Chapter 2 Literature Review

This chapter is addressing the general concept, literature, and theories on the previous study that has a close affiliation with this study. Those works of literature will be addressed accordingly by the interpretation of the current study problem and objective then will be explained in a subsequent chapter. This chapter is based on past researches, books, and journals in various parts and fields of the world. Overall this chapter will include the general concept of sugarcane production, wastewater, the material, and the chemical input used in the production process; also, the impacts of wastewater on the physiochemical characteristics of water, the consequences of wastewater on the community study area health, and the side effects of wastewater on the biodiversity (fishes). Lastly, the study will address spatial analysis and its role in distributing the factory's wastewater.

The study topic address wastewater that is resulting from sugarcane factory and its consequences on different environmental components, prior addressing the concept of wastewater the study should take the gap to define the source of the problem which is Sugarcane production.

2.1 Sugarcane production concepts

This process uses numerous arrangements to process sugarcane to white sugar which is grinding, purification, crystallize, refinement and crushing. It can be inferred that the factories can process sugarcane from raw sugarcane to white sugar. It can also be inferred that the factory with equipment and tools have the experience to crush and grind sugarcane sticks and to extract the juice or any kinds of sugarcane (Morgenroth & S. Pfauipro, 2010).

Sugar is a product, considered as one of energy materials that most of us consume on daily intake. Indeed it is widespread, even for the most of it has consequences on human being health and environment. However, sugar production becomes a vital commodity to the world’s population with its recognition and demand in the world market regardless of its health implications to the world population. In some tropical and subtropical countries, mass commercial sugarcane plantation has resulted in huge losses and pollution to the environmental component and biodiversity (Prasara-a & Gheewala, 2015).

Sugar product has several types of originations; all of them have been cultivation as cane and beet. Commonly sugar is processed from sugarcane (Nelson et al., 2013). Sugar production has different concepts; the differences mainly refer to the procedures or the components in terms of production stages as well as other concepts that the study will examine. Generally, sugar production is defined as a set of the process and stages which include agricultural, preparation and milling, purification, concentration, crystallization and centrifugation stage (Langenhove et al., 2009).

Sugars (saccharides) is a part of the carbohydrate compounds, produced from first to the last stage of the photosynthesis process, which combines carbon dioxide and water to generate oxygen and glucose. Chemically symbolize as a monosaccharide: $6CO2 + 6H2O$ ($C6H12O6 + 6O2$ (Prasara-a & Gheewala, 2015). Sugars are the process of sugar milling, juice clarification and treatment, Crystallization and Centrifugal separation (Chauhan et al., 2011).

Sugar production requires input materials in this case, the study addresses the chemical input materials that have been used because of the massive impact on the environment, human, and drinking water, as seen in figure (2.1), the primary purpose of this study to seek out the amount used in the process of production. The types of chemical compounds within wastewater are potential to destroy water quality.

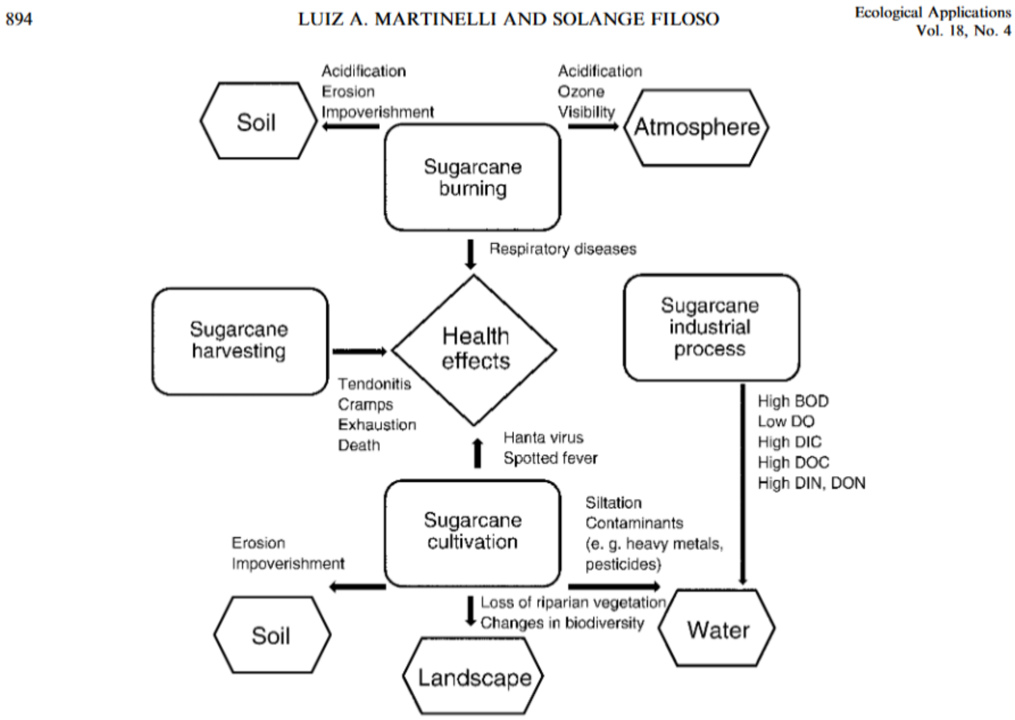

Figure 2.1. Diagram showing the main environmental and social impact of sugarcane agro-industry.

Source: Modification M.K. Chauhan et al. / Renewable and Sustainable Energy Reviews 15 (2011) 3445– 3453.

2.2 The material input of sugarcane factories

Commonly any industry needs input materials called as raw materials; nevertheless, the amount of them depends on factories size. Sugar factories require a considerable amount of input, both raw materials and chemicals materials.

2.2.1 Raw materials

There are considerable numbers of raw materials. However, the study has addressed the primary raw input materials needed for sugar production and have a role in wastewater formation, as follows:

2.2.1.1 Cane stalks (Saccharum)

Saccharum is considered as the main ingredient of sugar production. It can produce several by-products, such as bagasse and molasses. They can be used as a resource and input for other plants. Bagasse is the source for power plant energy, whereas molasses is the source for the ethanol production plant. Hence, bagasse and molasses are by-products of sugar mills, and they improve the environmental industry quality. Studies inform that 1 ton of raw sugar is produced from 0.38 tons of molasses, 2.4 tons of bagasse with 50% moisture content, and 368 kg of ashes where slugs are emitted (Chauhan et al., 2011).

According to Thailand's data, it is confirmed that 1 ton of sugarcane produces 103.6 kg sugar and 45.2 kg molasses (Prasertsri, 2007); and 1 ton of dry bagasse fed into acid hydrolysis process for producing 186 kg of ethanol (Botha, 2006).

2.2.1.2 Water

Water is a vital resource to cultivate and produce sugarcane, and it plays a significant role in the production process. Water can be used in the molting process or other usages. The study confirms that 1 ton of raw sugar can generate 17,000 m^3 of wastewater and needs 0.15 ha of land. Moreover, the expansion of sugarcane land depends on water resources around the local agro-meteorological conditions. Sometimes the total amount of rainfall is insufficient; therefore, any geographical area requires enough irrigation to meet plant water demands. However, sugar production has significant potential consequences on the indigenous water availability by reducing water quantity and quality for other usages (Hess et al., 2016).

A study conducted in India confirms that 1 ton of can processing requires around 1,500–2,000 dm3 of water, and generates about 1,000 dm^3 of wastewater (Sahu & Chaudhari, 2015). Other studies confirm that the total amount of water needed for producing one ton of cane is 2.1- 2.8 m3 (Bantacut & Novitasari, 2016).

2.2.2 Chemical materials

The most important chemical substance used in sugar production is lime water, calcium oxide, and calcium phosphate.

2.2.2.1 Lime water

The distillation of lime water can be made by adding water to calcium oxide: 2 Ca OH +2 H_2O ------- 2Ca $(OH)_2$. The preparation of lime should be into consideration and is called Baume (Be). The concentration degree of lime water should be added in the main tank 15 Be, then the concentration degree of lime water ought to be diluted to 3-5 in three tanks. The best condition the melting lime is when the cane juice gets cold. Therefore, adding lime water to the cane juice before heating could be able to melt much amount of lime. However, undiluted lime may cause an enormous number of technological problems; it will be deposited on pipes evaporators surface and leads to the exploitation of factories' energy. The primary purpose of adding lime water to cane juice is for increasing pH ion (concentration of hydrogen ion in the solution) which is ranging between 8-8.2. Through this understanding, the hydrogen ion concentration degree in juice sugar is essential. The retention time estimation of lime water with cane juice reaction is 15-20 minutes. If reacted without adequate retention time, it leads to the existence of calcium ions. Therefore, inside the evaporator tube, it leads to the viscosity of sugar solutions. Thus, it can reduce the working efficiency, evaporation, and boiling centrifugal-m crystallization machines (Chauhan et al., 2011).

2.2.2.2 Calcium phosphate

Phosphate plays a significant role in the process of cane juice purification; therefore, to complete the deposition process, the juice must contain a percentage of phosphate ranging from 250-300 PM. Phosphate should be added when the percentage of raw juice is lower. The most important reaction in the process of purification of juice is the formation of solutions, which is called as calcium phosphate

$P2O5 + Ca (OH) 2$ ------- $Ca (Po3)2 +H2O$

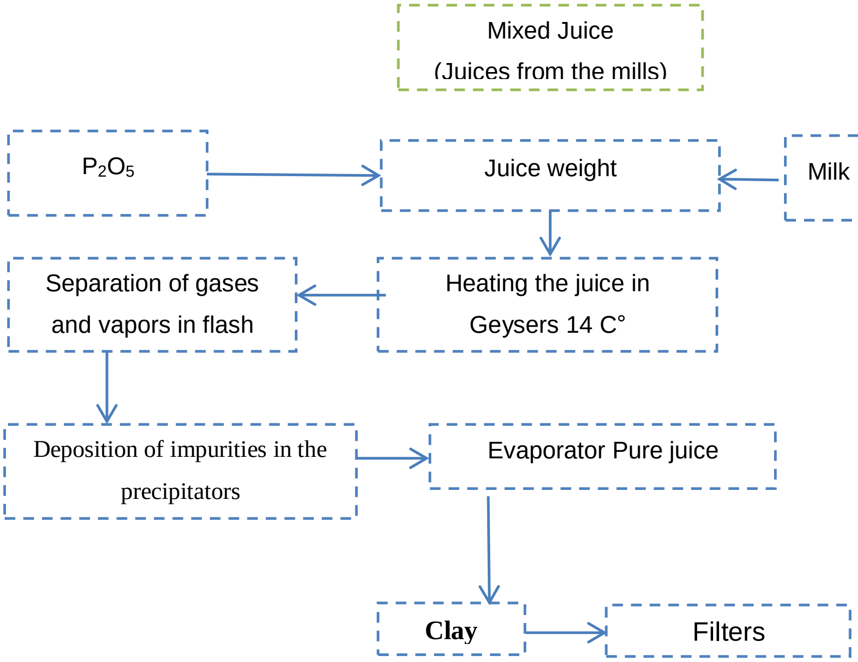

Figure 2.2. The process of producing sugar juice

Source: Modification M.K. Chauhan et al. / Renewable and Sustainable Energy Reviews 15 (2011) 3445.

Those materials during their output are in a different shape as liquid, solid and gas. Besides the multiple benefits, there are consequences to the environment. If the sugar factories outputs are not adequately managed with a proper system, it will pollute the environment such as the water, air, and human health (Chauhan et al., 2011).

The first process of sugar production is the cultivation of Sugarcane; its process consists of cane growing, pre-harvest burning, and harvesting. The second process is Sugar Mill, comprises of crushing, juice clarification, evaporation, crystallization, and CHP. Both of them require somewhat of a chemical substance; nevertheless, the study focuses on the chemical material used in the process of milling. A study conducted in South Africa about Environmental Impact Assessment of Lignocellulosic Lactic Acid Production: Integrated with Existing Sugar Mills, ratified that the auxiliary chemicals used in the production are magnesium hydroxide ($Mg(OH)_2$) and Triethylamine (TEA). The study found that those elements had a side effect on freshwater, eutrophication potential (FWEP) and marine eutrophication potential (MEP). Also, it can reduce the environmental burden by 95.4% and 95.8% for FWEP and MEP, and the eutrophication potential contribution attributed to the impacts associated with Mg (OH) 2, Triethylamine, and ethanol (Gezae et al., 2016).

2.3 Concepts of wastewater

Sugarcane factories are remarkable water consumers and also produce wastewater with more significant organic contents, typically discharged into the river or watercourses. For meeting the process, the factory may get the water from two kinds of sources: first, from the cane stalks itself, which can be used in various operations within the process such as evaporation, crystallization, and refinery. This kind of water may contain enough amounts to sustain the process of sugar manufacturing. The second one can be reached from wells, rivers, or lakes; mainly transported using barometric condensers, turbines, and machinery. Besides the consumption of large volumes of water, it also generates some organic compounds and problems the environment (Ingaramo et al., 2009). Wastewater is unwanted unserviceable water which commonly discharged to surrounding areas through river streams. This discharge is undesirable due to overburden the environment and contain a high percentage of biological and chemical oxygen demands. It is necessary to eliminate the waste using some process as treatment. Nevertheless, the treatment process depends on the type of pollutants that existed in wastewater. Some of them rely on chemical coagulation, bio-coagulation, filtration, and ion-exchange aerobic and anaerobic treatment (Sahu *et al.,* 2017).

Wastewater of sugar factories has externalities to the environmental components. Due to a high level of contaminants such as suspended solids, chemicals, organic, and inorganic matter, those chemical materials are harmful. If not appropriately treated, it might ultimately contribute adverse effects on the environment by reducing the freshwater bodies' quality (Sahu et al., 2017). The sugarcane factories can generate wastewaters with a massive amount of pollutants. The wastewater effluents from the sugar factories are highly variable both in quantity and quality. Such wastes contain high concentrations of organic materials, physical-chemical and biological pollutants with different concentration levels (Hamoda & Al-sharekh, 1999).

Some of the Wastewater with a high amount of sludge require special techniques to implement the treatment process — the extensive constituents from wastewater need proper handling, treatment, and disposal. Sludge is usually slurry, contains 0.25-12% solids by weight, based on operations and processes. Primary sludge is the solids fraction that settles from wastewater in the primary sedimentation tank and consists of organic solids, grit, and inorganic fines with the significant effect of the TSS, TDS, Turbidity, Color and Sediments (Rughoonundun & Holtzapple, 2017). The wastewater from sugar factories may have a different source. All of those wastes are gathering and congregating as wastewater contains various types of chemical ingredients, C-organic → microorganisms metabolism → Aerobic→ organic= CO2, NO3, NH3, H2O, NO2, SO4. While: C- organic → microorganisms metabolism → Aerobic→ inorganic= N2, NH3, CH4, H2S. Therefore, the study wants to address the consequences of wastewater on drinking water, human health, and organisms.

2.4 Wastewater Treatment of Sugarcane Factories

Discharging wastewater without proper treatment provisions will burden the elements of surrounding life; hence, several worldwide Sugarcane factories have addressed and performed the treatment sewage system. Sragi is a sugarcane factory, located in Pekalongan Regency, Central Java Province, Indonesia. The principle management of this factory is under three stepts, which comprises Reuse, Reduce, and Recycle methods. These comprehensive systems aim to resolve and control the balanced environment, starting from the equalization of wastewater by operating water pumping machine, neutralization by utilizing calcium oxide, and sedimentation control by separating solid from liquid waste.

Solid waste is sold as soil fertilizer, while liquid waste is recycled anaerobically using a boiler. The treated wastewater then uses a surplus of aerobic results in the evaporator condensation process; the condensation surplus is then used as fertilizer for agricultural irrigation. This process shows that the Sragi factory has an appropriate waste management system as it has considered the balance of the environment and has a role in achieving environmental sustainability. The mill has carried out efficiency manners and instilled the principle of ecological conservation by reducing waste disposal and reusing wastewater to deliver the concept of sustainability (Nihaya et al., 2018)

Sugarcane wastewater usually has high concentrations of BOD and COD. Nevertheless, the treatment approaches might depend on the character of pollutants existed in sewage. There are several types of Sugarcane wastewaters technologies, some of them are based on chemical coagulation, and others are on bio-coagulation, filtration, aerobic, and anaerobic treatment. The whole techniques require significant funds (Sahu et al., 2017).

The treatment of sugarcane wastewater is fundamental to protect the environment components, particularly water quality. Moreover, there are several approaches to reduce the wastewater concentration; the concentration of sugarcane wastewater can be investigated through the physiochemical and biological test.

The process of physiochemical treatment in Egypt is comprised of adsorption, coagulation/flocculation, oxidation processes, and membrane treatment. Those processes have been studied with particular focus on effluent decolorization and have been engaged and congenial with environmental regulations (Ghandour et al., 2017).

Sugarcane wastewater generates massive apprehensive and environmental problems associated with water, land pollution, and other kinds of ecological components. Some authors confirmed that sewage in groundwater could disturb the quality of groundwater by releasing its chemical composition. Untreated wastewater also could damage the ecosystem of water bodies by increasing the physiochemical components of water; therefore, it is necessary for enforcing the wastewater regulation to reduce the negative consequences. Many factories worldwide use conventional biological therapy to reduce the impacts, for instance, the typical processes of the treatments are the separation of oil-solid, equalization, anaerobic digestion, decomposition of wastewater by adding degrading bacteria, aerobic decomposition, and stabilization. Before releasing the wastewater to the river, the drain should be monitored through the bio-indicator process by breeding fish or other aqueous components in the ponds. The wastewater in ponds will be excellent if the concentrations are lower than the effluent standard before finally discharging them into the river (Qureshi et al., 2015).

2.5 Physiochemical characterization of the effluents wastewater on water

2.5.1 The physical influence

Wastewater has full ability to alter the physical characteristics of water, characterized by undesirable pollutants. Drinking water has several physical characteristics; nevertheless, the study limited the most important effects of wastewater from sugarcane factories such as Total Suspended Solids, Total Dissolved Solids, Turbidity, Odor, and Color**.** Based on the health regulation, treated wastewater from irrigation and other usage is prohibited in the vicinity of drinking water wells since it can bring effluent and pose several risks. The risks have a long-term influence and consequences which are difficult to evaluate. We are aware that the world today is suffering from water scarcity due to climate change phenomena and other threats (Shakir et al., 2016).

2.5.1.1 Total Suspended solids (TSS)

TSS is measured by the suspended particulate matter within the water. It has a significant relationship with the turbidity. A high suspended solid accompanied by the turbidity affects the water and aqueous life as it is constraining light penetration, damaging the fish gills, and damage the spawning habitat by smothering fish eggs. Analytically, suspended solids are determined by filtering a known volume of water through a 0.45 µm filter paper and noting the increase in weight of the filter paper. The study conducted in Haspolat Wastewater Treatment Plant (WWTP), in the northern part of Cyprus, confirmed that improving wastewater treatment plant by constructing anaerobic ponds developed the water quality in terms of TSS. It is clear that anaerobic ponds improve the effluent quality and rapidly stabilize the stable organic wastes, also make the wastes more liable for further treatment and reduce the oxygen demand in aerated and facultative ponds (Türker et al., 2009).

All upstream transport some suspended solids under natural situations; nevertheless, if concentrations are enhanced, for example, anthropogenic aggravation, this can lead to variations to the physiochemical and biological characteristics of the water (Bilotta & Brazier, 2008). Inorganic and organic compounds of TSS have been involved in different types of manufacturing, such as commercial chemical products. The process of wastewater contains different types of inorganic and organic compounds. The effects of organic pollutants can increase water turbidity, decrease water cleanliness, and affect other organisms (Wang & Zhang, 2009).

Total suspended solids (TSS) is one of the most polluted elements that affect watercourses around the world and is considered to be one of the major pollutants that deteriorates water quality. Also, it can contribute to higher expensive costs for water treatment, decreases fish resources, and affecting the general aesthetics of the water bodies. TSS reduces and depletes the amount of dissolved oxygen (DO) in drinking water. It is also necessary to understand the values of the TSS to maintain and manage the characters of the effluent (Verma et al., 2013).

The calculation of the TSS usually uses the gravimeter method. The test is done using filter paper. First, dry the solid residue on the filter until it reaches a constant weight. Second, weight and put it at the temperature between 103-105 Celsius degrees and weight it again. The weight of the filter is the value of the TSS; the amount of the TSS is the difference between total dissolved solids and total solids. TSS requires glass-fiber filter (Whatman Grade 934 AH with size 1,5 µm-Particle Retention Standard for TSS in water analysis also requires Gelman type A/E, with size 1,0 µm (Nasrabadi et al., 2016). In general, the TSS calculated using the following formula:

$$Mg\ TSS\ per\ Liter\ =\ (A - B)\ X\ 1000/the\ volume\ of\ the\ test\ sample$$

A is the weight of filter paper + dry residue. B is the weight of filter paper (Clesceri et al., 1998).

2.5.1.2 Turbidity

Turbidity is aesthetically unpleasant because the excess of turbidity leads to bacteria growth, damage photosynthesis inside the water, and decrease the fish amount. The permissible value of the standard differs from the one to another country. A higher level of turbidity poses numerous matter for stream systems. Higher turbidity levels are frequently related to higher levels of viruses, parasites, and some bacteria since they can occasionally attach themselves and let water dirtier; thus, turbid water typically has more pathogens. Turbidity blocks out the light transparency needed by submerged aquatic vegetation. It also can raise surface water temperatures above average because of suspended particles near the surface, which facilitate the process of absorption of heat from sunlight (Kale, 2016).

The unit for Turbidity is Nephelometric Turbidity Units (NTU). Turbidity can provide food, shelter, and protection for pathogens. If the Turbidity is not removed, it leads to waterborne diseases, which can cause significant cases of gastroenteritis. Fortunately, traditional water treatment processes can effectively remove Turbidity when it is appropriately operated (Kale, 2016). Turbidity is commonly caused by colloidal particles such as clay, silt, non-living organic particulates, plankton, and other microscopic organisms. The level of turbidity can measure pollution intensity, ranging between 21-62.5 and 8-26.5 NTU. Increasing values from up-stream to down-stream along the branch may be attributed to drains discharge (Abd et al., 2012).

Turbidity analysis requires distilled water with electrical conductivity less than 2 µS\cm, and two kinds of soluble in hydrazine Sulphate (NH2)2 H2SO4). Distilled water is diluted to 100 ml in a measuring flask and methylene tetra mine (CH2)6N4) with distilled water is diluted to 100 ml in a measuring flask. Combine 5.0 ml of the 1st solution and 5.0 ml of the 2nd solution into 100 ml of measuring flask. Let them stand for 24 hours at a temperature of 25 $C^0 \pm 3$ C^0. The instrument requirements are Nephelometric, beaker, spray bottle, pipette volume 5 ml and 10 ml, analytics scales, and flask with a size of 100 ml and 1000 ml (Nasrabadi et al., 2016).

The calculation of the Turbidity is Turbidity $NTU = A \times fp$. A is NTU Turbidity in the diluted sample, fp is a dilution factor (Clesceri et al., 1998).

2.5.1.3 Total Dissolved Solids (TDS)

TDS in drinking water is originated from natural sources of anthropogenic activities, manure, sewage, agricultural, urban run-off, factories wastewater, and other unwanted elements in water that produce unpleasant color, tastes, and odors and may also exert osmotic pressure that affects aquatic life or become carcinogenic especially halogenated compound. The TDS concentrations in drinking water can create some disease like cancer, coronary heart disease, arteriosclerotic heart disease, cardiovascular disease, inflammation of the gallbladder, and gallstones. TDS in levels >500 mg/L result in excessive scaling in water pipes, water heaters, boilers, and household appliances such as kettles and steam irons (Abd et al., 2012) & (WHO, 1996).

A study conducted in Egypt on the TDS evaluation of the Nile River Quality; the TDS was 183.5 mg/l, less than the permissible level stated by the Egyptian law 48/1982 (500 mg/l). Also, less than the value suggested by USEPA (500mg/l) (Shahata & Mohamed, 2015). TDS is the most significant factor in many drinking water developing plans. The freshwater is a basic human need for survival and perfect health. Nonetheless, most of the global water sources contain impurities and consequences, including TDS. Many influences that affect the concentration of TDS, some of them naturally occur while others could be the product of people's daily activities and also from industrial, domestic, and agricultural sectors. The principles of TDS testing is evaporating sample with a porous filter paper with a size 2 μm at a temperature of 180 C^0, then weighed to constant weight. The requirements of the TDS are analytical scales, a cup made of porcelain or silica, oven, furnace with a maximum temperature of 550 C^0, paper clip filter, and clip cup, filter device equipped with suction pump, heated water, pipette and desiccator. The calculation of the TDS is:

$$Total\ dissolved\ solids\ (mg\backslash l)\ =\ (B-A1)\ X\ 106/ml$$

Example Levels of total dissolved solids that bound

$$(mg\backslash L)=\ (C-A2)\ X\ 106/ML$$

Example Levels of total dissolved solids that evaporate (mg\L) = Total dissolved solids (mg\L) - Levels of total dissolved solids that bound (mg\L)

A1 is constant weight: empty plate after heating at a temperature of 180 C^0

A2 is constant weight: empty plate after burning at a temperature of 550 C^0

B: is constant weight: an empty plate of total dissolved solids after heating at 180 C^0

C: is constant weight: the contains plate of total dissolved solids after burning at 550 C^0 (Clesceri, 1998).

In drinking water, TDS is created from sewage and urban industrial wastewater. Hence, TDS assessment has reflected a sign to define the water quality. The study clears that in Islamic colony, the values of TDS are ranging between 290-595 ppm. In town, the range is 406-694 ppm, and in Shahdrah these values range from 401-429 ppm. Therefore, these ranges were suitable and acceptable; it is not harmful (Mohsin et al., 2013).

2.5.1.4 Odors of the water

Odors usually come from different sources as volatile organic compounds and might be produced by phytoplankton and aquatic plants or decaying organic matter or Industrial. Odors can be released into residential neighborhoods by wind due to the lack of treatment plants system of wastewater (TSOWW); it is causing inconvenience and nuisance. The control of Odors emissions has become a significant challenge in the wastewater treatment industries (Zhou et al., 2016).

Odors create environmental issues and adverse effects on human health. Some studies demonstrate that the exposure of Odors may cause various effects on human health, ranging from emotional stresses such as states of anxiety, unease, headache or depression to physical symptoms. The Odor is disturbing when there are many industrial activities run around residential areas (Capelli et al., 2011).

Odor emissions are inherently related to wastewater management. Odors can significantly decrease the life quality and have been connected to health-related problems such as nausea, headaches, insomnia, loss of appetite, and respiratory issues. Also, some Odors compounds such as H2S entail severe occupational risks in confined spaces within WWTP H2S, and sulphur-containing combinations can account for up to 80–90% of Odors compounds in WWTPs (Estrada, 2015). Odors can come directly or indirectly from human anthropogenic; the adverse effect is classified as a contaminant. Odors create massive environmental problems, damage the environment quality, injury and deteriorate animal living conditions, and harm or discomfort to anybody. Moreover, the adverse effect problems the health and safety of standard life property (Nicell, 2009).

2.5.1.5 Water Color

Watercolor can be measured when it possesses some level of Color. The Color of water is referring to the existence of organic and inorganic materials. It is expressed as Pt-Co the platinum-cobalt scale or TCU (True Color Unit). It might also be expressed as Hazen units which are equivalent to mg/l Pt-Co. The standard of watercolor can naturally range from 0-300 mg/l Pt-Co, and higher values are related to the presence of complex organic molecules such as humic acids. The study conducted in Egypt in Bahawalpur City, about Assessment of drinking Water Quality and its Impact on residents Health, confirms that 86% residents had clear water and minimal numbers of residents had diluted and faint water. The water quality was acceptable in this area because of the proximity to the river. In an Islamic colony, 48% of populations have perfect water, while 50% of citizens have diluted water. It was possible because of the suspended minerals and dead organic matter (Mohsin & Sahib, 2013).

2.5.2 The chemical influence

The wastewater has a significant role in altering the physical characteristic of drinking water; also, it has full power to change the chemical characteristic of water. Those characteristics are COD, BOD, NH3N, Hardness, Alkalinity, Do, pH, and Calcium.

2.5.2.1 Biological Oxygen demand (BOD)

Biological Oxygen demand is the amount of oxygen consumed by microorganisms for breaking down the organic substance. Biodegradable organic matter in water provides nutrients for the growth of bacteria and other microorganisms (Gorde & Jadhav 2013). Usually, titration is used to determine the value of BOD (Parande et al., 2009) & (Ali et al., 2014).

The study conducted in Vahirab River found that the BOD standard value for inland surface water was 6 mg/l or less; a higher amount can threat to the aquatic ecosystem. The BOD at Labanchara Rupsha was high due to the discharged of untreated wastewater from industries. Sewage from household latrines on the bank cause high BOD values. Through the data and discussion, the water from the river during the study period was in the safe limit for irrigation, domestic use, and other use such as recreational activities, but not for drinking purpose regarding its DO and BOD (Ahmed et al., 2015) &(Shahata & Mohamed, 2015).

The same study was done in El Nasria, Egypt linked to BOD, which confirms that changes and values in BOD along the sampling sites reflected the degree of organic matter pollution of the River Nile. The study found that BOD concentration sometimes reached the threshold of polluted waters. This phenomenon happens because of the low-quality water at El Nasria, chiefly during June, July, and August with much organic pollution at the location during these months (Ali et al., 2014).

The principle of BOD consists of sample dilution, requiring incubation period for five days at 20ºC. The measurements must be before and after the incubation period. Decreasing dissolved oxygen during incubation indicates the amount of oxygen required by the water sample. This measurement requires more than five solutions which are buffer Phosphate Solution, Magnesium Sulphate Solution, Magnesium Sulphate Solution, Ferric Chloride Solution, Dilution Water, and Wastewater. The calculation of BOD can be seen as follows:

BOD 5 days, 20ºC (mg/l) = $(B1 - B2) - (D1 - D2)\ x\ P\ x\ f$

Where D1 is DO 0 the blank day (mg/l)

D2 is DO 5 the blank day (mg/l)

B1 is DO 0 sample day (mg/l)

B2 is DO 5 sample day (mg/l)

P is dilution rate, f is seeding corrections (Leonore et al., 1998).

2.5.2.2 Chemical Oxygen Demand (COD)

Chemical oxygen demand determines the oxygen required for chemical oxidation of organic matter. Also, it measures the oxygen equivalent of the organic matter in a water sample that is susceptible to oxidation by a strong chemical oxidant, such as dichromate. The concentrations of COD in industrial wastewaters may have values ranging from 100 mg l-1 O2 to 60,000 mg l-1 O2. The minimum values of COD in different water samples refer to low organic pollutants, while maximum concentration indicates a higher concentration of pollutants (Divya & Belagali, 2012).

A study of the Nile River had checked COD with essential measurements of water quality. The result showed that Chemical Oxygen Demand COD reached the value of 19.5 mg/l and varied from 18 to 21 mg/l. The allowable level for COD stated by the law 48/1982 is < 10- 15, indicates that there is an increase due to the consumption of oxygen by aquatic organisms in water (Shahata & Mohamed, 2015).

COD may demand soluble as Standard Potassium Dichromate Solution 0.25 N (K2Cr2O7), Sulfuric Acid Reagent, Silver Sulfate (Ag2SO4), Ferroin Indicator Solution (FeSO4.7H2O), Ferro Ammonium Sulphate (FAS) solution 0.25 N (Fe(NH4)2(SO4).6H2O), and Mercury Sulfate (HgSO4); also, it may require equipment such as reflux apparatus, Liebig cooler 30 cm, hot plate or equivalent (100 ml and 1000 ml of measuring flask), (25 ml or 50 ml) of buret, (5 mL, 10 ml, 15 ml, 50 ml) of pipette volume, 250 ml of Erlenmeyer and analytical scales.

The measurement of COD as mg O2/Liter =

$$\frac{(A-B)Cx\ 8000}{mlsampel}$$

A = ml FAS for the blank, B = ml FAS for the sample

C = Normalition FAS, Normalition FAS =

$\frac{\text{ml } K_2Cr_2O_7 \text{ x Normalitas } K_2Cr_2O_7}{\text{ml FAS}}$ (Lenore, 1998).

2.5.2.3 Total Alkalinity, pH and Hardness

Hard water is considered with high mineral contents that are usually not harmful to humans, but an excessive amount of hard water has a side effect on water quality taste. It is often measured by calcium carbonate and magnesium carbonate Ca HCO3+ Mg HCO3 in the water. Other metallic ions may also contribute to hardness, which causes scale formation in the water network since it consists of calcium and carbonates. According to the World Health Organization, the hardness of water standard should be 500 mg/l. A study in Bahawalpur City, Pakistan, showed that hardness was ranging from 195-330 mg/l in Islamic colony, 190-310 mg/l in satellite town and from 265-285 mg/l in Shahdrah. According to the study results, the standardized amount by the WHO, the hardness does not become harmful for local inhabitants (Mohsin & Sahib, 2013).

Determination of hardness in water, either potable or domestic is importance. Hard water causes scaling, which is precipitation of minerals to form a deposit called lime scale. Hardness ion, along with alkaline ions, is the most critical factor in cardiovascular diseases and can potentially affect the health of humans and animals. According to a range of studies, from a health point of view, calcium and magnesium with 40–80mg/l and 20–30 mg/l−1, respectively, are dangerous with a total water hardness of 2–4mmolL (Lergaa & Sullivan, 2008). It is fundamental and necessary to recognize the hardness in water because the occurrence of calcium and magnesium in the water or other metal ions might also contribute to hardness; it is usually expressed as mg/l $CaCO_3$. Water hardness is classified in <50 is soft, 50-100 is moderately soft, 100-150 is slightly hard, 150-250 is moderately hard, 250-350 is hard, and >350 is excessively hard (Ali et al., 2014).

The method to find hardness is titration of complexometry with EDTA. The process demand many soluble such as Ethylene Diamine Tetra Acetate (EDTA), $MgSO_4$, Buffer solution of pH 10, solution of pH 12, KCN 10%, Eriochrome Black T, Murexida indicator, and calcium standard solution. There are three types of formula to calculate the hardness: Total hardness, Calcium hardness, and Magnesium hardness (Kaya & Kaya, 2015).

Total hardness=

$$\frac{1000}{100} \text{ x ml EDTA x } \frac{1}{28} \text{ xfaktor EDTA} - \text{EBT x } \frac{28}{10} = \quad {}^{o}\text{G}$$

Calcium hardness =

$$\frac{1000}{100} xmlEDTAx \frac{1}{28} xfaktor \text{ EDTA} - Murexidax \frac{28}{10} = \quad {}^{o}G$$

Alkalinity is indicated as the presence of carbonate or bicarbonates HCO3+CO3. Usually, it has a relationship with hardness; therefore, the excess alkalinity concluded from the hardness. Alk- TH×1.06 = Exc Alk. The alkalinity is the ability of water to neutralize acids; it refers to the existence of carbonate, limestone, bicarbonates, or hydroxides. It can be expressed as mg/l CaCO3. Alternatively, sometimes reported as mg/l HCO3 (Ali et al., 2014).

The calculation of the total Alkalinity (mg/l $CaCO_3$) =

$$100 \times \frac{V\ EDTA \times MEDTA \times 100}{V.\ sample}$$

Pollution of drinking water is considered enormous environmental challenges. Quick industrialization and growth of population have led to the problem of this issue, particularly of the aqueous environment with plenty of contaminants due to the alkaline wastewaters generated from soda ash, chloro-alkali, sugarcane, dye manufacturing, textile, pulp and paper, chemical, paint, food, and beverage industries (Jain et al., 2014).

pH is a significant parameter of industrial discharge that must be controlled. Worldwide, environment authorities such as the Environmental Protection Agency have set rules for permissible ranges of pH in numerous categories. These rules and authorities assert that the pH should be reduced within the permissible range before being discharged. The pH of wastewater discharged by industries should be within of 6.5 - 8.5. To neutralize the alkaline concentration from industrial wastewater, the factory used some chemical substances depending on the application such as sulfuric acid, hydrochloric acid, phosphoric acid, and carbon dioxide (Mohan et al., 2010).

The types of equipment required for the pH measurement are magnetic stirrer glass electrodes and pH meter. On the other hand, pH demands a pH buffer solution as well; the measurement is done digitally (Lenore, 1998).

2.5.2.4 Ammonia NH3-N

Usually comes from a different source. Ammonia can typically exist in water through the rising of the microbiological decomposition of nitrogenous compounds in organic material, from aquatic organisms that can excrete Ammonia, industries process, domestic sewage and animal slurry component that can be discharged directly into water bodies; the standard of Ammonia in water bodies is usually <0.02 mg/l as N (Suchetana et al., 2017).

A study conducted in the Nile River confirmed that Ammonia from the nitrogenous compounds existed in nature is a fundamental part for the growth and reproduction of plants and animals. Industrial processes can synthesize the ammonia ion from proteinaceous organic matter and urea. The recorded mean values violate the permissible limits of 48/1982 (not to exceed 0.5 mg/l). Regularly, NH concentrations were ranging from 1.25-8.35 mg/l in the Rosetta branch, and 1-22.3 mg/l in drains outfalls. The study attributed the massive increase of ammonia concentrations related to organic pollution resulting from domestic sewage, industries, and fertilizer runoff. This study confirmed the impact of sewage discharge and agricultural runoff in this area (Abd et al., 2012).

Providing safe drinking water and suitable sanitation is essential and indispensable for sustaining life. Treated wastewater discharged to water body improves and adapts the environmental parameters, both qualitative and quantitative. The study associated with wastewater on organismic biosensors confirms that the sugar plant wastewaters mostly exceeded and surpassed the raw municipal wastewaters inflowing the WWTP in many parameters and variables such as Suspended Solids, COD, COD-Mn, BOD, Nitrate, and Nitrite. In order to avoid the contaminants from the sugar plant, the actions for recycling and regenerating are a significant challenge. The environmental influence can be evaluated by measuring EPI (the environmental performance index), which measures the levels of COD above the regulated values. In this study, COD decreased below the standard values in the effluent and downstream waters (Topi et al., 2015) & (Rault et al., 2017).

A study conducted in china about wastewater discharge and its impact on drinking water confirms that the main factor of stressing water resources and water quality in many regions is increasing economic development and human migration. Because of wastewater, drinking water can contain chemicals and pathogens, absorb and accumulate sediments with potential risk both for aquatic organisms in the river and drinking water quality at downstream sites (Wang et al., 2017).

Ammonia can form complex compounds from yellow to brown. The intensity of the color is measured by absorption at 420 nm wavelength. NH4 requires some reagent as Nessler's reagent, NaOH with some milligram (ml) of aquades, Mercury Iodide HgI2 and Potassium Iodide KI, Seignette Salt Reagent, and Potassium Sodium Tartrate Tetrahydrate, KNaC4H4O6.4H2O. The second step is creating calibration curves to make a standard solution for the NH4. The third is calculating the NH4 presented in a concentration of NH4 + (ppm) = A x S = ppm. Where A is an absent sample, and S is the slope of the calibration curve (ppm NH4 /absorbance unit) (Lenore, 1998).

2.5.2.5 Calcium

Calcium comes from several sources of dissolved rocks that rich in calcium minerals mainly limestone and gypsum; presented as Ca2+ and is readily dissolved from rocks that rich in calcium minerals, particularly as carbonates and Sulphate. Calcium concentrations in natural waters are typically <15 mg l-1. Samples for calcium analysis should be collected in plastic or borosilicate glass bottles without a preservative. They should be analyzed immediately, or as soon as possible, after collection and filtration. If any calcium carbonate precipitated after filtration and during storage, it must be re-dissolved with hydrochloric or nitric acid and then neutralized before analysis. Acidification of unfiltered waters before analysis should be avoided since it causes the dissolution of carbonates, calcite, and dolomite (Chapman & Kimstach, 1996). Calcium is the fifth most abundant element in the earth crust and is very important for human cell physiology. About 95% calcium in human body stored in bones and teeth. The high deficiency of Calcium in humans may cause rickets, poor blood clotting, and bones fracture — and the exceeding limit of Calcium produced cardiovascular diseases. According to the WHO (1996) sandards, the permissible range of Calcium in drinking water is 75- 200 mg/l. However, an adult requires 1,000 mg/ day to work correctly (Mohsin & Sahib, 2013).

The calcium content as CaCO3 in the test sample can be calculated using the following formula: Calcium levels (mg Ca/L) = where VC.µ is volume of test sample solution (mL), VEDTA (a) is average volume of Na2EDTA and standard solution for titration of total hardness (mL), MEDTA is molarity of Na2EDTA standard solution for titration (mmol / mL), VEDTA (b) is average volume of Na2EDTA standard solution for calcium titration (mL). While the percentage feedback of calcium (% Recovery, % R) is calculated using the following formula; $\% R = A - B / C X 100 \%$.

R is recovery, A is sample rate of spike test (mg/L), B is sample test level not spike (mg / L); C is the standard value obtained (target value) (mg / L) how C=Yx Z/V. Where Y is additional standard volume (mL), Z is additional calcium levels (mg / L); and V is the final volume (mL) (Lenore, 1998).

2.5.2.6 Phosphate (PO_4)

Phosphate plays a vital role in the industrial process, and plant/animal metabolism; consequently, they can produce waste as products. Domestic detergent and effluents represent significant sources of phosphorus in natural water. High concentrations of nutrients can cause many problems to the water quality such as acidification, eutrophication, and impairing the aquatic organisms to survive and grow (Mohsin & Sahib, 2013).

Phosphates enter waterways from human and animal waste, industrial effluents, phosphorus-rich bedrock, laundry, cleaning, and fertilizer runoff. These phosphates become detrimental when they cause eutrophication. Phosphates exist in three forms: orthophosphate, phosphate (or polyphosphate), and organically bound phosphate. Each compound contains phosphorus in a different chemical formula. Natural processes produce Ortho and Poly for treating boiler waters and available in detergents. When the concentration of phosphates rises above 100 mg/liter, the coagulation processes in drinking water treatment plants may be adversely affecting. Orthophosphate with ammonium makes a yellow-colored complex, while with the addition of SnCl2 reducer will be reduced to blue colored compound-complex form; a specimen meter is used to measure the intensity of the blue color at a wavelength of 660 nm. There are three essential types of solution that need to check Phosphates; they are ammonium Molybdate solution, $SnCl_2$ solution, and Standard Phosphate Solution 100 mg/l.

The calculation is concentrations of orthophosphate (mg/l) = AxS, where A is absorbance example, and S is the slope of the calibration curve (mg/l per unit of absorbance). After measuring the physical and chemical parameter, it is essential to compare them with the water quality index (WQI) in order to understand the water quality in the study area through specific calculation. The result of it can put the water in the category and also be easy to recognize and estimate the ramifications on human health through health risk assessment.

2.5.2.7 Chloride

Chloride exists in river, and various industrial discharges may contain and increase chloride levels in the water. Chloride is typically determined by Photometers, colorimetric or chromatographic methods and reported as mg/l or ppm. CL is mostly gained from the dissolution of salts of hydrochloric acid (NaCl), $NaCO_2$, industrial waste, sewage, and seawater. Surface water bodies occasionally have a low concentration of chlorides comparing with groundwater. High CL concentration can cause impairment of metallic pipes and structure and also harms growing plants. Based on WHO standards concentration, chloride should not pass 250 mg/l. In study areas, the Cl value ranges from 16-66 mg/l in Islamic colony, 54-78 mg/l in Satellite town and from 51-88 mg/l in Shahdrah. Thus, all the samples have a lesser concentration of chloride (Mohsin & Sahib, 2013).

The study conducted in Egypt about Assessment the Physico-Chemical Characteristics of Water and Sediment in Rosetta Branch was recognizing the sources of the industrial activities pollutants. The results show that the concentrations of Chloride were higher than 200 mg/l. Those concentrations are considered as a danger for human health and may cause the disagreeable taste of water due to seawater intrusion (Ali et al., 2014). Another study about Assessment of Water Quality Parameters was assessing several physiochemical variables with WHO & BIS standard. The result showed that the value of Chloride was Cl- (49-167 mg/L) while the standard was 250 mg/L (Gorde & Jadhav, 2013).

2.5.2.8 Nitrate (NO_3)

Nitrate is one of the common parameters which affect water quality and causes several illnesses such as blue baby syndrome. The primary sources of Nitrate are nitrogen cycle, industrial wastewater, and nitrogenous fertilizers. In this part, the study concentrates on industrial wastewater as primary sources, the maximum allowable limit recommended by the WHO in drinking water is 10 mg/l. The result of the study in Bahawalpur City about Assessment of Drinking Water Quality and its Impact on Residents Health ranges from 4.5-6.4 mg/l in Islamic colony, 3.4-3.5 mg/l in Satellite town, and 3.2-3.6 mg/l in Shahdrah. The results indicate that the magnitude of Nitrate was satisfactory except in the Islamic colony where the range of Nitrate was exceeding in water and posing a threat to the health of populations (Mohsin & Sahib, 2013).

Nitrate is commonly found in drinking water sources, especially in agricultural regions primarily due to nitrogen fertilizer use. The protective health concentration for nitrate in drinking water has been a subject of public health interest for many years. The current World Health Organization (WHO) drinking water guideline is 50 ppm (mg/l), and the US Environmental Protection Agency's (EPA) national drinking water standard (maximum contaminant level, MCL) is 45 ppm (or 10 ppm nitrate-nitrogen) for nitrate were established to prevent methemoglobinemia in infants. Nitrate is a stable form of oxidized nitrogen, but it can be reduced by microbial action to Nitrite. Nitrite can be reduced to various compounds or oxidized to nitrate by chemical and biological processes. Sodium Nitrate is used as a fertilizer in a variety of industrial processes, curing meat products, and cereal products (Fan, 2011).

2.5.2.9 Nitrite (NO_2)

Its toxic and undesirable element in water has an impact on human bodies like kidney and lymph; Nitrite is formed by immediate oxidation of NH_3. It is coming from different sources such as sewage with rich in ammonia that can increase the concentrations of NO_2 in receiving waters. Hence, water bodies and rivers can be contaminated if it contains a considerable amount of Nitrite. Nitrite is harmful and toxic to aqueous life at comparatively little concentrations. In uncontaminated waters, it is commonly low (<0.01 mg/l N) and commonly detected by using spectrophotometric methods and reported as ppm or mg/l N or NO_2. The study conducted on Benthic Nitrite exchanges in the Seine River (France): An early diagenetic modeling analysis, the experimental and modeling results show that the benthic exchange fluxes of Nitrite in upstream were 5.3 and 15 in downstream (Akbarzadeh et al., 2018).

2.5.2.10 Sodium (Na)

Commonly, natural waters contain some amount of Sodium. Sodium is one of the most available elements on the Earth surface and is a necessary constituent for living organisms. It can be found in the ionic form (Na^+), plant, and animal matter. Human and animal activities significantly rely on local geological conditions and wastewater discharges; they have a significant role in increasing Na concentrations in natural waters. The standard values can range from 1- 105 mg/l or more in natural brines. The WHO specification limit for Sodium in drinking water is 200 mg/l, and Sodium can be measured in multiple sources such as agricultural and irrigation (Meng et al., 2019).

2.6 Water quality index (WQI)

Water Quality Index is a mathematical tool used to transform large quantities of water quality data into a single number. The obtained single number can emphasize drinking water quality status. In a drinking water quality evaluation, the decision making based on water quality data is considered to be a crucial issue. Usually, Water Quality is calculated by two steps: the first step is by selecting water quality parameters as raw analytical results, and the second step is by producing a WQI value. The quality assessment to those substances is essential for providing healthy drinking water with specific concentrations in the water source (Prasanna & Madhurambal, 2017).

WQIs have been used in some approaches to evaluate the quality of water. A combined score of nine chemical and physical tests (pH, Nitrate, Phosphate, DO, BOD, Turbidity, Fecal Coliform, TSS and Temperature) indicate the overall quality of a particular body of water; the higher the score, the better the water quality is (Dhany et al., 2018). WQIs have been used in some approaches to evaluate the quality of water. A combined score of nine chemical and physical tests (pH, Nitrate, Phosphate, DO, BOD, Turbidity, Fecal Coliform, TSS and Temperature) indicate the overall quality of a particular body of water; the higher the score, the better the water quality is (Dhany et al., 2018). WQI methods combine many environmental parameters and effectively convert them into a single value that can be reflecting the status of water quality. Thus, instead of comparing the different assessment results of various parameters, the WQI method is a practical approach to water quality assessment and management and provides integrated information regarding the overall water quality (Wu et al., 2018).

The study conducted in Sudan about Assessment of Drinking Water Quality According to Turbidity in Rabak Town, White Nile State showed that the turbidity level in drinking water ranged between 38- 76 NTU; this level is considered as very high. The guideline value of turbidity for drinking water must be less than 5 NTU. The author observed that the level of turbidity was too high, and the ability of the plant to remove the turbidity was meager. The calculation of the Water Quality Index is $[WQI] = QiWi/Wi$

Where Qi is water quality rating

$Qi = 100 * [VaVi]/[Vs - Vi]$

Va = Actual value of the parameters present in the water sample.

Vs = Standard value

Vi = ideal value

Wi = K/Sn

Where Wi = Unit weightage

K [constant] = $1/[\left(\frac{1}{S1}\right) + \left(\frac{1}{S2}\right) + \left(\frac{1}{S3}\right) \pm \cdots \ldots \ldots \ldots \ldots .. + (1/Sn)$.

Another study about Environmental and health risks is associated with reuse of wastewater for irrigation conducted in Iraq. The assessment method of the study is the Comprehensive Pollution Index (CPI). CPI is evaluated by using a measured concentration of parameters concerning their permissible limit in irrigation wastewater quality prescribed by Iraqi Fact standard to classify the wastewater quality status and its suitability for irrigation and human use (Devi et al., 2010).

$$\mathrm{CPI} = \frac{1}{n}\sum_{i=1}^{n}\mathrm{PI} \qquad (1)$$

$$\mathrm{PI} = \frac{\text{measured concentration of individual parameter}}{\text{standard permissible concentration of parameter}} \qquad (2)$$

n: parameters number. The water quality is ranked in the following categories:

Clean: (values of 0–0.2);

Sub clean: (values of 0.21–0.4),

Slightly polluted: (values of 0.41–1.0),

Moderately polluted: (values of 1.01–2.0), and severally polluted: (values of 2.01). Organic pollution index (OPI):

The measured concentration of BOD, COD, Nitrate, and Phosphate is used to evaluate OPI concerning their permissible limit in irrigation wastewater quality prescribed by Iraqi Fact standard, to classify the organic pollution due to organic compounds in the treated wastewater.

$$\mathrm{OPI} = \frac{\mathrm{BOD}}{\mathrm{BOD_s}} + \frac{\mathrm{COD}}{\mathrm{COD_s}} + \frac{\mathrm{Nitrate}}{\mathrm{Nitrate_s}} + \frac{\mathrm{Phosphate}}{\mathrm{Phosphate_s}} \qquad (3)$$

The water quality is ranked in the following categories: excellent: (OPI values of < 0);

Good: (OPI values of 0–1);

Being to be contaminated: (OPI values of 1–2);

Lightly polluted: (OPI values of 2–3);

Moderately polluted: (OPI values of 3–4), and

Heavily polluted: (OPI values of 4–5).

Application of the hazardous irrigation data :

Numerous water quality guidelines have been developed by many researchers on the water in irrigation under different conditions. However, the classification of US Salinity Laboratory (USSL) is the most commonly used. Parameters such as electrical conductivity (EC), Total Dissolved Solids (TDS), Sodium (Na+), Sodium Adsorption

Ratio (SAR), Soluble Sodium Percent (SSP), Residual Sodium Carbonate (RSC), and Chloride (Cl) were used to assess the suitability of wastewater for irrigation purposes. The result of irrigating wastewater can be both positive and negative. The positive effects are related to food security in impoverished areas. Adverse effects are due to the presence of pathogens and toxic chemical compounds in wastewater (Shakir et al., 2016).

Associated with the water quality index in Sudan, this study will check the physiochemical characteristics and calculate the water quality index based on human health index in Sudan (WQI- HHA). WQIs is one of the most common approaches used to evaluate the quality of water. The combined score of nine chemical and physical tests (pH, Nitrate, Phosphate, DO, BOD, Turbidity, Fecal Coliform, TSS, and Temperature) indicate the overall quality of a particular body of water; the higher the score, the better the water quality is (Dhany et al., 2018). Water quality index is defined as a technique of rating that provides the composite influence of individual water quality parameters on the overall quality of water. It reduces a large amount of water quality data to a single numerical value (Vasanthavigar et al., 2010). Calculation of Water Quality Index : $[WQI] = QiWi/Wi$ Where:

Qi is water quality rating

$Qi = 100 * [VaVi]/[Vs - Vi]$ Va = Actual value of the parameters present in water sample.

Vs = Standard value

Vi = ideal value

Wi = K/Sn

Where:

Wi = Unit weightage

$K[constant] = 1/[(1/S1) + (1/S2) + (1/S3) + \ldots\ldots + (1/Sn)$ WQI has been classified into five classes according to arithmetic method in the following table:

Table 2.1. Water Quality Index Structures

Values	Scales
91-100	Excellent water quality
71-90	Good water quality
51-70	Medium water quality
26-50	Fair water quality
0-25	Poor water quality

Source: Maruthi Devi et al., 2010

The final output in the study will categorize the water quality classes, as seen in Table 2.1. The study can identify the water quality, and also can declare whether if it is suitable for drinking so that the study can understand the consequence on human health. A study conducted in Sudan about the Assessment of Drinking Water Quality in Samrab and Dardog showed that drinking water quality in both Samrab and Dardog is suitable for human consumption since its physiochemical characteristics are falling the permissible limits recommended by the national, regional and international standards and guidelines. However, drinking water in Hattab community is highly saline; therefore, it was not suitable for human consumption. Bacteriological contamination is evident in drinking water in three communities. Roughly 55% of the investigated drinking water samples were found to be contaminated with coliform bacteria as there are random vendors in the study area distributed drinking water. Therefore, it is imperative to connecting these communities to the municipally treated non-saline drinking water network supply. In order to avoid microbial contamination, distribution network pipes should be installed throughout the three communities (Abdelmagid, 2017).

Another study was conducted in Iraq about Water quality index for Al-Gharraf River, Southern Iraq. The study evaluated the water quality of Al-Gharraf River, the main branch of the Tigris River in the south of Iraq. From the physiochemical analysis parameters with WQI calculation, the result confirmed the low water quality o the river (Hussein & Ali, 2017).

2.7 The consequences of wastewater on human health

Wastewater has massive consequences on human health, the effect can be direct, and other ramifications are indirect; both of them constitute a massive impact on human health. The world today is suffering from environmental health problems that translocate by wastewater. In this part, the study will address the impact through the recent studies that have been done previously — also a study on human health risk assessment to evaluate the symptoms related to wastewater.

2.7.1 Human Health

The World Health Organization (WHO) has defined human health in a broader sense in its 1948 constitution as "a state of complete physical, mental, and social well-being and not merely the absence of ailment, sickness, or infirmity (Munawer, 2017).

The field of human health is defined as the study of etiological role of various environmental toxicants in the pathogenesis of acute and chronic human diseases, to determine adverse effects of environmental toxicants on humans, and to design effective prevention and anticipation for reducing and the risks of human disease linked to environmental toxicants exposure (Flandroy et al., 2018).

A study conducted in Japan about Phosphate, a poison for humans and is the main chemical component used in the purification of sugar juice. Maintenance of phosphate balance is essential for life, and mammals have developed a sophisticated system to regulate phosphate homeostasis throughout evolution. Due to the dependence of phosphate elimination on the kidney, humans with modified kidney function are likely to be in a positive phosphate balance. The first is Kidney disease progression and followed by acute hypophosphatemia. Those problems can be encountered in patients with phosphate-containing enemas; it can cause acute or sub-acute kidney injury, referred to as acute phosphate nephropathy. The second is the bone disease; hypophosphatemia is one of the major contributors to the development of secondary hyperparathyroidism. Thus, an excess Phosphate can cause high-turnover bone disease through the stimulation of PTH secretion. Also, an increasing number of kidney disease or injury in the society emphasizes the potential importance of this issue. Further work is needed to characterize phosphate toxicity more thoroughly and to establish the optimal therapeutic strategy for managing phosphate in patients with chronic kidney disease (Komaba & Fukagawa, 2016).

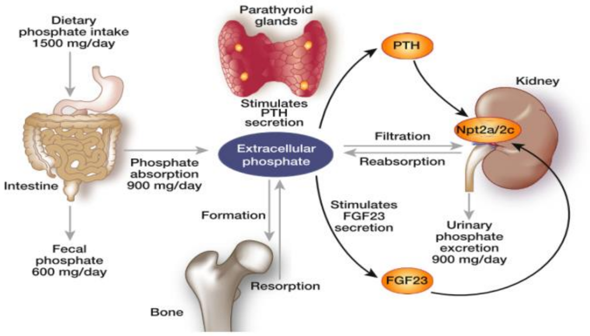

Figure 2.3. Phosphate homeostasis in normal physiology
Source: Komaba & Fukagawa 2016.

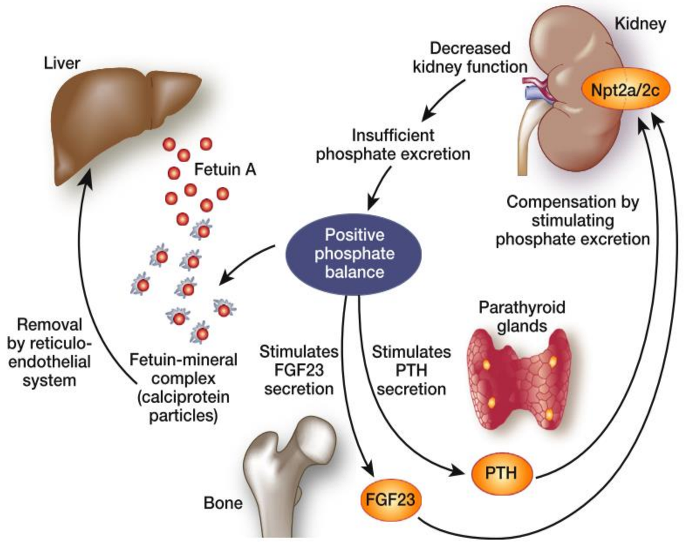

Figure 2.4 Compensatory mechanisms to maintain phosphate balance in early to moderate chronic kidney disease (CKD)
Source: Komaba & Fukagawa 2016

Phosphate has adverse effects on human health and natural ecosystems both for the short and long-term. The Engineered/designer for recovery of aqueous phosphate can be done using typical adsorbents, such as zeolite, montmorillonite, iron oxides, pumice, coir pith, and red mud. Although those adsorbents performed reasonably well for phosphate removal, they could be used under certain environmental conditions only. The environmental phenomenon, rainfall, can cause varying amounts of phosphates transported from farm soils into nearby waterways. Phosphate stimulates the growth of plankton and aquatic plants and provides food for fish; this may cause an increase in the fish population and improve the overall water quality. However, if an excess of phosphate enters the waterway, algae and aquatic plants will grow wildly, choke up the waterway and use up large amounts of oxygen; this condition is known as eutrophication.

The rapid growth of aquatic vegetation eventually dies, and as it decays, it uses up oxygen. This process, in turn, causes the death of aquatic life because of the lowering of dissolved oxygen levels. Phosphates are not toxic to people or animals unless their presence at very high levels. Digestive problems could occur from extremely high levels of phosphate (Vikrant et al., 2017).

A study was conducted in Iraq regarding the environmental and health risks associated with reuse of wastewater, confirmed that wastewater has risks on human health due to the existence of pathogens and toxic chemical compounds in wastewater. The subsequent is a bit explanation of the potential wastewater risks used in irrigation that poses several potential dangers to human health through consumption or exposure to pathogenic microorganisms, viruses, heavy metals, and harmful organic chemicals. The result through laboratory analysis was used in the assessment of different parameter to classify wastewater pollution. The first parameter is the Organic Pollution Index (OPI); it measures chemical variable or the concentration of BOD, COD, Nitrate, and Phosphate. It is also used to evaluate OPI and to classify the organic pollution due to organic compounds in the treated wastewater. The second parameter is the Comprehensive Pollution Index (CPI); the principle is using Iraqi Fact standard to classify the wastewater quality status and its appropriateness for irrigation and other human use (Shakir et al., 2016).

Another study was done in Mexico City related to health risks from the exposure of untreated wastewater. The study confirms that there are numerous of illness came from wastewater. This study compared between 556-850 households users of untreated wastewater and 470-930 households users of rainwater. In two-week, there were reports on diarrheal occurrence and infection with Ascaris lumbricoides, G. lamblia, and Entamoeba shistolytica. The study found that untreated wastewater was associated with a higher prevalence of bacteria. Sample appears that wastewater contained nitrate, implying possible leaching and infiltration from the agricultural fields into groundwater. In general, the study found higher risks of infection or illness associated with wastewater reuse (Contreras et al., 2017).

There is another study declaring that wastewater with pathogenic microorganisms like viruses, bacteria, and parasites can cause illness and impact human health. Also, other kinds of microorganisms, such as Protozoa and helminth eggs, are virulent; they are troublesome to be removed by treatment processes. They are often associated with several infectious and gastrointestinal diseases in developing countries and the investigations on public health effects of wastewater in the Middle East. Untreated wastewater released a higher risk and side effects to children and elderly. A higher occurrence of ascariasis and hookworm infections among children can occur because of the contamination of water sources with a higher risk of diarrhea in infants. The pollution of potable water storage in-house is likely to develop immunity to pathogens in the house. Investigations on the determinants of diarrhea disease in Jakarta also support these findings. High concentrations of heavy metals in wastewater also pose a health risk when it is ingested in high quantities. Transfer of metals to humans through the food chain may have serious public health consequences. A review of epidemiological studies on pathogenic disease transmission due to wastewater reuse is available, but there is no comprehensive risk assessment of heavy metals to public health (Hanjra et al., 2012).

Most of the studies confirm that the wastewater has a side effect on human health and other kinds of environment components. Over 100 virus groups that are pathogenic to humans can be found in wastewater. Human AdVs and another kind of viruses have been detected in sewage around the world (Libera & Rosa, 2017).

A study conducted in China associated with the impact of urban wastewater, confirms that pathogenic microbes characterize the urban wastewater; the majority of them belong to the kingdom of bacteria which poses a direct threat to human health in different diseases such as dermatitis, skin infections, diarrhea, and respiratory tract infections (Wang et al., 2017). Many tools have been used to recognize the side effects of polluted water on human health; nevertheless, this study confined on health risk assessment because it is one of the most critical tools to evaluate the risk of human health.

2.7.2 Health risk assessment

A human health risk assessment is the process to estimate the nature and probability of adverse health effects in humans. There are four steps of hazard identification: dose assessment, response assessment, exposure assessment, and risk characterization (EPA, 2017). A study conducted in China about the Industrial water pollution, water environment treatment, and health risks, evaluated the risk based on water pollution data, health outcomes and demographic data, mental health, self-reported physical health and Individual, and family characteristics. The result showed that water pollution intensity had a significant and independent effect on health outcomes. As expected, the effects of water environment treatment on health outcomes were favorable. Water treatment led to improve mental health by 0.07 and decreased the likelihood of adverse physical health by 0.8 percent in the absence of water pollution (Wang & Yang, 2016).

Most of the environmental matter come from the polluted water surface, especially the water that has been used directly. The main reason behind that is absent from the regulations and policies that have the power to organize the water usage and protect from the consequences. The waster surface should be used based on the regulations to avoid the consequences on human health. Health risk assessment can be used to understand the consequences on human health.

2.8 The regulation of surface water in Sudan:

The regulation of the water resources differs between the countries; therefore, the study will focus on the policies of the Nile River water in the Nile basin countries (NBC). Those countries are Burundi, Congo, Egypt, Ethiopia, Kenya, Rwanda, South Sudan, Sudan, Tanzania, and Uganda. These countries differ in terms of their dependence on the Nile water, where Egypt is the most reliant on it. Thus it was reasonable to extend the concept of water security to the primary sources In the Nile Basin. Overall the policies of water resources in Sudan encompass in several items under the Surface Water Quality Management umbrella, which constitute the role of water management in Sudan.

The surface water resources development should be integrated to achieve equity among different water users and to maximize socio-economic benefits, sustainability, and economic return. Efficient utilization of surface water resources call for research, exchange of information technology, and experiences can increase the efficiency of the systems and awareness of the users. A reliable database and information system is a prerequisite for sound assessment, planning, management & development of surface water resources. This database will entail the strengthening of existing water resources entities through training and motivating staff, ensuring the availability of necessary equipment and tools, and the rehabilitation of hydro-met stations. The operation and maintenance of surface water systems should be based on cost recovery. To ensure continuity of services, water users (for irrigation, industry, domestic supply) should pay for the actual cost of the service, including operation, maintenance, and replacement cost. Economical use of water and the use of appropriate technology would raise the ability to pay. The storage capacity has to be increased to meet the increasing demand for water. Optimum and equitable use of surface water should be promoted through cooperation between the national water users. The Government has a regulatory function to ensure that the water suppliers and users meet the appropriate standards of service quality, sustainability, and environment-friendliness.

In the policies of the Nile Basin countries, there is no specific paragraph related to water pollutants mentioned in the agreement. Nile Basin Initiative (NBI) aims to enhance cooperation on the use of the "common Nile Basin water resources." Under the auspices of the NBI, the riparian states began to work on what they believed as a permanent legal and institutional framework for governing the Nile River Basin. The Cooperative Framework Agreement (CFA), as this agreement is called, formally introduced the concept of equitable water allocation into discussions about Nile governance, as well as a complicated concept called "water security" (Mwangi et al., 2015).

2.9 The spatial analysis

The spatial analysis is one of the scientific techniques that play a role in decision-maker processing to identify the consequences and pollutants of the industries through specific criteria and characteristics as criteria of industries site selection. Also, it can be used as a sustainable development indicator to conserve the environment and compliment the purpose of development. For the most part, the spatial analysis is dealing with the spatial phenomena that inherently with economic, social, and environmental processes to give deep consideration into the spatial dimensions. The most crucial part of understanding the relationship between man and the environment is a reference to a particular location because of the accurate description for the environment through understanding the topological relationships among physical substrate (Taylor & Francis, 2006).

The spatial analysis is a technique to measure the spatial relationships between the phenomena and interpretation. The interpretation of spatial relationships can understand the causes of the phenomena on the Earth surface and predict the behavior of those phenomena in the future (Sharaf, 2008).

2.9.1 Spatial analysis interpolation

The interpolation can predict values for cells in a raster from a limited number of sample data points, unknown values for any geographic point data (elevation, rainfall, chemical concentrations, and noise levels). For example, to make a precipitation (rainfall) map for any country, you will not find evenly enough spread weather stations to cover the entire region. Hence, spatial interpolation can estimate the temperatures at locations by using the recorded temperature at nearby weather stations. This type of interpolation is often called as a statistical surface. Elevation data, precipitation, snow accumulation, water table, and population density are other types of data that can be computed using interpolation.

2.9.2 Functions of the spatial analysis

From the model as mentioned above, the study took it as an example of GIS-based multi-criteria analysis for industrial site selection. The primary purpose is to emphasize and explain the functions of the spatial analysis; therefore, the function of it presented in the most suitable site with desired conditions. Geospatial and geographical data are necessary for most kinds of studies because it has been estimated that 80% of data used by managers and decision-makers in nature are geospatial and geographical (spatial). Spatial decisions are multi-characteristics and criteria in nature (Rikalovic et al., 2014). The spatial analysis of the data is usually done in GIS program as defined as follows:

2.9.3 Definition of GIS

GIS software is considered as one of the important scientific technologies used for industries and can predict future ramifications as well as the influence of the factories through special techniques (Francis, 2006). Geographic Information System (GIS) is a software program with a methodological and conceptual approach that can connect the spatial data or any data based on a physical and natural space (Parker & Asencio, 2009)

Modern technology with different techniques like Spatial Analysis and Digital Elevation Model (DEM) is the best way of selecting the right position of factories in order to avoid the consequences caused by the factory wastes. If factories are well-sited, it will bring good both for economic and environmental (Athanassiadis et al., 2017). Digital Elevation Model (DEM) is suitable to exhibit the continuous change of the earth topography. It is the primary data source for terrain analysis and spatial applications. It can be used for studies related to science and engineering. The function of the DEM is supported by the widespread availability of digital topographic data (Thompson et al., 2001). A study was written by Yazidi et al. (2017) about the contribution of GIS to evaluate surface water pollution by heavy metals and nutrients in Casenof Ichkeul Lake (Northern Tunisia). Surface water samples collected from three locations. The finding was Nitrite ranged from 0.14 to 0.4 mg/l. Nitrates presented a concentration from 7 to 15 mg/l. The concentrations of dissolved phosphates are between 1.83 and 2.39 mg/l. The pollution indices the massive metal pollution located at the mouths of wadis and an increase of heavy metal concentrations as a result of uncontrolled releases of domestic and industrial wastewater. Moreover, the study revealed that heavy metals in lake waters have two origins; natural and anthropogenic. The first one is from rock leaching and another one from urban domestic and industrial wastewater (Thompson et al., 2001).