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Civil Engineering Department

Evaluation of Processes and their Environmental Impacts of the Wastewater Treatment Plant in Al-Muthanna Governorate

A Thesis Submitted to the Council of the Faculty of the College of the Engineering/University Of Kerbala in Partial Fulfillment of the Requirements for the Master Degree in Civil Engineering

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بسم الله الرحمن الرحيم

(وَأَنزَلَ اللَّهُ عَلَيْكَ الْكِتَابَ وَالْحِكْمَةَ

وَعَلَّمَكَ مَا لَمْ تَكُن تَعْلَمُ ۚ وَكَانَ فَضْلُ اللَّهِ

عَلَيْكَ عَظِيمًا)

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Dedication

I dedicate this work

To the owner of the age and time, Imam Mahdi (peace be upon him) in preparation for his state

To whom I draw my strength and my ambition, my dear father

To whom I learned diligence of which and love life, no matter what the difficulties, my mother

To my brother and sisters who were the best support in my continuation

To everyone who stood by me at this stage and bet on my success, my friends

Zahraa

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Abstract

Wastewater treatment plants (WWTPs) in Iraq are facing high challenges due to improper management. Till now, these WWTPs may be considered the major polluter of the country’s water bodies. Many researchers only evaluate the performance of the plants in their various units, but few of them evaluate the reason for the deterioration of the plants. This study tries to display the damages resulting from the WWTP stop using both life cycle assessment (LCA) and quantitative microbial risk assessment (QMRA). The study aims to employ an endpoint approach in LCA for evaluating impacts on human health, ecosystem quality, and resources. Al-Samawah WWTP located in Al-Muthanna Governorate was taken as a case study to analyze the processes in these plants. The plant was visited, available data was collected, and the staff responsible for operations was interviewed. Life cycle assessment (LCA) is one way of looking at the impact of WWTPS from holistic perspective,which is extensively used to compare technologies and is constantly improved as a process.Quantitative microbial risk assessment (QMRA) is a method for calculating the burden of disease caused by a specific pathogen has been developed. Data analysis showed a deficiency in treatment since the beginning of the plant’s operations mainly due to improperness in the management of the treatment train. As of now, there are approximately 76.9E+05kg of BOD_5, 3.24E+06 kg of TSS, 4.01E+07 kg of TDS, 1.55E+06 kg of COD, 9.35E+04 kg of nitrates, 1.097E+05 kg of ammonia,8.9E+06 kg of sulfates, 2.08E+03 kg of phosphates, 1.57E+06 kg of oils and greases (O&G), and 1.74E+05 kg of hydrogen sulfides loaded annually to Al-Samawah River from the plant making it as the major polluter in the Governorate.

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The results of LCA the results show that the highest impact on human health was related to the construction of WWTP (2.62E-07 DALY/m^3). The highest impact on the ecosystem was also related to the construction of WWTP (9.61E-10 spices, yr/m^3), while in the category of resources depletion, the sewer grid construction was the highest impact (0.437 \$/m^3). For QMRA, the results showed that among every 10^6 persons directly drink from downstream of the river, 172608 of them will expose to diarrheal disease. According to the assessment data, the final risk for E. coli and TC is 0.172608 and 0.149792, respectively.

The results of laboratory of the plant when it was operating show that the effluent in sometimes higher than influent , in addition, there were illogical results.This is evidence that the results are incorrect and unreliable and cannot be relied upon. The results of LCA show that due to stopping operation of the WWTP, most environmental burdens caused by this plant are related to the construction of the WWTP and the sewer system,and the results of the disease burden highly exceeded the 10^{-6} WHO reference level of risk and show the urgent need for stopping the direct discharge of wastewater to the river and do whatever needed to reactivate the processes in the plant.

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List of Abbreviations

ASTM	**American Society for Testing Materials**
CED	**Civil Engineering Department**
HRA	**Health Risk Assessment**
BOD	**Biochemical Oxygen Demand**
COD	**Chemical Oxygen Demand**
DO	**Dissolved Oxygen**
EAAS	**Extended Aeration Activated Sludge**
EPA	**Environmental Protection Agency**
NH3	**Total Ammonia**
RAS	**Return Activated Sludge**
SVI	**Sludge Volume Index**
TSS	**Total Suspended Solid**
WWTP	**Waste Water Treatment Plant**
TDS	**Total Disolved Solid**

List of Symbole

CR	**Raw Water Quality**
Pr	**Treatment Effect**
DWQ	**Drinking Water Quality**
V	**Consumption of Unheated Drinking Water**
E	**Exposure by Drinking Water**
r	**Dose-Response**
Pinf,d	**Risk of Infection per Day**
PO4	**Phosphorus**
NO_3	**Nitrate**
SO_4	**Sulfate**
O&G	**Oil and Grease**
H_2S	**Hygrogen Sulfide**

Chapter One :Introduction

Introduction

1.1 Background

Climate change is having a severe impact on many countries, resulting in declining freshwater resources. The world's population grows, so will the demand for freshwater. This adds to the stress currently being placed on water treatment systems. Furthermore, as a result of rapidly expanding industrial activity, water contamination has increased significantly (Al-wardy, 2021). Several studies have discovered that continually releasing wastewater into the environment exacerbates the problem of water sacristy by contaminating freshwater supplies (Zubaidi et al., 2020). The world's population is growing, and people's living conditions are improving around the world, resulting in increased demand for effective wastewater treatment. This need can be fulfilled by improving WWTPs or constructing new plants. The requirement to increase the quality and quantity of treated water adds to the environmental load by requiring the construction and operation of more facilities. The treatment in WWTPs had an objective that went beyond just conserving surface or ground water. The problems of energy efficiency, carbon footprint, and other sustainability issues must be integrated with the concerns of water quality in the next generation of WWTPs (Alyaseri & Zhou, 2017).

Wastewater is the water supply of a community that has been contaminated by a variety of sources. The main objective of wastewater treatment is to preserve human health and the environment by preventing pollution of the receiving watercourse (Metcalf et al., 2014). According to a report by the United Nations, in countries in crisis, such as Iraq, the problem of inappropriate wastewater treatment is critical. Iraq's national water infrastructure has been mostly destroyed as a result of decades of wars and sanctions, as well as a lack of environmental awareness among both the general public and government officials (Alyaseri, 2016a).

To evaluate alternative processes, improve design, and evaluate and analyze costs, dynamic modeling and simulation are now widely used in the wastewater treatment process (Rivas et al., 2008).The most popular programs used in evaluating enviromantal imapct is Life cycle assesment .

1.2 Problem Statement

Sanitation is the indicator of civilization and culture. Wastewater is the community's water supply after it has been used or contaminated by a variety of sources. During its use, the water given to a community collects a variety of chemical compounds and microbial flora, resulting in wastewater that has a polluting potential and causes a health and environmental danger. Uncontrolled wastewater disposal can spread diseases of the intestinal tract such as cholera, typhoid, dysentery, and water-borne diseases such as infectious hepatitis, among others. As a result, the primary goal of sanitary wastewater disposal is to prevent communicable diseases and protect public health (Ramadan et al., 2017).

Al-Samawah WWTP was operating through 2012 and gradually declinded in its processes until stopped in 2016, and it became the most pollution source in the province. It is important to evaluate the level of damages on human health and environment due to this deterioration.

1.3 The Scope of the Study

The objective of the this study is to :-

1- Evaluate the deterioration of WWTPs in Iraq
2- Evaluate their impact on human health, ecosystem and resourse depletion.

3- Make a health risk assessment .

1.4 Methodology of the study

The above mentioned aim of the study is achieved by:

1) evaluating operation of the plant of Al-Samawah and discuss the reason(s) for processes stopping. The evaluation include collecting avialable data related to Al-Samawah WWTP for period (2012 to 2016) from the laboratory of the plant .These data include concentration of influent and effluent of the wastewater treatment process for biochemical oxygen demand (BOD_5), chemical oxygen demand (COD), total suspended solids (TSS), phosphates (PO_4), Nitrates (NO_3), ammonia (NH_3), Hydrogen sulfide (H_2S), chlorides (CL), oil and grease (O&G), and the quantitative measure of acidity (PH). The evaluation also include discussing how these parameters were declined over time.
2) making an enviromental life cycle assesment(LCA) using data colloected from different sources and utilizing the SimaPro 9.0 program.
3) conducting a health risk assesment for Escherichia coli (E-coli) and total Coliform (TC) because of the stop in operations in the plant , LCA alone can not cover or show damages occur from discharging wastewater to rivers and contaminate water sources.Therefore,water a health risk assesment for E-coli and TC was conducted. The assessment involved testing E-coli and TC following Iraqi standards. The simplified risk assessment approach contained within the 3rd edition of WHO Guidelines of Drinking-Water Quality (2003) was used. The simplified risk assessment process was used

to show the damages to human health associated with wastewater discharge from plant.

4) analyzing and discussing the results with setting conclusions and suggesting recommendations.

1.5 Hypothesis

Wastewater treatment plants need focus and precision in design, maintenance, management and operation, otherwise they will fail and their failure will be at the expense of human health and the environment. The aim of this thesis is to review the causes of treatment plant failure and quantitatively evaluate of the damages resulting from this failure.

1.6 Layout of the Study

The following are the chapters that make up this study (figure 1-1)

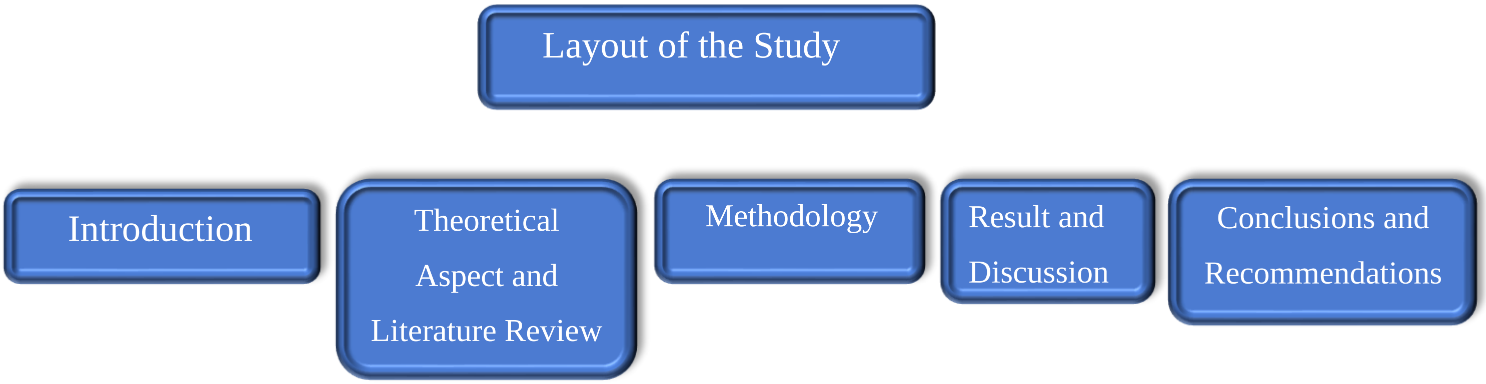


Figure 1-1: Schematic diagram of the present study.

Chapter Two: Theoretical Aspects and Literature Review

Theoretical Aspects and Literature Review

This chapter includes a general explanation of the wastewater properties ,the wastewater treatment processes , the biological treatment methods. It focuses on the extended aeration activated sludge. Also,this chapter describes the process of modeling of the treatment process and making an enviromental life cycle assessment (LCA) and conducting a health risk assesment. Finally, it presents the literature review about performance assessment of WWTP in Iraq , performance assessment of extended aeration, life cycle assessment and risk assessment. The layout of the above chapter is shown in Figure 2-1

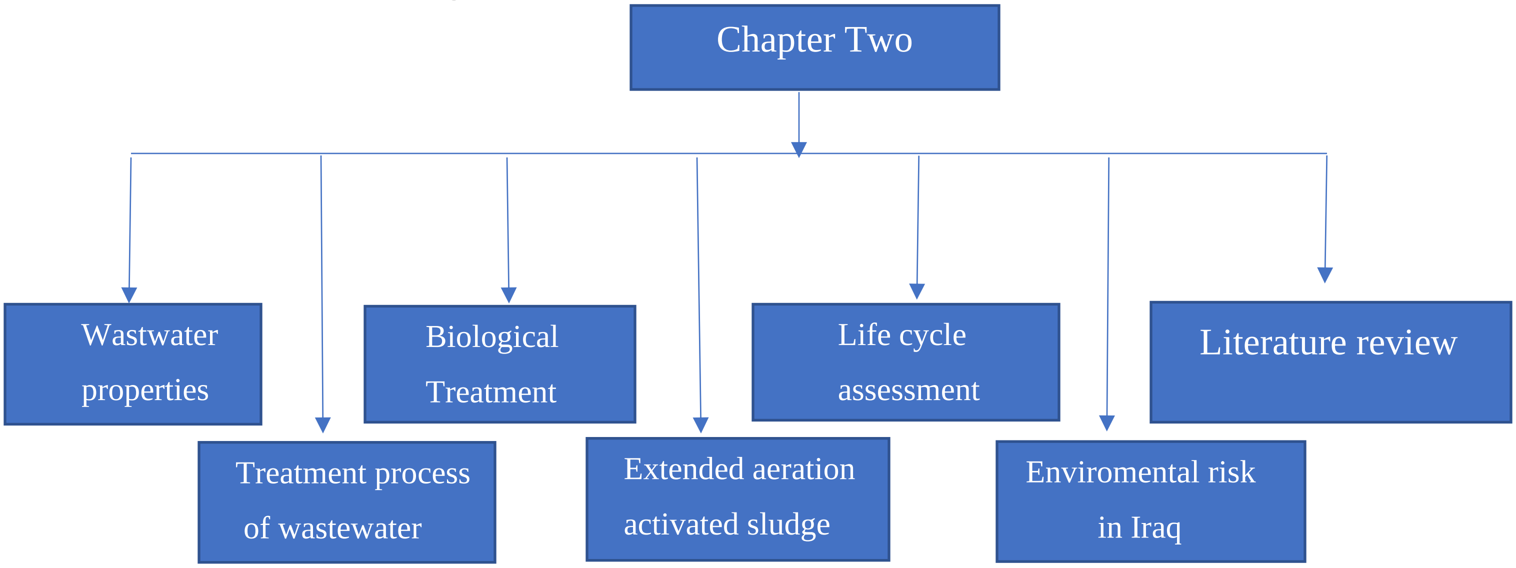


Figure 0-1 *Layout of chapter two*

2.1 Wastewater Properties

Wastewater comes from a variety of sources. It's a mix of bathing, washing, clothes, snow, toilet water, dishwater, and all cleaning tasks at home, in the rain, and in institutions. Water pollution is defined as the addition of substances or energy forms to a water body that affects its nature in a way that negatively effects its legitimate use, either directly or indirectly (Von Sperling, 2007). Many parts of the world lack legislation to protect river water quality and environmental integrity, and even where regulations do exist, they are typically not followed or enforced successfully. As a result, many rivers have become extremely polluted, endangering plant and the animal life, the environment, and the human health. The truest sign of civilisation and culture is sanitation. Like a beautiful statue, a good drain symbolizes the culture (Langergraber et al., 2004). Wastewater is the water supply of a community that has been contaminated by a variety of sources. The water provided to a community picks up a range of chemical compounds and microbial flora during its use, resulting in wastewater with polluting potential and a health and environmental concern. As a result, sanitary wastewater disposal's major purpose is to avoid communicable diseases and protect public health (Lagarde et al., 2005).Plant operations employees can use the information obtained through characterization of influent, effluent, and internal process streams to better control treatment processes. To get that information, the operator should collect and analyze representative samples throughout the plant to determine the properties of the raw wastewater and stream.

There is usually no interest in determining the numerous components that make up wastewater in the design of a WWTP. This is owing to the difficulty of performing the many laboratory tests, as well as the fact that the results cannot be immediately used as design and operation aspects. As a result, indirect metrics that describe the nature or polluting potential of the wastewater in question are frequently used (Von Sperling, 2007).

The influent properties wastewater can be classified into three types based on classical wastewater studies (Metcalf et al., 2014):-

- Physical properties: those components that can be detected using the physical senses and simple technology are included in the physical characteristics of wastewater. Temperature, color, smell, and solids are the variables.
- Chemical properties :- pH, dissolved oxygen (DO), oxygen demand, nutrients, and hazardous compounds are chemical properties of wastewater that are of particular interest to the research.
- Biological properties : The three types of biological organisms present in wastewater are bacteria, viruses, and parasites.

2.2 Treatment Process of Wastewater

Water makes up 99.9% of wastewater, while the remaining 0.1% contains organic and inorganic contaminants, both dissolved and suspended, as well as microorganisms. The aim of the treatment of wastewater is to eliminate these pollutants .Water pollution occurs as a result of this remainder percent,and wastewater must be treated as a result.The wastewater's composition is determined by the purposes to which the water was used. Climate, social and economic conditions, and population habits all influence these uses and how they were carried out (Von Sperling, 2007).

Traditional wastewater treatment uses a combination of physical and biological processes to remove particles, nutrients, and organic matter from wastewater. In the field of wastewater disposal and treatment, there are three basic stages of treatment; (primary, secondary, and sludge treatment), each of which contains a variety of procedures and addresses a specific type of pollution in the water. Some suggest that there should be two extra wastewater treatment processes, one at the start and one at the end (preliminary and tertiary treatment), for a total of five treatments (Al-wardy, 2021). Various stages of wastewater treatment are referred to as preliminary, primary, secondary, and tertiary (Janssen et al., 2002).

The initial stage in the treatment process is preliminary treatment. This procedure entails using screens to capture and remove large solid items, as well as pumping water into the plant through a hole where heavy materials were dropped to deposit sand and gravel. This stage is critical for preventing failure of the plant's equipment, particularly pipelines and pumps (Khiewwijit et al., 2015). Screen and grit chamber are examples of unit operations. Screens are used to remove big particles like rags, paper, plastics, and metals, while grit removal is used to remove grits and other heavier materials than organic waste.

The primary treatment stage, which includes primary sedimentation, is the second stage of treatment. The purpose of this unit is to remove solid materials that can settle. A primary sedimentation procedure typically removes 50-70 % of total suspended particles (Jasim, 2020). The preliminary and primary treatment procedure removes approximately 25% of the organic matter load and potentially all inorganic solids in water containing industrial effluents (Al-wardy, 2021).

The secondary treatment process, which is the third stage of treatment, then is used to dissolve any soluble organics that were not processed by the primary treatment and to remove any remaining suspended particles. During secondary treatment, more than 85% of the organics can be removed. There would also be no substantial removal of nitrogen, phosphate, heavy metals, degradable organics, microbes, or viruses. It's possible that more contaminants will need to be removed in the future (advanced one) (Soomaree, 2015). The biological treatment process is carried out by groups of microorganisms that take organic materials as food and convert them to metabolic end products such as carbon dioxide, water, and energy (Karia & Christian, 2013). This amount of energy is required for Germ replication and development. The biological process is aided by a well-designed ventilation system that pumps a large amount of air into the tank to aid in the decomposition of organic materials. The water is discharged into secondary sedimentation tanks after biological treatment, where residual sediments and living microbes settle to the bottom. They are handled separately from the liquid that is undergoing sterilization (Metcalf et al., 2014).Ventilation and mixing, sedimentation tanks, activated sludge, filtering, and disinfection are the five processes in this procedure.

Finally, advanced treatment may be used in exceptional cases. Additional treatment methods like filtering, carbon adsorption, and chemical phosphorus precipitation are used to separate components that were not properly eliminated in the secondary treatment facility. Nitrogen, phosphorus, and other soluble organic and inorganic compounds are among these components (Al-wardy, 2021).

2.3 Biological Treatment

Biological treatment is an important and integral aspect of any WWTP that treats soluble organic pollutants in wastewater from either a municipality or an industry or a combination of the two. Biological treatment has secured its place in any integrated wastewater treatment facility due to its evident economic advantage over other treatment methods such as chemical oxidation, thermal oxidation, and so on, both in terms of capital investment and operating costs (Mittal, 2011).

The biological treatment systems depend on microorganisms to decompose organic contaminants in wastewater. It mostly consists of two processes: suspended growth and attached growth (biofilm) (Al-wardy, 2021).

The microorganisms in the suspended process remain suspended in the wastewater with complete mixing and oxygen, where the microorganisms degrade the organic contaminants, and the activated sludge process is the most typical use of this type (Metcalf et al., 2014). The activated sludge method, which uses the ideas of mechanical aeration and biological flocs made of protozoa and bacteria to treat industrial and municipal wastewater, is one type of wastewater treatment technology (Henze et al., 2008).

2.4 Theory of Extended Aeration Activated Sludge

In an activated sludge plant, the biological removal and conversion of organic wastes can be divided into two stages, each of which occurs in the same tank at the same time. The organic waste is firstly partially oxidized for energy and then synthesized into new bacterial cells, the second stage, the formed biological cells undergo self-oxidation for additional energy as a result of continual aeration. Low organic loadings, high biological solids concentrations, and long durations of aeration are common in extended aeration-activated sludge systems . As a result, all of the parameters required for the effective biological removal of organic wastes in the first stage are present. As a result, around 98 % or more of the organic material added is removed during the extended aeration process and converted to carbon dioxide and water or new biological solids. The BOD removal efficiencies of less than 98 % that are commonly achieved in practice are connected to the release of degradable biological solids to the plant effluent, and not to the initial conversion of waste into biological solids (McCarty & Brodersen, 1962).

The extended aeration process makes use of a large aeration tank with a high concentration of mixed liquid suspended solids (MLSS). Normally, this system is used for small applications. This method is often used in prefabricated packaging plants (Qasim & Zhu, 2017).

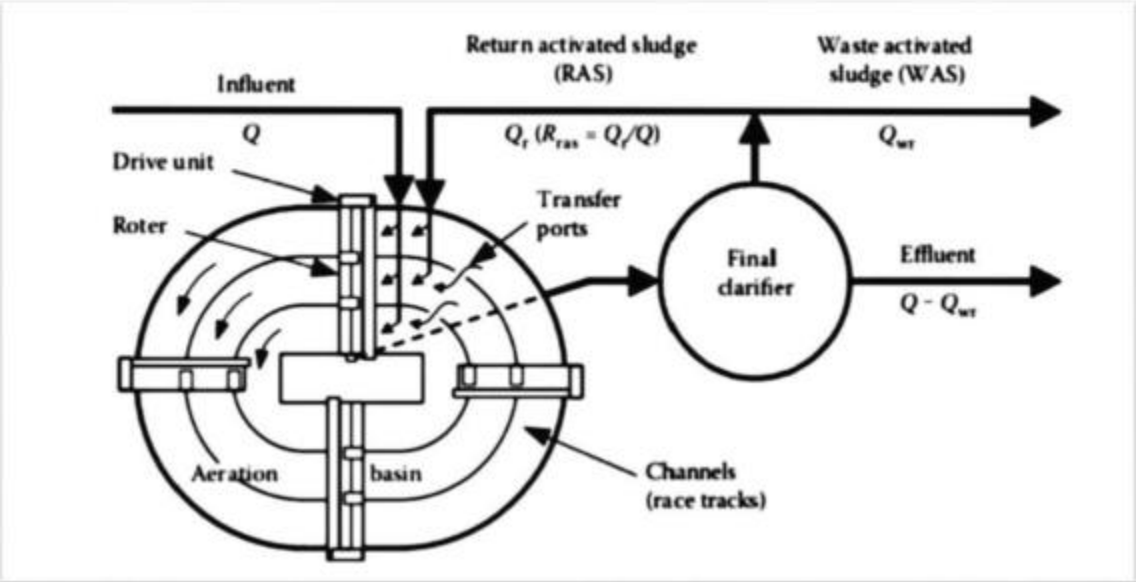


***Figure 0-2** Definition sketch of extended aeration*

2.5 Life Cycle Assessment

WWTP purpose is to reduce the environmental impact resulting from sewage water.On the other hand, it has an influence on the environment because they use resources during construction and operations. Hence, the development of treatment processes in WWTPs is needed to address the serious environmental issues (Lillenberg et al., 2010).

The use of a method called Life Cycle Assessment (LCA) is one way of looking at the impact of WWTPs from a holistic perspective, which is extensively used to compare technologies and is constantly improved as a process.(Lopsik, 2013). Therefore, it is one methodology to improve wastewater treatment processes. ISO 14040 is the standard that governs the use of this methodology (ISO, 2006). LCA is a process for compiling and evaluating a product's or service's inputs, outputs, and potential environmental consequences over the duration of its entire life cycle. LCA allows a complex assessment of the performance of a studied system or product. It also allows the quantitative assessment of impacts and the identification of factors that have the highest impact on environmental performance (Lopsik, 2013). However, LCAs, like other system analysis techniques in general, are a simplification of a complicated reality. LCA may applied to (Goedkoop et al., 2016):-

1) Identify opportunities for improvement by identifying environmental hotspots in a product's life cycle.
2) Analyze the contribution of each stage of the life cycle to the overall environmental burden.
3) Compare between products.
4) Assure compliance with standards.

According to (Dixon et al., 2003), if one of the main goals of wastewater treatment systems is to minimize environmental impacts, so they should be designed in such a way that their whole influence on the environment is minimized; therefore the system's life cycle must be considered. Water treatment technology that mainly relies on technology to produce high-quality effluent may not be the most environmentally sustainable option (Tangsubkul et al., 2005). LCA allows for a comprehensive assessment of a treatment system's environmental impact. It helps in bringing out factors in order to reduce negative consequences and generate the most advantageous overall alternative (Lopsik, 2013).

2.6 Environmental Risk in Iraq

Iraq's environment has been under pressure from a variety of sources, including population increase, the effects of three wars, climate change, poor land use planning, and encroachment on fragile ecosystems. Iraq suffers major environmental issues, including poor water quality, soil salinity, air pollution, and conflict pollution, as well as the degradation of key ecosystems, climate change impacts, and the threat of water shortages (Price, 2018).

Due to internal and external challenges such as poor water resource management, internal political conflicts, a lack of local policies, climate change, international development laws, and unstable relationships with neighboring countries, Iraq is currently facing a significant threat of water shortages(Al-Muqdadi et al., 2016).

According to (Al-Muqdadi et al., 2016), Iraq may also fall below the water poverty level, which is defined as less than 1000 m^3 of water per person per year.

(Al-Furaiji et al., 2016) analyzed the availability and demand for water resources in four oil-rich provinces in southern Iraq. They concluded that water shortage in southern Iraq is a major problem that will only deteriorate in the future as a result of population growth, increased upstream abstractions, poor management of available water resources, and climate change. In 2010, the four southern provinces of Iraq had a total water deficit of 430 m^3/year, according to their calculations.

2.7 Health Risk Assessment

River water is commonly used to supply drinking water and for recreational purposes. The control of sanitary risks requires special consideration due to the growth in the number of bathing locations and water sport activities. In fact, harmful bacteria like E. coli and C. perfringens, viruses like adenovirus, and pathogenic protozoa like G. duodenalis and C. parvum that can cause serious health issues frequently pollute river water (Pauline et al., 2015).

All mammalian feces contain large concentrations of E. coli. In accordance with drinking water standards, it has been selected as a biological indicator of water safety. Depending on the climate, E. coli can persist in drinking water for a number of weeks (Edberg et al., 2000) .

For many years, the water sector has relied on end-product standards compliance to ensure water safety. Recently, however, the water sector has begun to move in direction of using risk assessment together with risk management as a more useful instrument for the regulation of water safety. The third version of the Guidelines for Drinking-Water Quality (GDWQ) has incorporated this approach to water safety (Howard et al., 2006). The World Health Organization (WHO) specifically encourages the implementation of water safety plans, which are driven by health-based targets and have independent surveillance to confirm performance. These plans are akin to the Hazard Assessment Critical Control Point approach used in the food industry. The WHO emphasizes the use of quantitative risk assessment as a useful tool for establishing health-based targets and validating water safety plans (Organization & WHO., 2004).

A method for calculating the burden of disease caused by a specific pathogen has been developed, and it is called Quantitative Microbial Risk

Assessment (QMRA). The three main requirements for a QMRA are exposure assessment, dose-response analysis, and risk characterization, according to Haas & Eisenberg (2001). The use of disability adjusted life years (DALYs) has been recommended in risk assessment in order to capture and compare the various outcomes from different pathogens (Havelaar & Melse, 2003; Organization & WHO., 2004).

Health risk assessment requires extensive number of data which may not be available in the country. For example, several studies have been conducted about pathogen such as e-coli , rotavirus, and cryptosporidium parvum with assumptions (Howard et al., 2006) (Howard & Pedley, 2003).

The risk associated with discharging pathogens to river may have impacts in several ways which are:

a. Possibility of drinking river water by people living around the river.
b. Using this contaminated water for agriculture.
c. Using river water for recreation purposes.
d. Using contaminated river water by cattle.

2.8 Literature Review of Previous Studies

2.8.1 Performance Evaluation of WWTP in Iraq

In many Iraqi cities, WWTP showed accepted level of treatment , only in the first several years of operation, and after that they gradually deteriorate due to lack of focus into the causes of degradation after evaluation . In the following section, previous studies are presented related to performance assessment of WWTP in Iraq and showed their deterioration :-

(Alsaqqar et al., 2014) evaluated the performance of the wastewater treatment plant in Al- Diwaniya, one of Iraq's southern cities. The plant's removal percentages of BOD_5, COD, TSS, and NO_3 were estimated using regression analysis in order to reach the disposal limitations. The average removal percentages for BOD_5, COD, TSS, and NO_3 were 70%, 73%, 82%, and 48.74 %, respectively. According with previous analysis of the effluent from Al-Diwaniya STP, the plant is not operating according to design specifications, which could be due to operations in the working units. These problems have an impact on the plant's ability to remove various pollutants like as BOD_5, COD, TSS, and nutrients to the desired disposal point.

(Alyaseri & Al-Madi, 2017) evaluated the performance of wastewater treatment plant in a Barakia ; is one of the major wastewater treatment plants in Al-Najaf province in Iraq, the performance was evaluated using the following parameters: BOD_5, COD, TSS, PO_4, NO_3, NH_3, O&G, H_2S, and CL. Data was collected and evaluated over ten years. The plant shown a significant ability to efficiently reduce contaminants, and it has recently become one of the province's major polluters. The plant's poor performance was caused by overloading it beyond its intended capacity, frequent power outages, a lack of advanced treatment such as filtration and nutrient removal, and a shortage of maintenance and replacement components. Iraq may require international assistance to reverse this downward trend due to its current economic predicament.

(Al-Obady & Qasim, 2018) evaluated the performance of wastewater treatment plant in Al-Khadraa; Wastewater Treatment Plant in Mosul City, and the quality of treated water's compliance with Iraqi standards for discharge into rivers and valleys. The study revealed that there are considerable changes in the quantity and quality of the influent to the plant, which can lead to the plant's operational units being closed down, which has an adverse influence on the plant's function. The results revealed that the influent's strength ranges from weak to medium. The BOD5/COD ratio is about 0.6 on average. In addition, the treatment efficiency appeared to be low, and the effluent quality appeared to be below Iraqi standards for disposal into rivers and valleys. BOD, COD, TSS, PO_4, and NH_3 removal percentages were 83%, 79 %, 69.7 %, 56.15 %, and 41.88 %, respectively.

(Abbas et al., 2022) evaluate the performance of the sewage treatment plant in Al-Thagher City, in the north of Basrah Governorate, the southern part of Iraq. The plant's performance was evaluated based on monthly averages of influent and effluent wastewater quality data from February 2017 to December 2018. The results show that all collected samples from the plant's effluent met the Iraqi water quality standard (IWQS) for temperature (T), pH, NH_3–N, and BOD, In contrast, they did not meet the IWQS for the values of electrical conductivity (EC), and TDS . In some months, TSS, $SO4^{-2}$, and $PO4^{-2}$ met the Iraqi water quality standard (IWQS), whereas in others, they did not. The following is a list of the average removal efficiencies: BOD (77%) >TSS (62%) >NH3–N (60%) > PO4–P (12%) > Cl^{-1} (2%).

Al-Zuhari(2008) evaluated the efficacy of the sewage treatment plants on Baghdad's Al-Risafa and Al-Karkh sides, the estimates were performed based on the average and peak capacity of each plant for the period 2005-2025, using three various population growth rates in Baghdad. According to the report, the Al-Rustamiyah sewage treatment plant's treatment efficiency deficit ratio will reach 273 % by 2025. The situation at Al-Karkh sewage treatment facility will become even more critical when the efficiency deficit exceeds 700 %. Therefore, studies should be carried out in order to find alternative solutions to this problem.

(Al-Rawi & Al-Tayar, 1993) evaluated performance of a wastewater treatment plant of a residential area in the north of Mosul City . They reached the conclusion that the plant was ineffective in treating organic material in wastewaters for a variety of reasons, including the lack of skilled operators. Operational issues, such as a lack of dissolved oxygen, also contributed to the plant's aeration tank's efficiency drop.

(Alyaseri, 2016b) evaluated the performance of Al-Samawah wastewater treatment plant, one of the southern cities in Al-Muthanna Province-Iraq,to identify the deficiencies locations in the process and specify solutions and recommendations to enhance performance. The results showed that ,the lack of efficient grit removal and primary treatment, combined with lack of experience in managing operations and performing maintenance causeraw wastewater to receive no to little treatment in Alsamawah wastewater treatment plant. The plant was not able to reduce contaminants such as COD, TSS, oil and grease, or nutrients.The plant failed to comply with local regulations to reduce all tested contaminants. It comply only at the events when a contaminant is originally had low concentration in the raw sewage

2.8.2 Performance Assessment of Extended Aeration

Mohammadi et al,(2012) included the results of two high-strength wastewater treatment systems. Extended aeration activated sludge(EAAS) and a submerged membrane bioreactor (SMBR) were the systems used. In terms of COD, BOD_5, TSS, and NH_3, the SMBR system produced a substantially higher quality effluent than the EAAS system.

Typical extended aeration plants' performance and operational characteristics were evaluated. The three factors chosen for the research were, (a) the ratio of applied to design biochemical oxygen demand load, (b) the loading factor, and (c) the ratio of actual detention duration to design detention time. Overall performance can be improved by either increasing the clarifier, particularly in terms of surface area, or by introducing a sludge waste stage in the operating method, according to test results. Controlling the air supply resulted in a significant reduction in the nitrogen content of the effluent, but no net phosphate reduction was seen. To ensure adequate operation over long periods of time, near-constant operational management was required. The sludge was the source of the most frequent operational issues (Eye et al., 1969).

Nikmanesh et al.(2018) performed a performance evaluation of the aeration system in the removal of microbiological and physicochemical parameters from the WWTP. COD, BOD, and TSS, respectively, had mean removal efficiency of 61.4%, 57.7%, and 70.8 %. The hydraulic retention time (HRT), the sludge age , the index of sludge volume (SVI), the ratio of food to mass (F/M), and the mixed liquor suspended solids (MLSS) for the aeration tank were 25 h, 5.64 days, 48.83 ml/g, 0.28 day-1, and 180 mg/L, respectively.

Pirsaheb et al .(2014) compared the efficacy of an EAAS system in Paveh's WWTP and a conventional activated sludge (CAS) system in Kermanshah's WWTP in removing COD and TSS was compared. The average COD and TSS removal values in the CAS system were 84.4 % and 74.6 %, respectively, whereas the EAAS system was 89.4 % and 87.9 %, respectively. In comparison to the CAS system, the EAAS system was found to be more effective at removing COD and TSS from municipal wastewater.

2.8.3 Life Cycle Assessment Previous Studies

Several reviews on water treatment and LCA have been published. (Friedrich et al., 2007) published a review that summarized 20 studies on LCA and wastewater and highlighted major points, but did not go into detail on the studies' characterization.

A book chapter on Life Cycle Analysis in Wastewater(Ahmed, 2010) was also published, which included an LCA framework for wastewater treatment. LCA approach was recently included in an evaluation of recycled water system sustainability studies (Chen et al., 2012).

(Pasqualino et al., 2009) conducted a LCA study to improve the operation of a municipal WWTP in Spain. In this case study, 95 % of the biogas from anaerobic digestion was burned in a torch, and 99 % of the sludge was applied to the ground. The researchers advocated using biogas for electricity and heat generation to lessen environmental consequences.

(Renou et al., 2008) used five methods :- CML 2000, Eco Indicator 99, EDIP 96, EPS, and Eco points 97 in the Life Cycle Impact Assessment (LCIA). For the greenhouse effect, resource depletion, and acidification, there was a consistent evaluation between these methodologies. If the possible impact of a treatment scenario is considered rather than the characterization of the eutrophication condition of a given receiving stream, eutrophication can be accurately calculated. To provide a reliable integrated assessment of wastewater treatment system sustainability, LCA should be combined with other tools like chemical and microbial risk analysis (used by local governments to set discharge limits) and environmental impact assessment (required for large wastewater treatment plants).

LCA considers raw material selection, production processes, and waste management from a holistic perspective. LCA can be used to compare many items or processes. The environmental soundness of these items or processes may be improved as a result of this comparison. Understanding the available options to be compared is essential when utilizing LCA for comparison (Al-Yaseri, 2014).

(Alyaseri & Al-Madi, 2017) conducted an evaluation of Al-Samawah WWTP using the LCA to evaluate the environmental performance of the existing wastewater treatment train in the plant. Analysis of treatment showed that most damages are related to climate change, depletion in resources, and human toxicity.

2.8.4 Risk Assesment Previous Studies

Howard and Pedley (2006) used the QMRA as a means of assessing performance of water supplies in relation to health effects from microbial contamination in developing countries. This is related to an ongoing project to develop water safety plans (WSPs) for utility supplies in Uganda. They concluded that while these are still dependent on data from indicator organisms and need different assumptions, a quantitative bacterial risk assessment is achievable for underdeveloped countries. Although there is much ambiguity about the final outlook for piped water in Uganda, it appears reasonable and will support investment planning and decision-making to ensure safer water delivery. Additional information is needed to improve these estimates or, at least, to determine the extent to which the current risk assessment deviates from expectations based on pathogen data (Howard & Pedley, 2003).

Also, Howard, et al.(2006) described a simplified risk assessment procedure to calculate the disease burden from three reference pathogens – pathogenic .Escherichia coli, Cryptosporidium parvum and rotavirus – in water supplies in Kampala, Uganda showed how QMRA can be used in countries with limited data, and that the outcome can provide valuable information for the management of water supplies (Howard et al., 2006).

2.9 Summary of Previous Studies

Some studies directly focus on conducting physical, chemical, and biological parameters tests for the influent and effluent wastewater in order to determine the removal efficiency of these parameters by WWTP. Other studies deal with some software programs like LCA that are used to evaluate the WWTP. Two studies also used risk assessment techniques to determine the effects of microbial contamination on the environment. Through the previous studies, the following main essential points can be drawn.

1- Many previous studies only evaluate the performance of operations in plants , and do not evaluate the deterioration of the plants and their potential environmental impacts.
2- Improper operation of the WWTP units leads to a gradual deterioration in the plant's performance.
3- The extended areation tank suitable for small communities.
4- The LCA program is a good tool for evaluating the performance of WWTP and it is commonly used by many research .
5- Applying the risk assessment procedure by utilizing QMRA is too useful for developing countries and needs many different assumptions.

Chapter Three: Methodology

Methodology

3.1 Introduction

This chapter consists of four sections (Figure 3-1); First section includes full description of the sewage treatment plant in Al-Samawah and its components. Second section contains a process assessment of Al-Samawah WWTP.Third section includes modeling the Al-Samawah wastewater treatment plant using SimaPro 9.3.0 software program.The final section includes using the simplified procedure to perform a quantitative microbail risk assessment.

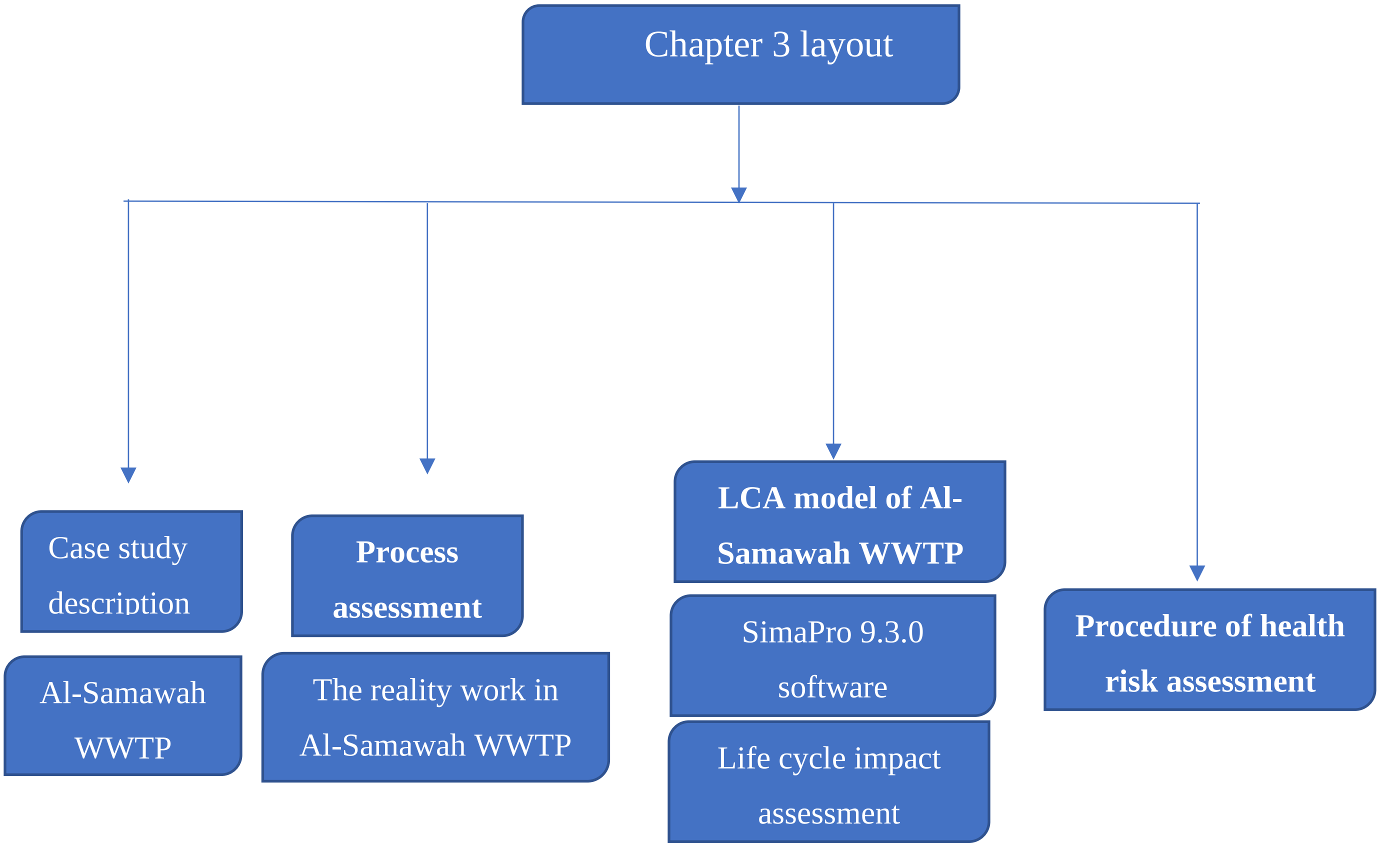


__Figure 3-1__ Layout of chapter three

3.2 Study Area

The present study was conducted for Al-Samawah WWTP located on the East part of Al-Samawah City which lies at about (8.19) km ditance from the center of the city. The geographical coordinates of the plant are (31°17'31.6"N, 45°21'32.1"E). The total area of this plant is 284,685 m^2.

3.3 Description of Al-Samawah WWTP

This plant was established in the year 2012 and it has maximum design capacity of 37,500 m^3/day (9.9 MGD) but current influent is 20,000 m^3/day. Figure 3-2 shows Al-Samawah WWTP plant diagram, which consists of preliminary treatment, secondary treatment and sludge handling unit, with the absence of a primary treatment stage because the system used in the secondary stage of this plant is extended aeration process, which suppose to guarantees a sufficient hydraulic retention time, and can replace the role of the primary sedimentation tanks presenting in the primary treatment stage.

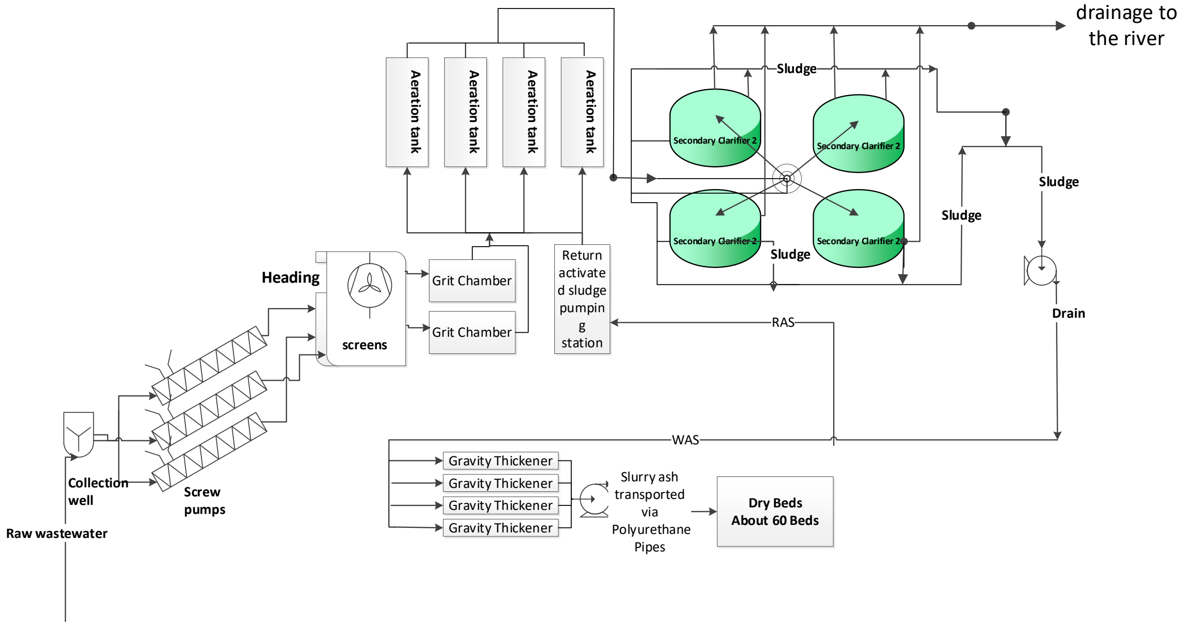


Figure 3-2. *Flow Diagram for Wastewater Treatment Process in AL-Samawah WWTP.*

The wastewater is collected in central station that consists of five pumps. Only one of them is on operation now and pumps wastewater to the WWTP. The pump raises water to the first reception unit across safety screens .The plant consists of the following units:

3.3.1 Preliminary Treatment Units

The preliminary treatment includes:

a) The inlet :- It consists of three screw pumps to riase wastewater to the screens and grit chambers. Two of these pumps are not available for work now, and the third one doesn't operate as shown in Figure 3.3.

b) Screens:- The screens are located at the beginning of the plant within the wastewater entry channel. In coarse screen (also known as bar rack or bar screen), which is the first step in the preliminary treatment, large objects such as rags, paper, plastics, cans, tree branches, and other items are removed. It usually made of parallel bars (or rods) or perforated plates that can be used as screening elements. These screens are either manually or mechanically cleaned. The manually cleaned coarse screens are used at small wastewater treatment plants. AL-Samawah WWTP is manually cleaned. These screens also used to protect the mechanical equipment that will be used in the subsequent stages of the processing. The fine screen is the second type, which is also a physical treatment of the preliminary stage used to remove fine solids, protect equipment that may be more sensitive to solids, or remove materials that may prevent biosolids from being reused in a beneficial way. In the plant, both coarse and fine screens, are not in operation now, and some parts are corroded. Figure 3.4 shows the corrosion in these parts.

***Figure 3-3**. Screw Pump in the Inlet of Flow to AL-Samawah WWTP taken by Zahraa on October 28th, 2021).*

***Figure 3-4**. Screens in WWTP of AL-Samawah (taken by Zahraa on October 28th, 2021).*

c) Grit removal basins:- A physical treatment unit with two grit removal tanks is used to remove sand and other grits using a physical mechanism. These basins do not work as of now, and grits were accumulated without maintenance which led to stop of operations in them as shown in Figure 3-5.

***Figure 3-5**. Grit Basins in AL-Samawah WWTP*

3.3.2 Secondary Treatment Units

An activated sludge process is used as a secondary treatment in the plant and consist of the following :-

a) Aeration Basins

The plant has four aeration basins of which three of them are working at any time and the fourth is offline for maintenance. Each basin has a rectangular shape (25 m x 70m) and depth of 3m with 1m free board. Aeration basins are supplied with three mechanical floating surface aerators (propeller type) for each basin. These basins doesn’t contain devices for measuring dissolved oxygen content so no information about the level of oxygen during operation was provided. Figure 3.6 shows aeration basins in the plant .

***Figure 3-6**. Aeration Basins in WWTP of AL-Samawah taken by Zahraa on October 28th, 2021).*

b) Secondary Clarifiers

There are four secondary clarifiers in the plant. Each one is 28 m in diameter and has an inlet in the center of the basin and skimmer for removing floating solids. By gravity, the sediments in these basins are settled in bottom of the clarifier. Some of the sludge accumulated in the bottom is returned back to the aeration tank to maintain the level of bacteria while the rest is pumped to the thickening ponds. At the top, the water is suppose to be free of sedimentary materials and discharged to the river . Figure 3.7 shows a stopped secondary clarifier basins in the plant .

(a) (b)

Figure 3-7. *Secondary Clarifier Basins in WWTP of AL-Samawah taken by Zahraa on October 28th, 2021).*

Becuase most of the plant units are not working now, the wastewater entering the plant is transformed into an open channel for bypassing without treatment. Figure 3.8 shows the bypass channel in the plant.

Figure 3-8. *Open channel in the WWTP of AL-Samawah taken by Zahraa on October 28th, 2021).*

c) Sludge Handling Unit

The sludge handling unit consists of the following :-

a) Thickener basins :- Thickening basin used to increase the solid content of sludge by removing a portion of the liquid fraction (Metcalf et al., 1991). The plant has four thickener basins with dimensions of (17 m*15 m) for each basin. Figure 3.9 shows thicheners in the plant.

(a) *(b)*

Figure 3-9. *Thickener Basins (taken by Zahraa on October 28th, 2021).*

b) Drying Beds **:-** the plant has (sixty drying beds) . Each dry bed contains layers of graded gravel, through which the activated sludge coming from the thickening tanks is dried and skimmed later. Figure 3.10 shows the dry beds of the plant.

***Figure 3-10**. Dry beds (taken by Zahraa on October 28th, 2021).*

Processes in the plant include a chlorination unit which was dismantled two year ago due to the lack of dechlorination. Also, processes don’t include tertiary treatment unit, that is very important for removal of nitrogen and phosphorouos.

3.4 Process Assessment of Al-Samawah WWTP

The performance evaluation of Al-Samawah WWTP is detailed in the following sections:

3.4.1 The Reality Work in Al-Samawah WWTP

Raw and treated wastewater should be analyzed for the purpose of evaluating wastewater treatment processes. It is important to evaluate the characteristics of the raw wastewater entering the plant in order to determine the pollutants' strength and investigate the impact of their concentrations on the plant's performance (Weiner et al., 2003).

For the WWTP of AL-Samawah , The quality of the raw wastewater that enters the plant and after treated has been assessed from the year 2012 to the year 2016. The following pollution parameters which are (BOD_5), (COD), (TSS), (PO_4), (NO_3), (NH_3), (H_2S), (CL), and (O&G) were previously tested in the plant lab. The values of these parameters in the plant's treated water were compared with the Iraqi quality standards (Table 3-1). Since the stop of operations in the plant in the year 2016, no measurements are conducted for these parameters till now.

As for the biological evaluation , no measurements were performed during the peroid of operations in the plant. Therefore, to assess the biological contamination, two parameters were selected for evaluation; E-coli and TC. These parameters were tested by the researcher. A grab sampling was conducted by the researcher and tests were done in the Laboratory of Environmental Protection Department in AL-Samawah City in two sampling events.

Table 3-1. *Iraqi's quality Standards for Effluent Disposal (Iraqi standard specification,1967)*

Parameter	Iraqi quality standards (mg/day)
BOD_5	40
TSS	60
COD	100
NO_3	50
NH_3	10
PO_4	3
O&G	4
CL	600
H_2S	0.5

It is not clear why plant do not measure biological contamination although the main objective of the WWTPs is to remove biological contaminants from wastewater, allowing the treated effluent to be discharged to natural waters (Erbe et al., 2002). However ,other parameters, such as TSS may work as an indicator for biological contamination.

3.4.2 Evaluating the Existing Plant

Data related to the design and plan of the plant was provided by sewer Department in the governorate. The data for the evaluation were provided by The WWTP Laboratory of Environmental Protection Department in AL-Samawah City. Data on pollutant parameters in the influent and effluent of the wastewater treatment process were collected from October / 2012 to January / 2016. These parameters were BOD5 , COD, TSS, PO4 , NO3, NH3, H2S, CL, O&G, and the quantitative measure of acidity (PH). The Iraqi standards values of the pollutant parameters BOD_5, COD, TSS, NH_3, PO_4 , O&G , CL, and H_2S are 40 mg/L, 100 mg/L, 60 mg/L, 10 mg/L, 3 mg/L, 4 mg/L , 600 mg/L, 0.5 mg/L, respectively. These standard values apply to all bodies of water, regardless of their quality or ability to tolerate pollution. It is unclear how these limits were adopted, but they are clearly less restrictive than any other standards for a country like the United States. For example, in Florida, effluent limits for BOD_5, TSS, total nitrogen, and total phosphorous are 5 mg/L, 5 mg/L, 3 mg/L, and 1 mg/L, respectively. In many developing nations, wastewater discharge standards are either accepted from WHO standards or other international standards without being adapted to local conditions (WHO, 2006).

After data collection (Appendix A), values of parameters were arranged in tables using EXCEL 2010 software for statistical analysis. The averages, standard deviations, and medians were calculated and compared with Iraqi's standards. The performances of every step in the treatment were analyzed to discover the possible deficiencies either in design or in operations and maintenance level. Also, the interlocking between these steps was discussed as well. A comparison between input and output for every parameter was performed. In addition, outputs of parameters were tested for linear trend analysis to examine the deterioration with time. Minitab 19 software was used for performing statistical analysis.

Since the plant's start until now, the level of plant performance is low in treatment, and the plant was unable to minimize the concentration of major pollutants to the standard levels allowed to be discharged into the River. The main reasons may be related to :-

a) The mechanical equipment that was equipped in the plant for which their spare parts were not easily available. In addition to the lack of financing for maintenance, most of these spare parts have to be imported from outside the country. Also, there is no periodic maintenance for the sedimentation basin

b) The quality control systems which most of them are absence in the units of the plant. For example, there is no oxygen measuring devices in the aeration tank of the plant, no flow measuring device at the inlet of the plant.

c) The lack of professionalism of the workers and the lack of training courses for the workers residing on the plant is obvious and gradually leads some units to stop working.

d) vaccum pumps which are turned off while it had to work continuously to reduce the formation of H2S.

3.5 LCA Model of Al-Samawah WWTP

The purpose of this section is to assess environmental impacts for the stop of processes by using Simapro 9.3.0 software to build a life cycle assessment (LCA) model of Al-Samawah WWTP. A database and a modeling module are the most common components of the software tool. On an interface, the data is handled and modeled. They build the process chain. Each process is characterized by its inputs and outputs and represents a stage in the process (Unger et al., 2004).

3.5.1 Simapro Software

SimaPro is a computer software tool that can be used to determine the pertinent environmental impacts of a process or product (Alanbari et al., 2014). It can be used to analyze models and make comparison between them. It can manage and store data, as well as perform calculations and sensitivity testing. It also includes Eco-invent database that can compensate missing data from plant. Therefore, this software was used for analysis in this study .

3.5.2 The Steps of LCA

There are four basic steps to the LCA study:-

1. Defining study's scope and goal :- The goal and scope define the most of wise choices, which are usually subjective, for example, the purpose of the LCA, a detailed description of the product and its life cycle, and a description of the system boundary.
2. Creating a product life cycle model that includes all environmental inputs and outputs which is usually referred to as:life cycle inventory (LCI). An inventory analysis must be started when the scope and system boundaries have been defined. LCI is a "systematic, objective, stepwise approach for estimating energy and raw material requirements, atmospheric emissions, waterborne emissions, solid wastes, and other releases over the complete life cycle of a product, package, process, material, or activity" (Bishop, 2000). To put it in other words, the inventory stage includes identifying all of the product's or process's inputs and outputs inside the system limits, as well as collecting data related to the input-output model (Al-Yaseri, 2014).

3. Understanding the environmental relevance of each input and output by conducting analysis using a life cycle impact assessment LCIA methodology. LCIA method is used in LCA studies to analyze and describe the environmental implications (Bishop, 2000). LCIA approaches take two methods: midpoint and endpoint. The midpoint approach adopts the categories in the middle of the cause-and-effect chain without going to calculate their end impacts, such as harm to human health or the environment. Examples of these midpoint categories include acidification, which is measured in H+ moles eq., ozone layer depletion, which is measured in kg CFC-11 eq., and global warming, which is measured in kg CO2 eq. (Alyaseri & Zhou, 2017).The endpoint approach takes it a step further by converting the midpoint effect categories into more specific human and ecosystem damage categories. The endpoint technique, for example, converted the amount of carcinogens computed in the categorization stage into equivalent cancer cases in people expressed in disability adjusted life years (DALY). It may compute the fraction of species affected by nutrients released into the environment, as well as the surplus energy or expenses required by future generations to obtain the resources they require due to current resource consumption (Alyaseri & Zhou, 2017). The endpoint approach is now used by a number of methods such as Eco-indicator 99, IMPACT 2002, and ReCipe(Goedkoop et al., 2010; Goedkoop et al., 2013; Goedkoop et al., 2016; Humbert et al., 2012; Jolliet et al., 2003)

4. Interpreting the results and set recommendations (Goedkoop et al., 2016) :- The decision-makers can choose the best product or method with the help of the LCA's recommendations. Concerns about the project's location must be taken into account during the selection process. The ISO 14044 standard describes several checks to see if conclusions are sufficiently supported by the data and by the methods that are used. In this manner, there will be no surprises when results and decisions for development are published to the world.

3.5.3 Life Cycle Impact Assessment Method

To describe the impacts on the environment, LCA studies applied the LCIA method (Bishop, 2000). Selection of the proper LCIA methodology is a vital step in LCA studies. For water sector, Lazarova et al., (2012) showed that the most commonly used LCIA methods are CML, Eco-indicator 99, and Eco-points 97. The CML method is a mid-point approach that does not combine damage assessment and weighting into a single score. Eco-point 97 (the updated version of this approach is called Ecological Scarcity) can calculate impacts in a single score, but it does so using 30 different impact categories and does not show the final damages to human health, ecosystems, or natural resource. Eco-indicator 99 is one of the approaches for interpreting the inventory into endpoint damages to human health, ecosystem quality and resources. The method may quantify each inventory element's contribution in a single score, which helps in identifying the significant contributors for additional sensitivity or uncertainty analysis (Alyaseri & Zhou, 2017).

The ReCipe method is a new version of the Eco-indicator 99 and CML 2002 methods. In a consistent way, the method combines midpoint and endpoint methods. Inventory data is divided into 17 impact categories. These categories are; climate change human health, ozone depletion, terrestrial acidification, freshwater eutrophication, human toxicity, photochemical oxidant formation, particulate matter formation , ionizing radiation, climate change ecosystem, terrestrial ecotoxicity, fresh water ecotoxicity, marine ecotoxicity, agriculture and occupation, urban land occupation, natural land transformation, metal depletion, and fossil fuel depletion. The methods for obtaining damage factors are described in detail in Goedkoop et al.,(2013). These impact categories are then divided into three damage categories (human health, ecosystem quality, and resource depletion), which are then weighted into a single score using normalization factors (points, Pt or millipoints, mPt). The damages to human health, ecosystem quality, and resources are measured in DALY, Species.yr, and $, respectively. The environmental damage caused by a typical product in LCA is smaller than the normalization values. As a result, most LCA findings are in micro or even nano points when using a scaling factor of 1; however, when using a scaling factor of 1000, the result is in millipoints. In this study, the version "World ReCipe H/A" will be used, which refers to the world's normalization values with an average weighting set based on a Hierarchist perspective.

The endpoint technique has a higher level of uncertainty than the midpoint approach since it requires more assumptions, data, and calculation steps to develop a complete environmental model Goedkoop et al., (2013). However, it is helpful for decision makers, designers, and manufacturers to comprehend the long-term effects of their decisions, processes, or products. The endpoint method makes it easier for them to understand and assess the long-term consequences of their decisions. Regulatory agencies can also use the endpoint technique to assess the long-term effects of rules they made and explain those effects to society. The damage categories in the endpoint method correspond to areas of protection that form the basis for sustainable development or policy choices. The midpoint methods require less data and assumptions to apply, but it is more difficult to evaluate the impacts. The effects of classified inventories, such as C_6H_6 equivalents, 2, 4-D equivalents, or CFC-11 equivalents, on our lives are difficult for decision-makers to comprehend, as is the distinction between releasing one kilogram or one ton of a substance in this or that place (Alyaseri & Zhou, 2017). As a result, human health, ecosystem quality, and resources depletion are the three categories for damages in many endpoint methods such as in ReCipe methodology. These categories are more straightforward for many decision-makers to evaluate than the midpoint impact categories, which some studies find to be ambiguous.

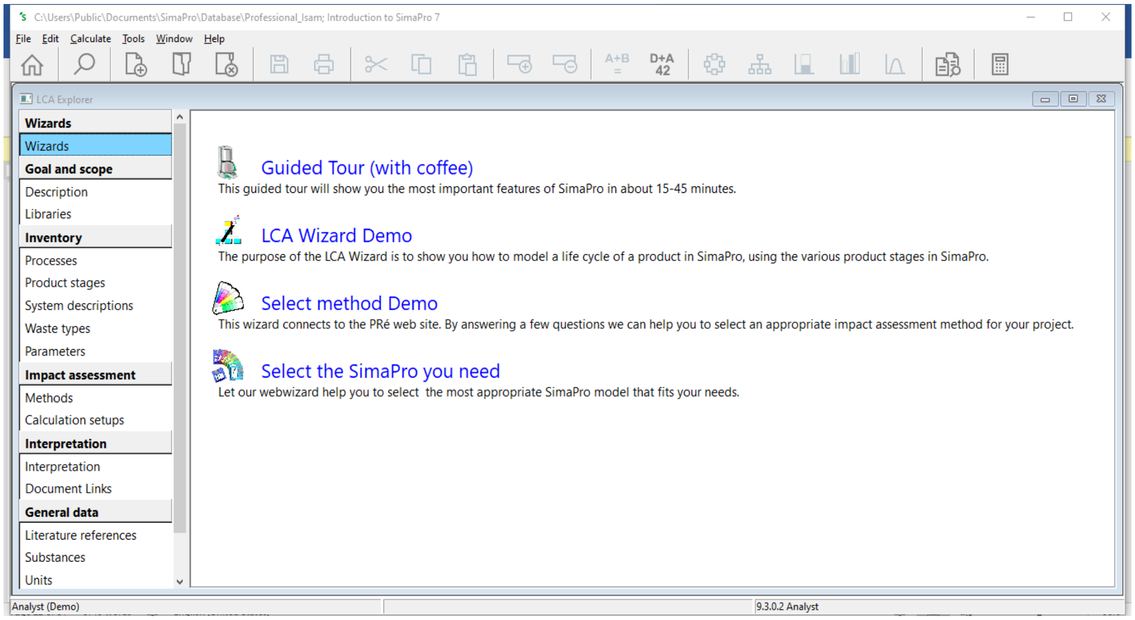
3.5.4 Function Unit

The most commonly used functional unit is one cubic meter of treated wastewater (Gallego et al., 2008). However, because it does not reflect the quality of the influent or the WWTP's removal effectiveness, this unit is not always representative especially when comparing two systems with varying influent loads or removal efficiencies. In some cases, the unit population equivalent that was defined as the organic biodegradable load with a five-day biochemical oxygen demand (BOD_5) of 60 g of oxygen per day, is used to account for both amount and quality of wastewater (Gallego et al., 2008). Because the objective of this study is not to compare to other WWTPs, the use of one cubic meter of influent wastewater to the WWTP in this case study is considered acceptable. The characteristics of this cubic meter of influent wastewater were explained in the case study description.

3.5.5 Layout of Al-Samawah WWTP LCA Model

To perform a LCA model, a SimaPro v9.3.0 software was downloaded from its manufacturar website (PRe' Consultants). The layout of this model is described in the steps below:

1) Starting SimaPro by double-clicking on the SimaPro v9.3.0 icon. The program interface will be shown in **Figure 3-11** at the first.
2) Using the Wizards section, choose the Guided tour after opening the project introduction to SimaPro. The wizard will guide you through some screens and provide an overview of SimaPro's capabilities.



Guided Tour (with coffee)

This guided tour will show you the most important features of SimaPro in about 15-45 minutes.

LCA Wizard Demo

The purpose of the LCA Wizard is to show you how to model a life cycle of a product in SimaPro, using the various product stages in SimaPro.

Select method Demo

This wizard connects to the PRé web site. By answering a few questions we can help you to select an appropriate impact assessment method for your project.

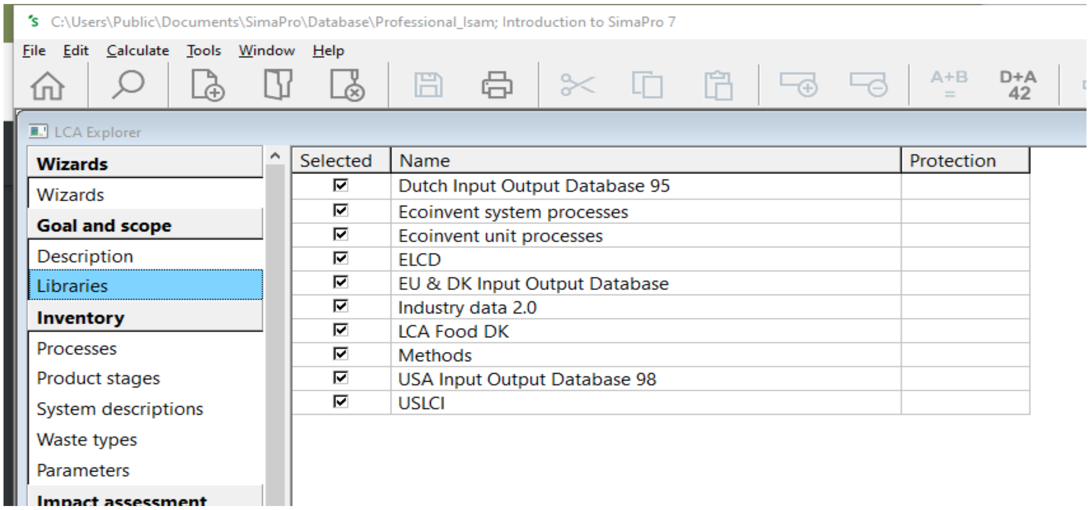
Select the SimaPro you need

Let our webwizard help you to select the most appropriate SimaPro model that fits your needs.

***Figure 3-11**. SimaPro Program Interface at the First.*

3) Inspecting goal and scope :- in the explorer bar, under goal and scope, there is a description of this fictional project.
4) Inspecting the processes in the database :-examine the range of processes available in the database by selecting processes from the inventory menu. Double-click on process (wastewater) and after that select wastewater treatment .The procedure has become up for inspection, and see how it is

defined. **Figure 3-12** shows database that used.The program has ready-made models, or a model can be designed by the assumptions of the program if the data is incomplete, using an appropriate database.



Selected	Name	Protection
☑	Dutch Input Output Database 95	
☑	Ecoinvent system processes	
☑	Ecoinvent unit processes	
☑	ELCD	
☑	EU & DK Input Output Database	
☑	Industry data 2.0	
☑	LCA Food DK	
☑	Methods	
☑	USA Input Output Database 98	
☑	USLCI	

***Figure 3-12**. Screenshot of Database Used in SimaPro .*

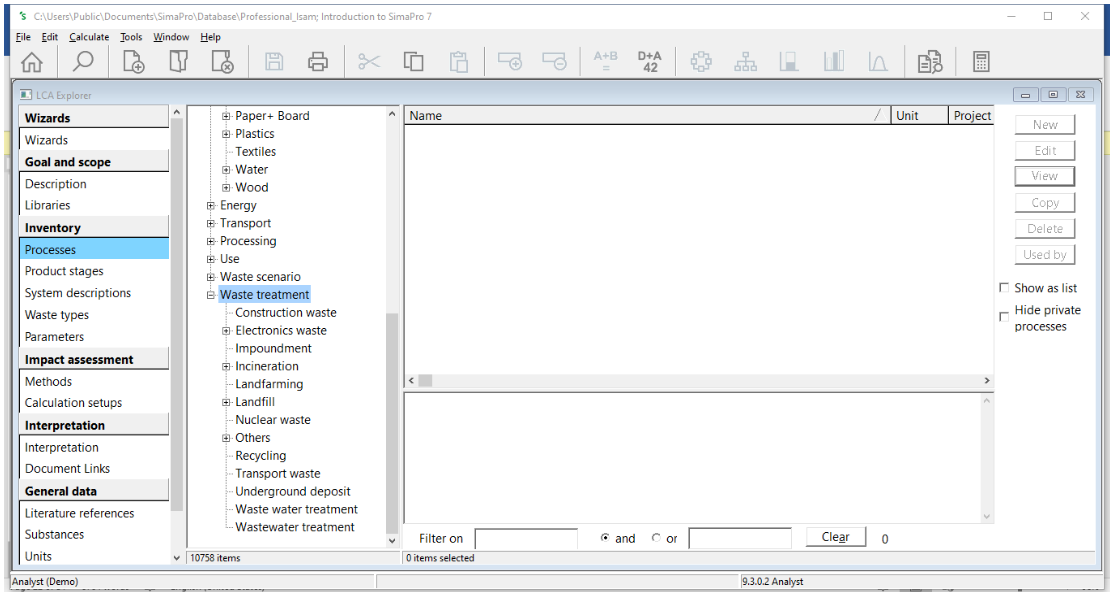
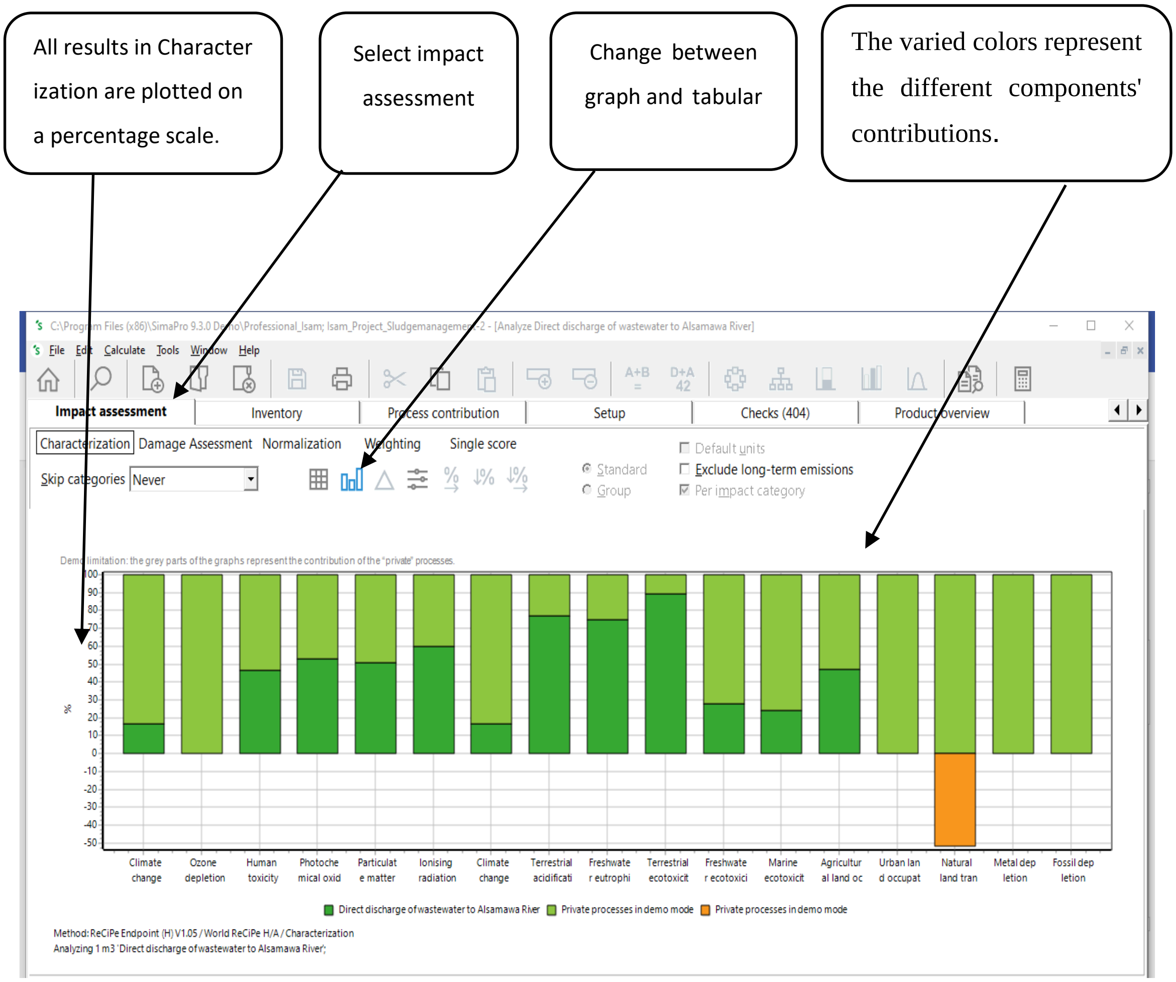


***Figure 3-13**. Process Used in Analysis .*

5) Analyze a product's environmental profile after entering data ,to get the inventory and impact assessment data, as well as the process contributions as shown in **Figure 3-14**, click the (Analyze) toolbar button and then (Calculate).



All results in Characterization are plotted on a percentage scale.

Select impact assessment

Change between graph and tabular

The varied colors represent the different components' contributions.

C:\Program Files (x86)\SimaPro 9.3.0 Demo\Professional_Isam; Isam_Project_Sludgemanagement-2 - [Analyze Direct discharge of wastewater to Alsamawa River]

Skip categories: Never

◉ Standard
○ Group

☐ Default units
☐ Exclude long-term emissions
☑ Per impact category

Demo limitation: the grey parts of the graphs represent the contribution of the "private" processes.

Method: ReCiPe Endpoint (H) V1.05 / World ReCiPe H/A / Characterization
Analyzing 1 m3 'Direct discharge of wastewater to Alsamawa River';

***Figure 3-14**. Results of the Inventory and Impact Assessment.*

6) Three of the many possibilities for the results window are presented as follows:

- LCI result : The result of the inventory is a comprehensive list of emissions and resources. Select the Inventory option. It can be found on the right hand side of the Impact Assessment tab.
- The different impact assessment phases can be followed by using the buttons characterization,damage assessment,normalization, weighting, and single score.These are sub-tabs of the tab impact assessment shown in **Figure 3-14**.

- Analysis of Process Contribution:- This displays how much each individual process contributes to a certain effect category or metric.

The option of right-clicking a graph or right-clicking the tables in this results window is a special aspect. The opportunity to further specify the findings is then available.

3.6 Procedure of Health Risk Assesment (HRA)

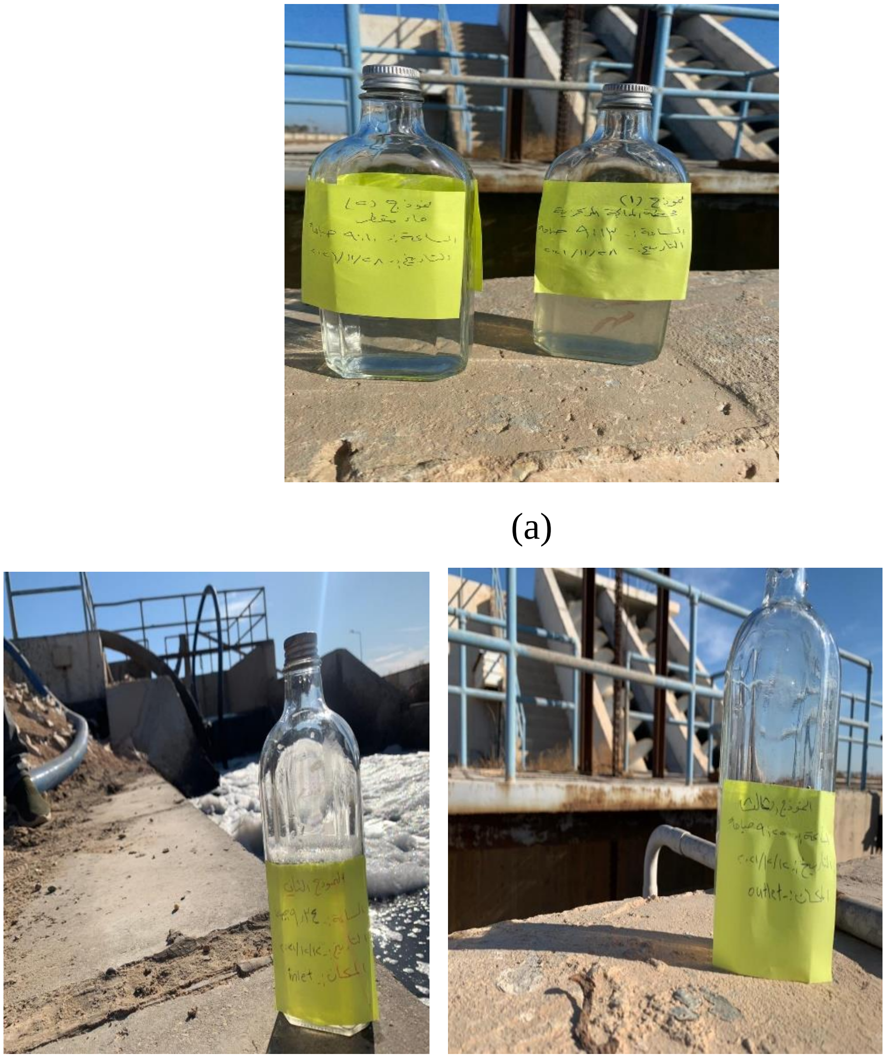
Due to limited measurement of pathogens in governorate labs and limited data ,only E-coli and TC causing diarrhea from consuming by people were considered in this study. This limited HRA may be used as an indicator for the damages caused by the direct discharge of wastewater to the river. A number of studies was conducted for a health risk assessment by using a simplified procedure (Howard & Pedley, 2003). Similar procedure was conducted to perform a health risk assessment for E-Coli in the wastewater discharged from AL-Samawah WWTP.

***Table 3-2**. The Simplified Procedure of Conducting the Health Risk Assessment(Howard & Pedley)*

Raw water quality, organisms per 100 ml (CR)	Will be calculated from concentrations in standard volumes (e.g 100 ml) and will be for E-Coli and TC.
Treatment effect (Pr) %	Estimated or calculated removal of pathogens
Drinking water Quality (DWQ) ml	DWQ = CR x (1-Pr)
Consumption of unheated drinking water (V) (number)	Estimated or calculated
Exposure by drinking water, organisms per liter (E)	E = DWQ x V
Dose-response(r)	From literature
Risk of infection per day (Pinf,d)	E x r
Risk of infection per years (Pinf,y)	Pinf,d x 365
Risk of diarrhoeal disease given infection (Pill|inf)	From literature
Risk of diarrhoeal disease (Pill)	Pinf,y x Pill|inf
Disease burden (db)	Calculated
Fraction susceptible (fs)	From literature
Disease Burden (DB) %	Pill x db x fs

3.7 Samples Collection of E. coli and Total Coliform

Three samples were taken to test E. coli and Total Coliform in the influent and effuent water of the plant. The first sample was taken for efflunt water (Figure 3-15-a), and the second and third one were taken for the influent and effluent water as shown in Figure 3-15-b,c, respectively. This procedure includes taking distilled water samples for quality assurance and quality control (Iraqi standards) based on(9221 A-C Multiple-Tube Fermentation Technique for Members of the Coliform Group, 9221D Presence-Absence Coliform Test & 9221E Fecal Coliform Procedure)(Cummings).



(a)

(b) (c)

Figure 3-15. *a) sample of effluent ,(b) and (c) Influent and effluent Samples, respectively(taken by Zahraa on October 28th, 2021)*

3.7.1 Biological Analysis of Experimental Works

Following the collection of samples from the selected locations, the samples were transferred to the environmental laboratory for examination. The tests were carried out in accordance to the Iraqi standard specification. The procedure of test in the laboratory were executed as follows:

1- Five tubes of the sterile Lauryl tryptose broth (monoconcentrate) culture medium prepared in advance as mentioned in the hypothetical examination method, are arranged in three groups and placed in the test tube rack to make dilutions (0.01,0.001, and 0.1 ml) or more according to the nature of the water sample.

2- To make the decimal dilutions, at first, shake the sample about (25) times and by means of a marked pipette by transferring (1) from the sample to the tube containing (9 ml) of a solution of Butter marked and prepared in advance, so the dilution of (0.1) and (0.01) was used. To transfer (1) from the first dilution to the bob containing (9) of the Buffer solution, and in the same way the rest of the dilutions was acheived.

3- Add (1 ml) from the tube containing the first dilution (0.1) to each tube of the first five tubes in the first group and (1 ml) from the tube containing the second dilution (0.01) to all tubes of the five tubes in the second group, and so on with the rest of the dilutions, the tubes are gently shaked to distribute the sample in a homogeneous manner in the feeding medium.

4- The injected tubes are placed in the incubator at 35± 0.5 °C for 24 ± 2 hours.

5- The tubes are read at the end of the incubation period by examining each tube to detect the presence of any growth (gas or acid, which changes the color of the medium).

6- The number of positive tubes is recorded and the negative tubes are re-incubated until 48±3 hours and at the end of this period, the tubes are checked again, and the number of positive tubes is recorded as well.

3.8 Summary

The model that was used to evaluate the environmental impact and understand the wastewater by modeling and performance evaluating of AL-Samawah WWTP. BOD, COD, TSS, and other metrics were utilized in modeling and performance evaluation of the plant. This chapter's summary as follows:

- The studied plant was described in all of its stages and units in this chapter.
- The plant's operational values were utilized to evaluate its performance.
- SimaPro 9.3.0 software has been used to model the environmental impact of Al-Samawah WWTP.
- Use the simplified procedure to perform a quantitative microbial risk assessment.

Chapter Four: Results and Discussion

Results and Discussion

4.1 Introduction

This chapter includes results and discussion presented in three sections: the first section is talked about the operational assessment of Al-Samawah WWTP from the year 2012 to 2016 until it stopped . The second section is dealt with the modeling of Al-Samawah WWTP by life cycle assessment through using SimaPro 9.3.0 software and made a damage assessment. The third section is devoted to conducting a health risk assesement .

4.2 WWTP Operational Assessment

Table 4-1 shows the characteristics of wastewater treatment system influent and effluent. This table shows the statistical parameters for BOD_5, COD, TSS, TDS, SO_4 , NO_3, CL, PO_4, NH_3,O&G, and H_2S concentrations.

***Table 4-1**. Influent and Effluent Concentrations Statistics and Standards for Ten Parameters in Al-Samawah WWTP.*

Parameter mg/l	Number of tests		Average		St. Deviation		Median		Range	Iraq's Standards
	In	Out	in	out	in	out	in	out	out	out
BOD_5	75	70	107	36	46	19	110	34	(5-105)	40
TSS	85	95	451	326	267	113	420	360	(20-540)	60
TDS	77	85	5573	5643	1856	1500	5580	6180	(1280-7800)	
COD	81	80	217	118	66	33	220	120	(12-188)	100
NO_3	69	70	13	12	9	10	10	9	(1-46)	50
NH_3	58.0	54.0	15.3	16.4	7.0	8.0	15.5	14.5	(0.7-43.6)	10
SO_4	82	82	1237	1318	555	523	1193	1288	(92-3872)	
PO_4	85	83	0.29	0.13	0.21	0.08	0.28	0.11	(0.01-0.3)	3.00
O&G	47	43	219	159	158	138	160	80	(18-480)	4
CL	95	95	2064	2066	850	725	1987	2194	(3365-222)	600

H_2S	76	34	24.2	3.9	11.3	2.4	22.0	3.4	(0.4-10.6)	0.5

4.2.1 BOD_5

The BOD_5 concentrations values of the plant's influent wastewater is 107 mg/L with a standard deviation (S.D) of 46 mg/L, whereas the wastewater leaving the plant contains an average BOD5 concentrations values of 36mg/L with (S.D) of 19 mg/L. For a biological unit operating in extended aeration activated sludge mode, the hydraulic detention period at the aeration tank is 24 hours (according to the average flow of the plant). Figure 4-1 shows the BOD_5 content of the influent and effluent wastewater, as well as the Iraqi standard concentration (40 mg/L). The plant was able to reduce the BOD_5 concentration in the raw wastewater from an average of 107 mg/L to an average of 36 mg/L in the discharged wastewater. This removal rate could be attributed to the stability of microorganisms that are performing well due to adequate oxygen transmission (Metcalf et al., 2014), and the long retention time in the aeration tank. According to Figure 4-1 the years 2013 to 2016 show the most noncompliance with the standards, most likely because of insufficient dissolved oxygen (DO) for aerobic decomposition due to improper aeration in the aeration basin. Continuous monitoring of DO concentrations in the basin (which is not recorded) will offer a clear picture of the amount of DO supplied and consumed for aerobic organic matter decomposition. Temperature, basin geometry, degree of mixing, and wastewater properties are all factors that determine the amount of DO in the aeration basin. In this plant, the DO is not measured in the aeration tank frequently. The aeration method utilized, whether mechanical aeration or air diffussion, is the most important factor (Eckenfelder et al., 2002). Now,the mechanical aerators are used in the plant. As shown in Figure 3-6, only three aerators per tank are used. However, considering the air required with the hydraulic retention time, one can imagine how these only three aerators can provide air to the tanks.

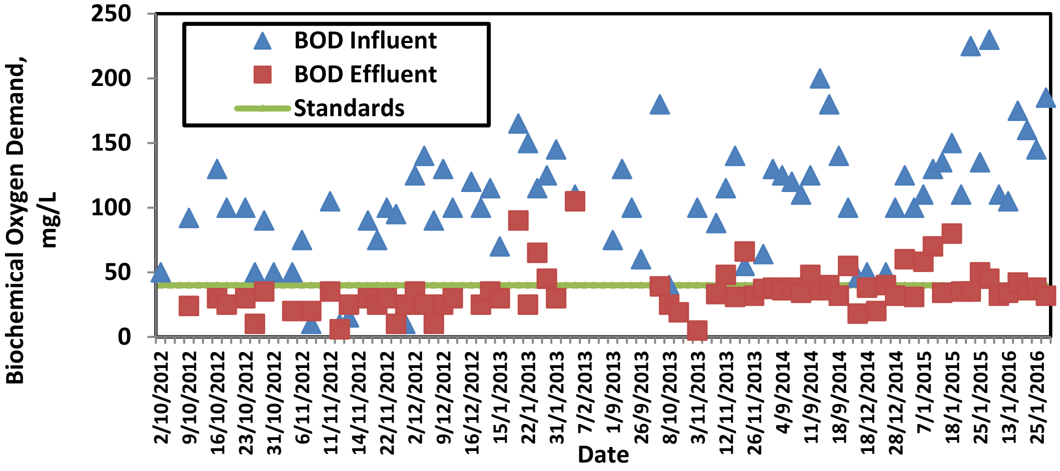


Figure 4-1. *BOD₅ in Input flow and Output Flow of Al-Samawah Wastewater Treatment Plant for the Period from October 2ed ,2012 to January 20th , 2016. Green Line Refers to the standard value of BOD₅.*

Figure 4-2 shows the trend of effluent concentration of (BOD_5) with years from the year 2012 to the year 2016.

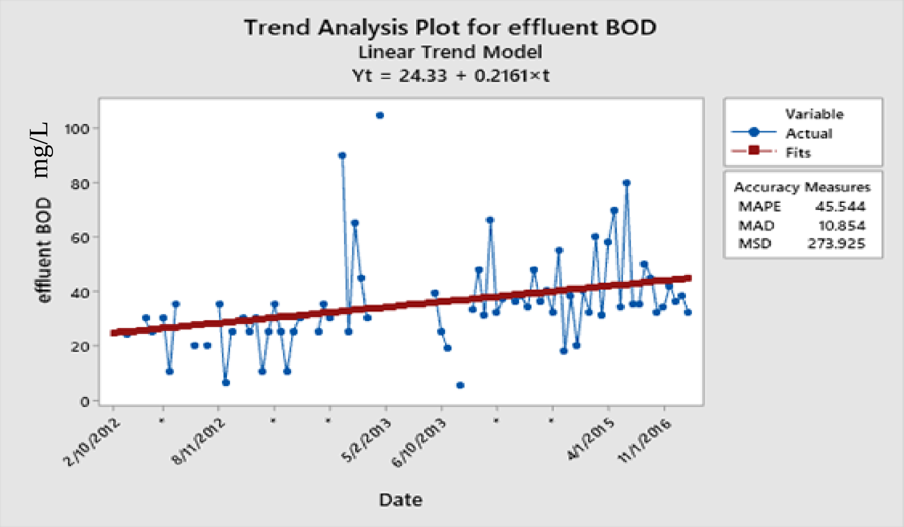


Figure 4-2. *Trend Analysis Plot for BOD₅ concentrations in the Effleunt.*

The main operating element in this system is the large masses of microorganisms that grow in the aeration basin and form flocs that settle in the secondary sedimentation tank (secondary clarifier) before being returned to the aeration basin as Return Activated Sludge (RAS) or wasted from the system as Waste Activated Sludge (WAS). If the clarifier's settling mechanism fails, the effluent will contain a high concentration of microbial material, which is measured as BOD_5 or COD (Espírito Santo et al., 2005). Starting from the year 2013, high percentage of sediments starts to be noticed in the aeration basins and the ability of the clarifies to settle flocs starts to be reduced. This may be attributed to the failure in the operation management of grit removal in addition to the accumulation of TSS in the aeration basins due to the lack of maintainance.

4.2.2 COD

The average concentrations value of COD and BOD_5 in the wastewater entering the plant is 217 mg/L and 107 mg/L with a standard deviation (S.D) of 66 mg/L and 46 mg/L, respectively, whereas the average concentrations value of COD and BOD5 in the effluent leaving the plant is 118 mg/L and 36 mg/L with a standard deviation of 33 mg/L and 19 mg/L, respectively. The difference between the average BOD5 and COD in the influent wastewater is 110 mg/L which refers that this wastewater is contaminated by highly non-biodegradable materials. One should noticed that this contamination will continue pollute river and will not be affected by river self purification which usually occurs after wastewater discharge . COD concentrations in discharged wastewater should not exceed 100 mg/L according to the Iraqi standards. Figure 4-3 shows the COD concentration values in influent and effluent with the limit of Iraqi specifications. These values of the effluent always exceed this limit except in a part of the year 2012 (the first year of operation) and then they began to exceed this limit due to the poor treatment of wastewater which resulted in raising the level of COD in the effluent and this is the same reason for the increase in the concentration of BOD5 (Metcalf et al., 2014). Figure 4-4 shows the trend of effluent concentration for COD from the year 2012 to the year 2016.

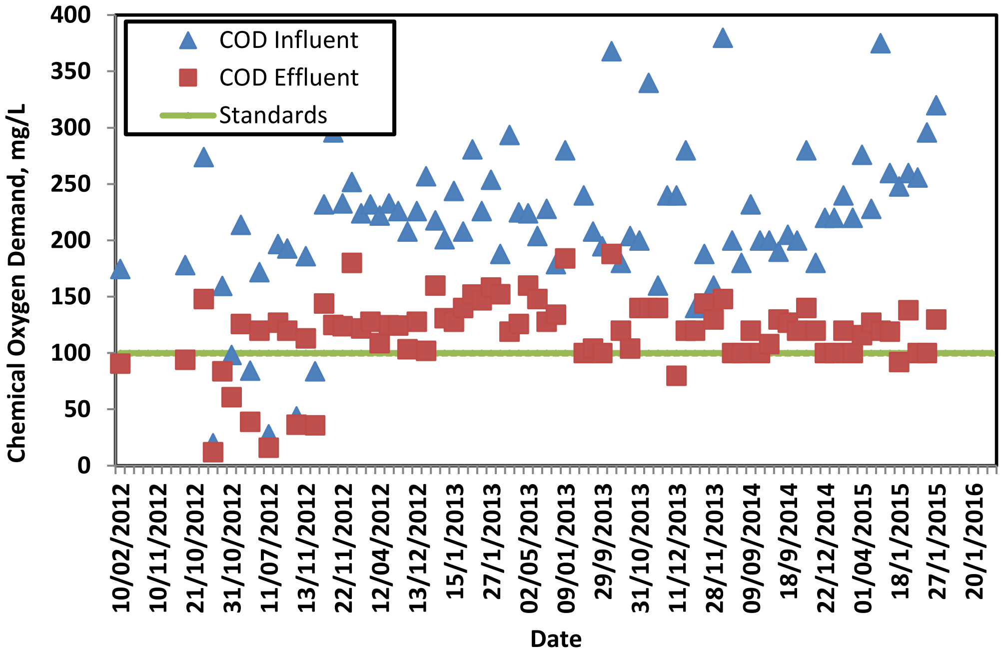


Figure 4-3. *COD Concentration Values in Input and Output Flow of Al-Samawah Wastewater Treatment Plant for The Period From February 10th 2012 , to January 20th , 2016. Green Line Refers to The Standard Value of COD.*

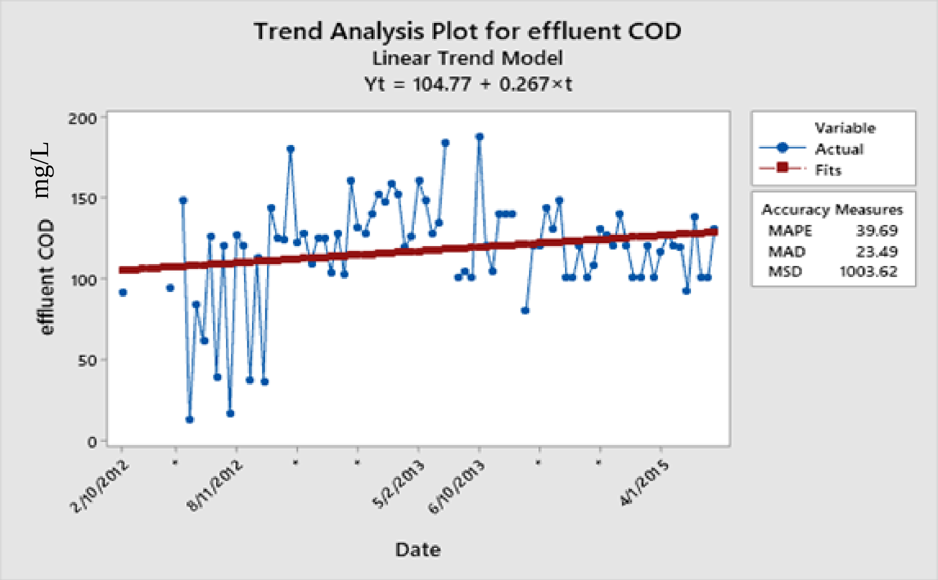


Figure 4-4 *Trend Analysis Plot for COD Concentrations in the Effleunt*

4.2.3 TSS

The average concentrations value of TSS in the influent is 451mg/L with a standard deviation of 267mg/L, whereas the average value of TSS concentrations in the effluent is 326mg/L with a standard deviation of 113mg/L.The Iraqi's standards for TSS concentrations in discharged wastewater is 60 mg/L. From ninety-five samples of effluent tested from the year 2012 to the year 2016, only three samples of TSS discharged into the river were below the maximum limits of 60 mg/L as shown in Figure 4-5. These three samples were tested in the year 2012. passes wastewater directly to the aeration tanks , the grit chambers were not hold wastewater and allow the grits to settle as shown in Figure 4-7. It is obvious that the plant does not comply with this standard even at the beginning of its operation. The results show that the deterioration of the processes in the plant is related to the lack of maintenance. Figure 4-6 shows the trend of TSS.

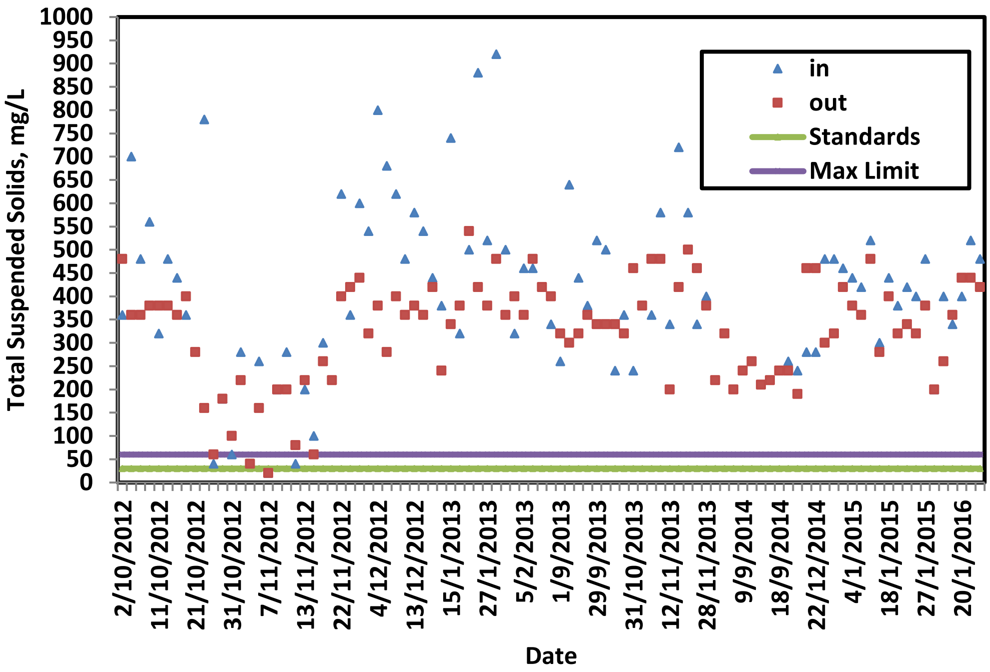


Figure 4-5. *TSS in Input and Output Flow of Al-Samawah Wastewater Treatment Plant for The Period From February 10th , 2012 to January 10th , 2016. Green Line Refers to The Standard Value of TSS.*

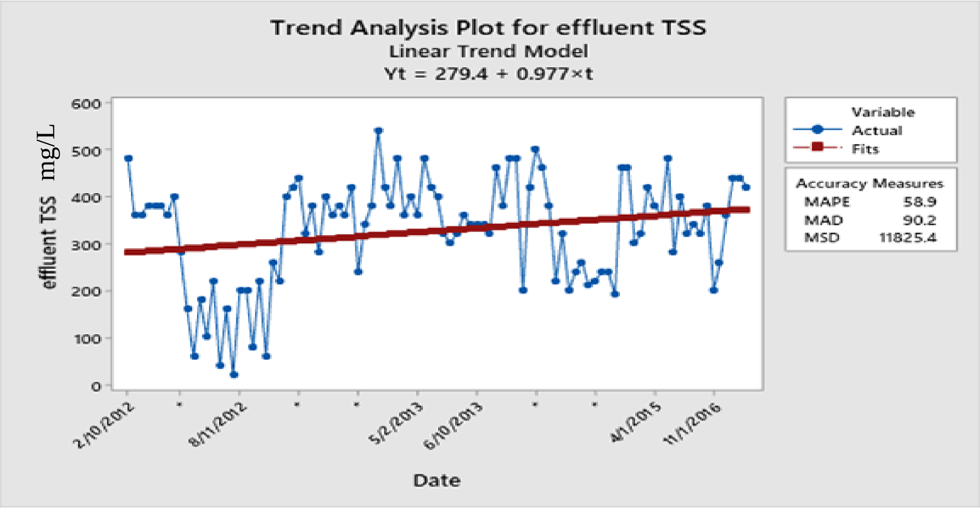
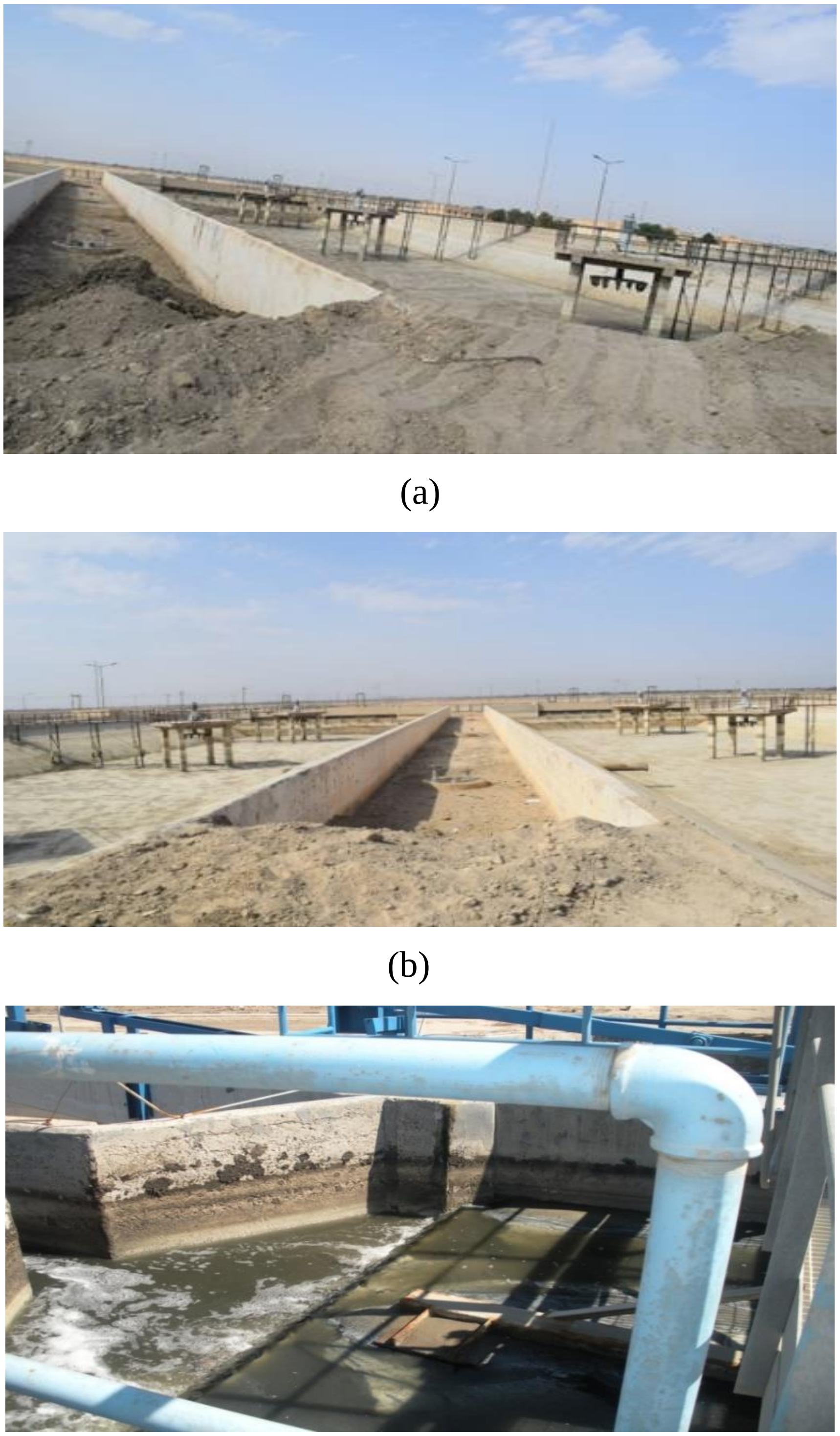


Figure 4-6. *Trend Analysis Plot For TSS Concentrations in The Effleunt.*



(a)

(b)

(c)

Figure 4-7*a, b, and c. Grits and Solids Accumulated in Aeration Tanks and Grit Removal Basins. (taken by Zahraa on October 28th, 2021)*

This case study shows the role of improper operation on plant’s operations. As mentioned by (Alyaseri, 2016b), it is unacceptable that a plant designed to treat wastewater of an average value of TSS concentration of 450 mg/L is arranged with an activated sludge process and no primary clarification, even if the purpose was to build an extended aeration process but this type of process is usually built for small towns only. Also, this process is used in places where small concentrations of TSS are found in the influent wastewater (Metcalf et al., 2014).The no treatment for TSS may consider the main reason for the gradual degradation in treatment processes in the plant.

4.2.4 Oil & Grease

Production of crude oil, oil refineries, petrochemical industries, metal processing, compressor condensates, lubricant and cooling agents, car washing, and restaurants all produce oil-contaminated wastewater (Lan et al., 2009). Oily water is increasingly polluting world water bodies; its impacts on aquatic living organisms can be irreversible, and the repercussions of these effects are conveyed indirectly or directly to people, who are also involved in the ecosystem's food chain. When oil and grease are present in water bodies, an oil layer forms causing substantial pollution issues such as reduced light penetration and photosynthesis. It also obstructs oxygen transport from the atmosphere to the aqueous medium, resulting in a reduction in dissolved oxygen (DO) at the water's bottom, which has a negative impact on aquatic life's existence in water (Jameel et al., 2011). In the present study, the average value of Oil and grease concentrations in the influent and effluent wastewater is 219mg/L and 159 mg/L with a standard deviation of 158 mg/L and 138 mg/L, respectively. Figure 4.8 shows the concentrations of oil and grease in the influent and effluent wastewater as well as the Iraqi standard concentration of 4 mg/L. The plant is not able to reduce oil and grease because the plant did not has a unit to treat it and the design is improper for floating grit removal. The concentrations value of oil and grease is far beyond the permissible limit of these concentrations which is 4 mg/L in the discharged wastewater. Figure 4-9 shows the trend of oil and grease concentrations in the effluent from 2012 to 2016.

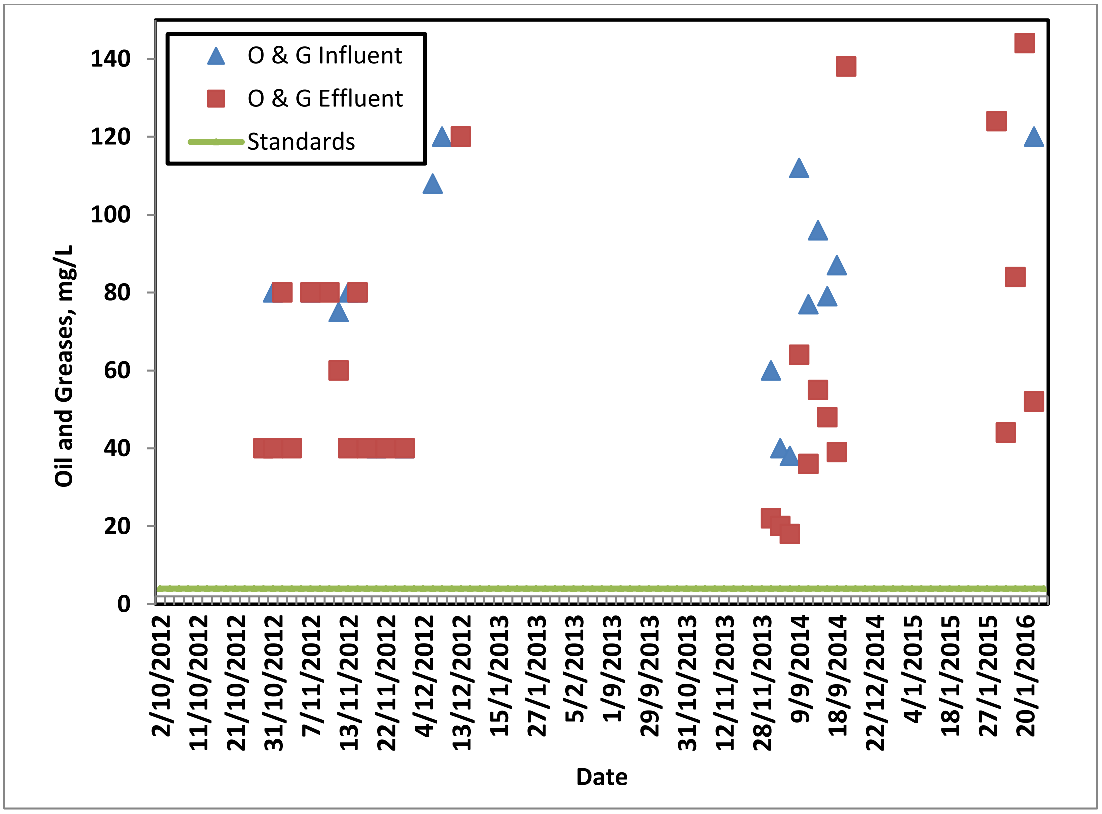


Figure 4-6.*O&G in Input and Output Flow of Al-Samawah Wastewater Treatment Plant for The Period From October 2*^{ed} *,2012 to January 20*th *, 2016****.*** *Green Line Refers to The Standard Value of O&G.*

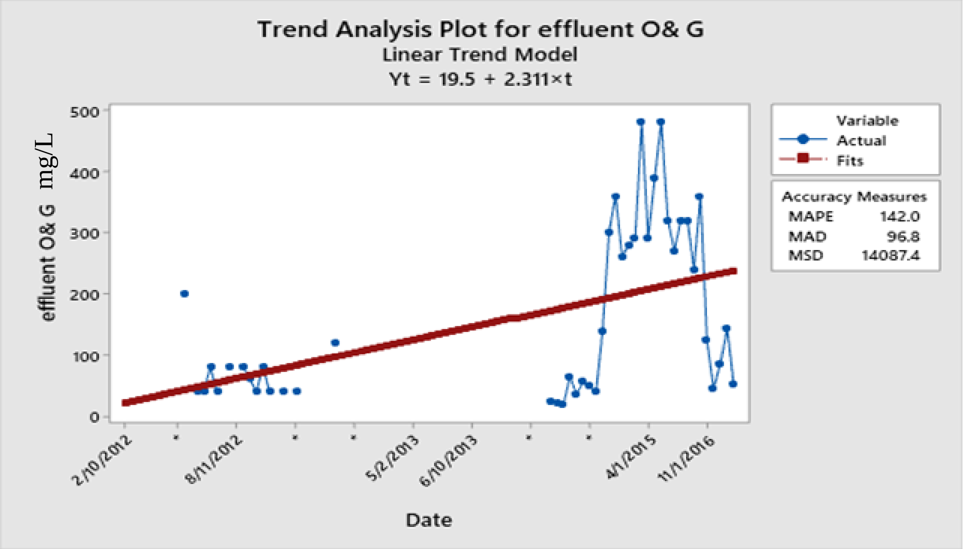


Figure 4-7. Trend Analysis Plot for O&G Concentrations in The Effleunt.

4.2.5 NH_3

The average value of NH_3 concentration in the influent is 15.3mg/L with a standard deviation of 7.0 mg/L, while in the effluent, the average value of NH_3 concentration is 16.4mg/L with (S.D) of 8.0 mg/L. The NH_3 concentrations values in the effluent are more than the Iraqi's standard value of 10 mg/L as shown in Figure 4-10. Although this high level of NH_3 concentration, the current activated sludge process in the plant isn't designed nor modified in later to remove nutrients. It is clear that not enough aeration is provided to the NH_3 to allow the nitrification process to occur.

4.2.6 NO_3

The average value of NO_3 concentration is slightly decreased from 13mg/L to 12 mg/L which indicate that not enough oxygen is provided to the ammonia to be converted to nitrate. These results indicate the need to extend the aeration time for nitrification process or add a new unit for nutrient removal to improve effluent quality (Metcalf et al., 2014). Although the increased hydraulic retention period in the aeration tank is expected to result in an increase in nitrate concentration in the effluent (Alyaseri, 2016b), the results showed the opposite. This may be related to the limited mechanical means of providing oxygen in the aeration basins. Figures 4-11 and 4-12 shows the trend of NH_3 and NO_3 concentrations in the effluent with years from 2012 to 2016.

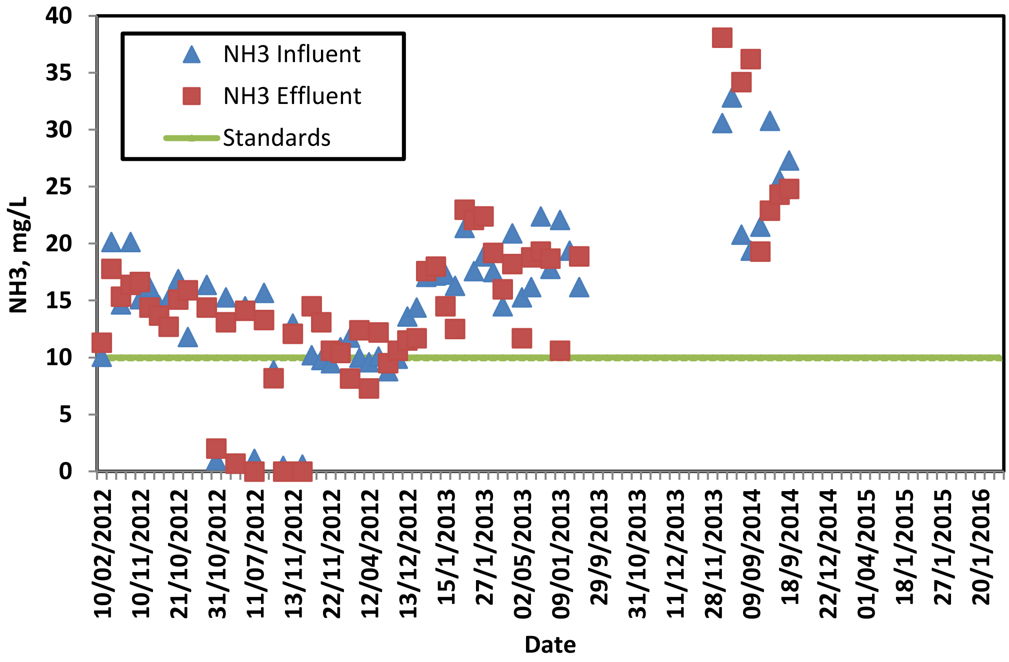


Figure 4-8. *NH_3 in Input and Output flow of Al-Samawah Wastewater Treatment Plant for The Period From February 10th ,2012 to January 20th,2016. Green Line Refers to The Standard Value of NH_3.*

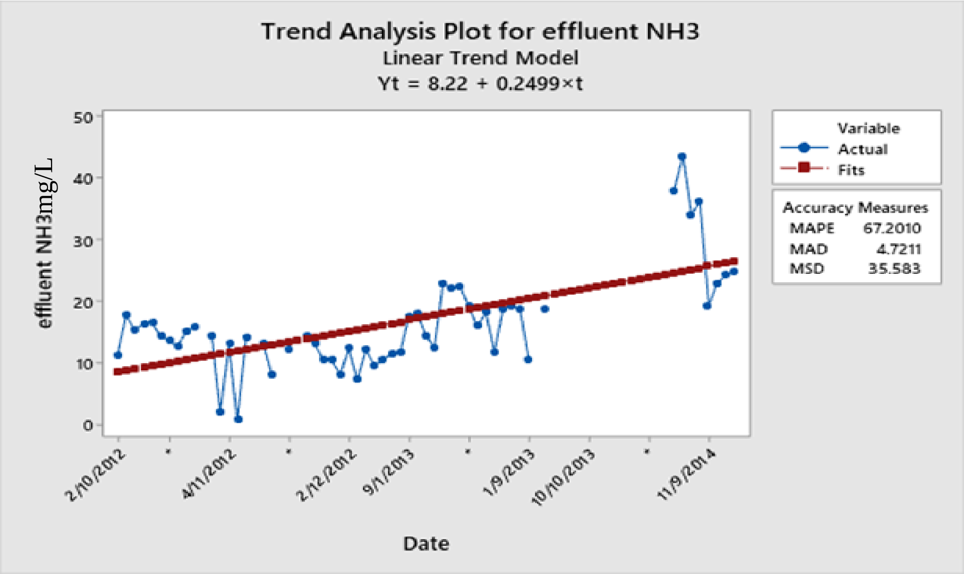


Figure 4-9. Trend Analysis Plot for NH_3 *Concentrations in the Effleunt.*

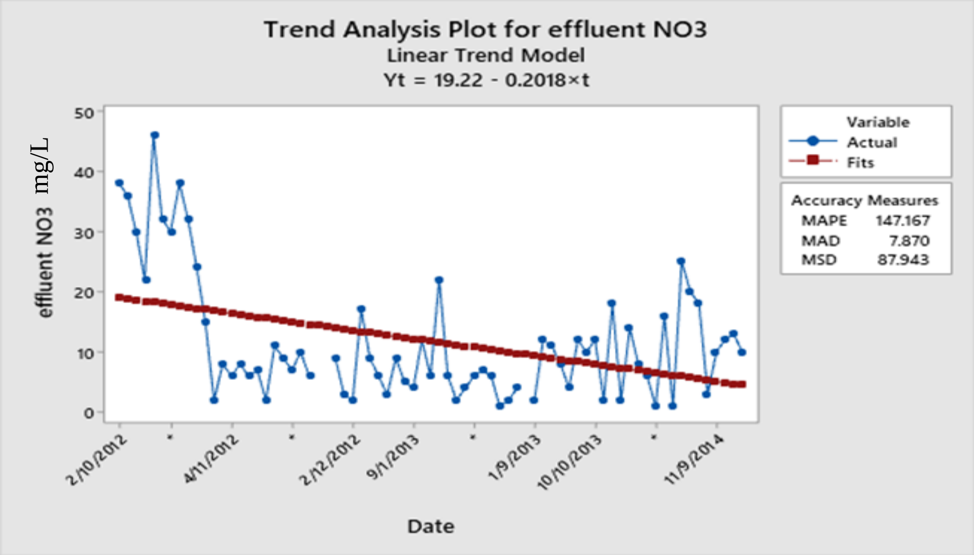


Figure 4-10. Trend Analysis Plot for NO_3 *Concentrations in The Effleunt.*

4.2.7 PO_4

For PO_4 ,the source of phosphate polluting the wastewater is the products used in cleaning powders that are rich in polyphosphate, the most common of them is tri-sodium polyphosphate, where much of it is consumed during daily cleaning operations, and microorganisms restore it to its simple state (orthophosphate) that can be consumed (Adewoye, 2010). In the plant, the average value of the PO_4 concentration in influent is 0.29 mg/L with S.D of 0.21 mg/L, while for effluent, the average value of its concentration is 0.13 mg/L with s.d. of 0.08 mg/L. The values of PO4 concentration in all the tested effluent samples which are eighty-five samples are below the local standards of 3 mg/L and typical US standards of 1 mg/L as presented in Figure 4-13. The presence of anaerobic conditions in the aeration tanks could explain the decrease in phosphorus levels. Figure 4-14 shows the trend of PO4 concentrations in the effluent.

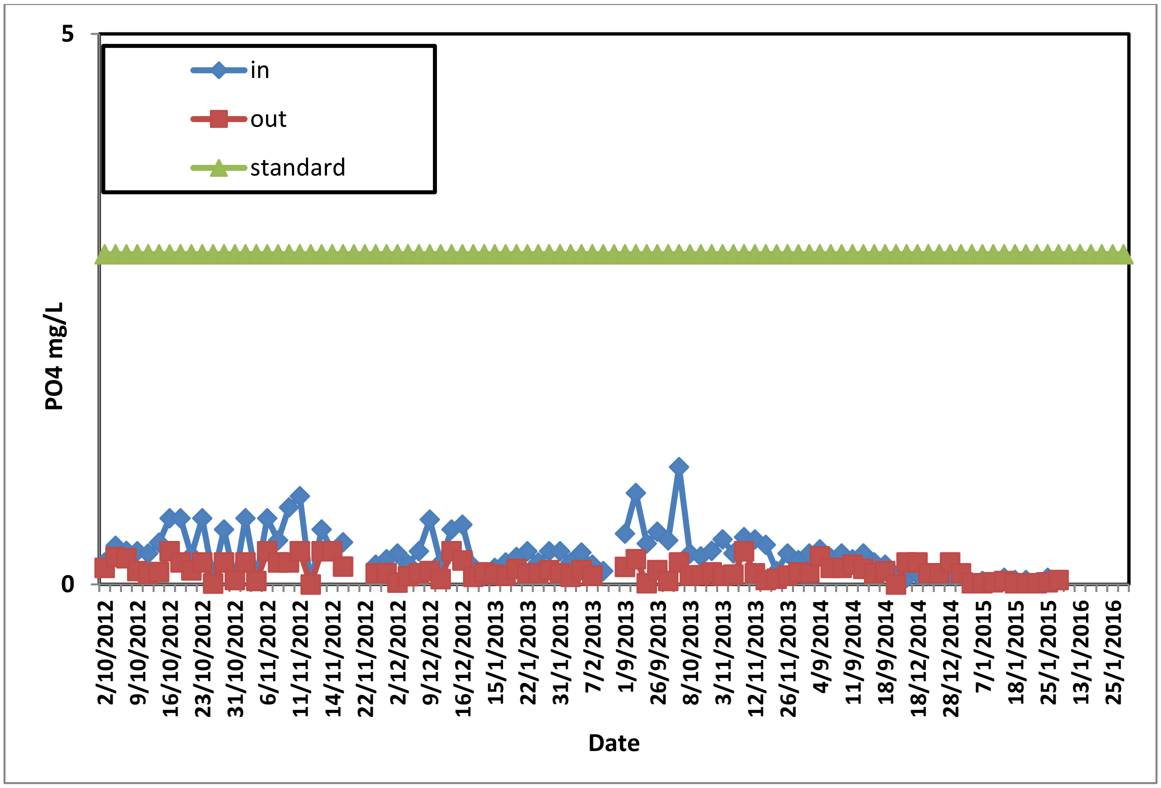


Figure 4-11. *PO_4 in Input and Output Flow of Al-Samawah Wastewater Treatment Plant for The Period From February 10th ,2012 to January 20th,2016. Green Line Refers to The Standard Value of PO_4.*

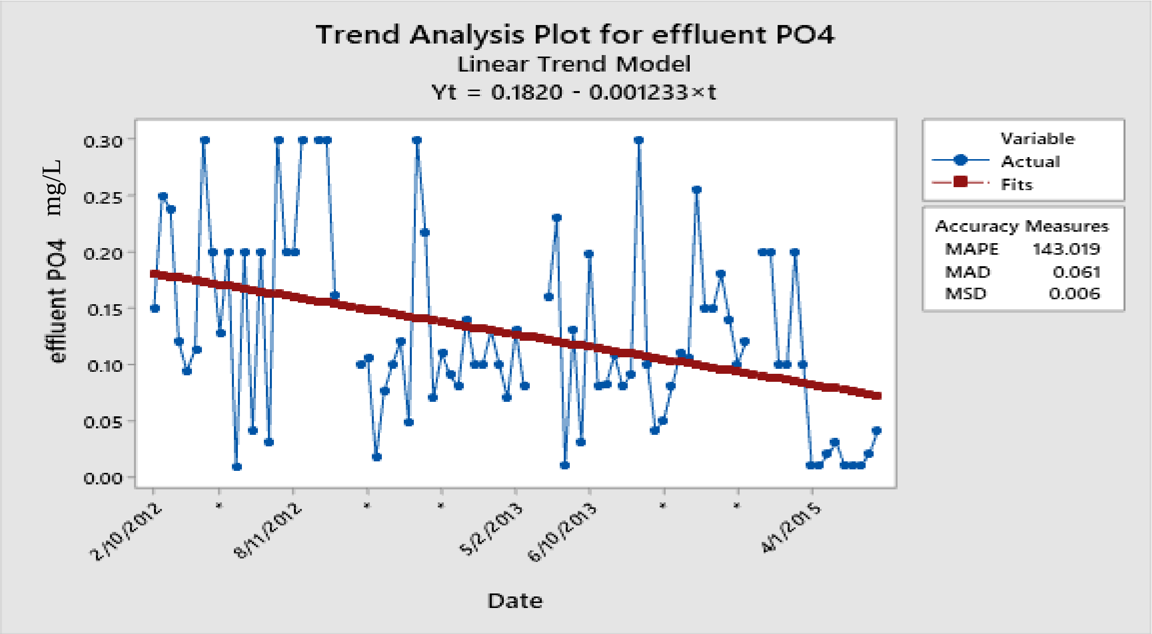


Figure 4-12. *Trend Analysis Plot for PO_4 Concentrations in The Effleunt.*

4.2.8 TDS

It was found that the average value of TDS concentration in the raw wastewater is of 5573 mg/L with S.D of 1856 mg/L, whereas the average value of TDS concentration in the effluent is of 5643mg/L with S.D of 1500mg/L. The biological treatment procedure usually cannot reduce TDS, and a high value of TDS concentration can have a significant impact on the system's efficiency (Pophali et al., 2003). Therefore, in the present study, there was no reduction in TDS concentration as a result of the treatment. The high rate of TDS has the potential to harm aquatic life as well as the area's drinking water supply. Although wastewater treatment plants have no restrictions on dumping the effluent containing a high-TDS into streams, this case study shows that such restrictions are necessary to protect aquatic life. The TDS discharging limits in the U.S is 500 mg/L. According to data from the City of Al-Samawah's Office of Environmental Protection, Al Samawah River has already passed these limits. Figure 4-15 illustrates how the values of TDS concentration in all measured samples of influent and effluent during the period from October 2012 to January 2016 were exceeded the American or WHO standards. Figure 4-16 shows the trend of TDS concentrations.

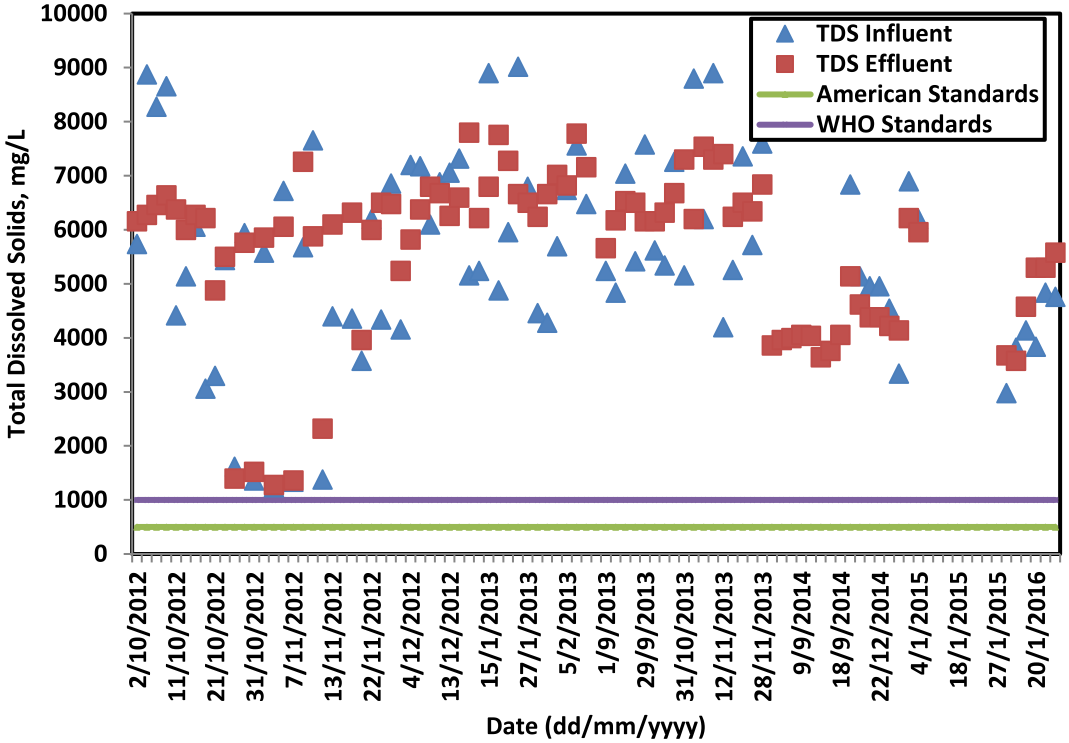


Figure 4-13. *TDS in Input and Output Flow of Al-Samawah Wastewater Treatment Plant for The Period from October 2ed ,2012 to January 20th ,2016. Green Line Refers to The Standard Value of TDS.*

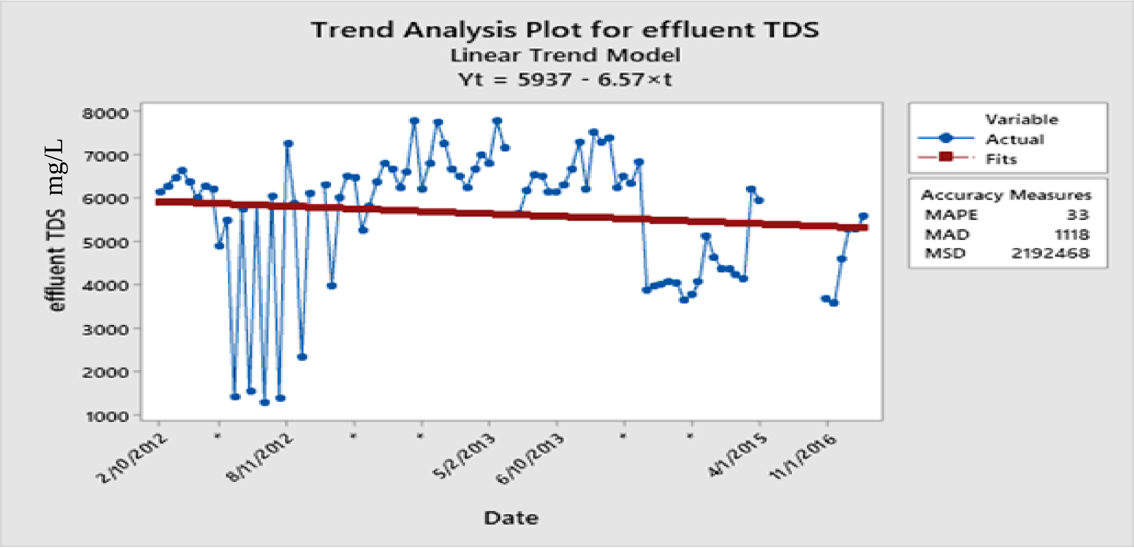


Figure 4-14. *Trend Analysis Plot for TDS Concentrations in the Effleunt.*

4.2.9 H_2S

The anaerobic decomposition of sulfur-containing organic materials forms hydrogen sulfide (H_2S) (Metcalf et al., 2014) .The average value of H_2S concentrations in raw sewage is 24.2 mg/L with (S.D) 11.3 mg/L, indicating a significant septic condition and odor pollution in the sewer system. In addition to odor issues, large amounts of H_2S in the sewer system can endanger operators' health and compromise the structural integrity of sewer systems. The excessive quantity of H_2S is likely due to the failure of vacuum pumps in the central collection tanks of sewer systems, or it could be related to the fact that the vacuum pumps aren't running continually. The average content of H_2S in the wastewater discharged was minimized to 3.9 mg/L with (S.D) 2.4 of mg/L during the plant's treatments. The H_2S standard for the discharged wastewater in Iraq is 0.5mg/L. Only 16 of the 34 effluent samples that are used to test the H_2S concentration in them during the study period are below this standard as in Figure 4-17. Sulfides, particularly hydrogen sulfide (H_2S), are water soluble and hazardous to people and fish alike. It is found that the odorous gas H_2S which is the most commonly linked with Sulfate concentrations in treated wastewater is increased on average. Thiobacillus bacteria oxidize H_2S to sulfate or sulfuric acid in hot or humid environments (Gram-negative) (Metcalf et al., 2014). Figure 4-18 shows the trend of H_2S concentrations with no change in it due to no treatment for this contamination.

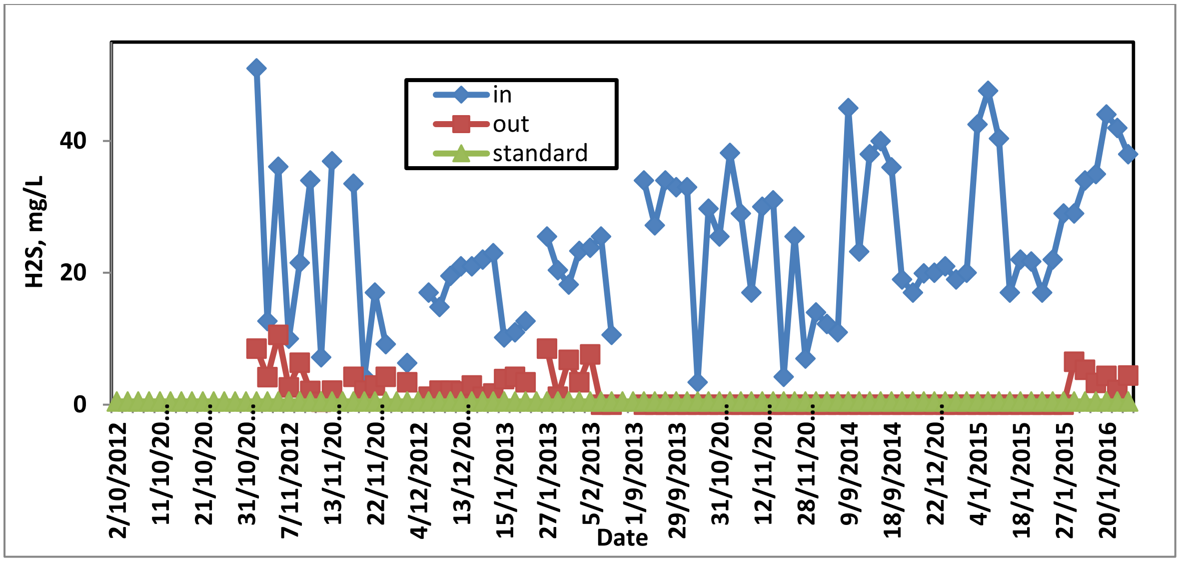


Figure 4-15. *H_2S in Input and Output flow of Al-Samawah Wastewater Treatment Plant for The Period From October 2ed ,2012 to January 20th ,2016. Green Line Refers to The Standard Value of H_2S Concentration.*

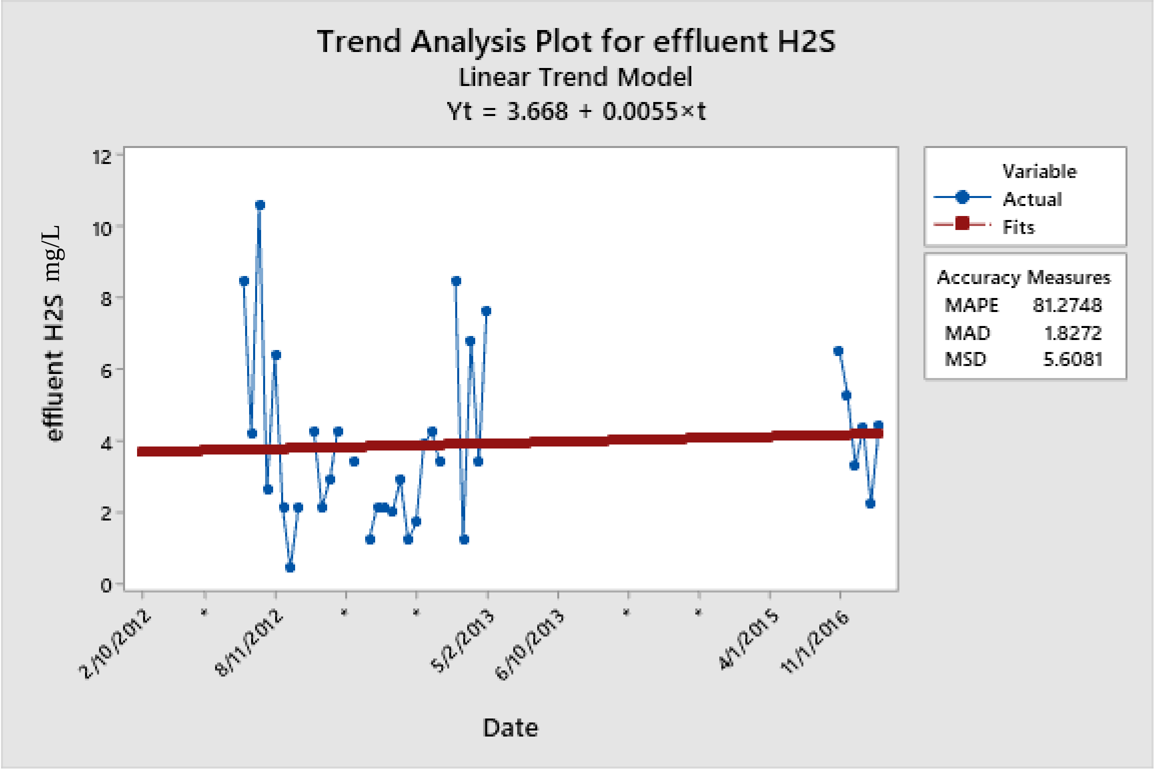


Figure 4-16. *Trend Analysis Plot for H_2S Concentrations in The Effleunt.*

4.2.10 Chloride

The average value of the chloride (CL) concentration in the raw wastewater is 2064 mg/L with a s.d. of 850 mg/L, while the average value of its concentration in the discharged wastewater is 2066 mg/L with a s.d. of 725 mg/L. The Iraqi standard value of CL concentration in the discharged wastewater is 600 mg/L. Like other dissolved solids, the CL concentration values refer that there is no treatment for chloride in the plant. Only a few tested samples in 2012 shown in Figure 4-19 revealed that the chloride concentration in the effluent discharged into surface water is below the Iraqi standard level of CL concentration. Data from the City of Alsamawah's Office of environment protection showed that the Al-Samawah river already exceed this level of CL. The agricultural and residential drainage activity upstream river affects the existing level of chloride. Salts may accumulate in the receiving water and present a risk to drinking water supplies and aquatic life-supporting waters. If the plant doesn't emphasize on implementing chloride treatment, the aquatic life in the river will continue to decline.

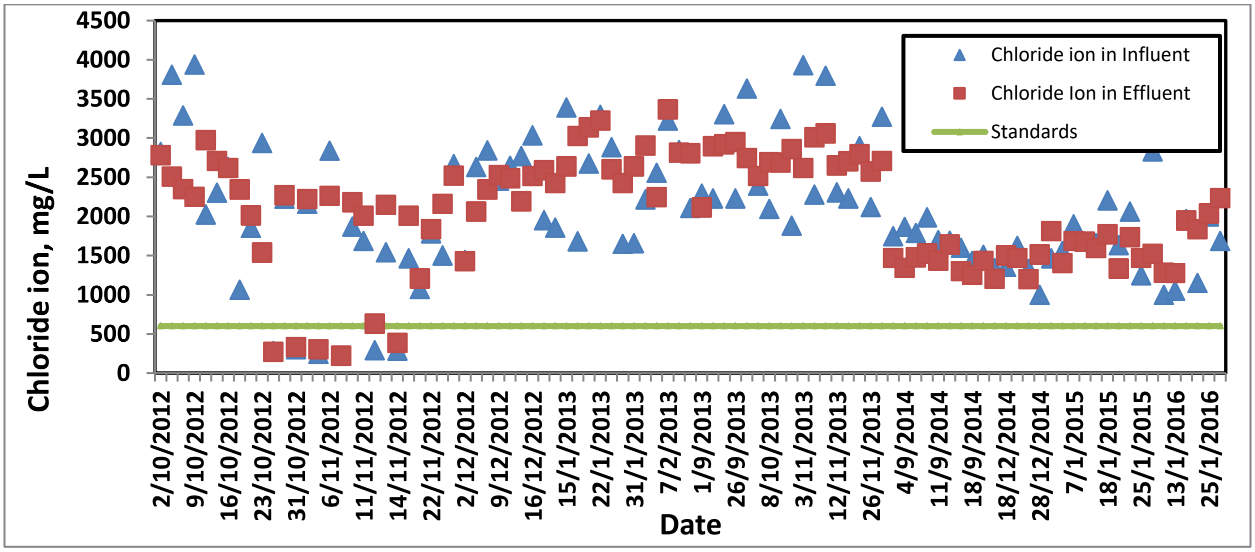


Figure 4-17. *CL in Input and Output Flow of Al-Samawah Wastewater Treatment Plant for The Period From October 2ed ,2012 to January 20th ,2016. Green Line Refers to The Standard Value of CL Concentration.*

4.3 Modeling of Al-Samawah Wastewater Treatment Plant

Al-Samawah WWTP was modeled by using LCA analysis within Simapro 9.3.0 software program according to the modeling steps mentioned in chapter three.

The impacts and damages caused by the processes were calculated using the ReCipe methodology for one cubic meter of raw sewage discharged to AL-Samawah River. Figure 4-20 shows four major groups contributing damage for three categories. Also, this figure shows that all damaged categories are affected by electricity, sewer grid, and WWTP. The damage caused by the direct discharge is limited to human health and ecosystem quality. The percentage of the highest damages to the human health and ecosystem quality caused by the construction of the WWTP is about 35.99% and 42.98%, respectively, while the percentage of the highest damage to resources caused by sewer grid installation is about 52.52%.

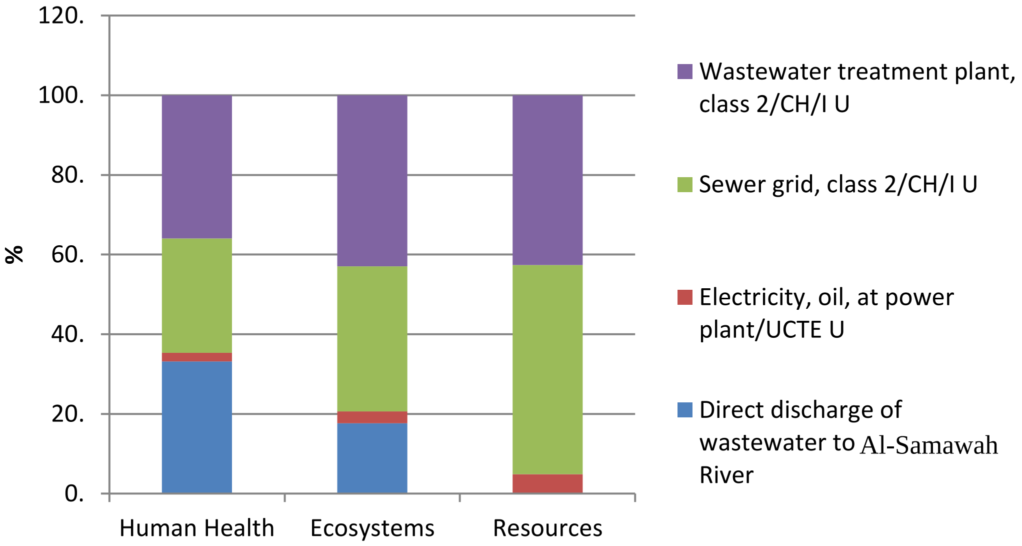


Figure 4-18. *Weighted Damage Assessment at Al-Samawah WWTP Due to The Direct Discharge of One Cubic Meter of Raw Sewage (Method: ReCiPe endpoint (H) V1.05 / world ReCiPe H/A / damage assessment).*

Table 4-2 shows the damages to every category associated with every main damage contributor. The table indicates that the highest damage value to the human health came from the construction of WWTP is 2.62x10-7 DALY/m^3 , while the lowest damages coming from the electricity is 1.59x10-8 DALY/m^3. The damage from electricity is low because the plant was stopped and the electricity is used in the administration room only. The higher damage value to the ecosystem which is 9.61x10-10 species. yr/m^3 is due to the burdens of constructing the WWTP, while the lowest damage value to the ecosystem which is 6.63x10-11 species. yr/m^3 is from the consumption of electricity. The higher depletion value of the resource which is \$0.437/ m^3 is mainly coming from the construction of the sewer grid that collects wastewater to the WWTP, while the lowest damage value of the resource which is \$0.0403/ m^3 is coming from emissions and electricity.

***Table 4-2**. Damage Assessment at Al-Samawah WWTP Due to The Direct Discharge of One Cubic Meter of Raw Sewage (Method: ReCiPe endpoint (H) V1.05 / world ReCiPe H/A / damage assessment).*

Damage category	**Direct discharge of WW**	**Electricity**	**Sewer grid**	**WWTP construction**
Humanhealth, DALY/m^3	$2.42x10^{-7}$	$1.59x10^{-8}$	$2.09x10^{-7}$	$2.62x10^{-7}$
Ecosystems, species.yr/m^3	$3.94x10^{-10}$	$6.63x10^{-11}$	$8.15x10^{-10}$	$9.61x10^{-10}$
Resources, \$/m^3	---	\$0.0403	\$0.437	0.355

Table 4-3 shows the 17 impact categories that are gathered to be in three damages categories. These impacts and damages that are related to human health, ecosystem quality, and depletion in resources all are calculated in DALY, Species.yr, and $, respectively. These three damages are then normalized and weighted to be as a single score measured in milli-points (mpt). The table indicates that the major impact value on human health from processes related to climate change human health is 3.57E-07 DALY. The two major contributors to climate change human health are WWTP and sewer grid whose values of damages caused by them are 1.49E-07 and 1.39E-07 DALY, respectively. The lowest impact value on human health related to ozone depletion is 2.69E-11 DALY. Regarding impact categories related to ecosystem quality, the highest impact of climate change ecosystem mostly comes from WWTP and sewer grid burdens and has a value of 2.02E-09 species.yr. while the lowest impact that comes from WWTP and sewer grid burdens is mostly related to marine eco-toxicity and has a value of 3.52E-15species.yr. For resources depletion, the main damage value due to the consumption of fossil fuel that mostly comes from WWTP and sewer grid burdens is $0.826.

Also, Table 4-3 shows that for every one cubic meter of untreated wastewater discharged directly to AL-Samawah River, the total damages to human health, ecosystem quality, and depletion in resources are 7.28E-07 DALY, 2.23E-09 species.yr, and $0.826, respectively. The total single score value of the damage is 30.18 mpt and the highest value of the damage single score is 11.43 mpt which comes from WWTP burdens. For the annual wastewater quantities discharged by 20000 m^3/day, the total damages to human health, ecosystem quality, and resources are 5.31 DALY, 0.016 species, and $6.03E+06, respectively. These damages are related only to operations and do not include the damages related to chemicals used in operations and pathogens discharged into the river. However, these damages are lower than the damages reported by Alyaseri (2016) when the plant was still working in 2016. This shows the need to do a health risk assessment to show the total damages related to the direct discharge of untreated wastewater into the river.

Table 4-3. Damage Assessment, and Single Score Levels of Deterioration of Treatment in Al-Samawah WWTP Using ReCipe Method.

Impact Category	Unit	Total	Direct discharge of WW	Electricity	Sewer grid	WWTP
Climate change human health	DALY	3.57E-07	5.89E-08	1.07E-08	1.39E-07	1.49E-07
Ozone depletion	DALY	2.69E-11	0	2.39E-12	1.06E-11	1.39E-11
Photochemical oxidant formation	DALY	5.77E-11	3.07E-11	1.22E-12	1.23E-11	1.35E-11
Human toxicity	DALY	1.42E-07	6.65E-08	5.13E-10	1.87E-08	5.64E-08
Particulate matter formation	DALY	2.28E-07	1.16E-07	4.76E-09	5.10E-08	5.68E-08
Ionizing radiation	DALY	1.13E-09	6.79E-10	2.36E-12	2.13E-10	2.39E-10
Natural land transformation	Species, yr	6.27E-12	0	5.11E-12	-6.72E-12	7.88E-12
Freshwater eutrophication	Species, yr	8.78E-12	6.58E-12	9.13E-15	8.17E-13	1.37E-12
Climate change Ecosystem	Species, yr	2.02E-09	3.33E-10	6.04E-11	7.87E-10	8.44E-10
Terrestrial acidification	Species, yr	1.62E-11	1.25E-11	4.06E-13	1.53E-12	1.77E-12
Terrestrial ecotoxicity	Species, yr	1.82E-11	1.62E-11	1.90E-13	8.04E-13	9.45E-13
Freshwater ecotoxicity	Species, yr	1.18E-12	3.31E-13	2.12E-15	3.98E-13	4.49E-13
Marine ecotoxicity	Species, yr	3.52E-15	8.40E-16	1.51E-17	1.26E-15	1.41E-15
Agricultural land occupation	Species, yr	5.32E-11	2.52E-11	4.55E-14	1.24E-11	1.56E-11
Urban land occupation	Species, yr	1.08E-10	0	2.20E-13	1.86E-11	8.86E-11
Fossil fuel depletion	$	0.82600	0	0.04026	0.43355	0.35217
Metal depletion	$	0.00617	0	2.41E-06	0.00348	0.00269
Damages Categories						
Human health	DALY	7.28E-07	2.42E-07	1.60E-08	2.09E-07	2.62E-07
Ecosystem quality	Species, yr	2.23E-09	3.94E-10	6.64E-11	8.15E-10	9.61E-10
Resources	$	0.826	0	0.040	0.437	0.355
Single score	mpt.	30.18	7.35	0.86	10.52	11.43

The impact of the 17 categories is depicted in Figure 4-20. This figure distinctly shows that the major impact from processes is related to climate change human health whose single score damage value is 10.60 mpt. The two major contributors to climate change human health are WWTP and sewer grid whose single score values are 4.42mpt and 4.12 mpt, respectively. The second highest impact related to fossil depletion has a single score damage value of 7.47mpt, it mainly comes from the sewer grid and WWTP whose single score damage values are 3.92 mpt and 3.19 mpt, respectively. Particulate matter formation was the third highest impact whose single score damage value is 6.77mpt, it largely comes from the direct discharge of wastewater to the Al-Samawah river. Also, Figure 4-20 presents the highest level of human toxicity with a single score damage value of 4.21mpt, and it mostly comes from the direct discharge and WWTP burdens whose single score damage values are 1.97mpt and 1.67mpt, respectively. As for the rest of the categories, the value of their impact is so small that it can be neglected.

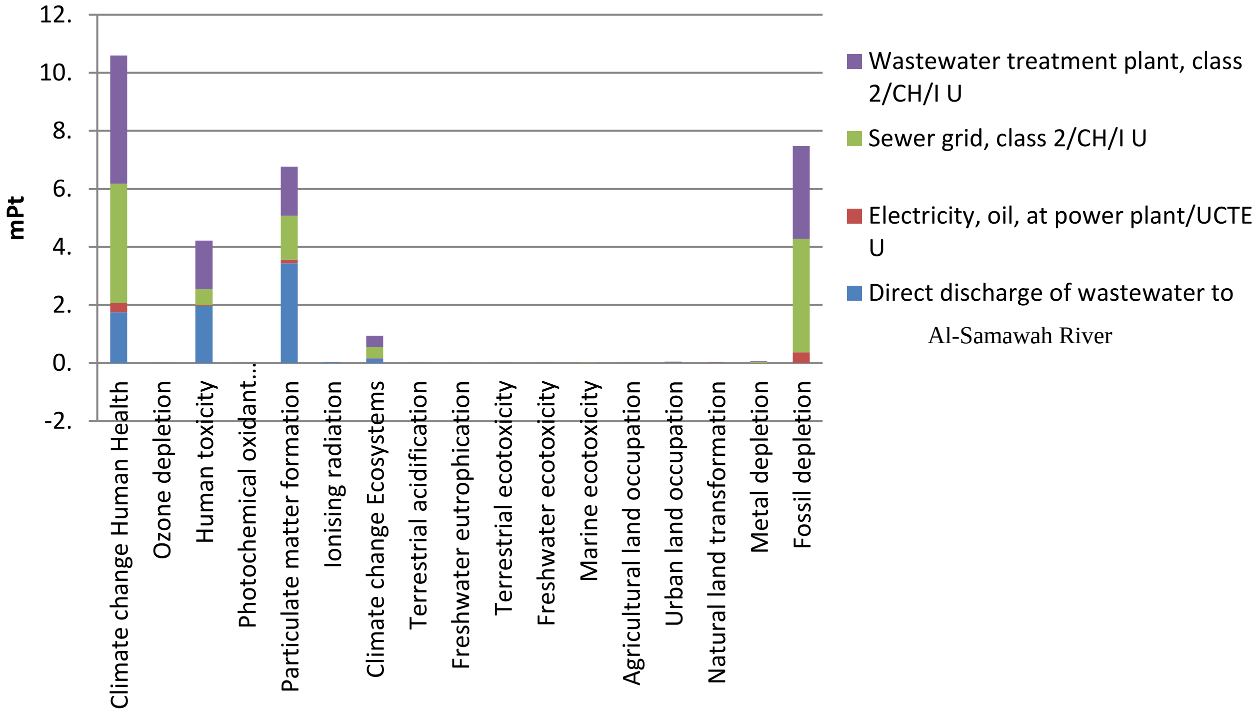


Figure 4-19. *Analysis 1 m3 Direct Discharge of Wastewater to Al-Samawah River (Method: ReCiPe Endpoint (H) V1.05 / World ReCiPe H/A / Weighting).*

Corominas, et al (2013) showed that only 38 of the 45 research on wastewater treatment considered the potential for global warming, and none looked at the potential for particulate matter formation or human toxicity .The use of ReCipe method weighting in this case study suggests that these impact categories should be given equal weight or that a damage category should be used to combine these impact categories, such as human health (Alyaseri & Zhou, 2017).

Chemicals such as alum contributions to damages are not shown in Figure 4-20 because the plant did not use them. Since no sludge has been removed from the plant since operations began, there has been no impact on transportation to farms.

As of now, the plant treats 20,000 cubic meters of wastewater every day on average. Total annual damages can be computed using the ReCipe method, which supports the analysis of environmental burdens from treatment processes in terms of final damages to human health, the environment, and resources.

The annual total damages are as following :-

- $7.28*10^{-7}\,\frac{DALY}{m3}*\,20000\,\frac{m3}{day}*\frac{365\ day}{yr}=5.314\,\frac{DALY}{yr}$
- $2.23*10^{-9}\,\frac{species}{m3}*\,20000\,\frac{m3}{day}*\frac{365\ day}{yr}=\ 0.0163\,\frac{species}{yr}$
- $0.826\,\frac{\$}{m3}*\,20000\,\frac{m3}{day}*\frac{365\ day}{yr}=6029800\,\frac{\$}{yr}$

In general the results show high burdens on the three main damage categories due to installation of the plant and sewer system which did not get its purpose because of the current-stop in processes.

When compared with results of (Alyaseri & Al-Madi, 2017) for evaluating the plant in 2017 using the LCA, we find that the results showed that most damages are related to climate change, depletion in resources, and human toxicity, construction phase had significant contribution to environmental burdens. Annual damages from Alsamawah WWTP was 7.3 (±0.8) years loss in human life, 2.5×10-2 (±2.9×10-3) species loss in the area, and $\$1.1\times10^{7}$ (±1.2×10+6) more expenses needed for future generations for resources.the reason is becouse the plant was operation in past .

4.4 Health Risk Assesment

The risk assessment figures are expressed in organisms per 100 ml . Because the main sign of Shigella infection is diarrheal, which often is bloody, the dose-response relationship is based on Shigella, which has a risk of infection of 1.0×10^{-3} when exposed to a single organism. Because there is a limitation of consolidated data, the risk of developing illness once infected is higher. Currently, the proportion is set at 25%, based on the Shigella morbidity ratio.

When exposed to the pathogen in water, only a small proportion of people may be susceptible to get diseases as indicated in the susceptible fraction in literature(Howard & Pedley, 2003). This term could be used to consider additional infection pathways. For example, the population's susceptibility may be decreased to reflect illness from other water sources if people regularly utilize multiple sources of water. Assumptions about the relationship between the indicator and pathogen must be made since indicator organisms rather than pathogen data serve as the foundation for the risk assessment. Depending on whether the indicator was used as an indicator, an index organism for a group of diseases, or just to simulate behavior, these may vary (in which case it would be more accurate to refer to it as a process indicator). The organisms used as the examples' index (0.31), which were based on the literature of (Howard & Pedley, 2003)

Results showed that among every 1000,000 persons directly using water from rivers, 172608 will expose to diarrheal disease. The National Contingency Plan of the U.S. describes this number as being significantly higher than the 10^{-6} upper-end risk level, which is the Environmental Protection Agency's generally acceptable risk range between 10^{-6} and 10^{-4} (EPA, 2020). According to the assessment data, the final risk of E.Coli is 0.172608 and of TC is 0.149792. The disease burden estimates exceed the WHO reference risk level of 10^{-6}.

Table 4-4. *Risk Assessment for E.coli O157:H7 at Treatment Works Using Assessment Data in 2002(Howard & Pedley, 2003)*

Raw water quality, organisms per 100 ml(CR)	38.76
Treatment effect (Pr)	0
Drinking water Quality (DWQ)	38.76
Consumption of unheated drinking water (V)	0.5
Exposure by drinking water, organisms per ml (E)	DWQ x V = 0.5 *38.76=19.38
Dose-response (r)	From literature=0.001
Risk of infection per day (Pinf,d)	E x r = 0.001 *19.38=0.019
Risk of infection per years (Pinf,y)	Pinf,d x 365= 0.019*365=6.94
Risk of diarrheal disease given infection(Pill|inf)	From literature= 0.25
Risk of diarrheal disease (Pill)	Pinf,y x Pill|inf = 1.74
Disease burden (db)	$3.2*10^{-1}$
Susceptible fraction (fs)	From literature=0.31
Disease Burden (DB)	Pill x db x fs= $0.172608=172608*10^{-6}$

Table 4-5*.Risk Assessment for Total Coliform (TC) at Treatment Works Using Assessment Data in 2002(Howard & Pedley, 2003)*

Raw water quality, organisms per 100 ml (CR)	32.92
Treatment effect (Pr)	0
Drinking water Quality (DWQ)	32.92
Consumption of unheated drinking water (V)	0.5
Exposure by drinking water, organisms per ml (E)	DWQ x V = 32.92*0.5=16.5
Dose-response(r)	From literature=0.001
Risk of infection per day (Pinf,d)	E x r = 0.001 *16.46 =0.0165
Risk of infection per years (Pinf,y)	Pinf,d x 365= 0.0165*365=6.02
Risk of diarrheal disease given infection (Pill|inf)	From literature= 0.25
Risk of diarrheal disease (Pill)	Pinf,y x Pill|inf = 1.51
Disease burden (db)	=$3.2*10^{-1}$
Susceptible fraction (fs)	From literature=0.31
Disease Burden (DB)	Pill x db. x fs=0.149792=149792*10^{-6}

Number of people use water directly from river is expected to be around 1000,000 persons which indicate that around 170000 diarrheal case will occur among them .

In general, the results indicate a high danger from the stop of processes in WWTPs. There is no real risk assessment in the plant to be compared with.

Chapter Five :Conclusions and Recommendations

Chapter Five

Conclusions and Recommendations

This chapter includes the main conclusions from assessing WWTP of Al-Samawah with recommendations for running and improving the plant and recommendations for conducting future studies.

5.1 Conclusions

Based on the study , the following conclusion are :-

1- The direct discharge of 20000m^3/day of wastewater to the river has significant contribution to the environmental burden.

2- Most environmental burdens caused by this plant are related to the construction of the WWTP and the sewer system. Results analysis of pollutant parameters such as BOD, COD, TSS, oil and grease, or nutrients in the direct discharge of WWTP into the river without treatment of these pollutants showed that most damages related to climate change, human health, fossil depletion, particulate matter formation, and human toxicity are caused by the construction of WWTP and sewer system. However, these results don’t mean that it is not necessary to build the plant.

3- The QMRA results showed that extremely high damages are related to the direct discharging of the wastewater into the river. The results showed that the risk of getting a diarrheal disease is higher than normal by 170000 infections when compared to the lower limit of the WHO reference level of risk of 10^{-6} .

4- For developing countries, QMRA appears to be necessary with many stopped plants in these countries. However, QMRA was difficult to be conducted on wastewater since it requires numerous assumptions that may not be available.

5- Generally the city of Al-Samawah did not get any benefit from the construction of the plant. On the contrary, it had all the environmental burdens from the plant and the sewer system.

5.2 Recommendations

They have been divided into two sections as follows:

5.2.1 Recommendations for rehabilitation of the plant and reducing Damage

To reduce the harmful effects of Al-Samawah WWTP on the human health and ecosystem of the Al-Samawah city and to rehabliate the plant to be efficiently operate, the following recommendations should be taken into consideration.

1- The results of laboratory of the plant when it was operating show that the effluent in sometimes higher than influent , in addition, there were illogical results.This is evidence that the results are incorrect and unreliable and cannot be relied upon.

2- The quality control systems should be supplied to all units in the plant.

3- The vacuum pumps should be continuously operated to reduce and remove the accumulated H_2S.

4- The maintenance should be periodically executed to the plant with the provision of spare materials constantly.

5- It is advised that the administration of Alsamawah city make more efforts to obtain adequate treatment to decrease the diseases and other pollutants discharged. If such treatment is attained, it is advised to employ solids as an energy source to reduce treatment-related costs, and it is necessary to make a health risk assessment for other pathogens.

5.2.2 Recommendations for Further Studies

The following recommendations can be suggested for further studies.

1- Assessing of Al-Samawah WWTP performance efficiency after rehabilitating it.
2- Studying the health risk assessment for other WWTP’s in Iraq by using the Quantitative Microbial Risk Assessment techniques (QMRA).
3- Using LCA techniques for assessing other WWTP’s in Iraq.
4- It is necessary to made QMRA for other pathogens and use other exposure methods.

References

Abbas, A. A., Yousif, Y. T., & Almutter, H. H. (2022). Evaluation of Al-Thagher Wastewater Treatment Plant. *Periodica Polytechnica Civil Engineering*, *66*(1), 112-126 .

Adewoye, S. (2010). Effects of detergent effluent discharges on the aspect of water quality of ASA River, Ilorin, Nigeria. *Agriculture and Biology Journal of North America*, *1*(4), 731-736 .

Ahmed, M. T. (2010). Life cycle analysis in wastewater: a sustainability perspective. *Waste water treatment and reuse in the mediterranean region*, 125-154 .

Al-Furaiji, M., Karim, U. F., Augustijn, D. C., Waisi, B., & Hulscher, S. J. (2016). Evaluation of water demand and supply in the south of Iraq. *Journal of water reuse and desalination*, *6*(1), 214-226 .

Al-Muqdadi, S. W., Omer, M. F., Abo, R., & Naghshineh, A. (2016). Dispute over water resource management—Iraq and Turkey. *Journal of Environmental Protection*, *7*(8), 1096-1103 .

Al-Obady, O. M. K., & Qasim, A. F. (2018). Performance Evaluation of Al-Khadraa'Wastewater Treatment Plant, Mosul-Iraq. *Tikrit Journal of Pure Science*, *23*(7), 42-46 .

Al-wardy, A. H. (2021). *Evaluation and modeling of the performance of wastewater treatment plant in Al-Muamirah in the province of Babylon for the removal pollutant of Municipal Wastewater* UNIVERSITY OF KERBALA .[

Al-Yaseri, I. (2014). *Qualitative and quantitative procedure for uncertainty analysis in life cycle assessment of wastewater solids treatment processes*. Southern Illinois University at Carbondale .

Al-Rawi, S., & Al-Tayar, T. (1993). Evaluation of the role of biological treatment in removing various wastewater pollutants. *Journal of Environmental Science & Health Part A*, *28*(3), 525-538 .

Alanbari, M. A., Al-Ansari, N., Altaee, S., & Knutsson, S. (2014). Application of Simapro7 on Karbala Wastewater Treatment Plant, Iraq. *Journal of Earth Sciences and Geotechnical Engineering*, *4*(2), 55-68 .

Alsaqqar, A. S., Khudair, B. H., & Mekki, A. (2014). Assessment Efficiency Evaluation of Al-Diwaniya Sewage Treatment Plant in Iraq. *Journal of Engineering*, *2*(20), 20-32 .

Alyaseri, I. (2016a). Performance of wastewater treatment plants in Iraq: life cycle assessment approach. *Journal of Environmental Science, Toxicology and Food Technology (IOSR-JESTFT) e-ISSN*, 2319-2402 .

Alyaseri, I. (2016b). Wastewater Treatment in Developing Countries: Case Study from Al-Muthanna, Iraq. *International Journal of Research in Engineering and Science*, *4*(9), 65-75 .

Alyaseri, I., & Al-Madi, W. (2017). Evaluation of Environmental Performance of Wastewater Treatment Plants in Countries with Crisis: Case Study from Iraq. *Muthanna Journal of Engineering and Technology (MJET)*, *5* .(3)

Alyaseri, I., & Zhou, J. (2017). Towards better environmental performance of wastewater sludge treatment using endpoint approach in LCA methodology. *Heliyon*, *3* ,(3)e00268 .

Bishop, P. L. (2000). *Pollution prevention: fundamentals and practice*. Waveland Press .

Chen, Z., Ngo, H. H., & Guo, W. (2012). A critical review on sustainability assessment of recycled water schemes. *Science of the Total Environment*, *426*, 13 .31-

Cummings, D. Literature Cover Sheet .

Eckenfelder, W., Malina, J., & Patterson, W. (2002). Aeration principles and practice. *CRC Pres* .

Edberg, S., Rice, E., Karlin, R., & Allen, M. (2000). Escherichia coli: the best biological drinking water indicator for public health protection. *Journal of applied microbiology*, *88*(S1), 106S-116S .

Erbe, V., Risholt, L., Schilling, W., & Londong, J. (2002). Integrated modelling for analysis and optimisation of wastewater systems–the Odenthal case. *Urban Water*, *4* .71-63 ,(1)

Espírito Santo, I., Fernandes, E. M. d. G., Araújo, M. M. T. d., & Ferreira, E. (2005). Biological process optimal design in a wastewater treatment plant .

Friedrich, E., Pillay, S., & Buckley, C. (2007). The use of LCA in the water industry and the case for an environmental performance indicator. *Water Sa*, *33* .(4)

Goedkoop, M., De Schryver, A., Oele, M., Durksz, S., & De Roest, D. (2010). Simapro 7: introduction to LCA. *P. Consultants* .

Goedkoop, M., Heijungs, R., Huijbregts, M., De Schryver, A ,.Struijs, J., & Van Zelm, R. (2013). ReCiPe 2008. A life cycle assessment method which comprises harmonized category indicators at the midpoint and the endpoint level; Report I: characterization, 6 January 2009. In.

Goedkoop, M., Oele, M., Leijting, J ,.Ponsioen, T., & Meijer, E. (2016). Introduction to LCA with SimaPro. Report version 5.2. In: Recuperado a partir de www. pre-sustainability. com.

Havelaar, A., & Melse, J. (2003). Quantifying public health risk in the WHO guidelines for drinking-water quality: a burden of disease approach .

Henze, M., van Loosdrecht, M. C., Ekama, G. A., & Brdjanovic, D. (2008). *Biological wastewater treatment*. IWA publishing .

Howard, G., & Pedley, S. Quantitative Microbial Risk Assessment .

Howard, G., & Pedley, S. (20 .(03Quantitative Microbial Risk Assessment, Evaluation of WSPS. *Water, Engineering and Development Centre (WEDC) at Loughborough University* .

Howard, G., Pedley, S., & Tibatemwa, S. (2006). Quantitative microbial risk assessment to estimate health risks attributable to water supply: can the technique be applied in developing countries with limited data? *Journal of Water and Health*, *4*(1), 49-65 .

Humbert, S., De Schryver, A., Bengoa, X., Margni, M., & Jolliet, O. (2012). IMPACT 2002+: user guide. *Draft for version Q*, *2* .

Jameel, A. T., Muyubi, S. A., Karim, M. I. A., & Alam, M. Z. (2011). Removal of oil and grease as emerging pollutants of concern (EPC) in wastewater stream. *IIUM Engineering Journal*, *12* .(4)

Janssen, P., Meinema, K., & Van der Roest, H .(2002) .*Biological phosphorus removal*. IWA publishing .

Jasim, N. A. (2020). The design for wastewater treatment plant (WWTP) with GPS X modelling. *Cogent Engineering*, *7*(1), 1723782 .

Jolliet, O., Margni, M., Charles, R., Humbert, S., Payet, J., Rebitzer ,G., & Rosenbaum, R. (2003). IMPACT 2002+: a new life cycle impact assessment methodology. *The international journal of life cycle assessment*, *8*(6), 324-330 .

Karia, G., & Christian, R. (2013). *Wastewater treatment: Concepts and design approach*. PHI Learning Pvt. Ltd .

Khiewwijit, R., Temmink, H., Rijnaarts, H., & Keesman, K. J. (2015). Energy and nutrient recovery for municipal wastewater treatment: how to design a feasible plant layout? *Environmental Modelling & Software*, *68*, 156-165 .

Lagarde, F., Tusseau-Vuillemin, M.-H., Lessard, P., Héduit, A., Dutrop, F., & Mouchel, J.-M. (2005). Variability estimation of urban wastewater biodegradable fractions by respirometry. *Water research*, *39*(19), 4768-4778 .

Lan, W., Gang, G., & Jinbao, W. (2009). Biodegradation of oil wastewater by free and immobilized Yarrowia lipolytica W29. *Journal of Environmental Sciences*, *21*(2), 237-242 .

Langergraber, G., Rieger, L., Winkler, S., Alex, J., Wiese, J., Owerdieck, C., Ahnert, M., Simon, J., & Maurer, M. (2004). A guideline for simulation studies of wastewater treatment plants. *Water Science and Technology*, *50*(7), 131-138.

Lillenberg, M., Yurchenko, S., Kipper, K., Herodes, K., Pihl, V., Lõhmus, R., Ivask, M., Kuu, A., Kutti, S., & Litvin, S. (2010). Presence of fluoroquinolones and sulfonamides in urban sewage sludge and their degradation as a result of composting. *International Journal of Environmental Science & Technology*, *7*(2), 307-312.

Lopsik, K. (2013). Life cycle assessment of small-scale constructed wetland and extended aeration activated sludge wastewater treatment system. *International Journal of Environmental Science and Technology*, *10*(6), 1295-1308.

McCarty, P. L., & Brodersen, C. (1962). Theory of extended aeration activated sludge. *Journal (Water Pollution Control Federation)*, 1095-1103.

Metcalf, Eddy, Abu-Orf, M., Bowden, G., Burton, F. L., Pfrang, W., Stensel, H. D., Tchobanoglous, G., Tsuchihashi, R., & AECOM. (2014). *Wastewater engineering: treatment and resource recovery*. McGraw Hill Education.

Metcalf, L., Eddy, H. P., & Tchobanoglous, G. (1991). *Wastewater engineering: treatment, disposal, and reuse* (Vol. 4). McGraw-Hill New York.

Mittal, A. (2011). Biological wastewater treatment. *Water Today*, *1*, 32-44.

Organization, W. H., & WHO. (2004). *Guidelines for drinking-water quality* (Vol. 1). world health organization.

Pasqualino, J. C., Meneses, M., Abella, M., & Castells, F. (2009). LCA as a decision support tool for the environmental improvement of the operation of a municipal wastewater treatment plant. *Environmental science & technology*, *43*(9), 3300-3307.

Pauline, J., Annabelle, H., Gaëlle, M., Nadine, C., Valérie, I., & Karim, H. (2015). Health Risk Assessment Related to Waterborne Pathogens from the River to the Tap. *Int J Environ Res Public Health*, *4*(3), 1660-4601.

Pophali, G., Kaul, S., & Mathur, S. (2003). Influence of hydraulic shock loads and TDS on the performance of large-scale CETPs treating textile effluents in India. *Water research*, *37*(2), 353-361.

Price, R. (2018). Environmental risks in Iraq.

Qasim, S. R., & Zhu, G. (2017). *Wastewater treatment and reuse, theory and design examples, volume 1: principles and basic treatment*. CRC Press.

Ramadan, A., Abdel-Rahman, A., Abdullah, A., & Eltawab, O. (2017). Evaluation of wastewater treatment plants in El-Gharbia Governorate, Egypt. *Organic Chemistry Current Research*, *6*(2), 1-12 .

Renou, S., Thomas, J., Aoustin, E., & Pons, M. (2008). Influence of impact assessment methods in wastewater treatment LCA. *Journal of Cleaner Production*, *16* .1105-1098 ,(10)

Rivas, A., Irizar, I., & Ayesa, E. (2008). Model-based optimisation of wastewater treatment plants design. *Environmental Modelling & Software*, *23*(4), 435-450 .

Soomaree, K. (2015). Detail design of wastewater treatment plant. *University of Mauritius* .

Unger, N., Beigl, P., & Wassermann, G. (2004). General requirements for LCA software tools. *Institute of Waste Management, BOKU–University of Natural Resources and Applied Life Sciences, Vienna Austria* .

Von Sperling, M. (2007). *Wastewater characteristics, treatment and disposal*. IWA publishing .

Weiner, R., Matthews, R., & Vesilind, P. A. (2003). *Environmental engineering*. Butterworth-Heinemann .

WHO, A. (2006). compendium of standards for wastewater reuse in the Eastern Mediterranean Region. *Regional Office for the Eastern Mediterranean, Cairo, Egypt* .

Zubaidi, S. L., Al-Bugharbee, H., Muhsin, Y. R., Hashim, K., & Alkhaddar, R. (2020). Forecasting of monthly stochastic signal of urban water demand: Baghdad as a case study. IOP Conference Series: Materials Science and Engineering ,

Al-Zuhari, M. S. H. (2008). Evaluation for future Baghdad wastewater treatments plants efficiency. AL-Taqani Joumal, 21, A14-A23.

Appendices

Appendix A

Table A-1. The Concentration Values of the Pollutant Parameters PH, BOD5, COD, and TSS in the Raw Wastewater of Al-Samawah WWTP.

DATE	**PH**		**BOD, mg/L**		**COD, mg/L**		**TSS, mg/L**	
Date	**in**	**out**	**in**	**out**	**In**	**out**	**in**	**out**
2/10/2012	7.5	7.6	50		175	91	360	480
4/10/2012	7.5	7.6					700	360
7/10/2012	7.1	7.4					480	360
9/10/2012	7.5	7.4	92	24			560	380
11/10/2012	7.5	7.6					320	380
14/10/2012	7.8	7.5					480	380
16/10/2012	7.7	7.6	130	30			440	360
18/10/2012	7.5	7.6	100	25	178	94	360	400
21/10/2012	7.5	7.6					2040	280
23/10/2012	8	7.7	100	30	274	148	780	160
24/10/2012	7.4	7.7	50	10	20	12	40	60
30/10/2012	7.4	7.5	90	35	160	84	180	180
31/10/2012	7.5	7.9	50		98	61	60	100
4/11/2012	7.4	7.6			214	126	280	220
5/11/2012	7.4	7.7	50	20	84	39		40
6/11/2012	7.3	7.3	75		172	120	260	160
7/11/2012	7.4	7.8	10	20	28	16	20	20
8/11/2012	7.5	7.6			197	127	200	200
11/11/2012	7.8	7.7	105	35	193	120	280	200
12/11/2012	7.4	7.7	10	6	44	36	40	80
13/11/2012	7.6	7.6	15	25	186	113	200	220
14/11/2012	7.2	7.7			84	36	100	60
18/11/2012	7.6	7.5	90	30	232	144	300	260
20/11/2012	7.4	7.4	75	25	296	125		220
22/11/2012	7.4	7.5	100	30	233	124	620	400
27/11/2012	7.7	7.6	95	10	252	180	360	420
29/11/2012	7.5	7.6	10	25	224	122	600	440
2/12/2012	7.8	7.6	125	35	232	128	540	320
4/12/2012	7.2	7.6	140	25	222	109	800	380
6/12/2012	7.4	7.6	90	10	233	125	680	280
9/12/2012	7.5	7.5	130	25	226	124	620	400
11/12/2012	7.7	7.6	100	30	208	104	480	360
13/12/2012	7.4	7.7			226	128	580	380

16/12/2012	7.4	7.5	120		257	102	540	360
9/1/2013	7.9	7.7	100	25	218	160	440	420
13/1/2013	7.7	7.7	115	35	201	131	380	240
15/1/2013	7.6	7.7	70	30	244	128	740	340
17/1/2013	7.7	7.4			208	140	320	380
20/1/2013	7.4	7.5	165	90	281	152	500	540
22/1/2013	7.8	7.4	150	25	226	147	880	420
27/1/2013	7.4	7.5	115	65	254	158	520	380
29/1/2013	7.6	7.6	125	45	188	152	920	480
31/1/2013	7.6	7.7	145	30	294	119	500	360
3/2/2013	7.6	7.7			225	126	320	400
5/2/2013	7.6	7.4	110	105	224	160	460	360
7/2/2013	7.4	7.4			204	148	460	480
10/2/2013	7.3	7.4			228	128	420	420
12/2/2013	7.3	7.4			179	134	340	400
1/9/2013	7.3	7.7	75		280	184	260	320
22/9/2013	7.5	7.9	130				640	300
24/9/2013	7.6	7.9	100		240	100	440	320
26/9/2013	7.4	7.8	60		208	104	380	360
29/9/2013	7.5	7.8			195	100	520	340
6/10/2013	7.4	7.8	180	39	368	188	500	340
8/10/2013	7.5	7.7	40	25	180	120	240	340
10/10/2013	7.5	7.8		19	204	104	360	320
31/10/2013	7.6	7.9			200	140	240	460
3/11/2013	7.4	7.8	100	5	340	140	1280	380
7/11/2013	7.7	7.8			160	140	360	480
10/11/2013	7.7	7.9	88	33	240		580	480
12/11/2013	7.5	7.7	115	48	240	80	340	200
17/11/2013	7.4	7.7	140	31	280	120	720	420
24/11/2013	7.4	7.6	55	66	140	120	580	500
26/11/2013	7.6	7.6		32	188	144	340	460
28/11/2013	7.8	7.6	64	37	160	130	400	380
2/9/2014	7.9	8	130	38	380	148		220
4/9/2014	8.2	8.3	125	36	200	100		320
7/9/2014	8	7.9	120	38	180	100		200
9/9/2014	8.2	8.3	110	34	232	120		240
11/9/2014	7.7	7.8	125	48	200	100		260
14/9/2014	7.6	7.8	200	36	200	108		210
16/9/2014	7.8	8	180	40	190	130		220
18/9/2014	7.3	7.6	140	32	205	127		240
2/12/2014	7.6	7.4	100	55	200	120	260	240

16/12/2014	7.7	7.3	46	18	280	140	240	190
18/12/2014	7.9	7.7	50	38	180	120	280	460
22/12/2014	7.9	7.8		20	220	100	280	460
24/12/2014	7.6	7.5	50	40	220	100	480	300
28/12/2014	8	7.7	100	32	240	120	480	320
30/12/2014	7.8	7.8	125	60	220	100	460	420
4/1/2015	7.8	7.8	100	31	276	116	440	380
7/1/2015	7.8	7.7	110	58	228	127	420	360
13/1/2015	8.1	8.1	130	70	375	120	520	480
15/1/2015	8	7.3	135	34	260	119	300	280
18/1/2015	7.9	7.9	150	80	248	92	440	400
20/1/2015	7.7	8	110	35	260	138	380	320
22/1/2015	8	7.8	225	35	256	100	420	340
25/1/2015	7.7	7.8	135	50	296	100	400	320
27/1/2015	7.8	7.9	230	45	320	130	480	380
11/1/2016	7.6	7.7	110	32			200	200
13/1/2016	7.6	7.7	105	34			400	260
18/1/2016	7.4	7.7	175	42			340	360
20/1/2016	7.1	7.7	160	36			400	440
25/1/2016	7.4	7.5	145	38			520	440
27/1/2016	7.5	7.6	185	32			480	420
Number of tests	95	95	75	70	81	80	85	95
Max	8.2	8.3	230	105	380	188	2040	540
Min	7.1	7.3	10	5	20	12	20	20
Average	7.6	7.7	107	36	217	118	450	326
Median	7.6	7.7	110	34	220	120	420	360
St. deviation	0.2	0.2	46	18	66	33	267	113

Table A-2. The Concentration Values of the Pollutant Parameters TDS, SO_4, PO_4, and NH_3 in the Raw Wastewater of Al-Samawah WWTP.

DATE	TDS, mg/L		SO4		PO4		NH3	
Date	**in**	**out**	**in**	**out**	**in**	**out**	**in**	**out**
2/10/2012	5740	6160	1070	1111	0.20	0.15	10.08	11.30
4/10/2012	8880	6280	1523	1029	0.35	0.25	20.16	17.80
7/10/2012	8280	6460	1399	1523	0.30	0.24	14.67	15.34
9/10/2012	8660	6640	1399	1481	0.30	0.12	20.16	16.40
11/10/2012	4420	6380	823	1358	0.28	0.09	15.12	16.63
14/10/2012	5140	6000	1193	1235	0.38	0.11	16.20	14.40
16/10/2012	6060	6280	1193	1523	0.60	0.30	14.60	13.70
18/10/2012	3060	6220	865	1317	0.60	0.20	15.12	12.70
21/10/2012	3300	4880	988	1276	0.26	0.13	16.90	15.10
23/10/2012	5440	5500	781	1193	0.60	0.20	11.80	15.90
24/10/2012	1620	1400			0.06	0.01		
30/10/2012	5940	5760	1399	1316	0.50	0.20	16.40	14.40
31/10/2012	1360	1520	617	206	0.04	0.04	1.00	2.00
4/11/2012	5580	5860	1317	1111	0.60	0.20	15.30	13.10
5/11/2012	1240	1280	165	206	0.05	0.03	0.70	0.70
6/11/2012	6720	6060	1235	1152	0.60	0.30	14.50	14.10
7/11/2012	1340	1360	57	92	0.40	0.20	1.10	NIL
8/11/2012	5680	7260	1137	1206	0.70	0.20	15.70	13.30
11/11/2012	7660	5880	1111	1317	0.80	0.30	8.90	8.20
12/11/2012	1380	2320	453	782	NIL	NIL	0.50	NIL
13/11/2012	4400	6100			0.50	0.30	13.00	12.10
14/11/2012			412	206	0.30	0.30	0.60	NIL
18/11/2012	4360	6320	579	1399	0.38	0.16	10.20	14.50
20/11/2012	3580	3960	1811	1728			9.80	13.10
22/11/2012	6200	6000					9.50	10.60
27/11/2012	4340	6500	781	1646	0.18	0.10	10.90	10.40
29/11/2012	6860	6480	946	1235	0.23	0.11	11.76	8.17
2/12/2012	4160	5240	988	1235	0.28	0.02	10.00	12.40
4/12/2012	7200	5820	1481	1510	0.18	0.08	9.60	7.30
6/12/2012	7180	6380	1518	1593	0.30	0.10	10.10	12.20
9/12/2012	6100	6800	1399	1564	0.59	0.12	8.80	9.50
11/12/2012	6880	6680	1440	1523	0.20	0.05	9.90	10.60
13/12/2012	7060	6260	1646	1440	0.50	0.30	13.60	11.50
16/12/2012	7320	6600			0.54	0.22	14.40	11.70
9/1/2013	5160	7800	1358	1687	0.16	0.07	17.10	17.60
13/1/2013	5240	6220	1276	1605	0.08	0.11	17.20	18.00

15/1/2013	8900	6800	2346	1852	0.15	0.09	17.30	14.50
17/1/2013	4880	7760	1276	1687	0.20	0.08	16.30	12.50
20/1/2013	5960	7280	1276	1893	0.25	0.14	21.40	23.00
22/1/2013	9020	6660	1276	1769	0.30	0.10	17.60	22.10
27/1/2013	6800	6500	1567	1481	0.20	0.10	18.90	22.40
29/1/2013	4460	6240	905	1070	0.30	0.13	17.50	19.20
31/1/2013	4280	6660	1687	1112	0.30	0.10	14.50	16.00
3/2/2013	5700	7020	864	1481	0.20	0.07	20.90	18.20
5/2/2013	6740	6820	1193	1852	0.29	0.13	15.30	11.70
7/2/2013	7560	7780	1193	1646	0.18	0.08	16.20	18.80
10/2/2013	6480	7160			0.12		22.40	19.30
12/2/2013							17.80	18.70
1/9/2013	5240	5660	992	1193	0.46	0.16	22.10	10.60
22/9/2013	4840	6180	1004	1354	0.83	0.23	19.40	
24/9/2013	7040	6530	1329	1728	0.37	0.01	16.20	18.90
26/9/2013	5420	6500	1029	1469	0.48	0.13		
29/9/2013	7580	6160	1337	1477	0.40	0.03		
6/10/2013	5620	6160	963	1383	1.07	0.20		
8/10/2013	5340	6320	1226	1173	0.28	0.08		
10/10/2013	7260	6680	1465	1860	0.26	0.08		
31/10/2013	5160	7300	1152	1560	0.31	0.11		
3/11/2013	8800	6200	1613	1255	0.41	0.08		
7/11/2013	6200	7540	1296	1300	0.28	0.09		
10/11/2013	8900	7300	1121	1087	0.43	0.30		
12/11/2013	4200	7400	1239	1753	0.41	0.10		
17/11/2013	5260	6240	1148	810	0.36	0.04		
24/11/2013	7360	6500	1461	1654	0.12	0.05		
26/11/2013	5720	6340	1514	1741	0.28	0.08		
28/11/2013	7600	6840	1745	1737	0.22	0.11		
2/9/2014		3860	955	1078	0.28	0.11	30.60	38.10
4/9/2014		3960	1109	1120	0.32	0.26	32.84	43.62
7/9/2014		4000	999	1081	0.24	0.15	20.80	34.20
9/9/2014		4060	992	1011	0.28	0.15	19.40	36.20
11/9/2014		4040	1451	1209	0.23	0.18	21.50	19.30
14/9/2014		3640	1135	989	0.28	0.14	30.80	22.90
16/9/2014		3760	1281	999	0.20	0.10	25.60	24.30
18/9/2014		4060	1451	1121	0.18	0.12	27.30	24.80
2/12/2014	6840	5140			0.08	1 .0		
16/12/2014	5140	4620			0.06	0.20		
18/12/2014	4960	4380			0.09	0.20		
22/12/2014	4960	4380			0.08	0.10		

24/12/2014	4540	4220			0.09	0.10		
28/12/2014	3340	4140			0.08	0.20		
30/12/2014	6900	6220			0.08	0.10		
4/1/2015	6200	5960	1120	919	0.02	0.01		
7/1/2015			1200	1012	0.03	0.01		
13/1/2015			996	911	0.02	0.02		
15/1/2015			3236	2882	0.06	0.03		
18/1/2015			2980	2200	0.04	0.01		
20/1/2015			3884	3872	0.04	0.01		
22/1/2015			1820	1640	0.02	0.01		
25/1/2015			889	753	0.06	0.02		
27/1/2015			1220	989	0.04	0.04		
11/1/2016	2980	3680	842	840				
13/1/2016	3820	3580	860	880				
18/1/2016	4140	4580	860	840				
20/1/2016	3840	5300	890	830				
25/1/2016	4840	5300	856	864				
27/1/2016	4760	5580	870	865				
number of tests	77	85	82	82	85	83	58	54
max	9020	7800	3884	3872	1.06	0.30	33	44
Min	1240	1280	57	92	0.02	0.01	0.5	0.7
average	5573	5643	1237	1318	0.29	0.13	15	16
Median	5580	6180	1193	1288	0.28	0.11	16	15
St. deviation	1856	1500	555	523	0.21	0.08	7	8

Table A-3. The Concentration Values of the Pollutant Parameters NO_2, NO_3, O&G, H_2S, and CL in the Raw Wastewater of Al-Samawah WWTP.

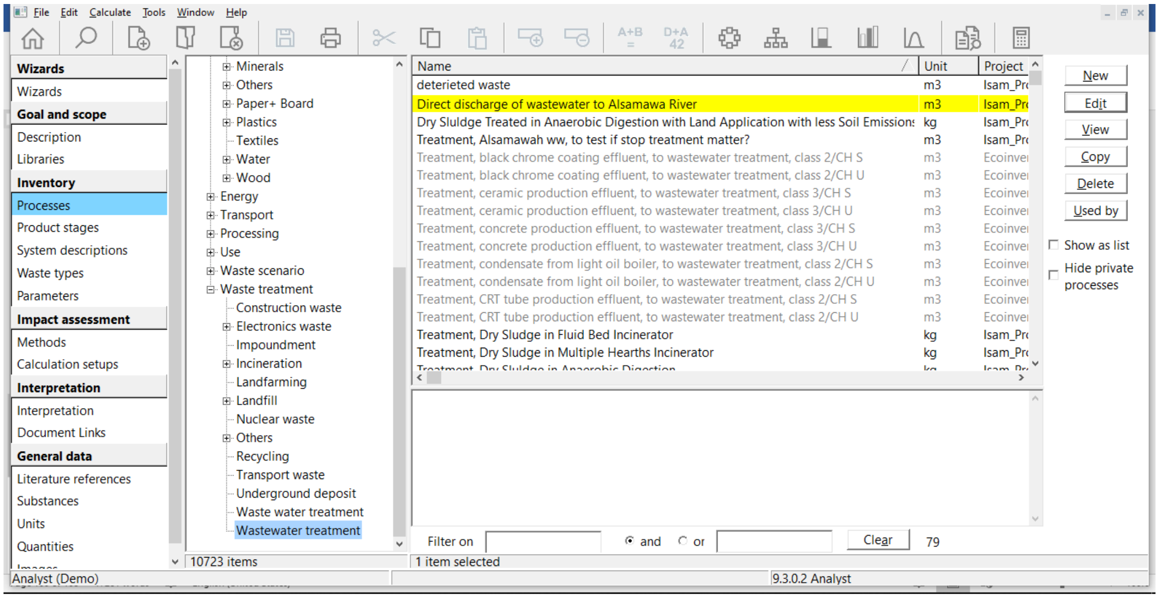
DATE	NO2		NO3		G&O		H_2S		CL	
Date	**in**	**out**	**in**	**out**	**in**	**out**	**in**	**out**	**in**	**out**
2/10/2012	0.04	0.53	22	38					2824	2779
4/10/2012	0.09	0.03	16	36					3807	2505
7/10/2012	0.08	0.05	13	30					3286	2348
9/10/2012	0.12	0.34	50	22					3937	2249
11/10/2012	0.10	0.17	23	46					2025	2974
14/10/2012	0.16	0.05	36	32					2303	2706
16/10/2012	0.50	0.02	26	30					2631	2616
18/10/2012	0.17	0.06	21	38					1062	2343
21/10/2012	0.03	0.01	30	32					1852	2011
23/10/2012	0.16	0.04	27	24	240	200			2934	1538
24/10/2012	NIL	0.17	6	15					284	270
30/10/2012	0.22	0.13	7	2	160	40			2225	2269
31/10/2012	0.02	0.19	3	8	80	40			301	332
4/11/2012	0.10	0.15	14	6	120	80	51.00	8.50	2159	2221
5/11/2012	NIL	0.75	30	8	120	40	12.70	4.20	244	301
6/11/2012	0.06	0.45	11	6			36.10	10.60	2837	2261
7/11/2012	0.01	0.16	8	7	80	80	10.00	2.60	222	222
8/11/2012	0.25	0.06	13	2			21.50	6.37	1871	2181
11/11/2012	0.02	0.30	16	11	120	80	34.00	2.10	1684	2008
12/11/2012	0.02	0.55	5	9	75	60	7.20	0.42	293	629
13/11/2012	0.12	0.15	14	7	80	40	36.90	2.13	1543	2145
14/11/2012	0.15	0.46	3	10	80	80			288	386
18/11/2012	0.15	0.02	30	6	120	40	33.50	4.25	1463	2008
20/11/2012					40		4.25	2.12	1073	1206
22/11/2012					160	40	17.00	2.90	1782	1835
27/11/2012	0.03	0.01	7	9			9.20	4.25	1503	2159
29/11/2012	0.02	0.05	5	3	40	40			2668	2518
2/12/2012	0.08	0.02	10	2	160		6.30	3.40	1445	1428
4/12/2012	0.05	0.02	32	17					2628	2061
6/12/2012	0.11	0.02	10	9	108		17.00	1.20	2841	2345
9/12/2012	0.45	0.05	16	6	120		14.80	2.13	2456	2527
11/12/2012	0.08	0.03	8	3			19.55	2.13	2646	2487
13/12/2012	0.15	0.02	16	9	160	120	21.00	2.00	2770	2194
16/12/2012	0.02	0.15	8	5			21.00	2.90	3036	2513
9/1/2013	0.12	0.11	8	4			22.00	1.20	1950	2589

13/1/2013	0.13	0.02	22	12			23.00	1.70	1857	2425
15/1/2013	0.12	0.11	7	6			10.20	3.90	3389	2637
17/1/2013	0.19	0.09	4	22			11.00	4.25	1680	3025
20/1/2013	0.20	0.23	8	6			12.70	3.40	2676	3136
22/1/2013	0.10	NIL	6	2					3298	3221
27/1/2013	0.90	0.13	11	4			25.50	8.50	2882	2599
29/1/2013	0.07	0.04	4	6			20.40	1.20	1647	2427
31/1/2013	0.13	0.09	10	7			18.20	6.80	1656	2638
3/2/2013	0.08	0.04	9	6			23.30	3.40	2216	2905
5/2/2013	0.09	0.001	4	1			23.80	7.65	2556	2245
7/2/2013	0.03	0.13	8	2			25.50	NIL	3222	3365
10/2/2013	0.05	0.02	9	4			10.60	NIL	2848	2814
12/2/2013									2106	2805
1/9/2013	0.11	NIL	NIL	2					2292	2113
22/9/2013	0.27	0.02	20	12			34.00	NIL	2231	2896
24/9/2013	0.01	0.02	23	11			27.20	NIL	3306	2919
26/9/2013	0.28	0.22	3	8			34.00	NIL	2231	2948
29/9/2013	0.01	0.06	6	4			33.00	NIL	3631	2745
6/10/2013	0.27	0.09	16	12			33.00	NIL	2391	2514
8/10/2013	0.25	0.16	20	10			3.40	NIL	2094	2693
10/10/2013	0.31	0.26	8	12			29.75	NIL	3245	2688
31/10/2013	0.20	0.19	3	2			25.50	NIL	1882	2858
3/11/2013	0.20	0.19	16	18			38.20	NIL	3929	2617
7/11/2013	0.14	0.15	3	2			29.00	NIL	2278	3009
10/11/2013	0.17	0.14	10	14			17.00	NIL	3797	3061
12/11/2013	0.14	0.14	12	8			30.00	NIL	2306	2650
17/11/2013			7	6			31.00	NIL	2231	2702
24/11/2013	0.01	0.05	6	1			4.25	NIL	2896	2792
26/11/2013	0.14	0.08	14	16			25.50	NIL	2118	2570
28/11/2013	0.06	0.03	8	1			7.00	NIL	3273	2707
2/9/2014	0.09	0.04	12	25	60	22	14.00	NIL	1745	1467
4/9/2014	0.10	0.8	10	20	40	20	12.25	NIL	1866	1340
7/9/2014	0.10	0.8	7	18	38	18	11.00	NIL	1788	1475
9/9/2014	0.09	0.02	5	3	112	64	45.00	NIL	1987	1524
11/9/2014	0.19	0.29	16	10	77	36	23.20	NIL	1698	1434
14/9/2014	0.24	0.19	16	12	96	55	38.00	NIL	1688	1641
16/9/2014	0.28	0.18	18	13	79	48	40.00	NIL	1599	1300
18/9/2014	0.20	0.18	15	10	87	39	36.00	NIL	1430	1250
2/12/2014					172	138	19.00	NIL	1508	1430
16/12/2014					420	300	17.00	NIL	1338	1202
18/12/2014					480	360	19.90	NIL	1355	1502

22/12/2014					380	260	20.00	NIL	1624	1468
24/12/2014					420	280	21.00	NIL	1329	1198
28/12/2014					370	290	19.00	NIL	998	1512
30/12/2014					560	480	20.00	NIL	1463	1810
4/1/2015					380	290	42.50	NIL	1558	1402
7/1/2015					460	390	47.60	NIL	1898	1683
13/1/2015					510	480	40.37	NIL	1678	1678
15/1/2015					430	320	17.00	NIL	1658	1595
18/1/2015					350	270	22.00	NIL	2206	1771
20/1/2015					410	320	21.70	NIL	1631	1332
22/1/2015					480	320	17.00	NIL	2060	1733
25/1/2015					360	240	22.00	NIL	1247	1468
27/1/2015					400	360	29.00	NIL	2828	1521
11/1/2016					164	124	29.00	6.50	998	1282
13/1/2016					216	44	34.00	5.29	1052	1277
18/1/2016					332	84	35.00	3.30	1966	1946
20/1/2016					216	144	44.00	4.36	1149	1835
25/1/2016					120	52	42.00	2.21	2001	2035
27/1/2016							38.00	4.40	1685	2232
number of tests	67	67	69	70	47	43	76.00	34.00	95	95
max	0.9	0.8	50	46	560	480	51.00	10.60	3937	3365
Min	0.01	0.001	3	1	38	18	3.40	0.42	222	222
average	0.1	0.2	13.3	11.7	218.8	158.8	24.20	3.89	2064	2066
Median	0.1	0.1	10.0	8.5	160.0	80.0	22.00	3.40	1987	2194
St. deviation	0.1	0.2	9.2	10.4	157.5	138.4	11.30	2.41	850	725

Appendies B

SimaPro 9.3.0 program



Name	Unit	Project
deterieted waste	m3	Isam_Pr
Direct discharge of wastewater to Alsamawa River	m3	Isam_Pr
Dry Sluldge Treated in Anaerobic Digestion with Land Application with less Soil Emission	kg	Isam_Pr
Treatment, Alsamawah ww, to test if stop treatment matter?	m3	Isam_Pr
Treatment, black chrome coating effluent, to wastewater treatment, class 2/CH S	m3	Ecoinve
Treatment, black chrome coating effluent, to wastewater treatment, class 2/CH U	m3	Ecoinve
Treatment, ceramic production effluent, to wastewater treatment, class 3/CH S	m3	Ecoinve
Treatment, ceramic production effluent, to wastewater treatment, class 3/CH U	m3	Ecoinve
Treatment, concrete production effluent, to wastewater treatment, class 3/CH S	m3	Ecoinve
Treatment, concrete production effluent, to wastewater treatment, class 3/CH U	m3	Ecoinve
Treatment, condensate from light oil boiler, to wastewater treatment, class 2/CH S	m3	Ecoinve
Treatment, condensate from light oil boiler, to wastewater treatment, class 2/CH U	m3	Ecoinve
Treatment, CRT tube production effluent, to wastewater treatment, class 2/CH S	m3	Ecoinve
Treatment, CRT tube production effluent, to wastewater treatment, class 2/CH U	m3	Ecoinve
Treatment, Dry Sludge in Fluid Bed Incinerator	kg	Isam_Pr
Treatment, Dry Sludge in Multiple Hearths Incinerator	kg	Isam_Pr
Treatment, Dry Sluldge in Anaerobic Digestion	kg	Isam_Pr

Figure B-1. SimaPro 9.3.0 preview and create a model of the plant.

Table B-1. Inputs From Technosphere in the Life Cycle Inventory Project for Al-Samawah WWTP (Input).

Inputs from Technosphere: electricity/heat	Amount	Unit	Distribution	SD2 or 2SD
Electricity, oil, at power plant/UCTE U	0.0086	kWh	Undefined	0
Sewer grid, class 2/CH/I U	1.58E-07	km	Lognormal	1
Wastewater treatment plant, class 2/CH/I U	1.85E-09	p	Lognormal	1

Table B-2. Emissions In the Life Cycle Inventory Project for Al-Samawah WWTP(Output).

Emissions to air	Sub-compartment	Amount	Unit	Distribution	SD2 or 2SD
NMVOC, non-methane volatile organic compounds, unspecified origin	high. pop.	2.28E-06	kg	Lognormal	2.5254
Carbon monoxide, biogenic	high. pop.	0.000171	kg	Lognormal	1.9653
Carbon dioxide, biogenic	high. pop.	0.19253	kg	Lognormal	1.3449
Methane, biogenic	high. pop.	0.000502	kg	Lognormal	1.8727
Sulfur dioxide	high. pop.	0.000886	kg	Lognormal	1.6648
Nitrogen oxides	high. pop.	0.0007	kg	Lognormal	1.5125
Ammonia	high. pop.	0.000356	kg	Lognormal	2.639
Dinitrogen monoxide	high. pop.	0.000104	kg	Lognormal	1.4291
Cyanide	high. pop.	1.29E-06	kg	Lognormal	2.4331
Phosphorus	high. pop.	1.33E-06	kg	Lognormal	1.5989
Arsenic	high. pop.	2.53E-10	kg	Lognormal	5.2875
Cadmium	high. pop.	4.73E-12	kg	Lognormal	5.2987
Cobalt	high. pop.	1.55E-14	kg	Lognormal	5.7992
Chromium	high. pop.	2.73E-13	kg	Lognormal	5.7387
Copper	high. pop.	1.26E-10	kg	Lognormal	5.4806
Mercury	high. pop.	3.37E-13	kg	Lognormal	5.3142
Manganese	high. pop.	8.72E-14	kg	Lognormal	5.9374
Molybdenum	high. pop.	5.78E-10	kg	Lognormal	5.2398

Nickel	high. pop.	6.86E-14	kg	Lognormal	5.7649
Lead	high. pop.	1.75E-10	kg	Lognormal	5.3867
Tin	high. pop.	1.61E-09	kg	Lognormal	5.267
Zinc	high. pop.	7.57E-10	kg	Lognormal	5.4328
Silicon	high. pop.	4.2E-06	kg	Lognormal	5.2527
Iron	high. pop.	2.72E-07	kg	Lognormal	2.2508
Calcium	high. pop.	5.1E-06	kg	Lognormal	5.2359
Aluminium	high. pop.	1.41E-06	kg	Lognormal	3.7166
Magnesium	high. pop.	4.73E-07	kg	Lognormal	5.2359
Heat, waste	high. pop.	1.2982	MJ	Lognormal	1.2928
Add					
Emissions to water	Sub-compartment	Amount	Unit	Distribution	SD2 or 2SD
Ammonium, ion	river	0.0304	kg	Lognormal	1.342
Nitrite	river	0.00313	kg	Lognormal	1.5041
Nitrogen	river	0.00049	kg	Lognormal	1.5053
BOD5, Biological Oxygen Demand	river	0.105	kg	Lognormal	0.091
COD, Chemical Oxygen Demand	river	0.214	kg	Lognormal	0.13
TOC, Total Organic Carbon	river	0.007299	kg	Lognormal	1.4594
DOC, Dissolved Organic Carbon	river	0.007538	kg	Lognormal	1.458
Sulfate	river	1.219	kg	Lognormal	1.094
Nitrate	river	0.0131	kg	Lognormal	0.018

Phosphate	river	0.00024	kg	Lognormal	0.00041
Hydrogen sulfide	river	0.024	kg	Undefined	0.022
Chloride	river	2.034	kg	Lognormal	1.68
Fluoride	river	3.28E-05	kg	Lognormal	4.9019
Arsenic, ion	river	7.59E-07	kg	Lognormal	4.5002
Cadmium, ion	river	1.42E-07	kg	Lognormal	4.8388
Cobalt	river	8.21E-07	kg	Lognormal	4.8396
Chromium VI	river	6.33E-06	kg	Lognormal	4.7244
Copper, ion	river	9.71E-06	kg	Lognormal	4.7444
Mercury	river	6.27E-08	kg	Lognormal	4.6953
Manganese	river	2.69E-05	kg	Lognormal	4.8496
Molybdenum	river	5.35E-07	kg	Lognormal	4.3594
Nickel, ion	river	4E-06	kg	Lognormal	4.8551
Lead	river	9.49E-07	kg	Lognormal	4.4903
Tin, ion	river	1.42E-06	kg	Lognormal	4.8281
Zinc, ion	river	3.38E-05	kg	Lognormal	4.7746
Silicon	river	0.000188	kg	Lognormal	4.2869
Iron, ion	river	0.003602	kg	Lognormal	4.8563
Calcium, ion	river	0.045858	kg	Lognormal	4.8941
Aluminum	river	6.23E-05	kg	Lognormal	4.1644
Potassium, ion	river	0.000399	kg	Lognormal	4.9019

Magnesium	river	0.005148	kg	Lognormal	4.8942
Sodium, ion	river	0.002186	kg	Lognormal	4.9019
Chromium, ion	river	1.18E-08	kg	Lognormal	5.221
BOD5, Biological Oxygen Demand	groundwater, long-term	8.56E-05	kg	Lognormal	1.7125
COD, Chemical Oxygen Demand	groundwater, long-term	0.000262	kg	Lognormal	1.7125
TOC, Total Organic Carbon	groundwater, long-term	0.000104	kg	Lognormal	1.7125
DOC, Dissolved Organic Carbon	groundwater, long-term	0.000104	kg	Lognormal	1.7125
Sulfate	groundwater, long-term	0.002367	kg	Lognormal	1.6594
Nitrate	groundwater, long-term	5.13E-05	kg	Lognormal	1.5118
Phosphate	groundwater, long-term	0.000156	kg	Lognormal	60.612
Arsenic, ion	groundwater, long-term	6.54E-08	kg	Lognormal	5.1329
Cadmium, ion	groundwater, long-term	8.5E-10	kg	Lognormal	188.16
Cobalt	groundwater, long-term	4.28E-07	kg	Lognormal	5.1453
Chromium VI	groundwater, long-term	3.91E-07	kg	Lognormal	7.7721
Copper, ion	groundwater, long-term	1.37E-05	kg	Lognormal	5.2413
Mercury	groundwater, long-term	4.41E-09	kg	Lognormal	30.745

Manganese	groundwater, long-term	1.38E-05	kg	Lognormal	6.1702
Molybdenum	groundwater, long-term	2.39E-07	kg	Lognormal	5.133
Nickel, ion	groundwater, long-term	1.49E-06	kg	Lognormal	5.1316
Lead	groundwater, long-term	3.36E-07	kg	Lognormal	189.49
Tin, ion	groundwater, long-term	6.1E-07	kg	Lognormal	9.1263
Zinc, ion	groundwater, long-term	7.18E-07	kg	Lognormal	107.35
Silicon	groundwater, long-term	0.000157	kg	Lognormal	105.04
Iron, ion	groundwater, long-term	0.003812	kg	Lognormal	7.0606
Calcium, ion	groundwater, long-term	0.002661	kg	Lognormal	5.1447
Aluminum	groundwater, long-term	0.000669	kg	Lognormal	3.6817
Magnesium	groundwater, long-term	0.000317	kg	Lognormal	5.1323
Heat, waste	river	1.189	MJ	Lognormal	1.3796
Phosphate	groundwater	1.47E-05	kg	Lognormal	1.801
Suspended solids, unspecified	river	0.444	kg	Lognormal	0.53
Solved solids	river	5.717	kg	Undefined	0
Oils, unspecified	river	0.216	kg	Undefined	0.311
Waste water/m3	river	1	m3	Undefined	0
Methane, dibromo-	groundwater	3.80E-113	kg	Undefined	0

Propane, 1,2-dichloro-	groundwater	8.61E-116	kg	Undefined	0
Dioxin, 2,3,7,8 Tetrachlorodibenzo-p-	groundwater	2.39E-21	kg	Undefined	0
Acenaphthene	ocean	3.01E-09	kg	Undefined	0
Acenaphthene	groundwater	9.38E-11	kg	Undefined	0
Acenaphthylene	ocean	1.15E-09	kg	Undefined	0
Acenaphthylene	groundwater	3.75E-11	kg	Undefined	0
Acetic acid	ocean	8.21E-09	kg	Undefined	0
Acetic acid	groundwater	5.50E-07	kg	Undefined	0
Acidity, unspecified	groundwater	6.00E-08	kg	Undefined	0
Acrylonitrile	groundwater	6.30E-11	kg	Undefined	0
AOX, Adsorbable Organic Halogen as Cl	groundwater	1.15E-06	kg	Undefined	0
AOX, Adsorbable Organic Halogen as Cl	ocean	5.06E-13	kg	Undefined	0
Aluminum	groundwater	7.66E-06	kg	Undefined	0
Aluminum	ocean	3.90E-13	kg	Undefined	0
Americium-241	groundwater	6.67E-06	kBq	Undefined	0
Ammonia	ocean	1.16E-09	kg	Undefined	0
Ammonia	groundwater	8.23E-04	kg	Undefined	0
Anthracene	ocean	7.14E-10	kg	Undefined	0
Anthracene	groundwater	1.38E-10	kg	Undefined	0
Antimony	groundwater	3.64E-14	kg	Undefined	0
Antimony-124	groundwater	6.93E-09	kBq	Undefined	0
Antimony-125	groundwater	4.72E-09	kBq	Undefined	0
Arsenic, ion	groundwater	1.35E-08	kg	Undefined	0
Arsenic, ion	ocean	2.34E-08	kg	Undefined	0
Barium	groundwater	4.63E-07	kg	Undefined	0
Barium	ocean	1.86E-06	kg	Undefined	0
Benzene	groundwater	3.37E-07	kg	Undefined	0
Benzene	ocean	4.98E-07	kg	Undefined	0
Benzo(a)anthracene	groundwater	1.27E-11	kg	Undefined	0
Benzo(a)anthracene	ocean	6.81E-10	kg	Undefined	0
Benzo(b)fluoranthene	ocean	7.62E-10	kg	Undefined	0
Benzo(b)fluoranthene	groundwater	7.07E-12	kg	Undefined	0
Beryllium	groundwater	2.85E-10	kg	Undefined	0
Beryllium	ocean	2.85E-09	kg	Undefined	0
BOD5, Biological Oxygen Demand	groundwater	1.20E-05	kg	Undefined	0
BOD5, Biological Oxygen Demand	ocean	5.58E-07	kg	Undefined	0
Boron	groundwater	1.85E-06	kg	Undefined	0
Boron	ocean	6.31E-10	kg	Undefined	0
Bromine	groundwater	3.54E-10	kg	Undefined	0

Cadmium	ocean	5.24E-08	kg	Undefined	0
Cadmium	groundwater	8.00E-07	kg	Undefined	0
Calcium, ion	ocean	6.89E-08	kg	Undefined	0
Calcium, ion	groundwater	2.78E-03	kg	Undefined	0
Carbon-14	groundwater	3.38E-04	kBq	Undefined	0
Carbonate	ocean	1.16E-04	kg	Undefined	0
Carbonate	groundwater	2.80E-05	kg	Undefined	0
Cesium-134	groundwater	3.40E-04	kBq	Undefined	0
Cesium-137	groundwater	3.13E-03	kBq	Undefined	0
COD, Chemical Oxygen Demand	ocean	1.46E-05	kg	Undefined	0
COD, Chemical Oxygen Demand	groundwater	3.07E-02	kg	Undefined	0
Chloride	ocean	9.17E-03	kg	Undefined	0
Chloride	groundwater	1.69E-02	kg	Undefined	0
Chlorine	groundwater	1.02E-05	kg	Undefined	0
Chromium	ocean	6.01E-08	kg	Undefined	0
Chromium	groundwater	2.28E-07	kg	Undefined	0
Chromium, ion	groundwater	2.28E-08	kg	Undefined	0
Chromium VI	groundwater	4.36E-11	kg	Undefined	0
Chrysene	ocean	3.86E-09	kg	Undefined	0
Chrysene	groundwater	5.71E-11	kg	Undefined	0
Cobalt	ocean	4.99E-08	kg	Undefined	0
Cobalt	groundwater	2.11E-10	kg	Undefined	0
Cobalt-58	groundwater	2.59E-06	kBq	Undefined	0
Cobalt-60	groundwater	1.45E-03	kBq	Undefined	0
Copper	groundwater	5.10E-07	kg	Undefined	0
Copper	ocean	6.32E-08	kg	Undefined	0
Cresol	ocean	8.74E-12	kg	Undefined	0
Cresol	groundwater	1.14E-11	kg	Undefined	0
Curium alpha	groundwater	8.84E-06	kBq	Undefined	0
Cyanide	groundwater	2.18E-09	kg	Undefined	0
Decane	ocean	4.38E-06	kg	Undefined	0
Decane	groundwater	2.61E-06	kg	Undefined	0
Benzene, ethyl-	ocean	9.18E-08	kg	Undefined	0
Benzene, ethyl-	groundwater	3.68E-08	kg	Undefined	0
Fluoranthene	ocean	7.96E-10	kg	Undefined	0
Fluoranthene	groundwater	2.06E-11	kg	Undefined	0
Fluoride	groundwater	8.42E-04	kg	Undefined	0
Fluorine	groundwater	2.07E-08	kg	Undefined	0
Hexane	ocean	9.54E-13	kg	Undefined	0
Hexane	groundwater	1.25E-12	kg	Undefined	0
Hydrocarbons, unspecified	groundwater	3.41E-07	kg	Undefined	0

Hydrogen chloride	groundwater	1.30E-08	kg	Undefined	0
Hydrogen fluoride	groundwater	4.46E-10	kg	Undefined	0
Hydrogen-3, Tritium	groundwater	0.09852	kBq	Undefined	0
Hydroxide	groundwater	3.58E-07	kg	Undefined	0
Iodine-129	groundwater	9.65E-04	kBq	Undefined	0
Iodine-131	groundwater	4.95E-08	kBq	Undefined	0
Iron	groundwater	8.03E-04	kg	Undefined	0
Iron	ocean	6.13E-07	kg	Undefined	0
Lead	ocean	1.33E-08	kg	Undefined	0
Lead	groundwater	3.20E-07	kg	Undefined	0
Magnesium	ocean	1.14E-07	kg	Undefined	0
Magnesium	groundwater	4.94E-12	kg	Undefined	0
Manganese	groundwater	1.26E-06	kg	Undefined	0
Manganese	ocean	6.42E-08	kg	Undefined	0
Manganese-54	groundwater	2.25E-04	kBq	Undefined	0
Mercury	ocean	4.82E-10	kg	Undefined	0
Mercury	groundwater	4.47E-09	kg	Undefined	0
Methanol	groundwater	2.67E-04	kg	Undefined	0
Molybdenum	ocean	3.35E-12	kg	Undefined	0
Molybdenum	groundwater	2.31E-07	kg	Undefined	0
Naphthalene	groundwater	4.96E-09	kg	Undefined	0
Naphthalene	ocean	9.30E-08	kg	Undefined	0
Nickel	ocean	3.97E-08	kg	Undefined	0
Nickel	groundwater	2.32E-07	kg	Undefined	0
Nitrate	groundwater	4.93E-03	kg	Undefined	0
Nitrate	ocean	1.52E-07	kg	Undefined	0
Nitrogen	groundwater	5.28E-04	kg	Undefined	0
Particulates, > 10 um	groundwater	7.15E-04	kg	Undefined	0
Particulates, > 10 um	ocean	4.44E-04	kg	Undefined	0
Particulates, < 10 um	groundwater	7.84E-10	kg	Undefined	0
Phenol	ocean	9.69E-07	kg	Undefined	0
Phenol	groundwater	3.36E-07	kg	Undefined	0
Phosphate	groundwater	3.66E-06	kg	Undefined	0
Plutonium-alpha	groundwater	2.66E-05	kBq	Undefined	0
Hydrocarbons, aromatic	groundwater	2.36E-07	kg	Undefined	0
Potassium	groundwater	8.21E-07	kg	Undefined	0
Methane, monochloro-, R-40	groundwater	4.08E+00	kg	Undefined	0
Radium-226	groundwater	1.10E+00	kBq	Undefined	0
Ruthenium-106	groundwater	6.67E-01	kBq	Undefined	0
Selenium	groundwater	4.23E-08	kg	Undefined	0
Silver, ion	groundwater	9.16E-10	kg	Undefined	0

Silver, ion	ocean	9.93E-12	kg	Undefined	0
Silver-110	groundwater	1.01E-08	kBq	Undefined	0
Sodium, ion	groundwater	4.08E-03	kg	Undefined	0
Sodium, ion	ocean	1.11E-05	kg	Undefined	0
Strontium	groundwater	3.95E-06	kg	Undefined	0
Strontium	ocean	3.90E-07	kg	Undefined	0
Strontium-90	groundwater	3.22E-04	kBq	Undefined	0
Sulfate	ocean	5.18E-05	kg	Undefined	0
Sulfate	groundwater	2.79E-03	kg	Undefined	0
Sulfide	ocean	2.06E-05	kg	Undefined	0
Sulfide	groundwater	5.27E-06	kg	Undefined	0
Sulfite	groundwater	5.59E-07	kg	Undefined	0
Sulfur	ocean	3.37E-10	kg	Undefined	0
Sulfur	groundwater	4.38E-10	kg	Undefined	0
Thallium	groundwater	1.31E-11	kg	Undefined	0
Tin	ocean	1.19E-11	kg	Undefined	0
Tin	groundwater	2.32E-11	kg	Undefined	0
Titanium	groundwater	5.17E-08	kg	Undefined	0
Titanium	ocean	1.21E-12	kg	Undefined	0
Toluene	groundwater	2.45E-07	kg	Undefined	0
Toluene	ocean	3.25E-07	kg	Undefined	0
TOC, Total Organic Carbon	ocean	5.58E-07	kg	Undefined	0
TOC, Total Organic Carbon	groundwater	3.47E-05	kg	Undefined	0
Uranium-238	groundwater	1.96E-03	kBq	Undefined	0
Vanadium	ocean	3.42E-08	kg	Undefined	0
Vanadium	groundwater	7.72E-08	kg	Undefined	0
Ethene, chloro-	groundwater	1.29E-13	kg	Undefined	0
VOC, volatile organic compounds, unspecified origin	ocean	5.58E-09	kg	Undefined	0
VOC, volatile organic compounds, unspecified origin	groundwater	8.32E-08	kg	Undefined	0
Heat, waste	groundwater	0.001315	MJ	Undefined	0
Xylene	groundwater	1.15E-06	kg	Undefined	0
Xylene	ocean	2.11E-07	kg	Undefined	0
Zinc	ocean	1.00E-06	kg	Undefined	0
Zinc	groundwater	1.86E-07	kg	Undefined	0

Table B-3. ReCiPe Endpoint (H) V1.05 / World ReCiPe H/A / Normalization.

Label	Direct discharge of wastewater to Al-Samawah River	Electricity, oil, at power plant/UCTE U	Sewer grid, class 2/CH/I U	Wastewater treatment plant, class 2/CH/I U
Climate change Human Health	4.36E-06	7.9E-07	1.03E-05	1.1E-05
Ozone depletion	0	1.77E-10	7.86E-10	1.03E-09
Human toxicity	4.93E-06	3.81E-08	1.39E-06	4.18E-06
Photochemical oxidant formation	2.27E-09	9.04E-11	9.12E-10	1.0E-09
Particulate matter formation	8.58E-06	3.53E-07	3.78E-06	4.21E-06
Ionising radiation	5.03E-08	1.75E-10	1.58E-08	1.77E-08
Climate change Ecosystems	3.88E-07	7.03E-08	9.16E-07	9.83E-07
Terrestrial acidification	1.45E-08	4.73E-10	1.78E-09	2.06E-09
Freshwater eutrophication	7.66E-09	1.06E-11	9.51E-10	1.59E-09
Terrestrial ecotoxicity	1.89E-08	2.21E-10	9.36E-10	1.1E-09
Freshwater ecotoxicity	3.85E-10	2.47E-12	4.63E-10	5.22E-10
Marine ecotoxicity	9.77E-13	1.76E-14	1.46E-12	1.64E-12
Agricultural land occupation	2.93E-08	5.3E-11	1.45E-08	1.81E-08
Urban land occupation	0	2.56E-10	2.17E-08	1.03E-07
Natural land transformation	0	5.94E-09	-7.82E-09	9.18E-09
Metal depletion	0	1.09E-10	1.57E-07	1.22E-07
Fossil depletion	0	1.82E-06	1.96E-05	1.59E-05

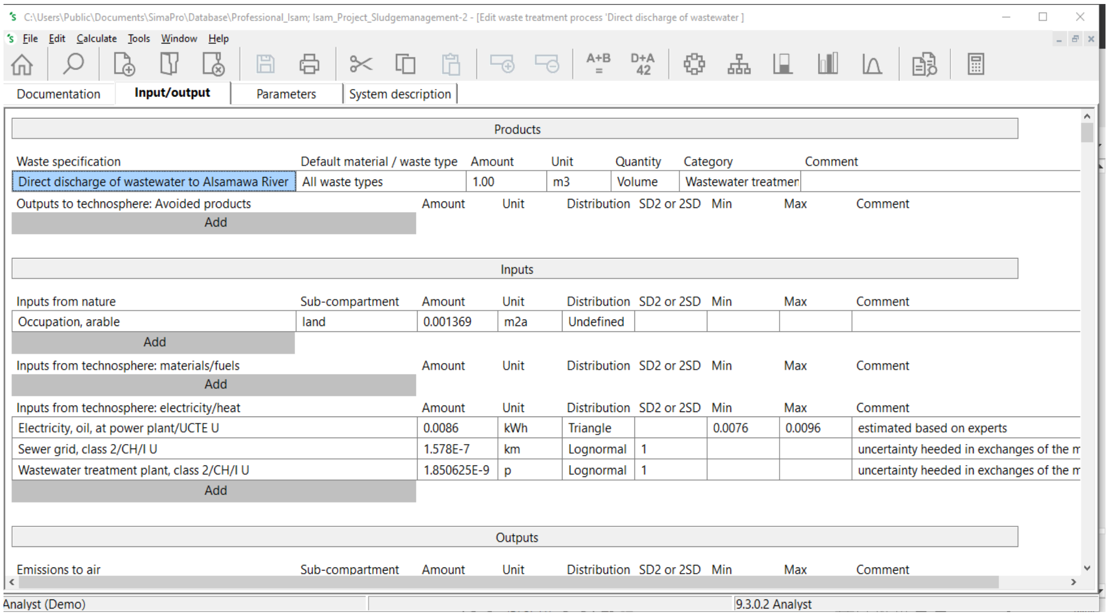
Table B-4. Method: ReCiPe Endpoint (H) V1.05 / World ReCiPe H/A / Characterization.

Label	Direct discharge of wastewater to Alsamawa River	Electricity, oil, at power plant/UCTE U	Sewer grid, class 2/CH/I U	Wastewater treatment plant, class 2/CH/I U
Climate change Human Health	16.4728	2.981	38.8525	41.6937
Ozone depletion	0	8.8928	39.4528	51.6544
Human toxicity	46.8075	0.3612	13.1713	39.6599
Photochemical oxidant formation	53.1466	2.112	21.3053	23.436
Particulate matter formation	50.6989	2.0857	22.347	24.8683
Ionising radiation	59.9074	0.2082	18.7816	21.1028
Climate change Ecosystems	16.4499	2.9819	38.8627	41.7055
Terrestrial acidification	77.1147	2.5125	9.4338	10.939
Freshwater eutrophication	75.0015	0.104	9.3041	15.5904
Terrestrial ecotoxicity	89.337	1.0453	4.4224	5.1954
Freshwater ecotoxicity	28.038	0.1798	33.7303	38.0518
Marine ecotoxicity	23.8814	0.4302	35.7123	39.9761
Agricultural land occupation	47.3441	0.0855	23.3346	29.2358
Urban land occupation	0	0.2048	17.3428	82.4524
Natural land transformation	0	39.3136	-52	60.6864
Metal depletion	0	0.039	56.3742	43.5868
Fossil depletion	0	4.8742	52.4888	42.6369

Table B-5. Method: ReCiPe Endpoint (H) V1.05 / World ReCiPe H/A / Weighting.

Label	Direct discharge of wastewater to Al-Samawah River	Electricity, oil, at power plant/UCTE U	Sewer grid, class 2/CH/I U	Wastewater treatment plant, class 2/CH/I U
Climate change Human Health	1.7457	0.3159	4.1174	4.4185
Ozone depletion	0	7.09E-05	0.0003	0.0004
Human toxicity	1.9724	0.0152	0.555	1.6712
Photochemical oxidant formation	0.0009	3.62E-05	0.0004	0.0004
Particulate matter formation	3.4312	0.1412	1.5124	1.683
Ionising radiation	0.0201	7.0E-05	0.0063	0.007
Climate change Ecosystems	0.155	0.0281	0.3663	0.393
Terrestrial acidification	0.0058	0.0002	0.0007	0.0008
Freshwater eutrophication	0.003	4.25E-06	0.0004	0.0006
Terrestrial ecotoxicity	0.0076	8.85E-05	0.0004	0.0004

Freshwater ecotoxicity	0.0002	9.87E-07	0.0002	0.0002
Marine ecotoxicity	3.91E-07	7.04E-09	5.85E-07	6.55E-07
Agricultural land occupation	0.0117	2.12E-05	0.0058	0.0072
Urban land occupation	0	0.0001	0.0087	0.0413
Natural land transformation	0	0.0024		0.0037
Metal depletion	0	2.18E-05	0.0315	0.0243
Fossil depletion	0	0.3641	3.921	3.185



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Products

Waste specification	Default material / waste type	Amount	Unit	Quantity	Category	Comment
Direct discharge of wastewater to Alsamawa River	All waste types	1.00	m3	Volume	Wastewater treatmer	

Outputs to technosphere: Avoided products	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment

Inputs

Inputs from nature	Sub-compartment	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment
Occupation, arable	land	0.001369	m2a	Undefined				

Inputs from technosphere: materials/fuels	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment

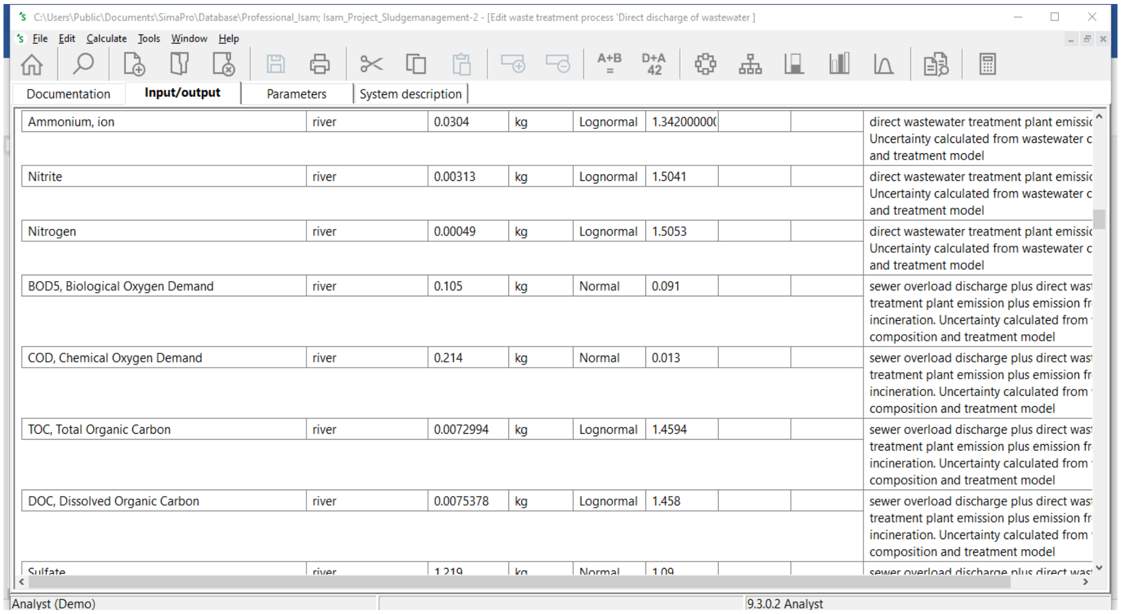
Inputs from technosphere: electricity/heat	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment
Electricity, oil, at power plant/UCTE U	0.0086	kWh	Triangle		0.0076	0.0096	estimated based on experts
Sewer grid, class 2/CH/I U	1.578E-7	km	Lognormal	1			uncertainty heeded in exchanges of the
Wastewater treatment plant, class 2/CH/I U	1.850625E-9	p	Lognormal	1			uncertainty heeded in exchanges of the

Outputs

Emissions to air	Sub-compartment	Amount	Unit	Distribution	SD2 or 2SD	Min	Max	Comment

Analyst (Demo) 9.3.0.2 Analyst

Figure B-2. Data Entry For One m^3 of the Wastewater of the Plant.



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Ammonium, ion	river	0.0304	kg	Lognormal	1.342000000			direct wastewater treatment plant emissi Uncertainty calculated from wastewater and treatment model
Nitrite	river	0.00313	kg	Lognormal	1.5041			direct wastewater treatment plant emissi Uncertainty calculated from wastewater and treatment model
Nitrogen	river	0.00049	kg	Lognormal	1.5053			direct wastewater treatment plant emissi Uncertainty calculated from wastewater and treatment model
BOD5, Biological Oxygen Demand	river	0.105	kg	Normal	0.091			sewer overload discharge plus direct was treatment plant emission plus emission f incineration. Uncertainty calculated from composition and treatment model
COD, Chemical Oxygen Demand	river	0.214	kg	Normal	0.013			sewer overload discharge plus direct was treatment plant emission plus emission f incineration. Uncertainty calculated from composition and treatment model
TOC, Total Organic Carbon	river	0.0072994	kg	Lognormal	1.4594			sewer overload discharge plus direct was treatment plant emission plus emission f incineration. Uncertainty calculated from composition and treatment model
DOC, Dissolved Organic Carbon	river	0.0075378	kg	Lognormal	1.458			sewer overload discharge plus direct was treatment plant emission plus emission f incineration. Uncertainty calculated from composition and treatment model
Sulfate	river	1.219	kg	Normal	1.09			sewer overload discharge plus direct was

Analyst (Demo) 9.3.0.2 Analyst

Figure B-3. Data Entry of Concentation of WWTP.

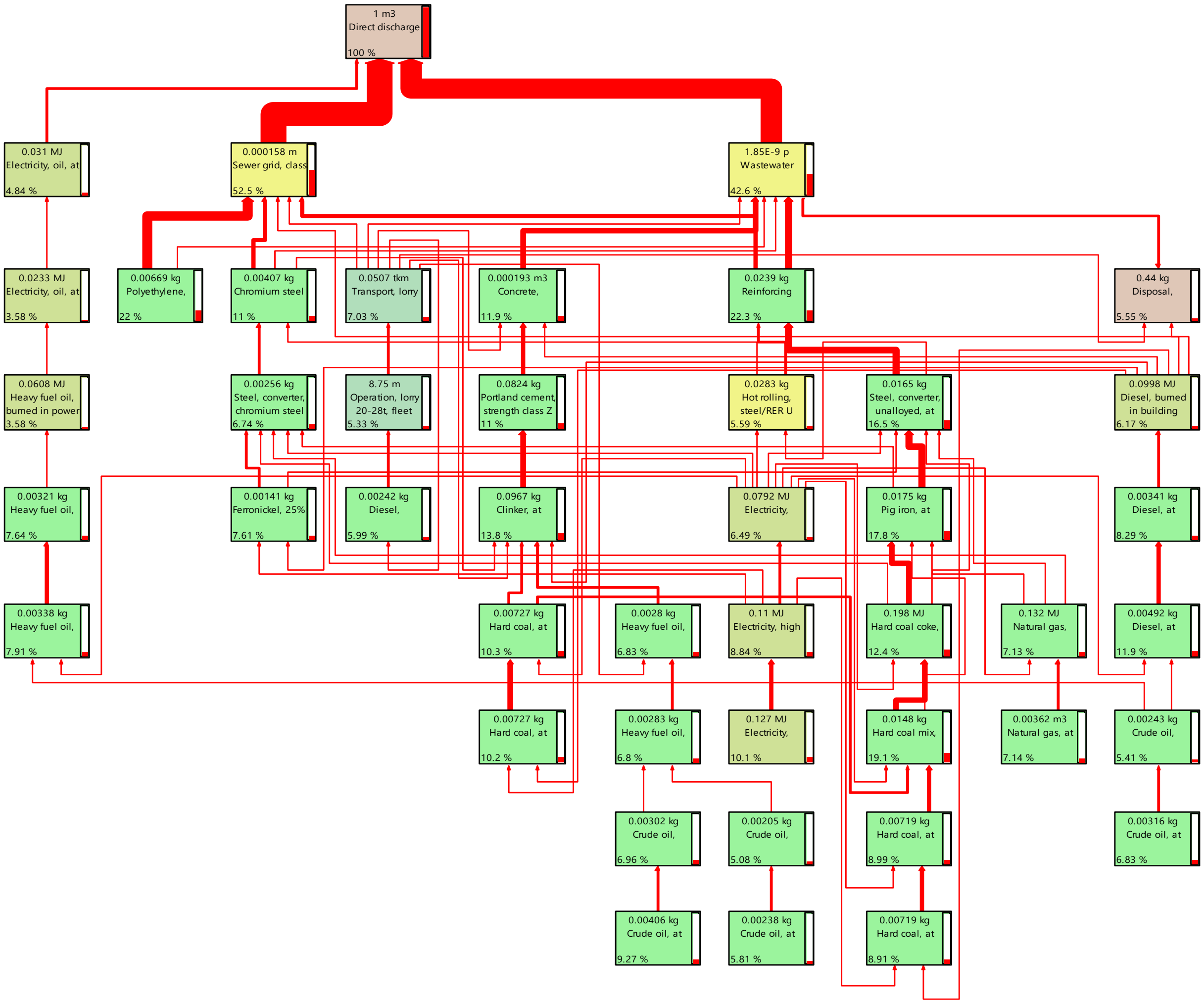

Figure B-4. Network Diagram Shows High Contributions from Construction of WWTP , Sewer Grid and Small Contribution from Electricity.

Appendix C

Sample calculations for overflow rate

$$\text{Surface Flow Rate(SOR)} = \frac{Flow\,\frac{gallons}{day}}{Surface\ Area,ft^2}$$

$$\text{Surface Flow Rate(SOR)} = \frac{9.7\,\frac{MG}{L}*1000000\frac{g}{MG}}{(10^2-1^2\,)\pi\,m^2\,*4(basins)*\frac{10.76\,ft^2}{m^2}} = 724.6\ \text{gpd/ft}^2$$

Where :-

Q = influent flowrate, gallons/day

A= clarifier surface area, ft^2

الخلاصة

تعد معالجة مياه الصرف الصحي أحد العناصر في الحد من تلوث المياه في أي بلد. تواجه محطات معالجة مياه الصرف الصحي في العراق تحديات كبيرة بسبب الإدارة غير السليمة. حتى الآن ، قد تعد محطات معالجة مياه الصرف الصحي هذه الملوث الرئيس للمسطحات المائية في البلاد. تم أخذ معالجة مياه الصرف الصحي في السماوة الواقعة في محافظة المثنى كدراسة حالة لتحليل العمليات في هذه المحطات. تمت زيارة المحطة وجمع البيانات المتوفرة ومقابلة الموظفين المسؤولين عن العمليات. أظهر تحليل البيانات وجود نقص في المعالجة منذ بداية عمليات المحطة ويرجع ذلك أساسًا إلى عدم الكفاءة في تصميم وبناء وإدارة مراحل المعالجة. حاليا ، يوجد ما يقرب 76.9 E + 05 كجم من BOD5، و 3.24 E + 06 كجم منTSSو 4.01 E + 07, كجم من TDS، و 1.55 E + 06 كجم من COD، و 9.35 E + 04 كجم من النترات ، و1.097 E + 05 كجم من الأمونيا ، و 8.90 E + 06 كجم من الكبريتات ، و 2.08 E + 03 كجم من الفوسفات ، و 1.57 E + 06 كجم من الزيوت والشحوم و 1.74 E + 05كجم من كبريتيد الهيدروجين يطرح سنويًا إلى نهر السماوة من المحطة مما يجعلها الملوث الرئيسي في المحافظة. لا يوجد قياس لمستوى التلوث بالمعادن الثقيلة والهيدروكربونات والمواد السامة الأخرى ، ولكن من المتوقع أن تكون عالية أيضًا. لوحظ أعلى معدل تغير من مدة إلى أخرى في نموذج تحليل الاتجاه الخطي في التلوث بالزيت والشحوم (ß1 = 2.311) مما يشير إلى مستوى عالٍ من التدهور في العملية ، قبل التوقف في عام 2016 ، أثناء العمليات ، تجاوزت مياه الصرف المصروفة معايير تراكيز المولوثات BOD_5 و COD و TSS و NH_3 و G&O و H_2S لـ 1.6 و 0.88 و 8 و 3.36 و 119 و 20.2 مرة على التوالي. يوصى بتنفيذ قائمة طويلة من إجراءات التصحيح من أجل الامتثال للحد الأدنى من معايير منع تلوث المياه في الدولة.

حاولت هذه الدراسة عرض الأضرار الناتجة عن توقف محطة معالجة مياه الصرف الصحي باستخدام كل من تقييم دورة الحياة (LCA) والتقييم الكمي للمخاطر الميكروبية (QMRA). تهدف الدراسة إلى استخدام نهج نقطة النهاية في تقييم دورة الحياة لتقييم التأثيرات على صحة الإنسان وجودة النظام البيئي والموارد. قدمت الدراسة أيضًا QMRA يقتصر على بكتيريا Escherichia coli (E. Coli) و Total Coliform (TC) التي تسبب مرض الإسهال وتوفر أداة لتقدير عبء المرض من الكائنات الحية الدقيقة المسببة للأمراض في الماء. يقتصر نظام QMRA أيضًا على التعرض لمسببات الأمراض عن طريق الشرب المباشر من النهر من قبل الأشخاص الذين يعيشون على الضفة أسفل نقطة التصريف. من أجل بناء جرد ، بيانات خاصة بالمحطة وكذلك الأدبيات ، تم استخدام البيانات من المنشورات الفنية. كان ReCipe 2008 هو الأسلوب المفضل لتقييم

تأثير دورة الحياة. بعد تحليل العواقب البيئية ، ونظرًا لعدم استخدام الكهرباء والمواد الكيميائية في المحطة ، أظهرت النتائج أن التأثير الأكبر على صحة الإنسان كان مرتبطًا بإنشاء محطة معالجة مياه الصرف الصحي (2.62 E-07 DALY / m^3). كان التأثير الأكبر على النظام البيئي مرتبطًا أيضًا بإنشاء محطة معالجة مياه الصرف الصحي (9.61 E-10 yr/m^3) ، بينما في فئة استنفاد الموارد ، كان إنشاء شبكة الصرف الصحي هو التأثير الأكبر (0.437 $\$/m^3$). بالنسبة QMRA ، أظهرت النتائج أنه من بين كل مليون شخص يشربون مباشرة من مجرى النهر ، سوف يتعرض 172608 لمرض الإسهال. وفقًا لبيانات التقييم ، فإن الخطر النهائي للإشريكية القولونية هو 0.172608 و TC هو 0.149792. لقد تجاوزت نتائج عبء المرض إلى حد كبير المستوى المرجعي 10^{-6} لمنظمة الصحة العالمية للمخاطر وإظهار الحاجة الملحة لوقف التصريف المباشر لمياه الصرف في النهر والقيام بكل ما يلزم لإعادة تنشيط العمليات في المحطة.

جمهورية العراق
وزارة التعليم العالي و البحث العلمي
جامعة كربلاء
كلية الهندسة
قسم الهندسة المدنية

عنوان الرسالة

تقييم العمليات وتأثيراتها البيئية لمحطة معالجة مياه الصرف الصحي في محافظة المثنى

رسالة مقدمة الى مجلس كلية الهندسة / جامعة كربلاء وهي جزء من متطلبات نيل درجة الماجستير في علوم الهندسة المدنية

كتبت بواسطة:
زهراء محمد العامري
(بكالوريوس في علوم الهندسة المدنية 2019)
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