---|---|---|---|---|---|
| FC | 0.989 | | | | | | | | |
| | 0.094 | | | | | | | | |
| TEMP | 0.840 | 0.751 | | | | | | | |
| | 0.365 | 0.459 | | | | | | | |
| DO | 0.725 | 0.818 | 0.236 | | | | | | |
| | 0.483 | 0.390 | 0.848 | | | | | | |
| PH | 0.758 | 0.655 | 0.991 | 0.101 | | | | | |
| | 0.452 | 0.546 | 0.087 | 0.935 | | | | | |
| EC | 0.687 | 0.573 | 0.971 | -0.002 | 0.995 | | | | |
| | 0.518 | 0.612 | 0.153 | 0.999 | 0.066 | | | | |
| CHLOR | -0.599 | -0.475 | -0.938 | 0.117 | -0.976 | -0.993 | | | |
| | 0.591 | 0.685 | 0.226 | 0.926 | 0.139 | 0.073 | | | |
| TURB | -0.799 | -0.878 | -0.345 | -0.994 | -0.214 | -0.111 | -0.003 | | |
| | 0.411 | 0.317 | 0.776 | 0.072 | 0.863 | 0.929 | 0.998 | | |
| NITR | 0.957 | 0.904 | 0.961 | 0.495 | 0.915 | 0.868 | -0.805 | -0.590 | |
| | 0.187 | 0.281 | 0.178 | 0.671 | 0.265 | 0.331 | 0.404 | 0.598 | |
| PHOSP | 0.809 | 0.715 | 0.999 | 0.183 | 0.997 | 0.983 | -0.955 | -0.293 | 0.945 |
| | 0.400 | 0.493 | 0.035 | 0.883 | 0.052 | 0.118 | 0.191 | 0.811 | 0.212 |

Wet inlet

| | TC | FC | temp | ph | do | EC | Chlo | nitrate | Phosp |
|---|---|---|---|---|---|---|---|---|---|
| FC | 0.989 | | | | | | | | |
| | 0.093 | | | | | | | | |
| temp | -0.993 | -1.000 | | | | | | | |
| | 0.075 | 0.018 | | | | | | | |
| ph | -0.003 | 0.143 | -0.115 | | | | | | |
| | 0.998 | 0.909 | 0.927 | | | | | | |
| do | 0.973 | 0.929 | -0.940 | -0.232 | | | | | |
| | 0.147 | 0.241 | 0.222 | 0.851 | | | | | |
| ec | -0.740 | -0.830 | 0.814 | -0.671 | -0.565 | | | | |
| | 0.470 | 0.377 | 0.395 | 0.532 | 0.617 | | | | |
| chlo | -0.330 | -0.189 | 0.217 | 0.945 | -0.538 | -0.391 | | | |
| | 0.786 | 0.879 | 0.861 | 0.212 | 0.638 | 0.744 | | | |
| nitrate | 0.818 | 0.894 | -0.880 | 0.572 | 0.665 | -0.992 | 0.272 | | |
| | 0.390 | 0.296 | 0.315 | 0.612 | 0.537 | 0.080 | 0.825 | | |
| phosp | -0.386 | -0.517 | 0.492 | -0.921 | -0.164 | 0.907 | -0.743 | -0.846 | |
| | 0.748 | 0.654 | 0.672 | 0.254 | 0.895 | 0.277 | 0.467 | 0.358 | |
| turb | -0.848 | -0.916 | 0.905 | -0.527 | -0.704 | 0.984 | -0.220 | -0.999 | 0.816 |
| | 0.355 | 0.262 | 0.280 | 0.647 | 0.503 | 0.115 | 0.859 | 0.034 | 0.392 |

One way ANOVA TC output in dry season

| Source | DF | Adj SS | Adj MS | F-Value | P-Value |
|---|---|---|---|---|---|
| code | 3 | 271687033 | 90562344 | 2.21 | 0.165 |
| Error | 8 | 328305467 | 41038183 | | |
| Total | 11 | 599992500 | | | |

| code | N | Mean | StDev | 95% CI |
|---|---|---|---|---|
| p1 | 3 | 10847 | 8926 | (2318, 19376) |
| p2 | 3 | 10793 | 9018 | (2264, 19322) |
| p3 | 3 | 2013 | 1539 | (-6516, 10542) |
| p4 | 3 | 687 | 887 | (-7842, 9216) |

| code | N | Mean | Grouping |
|---|---|---|---|
| p1 | 3 | 10847 | A |
| p2 | 3 | 10793 | A |
| p3 | 3 | 2013 | A |
| p4 | 3 | 687 | A |

*Means that do not share a letter are significantly different*

One way ANOVA TC output in wet season

| Source | DF | Adj SS | Adj MS | F-Value | P-Value |
|---|---|---|---|---|---|
| code | 4 | 87025667 | 21756417 | 14.88 | 0.000 |
| Error | 10 | 14616867 | 1461687 | | |
| Total | 14 | 101642533 | | | |

| code | N | Mean | StDev | 95% CI |
|---|---|---|---|---|
| p1 | 3 | 7933 | 2194 | (6378, 9489) |
| p2 | 3 | 3900 | 1345 | (2345, 5455) |
| p3 | 3 | 3250 | 391 | (1695, 4805) |
| p4 | 3 | 2450 | 606 | (895, 4005) |
| p5 | 3 | 650 | 406 | (-905, 2205) |

| code | N | Mean | Grouping | | |
|---|---|---|---|---|---|
| p1 | 3 | 7933 | A | | |
| p2 | 3 | 3900 | | B | |
| p3 | 3 | 3250 | | B | C |
| p4 | 3 | 2450 | | B | C |
| p5 | 3 | 650 | | | C |

*Means that do not share a letter are significantly different*

One way ANOVA FC output in wet season

| code | N | Mean | StDev | 95% CI | P value |
|---|---|---|---|---|---|
| p1 | 3 | 76.7 | 30.6 | (52.9, 100.4) | 0.036 |
| p2 | 3 | 46.7 | 25.2 | (22.9, 70.4) | |
| p3 | 3 | 40.00 | 0.00 | (16.28, 63.72) | |
| p4 | 3 | 33.33 | 11.55 | (9.61, 57.05) | |
| p5 | 3 | 20.00 | 0.00 | (-3.72, 43.72) | |

| code | N | Mean | Grouping | |
|---|---|---|---|---|
| p1 | 3 | 76.7 | A | |
| p2 | 3 | 46.7 | A | B |
| p3 | 3 | 40.00 | A | B |
| p4 | 3 | 33.33 | A | B |
| p5 | 3 | 20.00 | | B |

One way ANOVA phosphate out put

| Source | DF | Adj SS | Adj MS | F-Value | P-Value |
|---|---|---|---|---|---|
| code | 3 | 1414.6 | 471.52 | 13.14 | 0.002 |
| Error | 8 | 287.2 | 35.89 | | |
| Total | 11 | 1701.7 | | | |

| code | N | Mean | StDev | 95% CI |
|---|---|---|---|---|
| p1 | 3 | 25.67 | 10.69 | (17.69, 33.64) |
| p2 | 3 | 30.33 | 4.51 | (22.36, 38.31) |
| p3 | 3 | 7.67 | 2.84 | (-0.31, 15.64) |
| p4 | 3 | 5.517 | 0.909 | (-2.460, 13.493) |

| code | N | Mean | Grouping | |
|---|---|---|---|---|
| p2 | 3 | 30.33 | A | |
| p1 | 3 | 25.67 | A | |
| p3 | 3 | 7.67 | | B |
| p4 | 3 | 5.517 | | B |