Chapter 1 GENERAL INTRODUCTION

1.1 Background of the study

Sugarcane, one of the essential commodities, is cultivated in over 100 countries around the world. Its production is estimated at 1.7 billion tons in 2012, indicated as an economical product for human consumption and other different purposes. White sugar is mainly produced from sugarcane, commonly grown in tropical and subtropical regions. It is the first form of carbohydrates which is found undoubtedly in whole green plants and substantial amounts in most fruits and vegetables. Sugar can be found in three primary forms, sucrose, fructose, and glucose. Sucrose is a mixture of fructose and glucose. (Chauhan et al., 2011).

Even though sugar factory has become an excellent industry to achieve economic development and improve the people's livelihood, nevertheless it does have consequences on the environment and humans. It affects and pollutes the sources of water and agricultural land. The wastewater befalls because the industry does not have inadequate infrastructures, facilities, proper treatments, and the lack of pollution control. Those barriers are worsening the environment condition as it pollutes and reduces the water quality that can damage human health and environment (Dimitrovska et al., 2012).

The sugar production process requires a considerable number of inputs, such as cane stalks, water, and chemical compounds (Calcium Phosphate Ca $(Po_3)_2$, calcium oxide, sulfide, and sodium). These materials, especially chemical input, have a significant consequence and side effects on the environment, water, microorganisms, and human health (IPCC, 2006).

Some previous studies were conducted in Sudan about the extraction of some heavy metals from wastewater and animal's milk in many factories; however, this study evaluate the wastewater from one factory only, Assalaya, and its ramifications on water and human health. The result of the previous study was all about heavy metals found in wastewater from sugarcane factory except Cr. The study revealed that the concentrations are higher in heavy metals from vegetation and grass contamination. Its primary source is fertilizer that used in the cultivation process; it can be from different types of pesticides and also attributed to the congested road (Abdalla et al., 2015).

1.1.1 The major consequences of sugarcane production

A study about the extraction of sugarcane production in Brazil: environmental and social challenges stated that sugar production had several impacts on environmental such as soil degradation, deterioration of aquatic systems, nitrogen pollution, destruction of riparian ecosystems, environmental consequences of sugarcane burning, respiratory diseases, public health, and social issues. The first ramification is soil degradation: this issue is related to sugarcane cultivation caused erosion and compaction. Soil compaction is a result of the continuous practice of heavy agricultural machinery (cultivation and harvesting operations in sugarcane fields). The main consequence in this point is the destruction of soil physical properties such as soil porosity and density (Cheesman, 2004).

The second ramification is the destruction of aquatic systems and drinking water because of wastewaters generated from different types of operation with a large quantity of organic matter. The BOD, chemicals compounds, and high nutrient concentrations encourage eutrophication which also leads to the issues of enhancing algal blooms, colluvium sediments, and deposition that affect on the quality of water, ecosystem biodiversity, and ecosystem functions. The accumulation of heavy metals in aquatic systems can be found in the fish body (Cheesman, 2004).

The third ramification is Nitrogen pollution in the fertilization process needed for the annual crops of cane. In Brazil, 3.13 million tons of fertilizers such as nitrogen, phosphorus, and potassium have been applied to sugarcane fields. The increasing applications fertilizer in sugarcane crops is likely to accumulate excess nutrients in the environment. The high flux of N can be transported to aquatic systems (Howarth, 2005). The fourth ramification is the destruction of a riparian ecosystem; this problem is affected by the movement of the solute and eroded soil erosion from the uplands to surface waters. This issue should be managed and prevented by riparian forests which usually occupy a narrow belt of land along streams and rivers. Upon the removal of riparian forests, impacts of sugarcane cultivation and ethanol production on aquatic systems are detrimental; also, exacerbated by degrading water quality, decreasing biodiversity, and increasing sedimentation. The study mentions that from total major watersheds having the most substantial percentage cover of sugarcane in 1997, only 13–18 % of the riparian vegetation was preserved. The estimated restoration cost of riparian forest in the region was US$3500/ha. The study stated that sugarcane areas in Brazil were degrading riparian forests and animal communities. Numbers of fish species, small-mammal species, common species (which can tolerate environmental changes) were decreasing, because of land expansion (Silva et al., 2007).

The fifth ramification is the environmental consequences of sugarcane burning. The study estimated 2.5 million hectares or 70 % area was burned in 2006 in the state of

Sao Paulo. Decreasing soil water content and density causes soil compaction because of compound contamination. The problems of soil burning are often carcinogenic, can risk human health when absorbed to water bodies, higher surface water runoff, and soil erosion. The high concentrations of polycyclic aromatic hydrocarbons identified in the soil are located near the smoking area of sugarcane, recently detected in deposits in lakes and rivers. The average concentration of total suspended aerosol particles (particulate matter ≤10 m) collected in Piracicaba county during sugarcane burning season was significantly higher (91μg/m 3) than the average in the non-burning season (34 μg/m 3) (Cheesman, 2004).

The sixth concern is public health and social issues. Sugarcane burning also has massive effects on the social health for those who live in areas where burning is excessive. The result found from Epidemiological studies said that the surrounding area of sugarcane fields show respiratory morbidity because of aerosol particles concentration of sugarcane burning. During the season of sugarcane burning in Araraquara, the study found a significant correlation on the daily number of patients who were visiting hospitals in the study area for breathing and inhalation treatment.

Another study in Piracicaba region, found a significant correlation between PM 2.5 (particulate ≤ 2.5 μm), PM 10 (particulate matter ≤ 10 μm), black carbon concentrations, and the number of hospitalized children and elderly patients. The results found that ten μg/m3 increment of the PM 2.5 concentration leads to 20 % increment of hospital admissions. In general, sugarcane burning is aggravating social health, which is manifested by respiratory diseases, this issue increases the demand and expenditure on the public health system (Silva et al., 2007).

1.1.2 The major impact of sugarcane to wastewater

The sugarcane wastewater has significant consequences like the impact on water quality, human health, and organisms, although sugarcane business is one of the largest agro-based industry. A study conducted in India confirms that 1 ton of can processing require around 1500–2000 dm^3 of water, and generated about 1000 dm^3 of wastewater. Wastewater mainly comes from floor washing, condensation, leakage, spillage of sugarcane of valve and pipelines, syrup and molasses in different sections. The composition comes from SI has a high content of organic material because of the existence of sugar and organic material in the beet or cane. The most acceptable approach for processing organic wastewater is aerobic and anaerobic treatment due to its high capability of COD and BOD removal (Sahu & Chaudhari, 2015).

Sugarcane industries have the most crucial part for aquatic systems deterioration through transported colluvium sediments downhill across the landscape from sugarcane fields are deposited onto wetlands, small streams, rivers, and reservoirs. The deterioration impacts water quality, ecosystem biodiversity, and ecosystem functions. The overwhelming sedimentation issues are further aggravated by the transported contaminants such as pesticides and heavy metals used in sugarcane cultivation to aquatic systems and organ chlorines found in sediment and fish samples. The processing of sugarcane for the production of ethanol and sugar cause pollution for aquatic systems when the mills generate large amounts of wastes. Waste products are rich in organic matter, and water BOD increment is unavoidable due to the dumping of these wastes. Elevated BOD encourages dissolved oxygen depletion in the water and frequently causes anoxia. High nutrient concentrations in these effluents are encouraging eutrophication of surface waters and contribute the issues enhancing algal blooms (Luiz & Solange, 2008).

The study associated with a small monitoring stream adjacent to a sugarcane mill in Piracicaba County- Brazil, reported changes of water quality along a 1.8-km reach downstream of a sugarcane mill. Increment of water temperature, electrical conductivity, dissolved organic carbon (DOC), and dissolved inorganic nitrogen (DIN), were observed at downstream from the mill. Also, the DO concentrations were significantly lower at downstream, while dissolved inorganic carbon was high. Therefore, these findings suggested that the discharge of waste into streams accelerated erosion in sugarcane fields transported organic materials to the water (Gunkel et al., 2007).

1.1.3 Sugar production in Sudan

Assalaya Sugar factory is located at the White Nile State, Sudan and is considered as one of the four factories of the Sudanese Sugar Company (SSC). Based on the report of SSC (2018), entire of them belong to the government system, these are;

Guneid factory lies at Nile's Eastern Bank, Gazira locality, Gazira state, 120kms south to Khartoum – 17kms north to Rufaa City since 1962–1963. Its annual capacity is 60.000 tons of sugar with a total area of 38.716 acres of land, with 37.000 Feddans as a plantation with the pumping irrigations means by pumps at Guneid village at the bank of the Blue Nile. (SSC, 2018).

New Halfa Factory is located at the River Atbara Locality of Kassala State, some 400 km to the east of Khartoum & 17 km to the North of New Halfa CityThe construction of this factory started in 1963 by a joint venture of the two German companies, BW & BMA. The construction was completed in 1965. Trial operation of the factory started during the 1965 - 1966 crops. The maximum production capacity of the factory was 60.000 tons. However, it was improved to increase its capacity to 75.000 tons. A refined sugar plant was built to produce refined sugar for the export market. The cultivated area is 37.000 acres of land, irrigated by flow irrigation method, flowing from Khashm Alqirba Dam. (SSC, 2018).

Sennar Factory; lies in Sennar State, some 40 km to the west of Sennar City, 300 km to the south of Khartoum & 12 km to the west of Wad Alhaddad City. The Dutch HVA Company conducted the factory's feasibility study. The British Fletcher & Stewart Company constructed the factory during the period 1971-1979. The annual production capacity of the factory was 110.000 ton of sugar. The area of sugarcane plantation is 34.5 thousand acres of land, 22.5 thousand acres are arable. The first production season started in October 1976. The project is irrigated from Irraideeba pump station at the bank of the Blue Nile, some about 56 km from the factory. The factory has 1.550 permanent worker and 1,932 seasonal workers. Production during the 2010-2011 season amounted to 70844.75 tons. A sugar refinery to produce high-quality refined sugar was built during 2008 - 2009 crops for local and export markets. The workers are about 1,218 permanent & 1.383 seasonal. All the surrounding villages are provided with portable water & electric power, schools of different levels, hospital, pharmacies health & social centers. Total production in 2010-2011 was 91.756.75 tons. (SSC, 2018).

Assalaya Factory is located in Assalaya Locality of the White Nile State, some about 280 km to the south of Khartoum & 5 km to the north of Rabak. The British Fletcher & Stewart Company constructed the factory. The first production season started on January 15th, 1980. The factory’s production capacity was 110.000 tons at 6.500 tons of sugarcane with 28. 000 acres of land as total area. The area was expanded by 15.000 acres of land to secure cane producing. The scheme is irrigated by pumps directly from the White Nile. Total production during the 2010-2011 season amounted to 93.676.05 tons. The Factory employs 1.455 as permanent staff and about 2.129 as seasonal workers. A sugar refinery to produce high-quality refined sugar was built during 2008- 2009 crops for local and export markets (SSC, 2018).

In the last ten years, the SSC has seen a steady increase in its sugarcane and sugar production. The expansion in sugarcane production is horizontal and vertical, accompanied by the factories excellent performance from rehabilitation work carried out during these years: (1) remarkable increase in area under cane, horizontally from 70.000 to 81.200 acres; (2) cane yield per Faddan increased from 29 to 44.6 tons; (3) the crushing capacity per day increased from 8876 tons per day to approximately 20.000 tons of cane per day; (4) the total sugar production increased from 175.000 to 327.000 tons of sugar per year and (5) factory time efficiency increased and the downtime i.e., time lost for the milling plant decreased from 40% to less than 15%. All of these points reflect the necessity to improve harvesting practices such as cutting windrowing, loading, and haulage in order to improve cane delivery from fields to the factory at night (Ahmed & Alam-Eldin 2015).

Despite the sugar production is considered as the significant strategic commodities in Sudan, its production started to reform the economy; nevertheless, some of the factories have discharged their wastewater during the production process and irrigation into either Blue Nile or White Nile River. Most of sugarcane factories have environmental consideration (Eco- industry) and wastewater treatment; however, some of them do not have and therefore cause severe risks for the rivers, agriculture arable land, humans and animals grazing on the vegetation as well (Abdalla Hassabo et al., 2013).

The harvesting system of Sudanese cane was previously old-fashioned. However, since 2002, they have introduced mechanical harvest. Commonly all of the Sudanese Sugar factories have introduced mechanical harvester covering approximately 30–40% of the total area under harvest in each season since the year 2000. The uncertainty of the constant daily cane supply resulting from manual cane cutting encourages the increment of mechanically harvested area. Most factories with manual harvesting burn the cane to reduce harvesting costs and labor. Generally, the harvesting system has side effects on the social and the environment due to the process of burning (Jeongwoo et al., 2012).

Despite the primary purpose of sugar factories are to achieve economic and development sector progress; nevertheless, it gives negative impacts on the environment. This study investigated the consequences of Assalaya sugar factories on the water when it is necessary for the survival of entire living organisms, including humans, food production, and economic development. Today there are many cities worldwide facing an acute shortage of water and nearly 40 percent of the world’s food supply is grown under irrigation, and a wide variety of industrial processes depends on water (Halder & Islam 2015).

One of the critical sources of the water is a river, considered as the primary source to provide essence life - water - for the most living organisms, including humans, plants, and animals. Pollutant discharge causes widespread organic pollution, toxic pollution, and eutrophication, along with severe ecological destructions (Wang & Yang, 2016).

The amount of freshwater is limited because we only have 3% of them from the total contain on earth. Unfortunately, this small proportion is facing enormous stress because of the rapid increase in the world's population, urbanization, unsustainable consumption of water in industries, agriculture, and daily practices, many countries in Africa, the Middle East, and South Asia will have severe threats of freshwater. In developing countries, the problem is further aggravated due to the lack of proper management, financial constraint, and inactive regulation (Azizullah et al., 2011).

Overall the regulations of water resources in Sudan is designated in environmental protection act 2008, approved by parliament, to prevent the environmental pollution encompass several items and still under surface water quality Management umbrella. The regulations of water in Sudan mention that surface-water planning and development must be integrated at all levels. The whole people and institutions must protect surface water resources; thus, surface water development policy should be clear and accessible to communities. A reliable database and information system is a prerequisite for assessment, planning, management, and development of surface water resources. The operation and maintenance of surface water systems should be based on cost recovery which the user pays. The storage capacity has to be increased to meet the increasing demand for water, and 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-friendly (Sudanese Environmental Act, 2008).

The policy also mentions that the primary sources of surface water pollutants are critical to establishing a monitoring and evaluation (M&E) systems for pollutants types. Generally, the primary polluters mentioned in the regulation with a massive amount of matter in the Nile River are: Industry, it has been estimated that industrial water use represents a significant amount of the total consumption of water in Sudan. This consumption includes the sugar industry, mining, dairies, tanneries, abattoirs, slaughterhouses, oil, soap, refineries, and pulp and paper. However, with the increased pace of industrial development in agro, oil, and mining industry, the water requirement for industrial applications may increase to 5% of the water utilization in Sudan by the year 2025. Besides, there are also hydropower, navigation, and fisheries (Kimenyi & Mbaku, 2015).

The scientific and engineering industries must have optimal processes design. Sugarcane factories or any others kind of industries should be under the industrialization standard establishment and should have homeostasis consideration between environment, economy and social aspect to achieve higher value and avoid the environmental impacts on natural resources and human health (Bechara et al., 2016).

There are several reasons for the selection of this research. First, the world today is suffering from water scarcity, especially in the study area due to water future start from upstream of river Nile until downstream. Second, fluctuation of precipitation as a result of the climate change phenomena decrease the amount of freshwater. Third, the industry's wastewater treatment is discharged in the White Nile River; meanwhile, the river is considered as the main branch of the Nile River and the fundamental source of water drinking water in Sudan. The reasons, as mentioned earlier, are why factories or industries must have a consideration on the environment component and keep the environment well. So that the externalities and pollution can be reduced by applying a green economy, eco-factory, and eco-efficiency in Assalaya sugarcane factory. All pollutants, both industrial and domestic, have a significant role in water and environment pollution. This study uses physiochemical analysis to investigate the amount of industrial pollution in the river.

1.2 Research problem

The research problem encompasses the influence of Assalaya Sugarcane factory wastewater discharged in White Nile River and cause ramifications on water through alteration of the physical and chemical characteristics that can affect human health. The process of discharging without treatment pollute the water and furthermore can impact human health due to the input of chemical substances and raw materials. As it is understood that the wastewater contains organic carbon C- organic → microorganisms metabolism → Aerobic→ organic= CO_2, NO_3, NH_3, H2O, NO_2, SO_4. While: C- organic → microorganisms metabolism → Aerobic→ inorganic= N_2, NH_3, CH_4, H_2S.

The Assalaya factory lies in White Nile State, one of Sudan states located in central Sudan, 5 km to the north of Rabak, the capital city of the state. Assalaya factory was established in 1980 with a designed production capacity of 110.000 tons at 6.500 tons of sugarcane. The cultivation area of cane is 34.405.66 acres. The mentioned components emphasized the extension of the factory's area. However, it does have bad effects concerning the environmental factors since the wastewater discharged into the White Nile River destroys the environment and produce externalities. Also, the location of the factory is not fit for community resident and water resources. Based on the observations, it seems that the water around the study area generates some destructive environments impact such as the unpleasant smell.

White Nile River actually has a good quality freshwater in Sudan and other countries. It is necessary to select an appropriate factories' location according to the international standard; also for reducing the unfriendly ramifications and accomplishing the concept of sustainability (Abd et al., 2012).

The world today is suffering from water scarcity, and Sudan is no exception from this global crisis even though there is the Nile River. Many factors are aggravating and reducing the amount of water such as climate variability, a rapid increase of the population, and water dependency for the agricultural purpose. Establishment of dams also gives rise to the water scarcity crisis. Logically, rapid growth increase requires abundant water to meet the need and demand for essential purposes such as drinking, agriculture, and other vital usages. Therefore, sugarcane factory should apply the environmentally friendly principles. Sudan has to meet the need to overcome our water scarcity, reduce pollutants, and to apply the concept of green economy and clean production.

To recognize more clearly about the consequence of Assalaya factory on the water and human health, the study has summarized all of the problems in some nomenclature of quotations called as research questions.

1.3 The research question

1.3.1 The general research question

Generally, the research statement represents in the spatial analysis interpolation of Sugarcane wastewater and its impact on water quality and human health, which are inculcated into the following specific questions.

1.3.2 The specific research questions

A. What kind of raw materials and chemical substances used and how much is the wastewater generation by Assalaya Sugarcane factory in Sudan?

B. Is there any consequence of the wastewater on the physiochemical characteristics of water quality around the factory?

C. How spatial analysis have a significant role in detecting the distribution of the locations that have a high concentration of wastewater?

D. What are the consequences of the wastewater on the local community health?

1.4 The objectives of the research

The research purpose is divided into main objective and specific objective.

1.4.1 The main objectives of the research

To evaluate the consequences of Assalaya sugarcane wastewater on water quality and human health.

1.4.2 The specific objectives of the research

The specific research objectives are as follows:

A. To analyse the production process of Assalaya sugarcane factory and recognize the amount of wastewater and the capacity of the factory wastewater plant;
B. To analyse the consequence of the physiochemical characteristics of wastewater on water quality;
C. To analyse the spatial analysis interpolation using IDM method to understand the locations of wastewater concentration status through the maps
D. To analyse the influence of the factory wastewater on human health.

1.5 Research Originality

The originality is the differences between this study and the others; the study topic, in general, is the consequences of sugarcane on the environment with natural environment biophysics (water) and human environment. Other scholars had already studied this topic; nevertheless, different angles from the same topic give the originality in several studies and fields. This study is original becase ues special technic are as the comprehensive assessment of the production process to recognize the amount of wastewater generation; second, laboratory analysis to seek out the impact on the water; third, interpolation analysis to understand the distribution rage of the physiochemical impact; last, questionnaire, interview, and physical inspection to realize the impact on human health. Regarding the laboratory analysis, the study has analyzed five physical parameters and 12 chemical parameters, including the chemical substances that have been used as input materials to produce sugar.

Overall, several previous studies associated with this study have differences in variables, parameters, and study area. The originality will be perspicuous when this study addresses more detail about the similarities and differences of earlier studies. Moh Med F. Hamoda J wrote the study about sugar wastewater treatment with aerated fixed-film biological systems. The differences are the study address the sugar wastewater on an organism by specific parameter on chemical factors; nevertheless, the current study will address chemical and physical factors. The similarity is both of them addressing chemical factors, but the current study addressing more than the previous study.

A study of some heavy metals in wastewater and milk of animals grazed around sugarcane plants in Sudan was written by M O M Abdalla et al., (2015), which addresses the heavy metal that comes from all Sudanese sugar wastewater. However, the current study addresses only the impact of wastewater that comes from one factory, Assalaya. Meanwhile, Alejandra Ingaramoa (2009), wrote a study regarding water and wastewater eco-efficiency indicators for sugarcane industry. The study evaluates the environmental impacts of sugarcane wastewater on WIN, which indicates the efficiency of water use, which quantifies Chemical Oxygen Demand of wastewater. The current study is addressing the same thing but more extensively, which include chemical and physical. The differences are in the variable and location.

A study conducted in Brazil was written by Ricardo de Oliveira Bordonal et al. (2017), about changes in quantity and quality of soil carbon due to the land-use conversion to a sugarcane plantation. The study was aimed to reveal the soil quality in terms of soil organic carbon after converting land use from crops to sugarcane cultivation with different levels of soil depth (0-10), (10-20), (20-100 cm). The similarity of both studies (previous study & current study) is to understand the aftermath of the soil. The previous study was concerned in the effect of crops conversion on the soil; whereas, this study will focus on the impacts of irrigation output (chemical fertilization residues- salt) on the local community of agriculture land.

Study written by Adam E. Ahmed et al (2014), about an assessment of mechanical vs manual harvesting of sugarcane in Sudan – The case of Sennar Sugar Factory aims to compare and evaluate between manual and mechanical harvesting systems with regard to production efficiency, cost-effectiveness, cane loading efficiency, infield losses, and the effect of trash in factory process. The previous study concerns the economic sectors even though the study addressed the environment issue; the similarity is only on the environmental aspects.

A study done in Brazil was about the influence of sugarcane burning on indoor/outdoor PAH air pollution. This study addressed the health aspect of laborers and neighbors using PAC, area to evaluate the respiratory disease that came from sugarcane burning around the community area. The study compared two periods, during the burning period and non-burning period. The similarity is regarding the health impact evaluation caused by sugarcane burning. The previous study was evaluating the consequences of burning against laborers who had been working at the factory, whereas the current study aims to assess the impacts of combustion only in communities. Also, the previous study did not evaluate the fly ashes as a result of the burning process because it has a massive impact on human health who have been abode around the factory. Therefore, the difference in the studies is variables, parameters, and the method of analyzing the results.

A study was entitled as reassessing the environmental impacts of sugarcane ethanol production in Brazil to help meeting sustainability goals, written by Solange Filoso, at el (2015). The study assessed the environmental impacts of sugarcane cultivation, harvesting, and ethanol production. It focused on the effect on water resources, atmosphere, soil, and land-use changes on threatened biomes and discussed some of the present obstacles regarding conservation and restoration efforts.

The current study focus on the water quality discharged by Assalaya sugarcane factory, whereas the previous study was concerned about the water residues from the farming operations. Regarding the impact of combustion on the atmosphere or air pollution, the previous study specifies on the atmosphere (carbon dioxide-co2), whereas this study will pay attention to the ambient air of surrounding environment in study community area (residues- fly ash burning). The current study depend on the spatial analysis in disteribuing the impacts with some standard variables and some differences in the parameters and methodology.

A study conducted in Brazil was written by Dener Márcio da Silva Oliveiraa et al. (2015), about soil carbon changes in expansion areas of sugarcane into pastures. This study focused on assessing the C and N rate that present in the soil. This study was addressing the conversion from vegetation, pasture to sugarcane, with the use of special tools and instrument to do soil inspection with various depth. The previous study was concerned on a ramification of sugarcane cultivation, whereas the current study will pay attention to the impacts of sugarcane (salts). Also, the study will use different variables that were not used in the previous study.

A study was done in Africa, Zimbabwe about the impacts of irrigation based on sugarcane cultivation on the Chiredzi and Runde Rivers quality written by Tamuka Nhiwatiwa et al. (2017). The study evaluated the effects of irrigation residues from sugarcane cultivation on chemical and physical water quality. Both studies aim to investigate the sugar factory adverse effects on water quality. The previous study focused on the effects of sugarcane culture on water, whereas the current study will focus on the impacts of sugarcane production on water quality. The prime difference is in the variables that the previous studies have not covered (Rivers et al., 2017).

The study was written by Gustavo Faibischew Prado et al. (2012), about burnt sugarcane harvesting: particulate matter exposure and the effects on lung function, oxidative stress, and urinary 1-hydroxypyrene. This study addressed the effects of manual harvesting on environmental pollution and the impacts on the workers and surrounding community area, where also evaluate the health effects from manual harvesting (burning) and its impact on respiratory diseases.

The variation in the current study was confined in the effect of burning. The previous study was focused on the surrounding air environment, whereas this study will focus more on the impacts on water, human, and the health aspects, which is considered to be mutual with the previous study. Both studies are similar with the impacts on the population and the surrounding area, which confirms that the location of the factory itself has the most substantial role on the impact, not the factory only.

A study was conducted in north-eastern Thailand, written by Jittima Prasara-A et al. (2015), about the sustainability of sugarcane cultivation. The study aimed to provide some advice for achieving sugarcane cultivation sustainability in terms of assessing environmental and economic aspects by using several variables such as global warming, human toxicity, terrestrial acidification, freshwater eutrophication, marine eutrophication, terrestrial ecotoxicity, freshwater ecotoxicity, marine ecotoxicity, agricultural land occupation, water depletion, fossil fuel depletion, employment generation, worker income, wages, and working conditions. This current study aims to detect the impacts and its causes, whereas the previous study aimed to clarify the factors to achieve sustainability, homeostasis between the economic and environmental aspects. On the other hand, this study will address some of the economic aspects, which will be considered to be similar.

There is a study about Multi-criteria decision support system for wind farm site selection using GIS, written by Younes Noorollahi et al. (2016). The previous study aimed to select the location of a wind farm with specific criteria, including technical, environmental, economic, and geographic standards. Whereas this study will make sure how far the Assalaya sugarcane factory has an appropriate site for production based on the right standard of the selection site such as water catchment, proximity, and contour. Both of the studies use GIS to prove the results.

Another study conducted in China was on selecting photovoltaic generation sites in Tibet using remote sensing and geographic analysis, written by Siheng Wang et al., (2016); it concerned about how to determine the best potential sites for potential PV investments. The similarity is on the use of Geographic information system to select the proper location. The variation is on technical application systems because the previous study was applied to selected electricity locations, whereas this study will be applied to a sugarcane factory selection.

Study about GIS-modelling based coal-fired power plant site identification and selection, written by Jiuping Xu et al., (2016), aimed to select the best location for Coal-fired power plant. The similarity is on the use of Geographic information system to select the proper location. The variation is on technical application systems because this previous study identified and selected proper location for Coal-fired power plant, whereas this study will be investigating and selecting the suitable site for sugarcane factory.

Table 1.1. Research originality

Author Names	Topics	Methodology	Result
L**uiz a. martinelli et al** (2008**)**	Expansion of sugarcane ethanol production in Brazil: environmental and social challenges.	Evaluates the environmental impacts of sugarcane in soil degradation, deterioration of aquatic systems, nitrogen pollution, destruction of riparian ecosystems, environmental consequences of sugarcane burning, public health, and social issues	The increases in water temperature, electrical conductivity, DOC, and dissolved inorganic nitrogen (DIN) were observed downstream from the mill. Moreover, concentrations of dissolved oxygen were significantly lower downstream
M O M Abdalla et al. (2015)	Assessment of some heavy metals in wastewater and milk of animals grazed around sugarcane plants in Sudan	Evaluation of the heavy metal concentration of wastewater from sugarcane plants and milk from animals grazed around the plants	Indicated that the heavy metals were detected in the wastewater of all sugarcane plants except Assalaya and Kenana
Mohn med F. Hamoda J, et al. (**1999**)	Sugar wastewater treatment with aerated fixed-film, biological systems	This study examined the performance of a four-compartments, fixed-film system in which the biofilm is attached to submerged ceramic tiles under diffused aeration	The study found severe organic loads increasing from about 5 to 120 g BOO/m2.d with a slight decrease in organic removal efficiency from 97.9% to 88.5% for BOD and from 73.6 to

Author Names	Topics	Methodology	Result
			67.8% for COD
Yazidi, Saidi, Mbarek, & Darragi (**2017**)	Contribution of GIS to evaluate surface water pollution by heavy metals and nutrient in surface water: Case Northern Tunisia	The method used Spatial interpolation IDW technique, to distribute the metal elements (mg/l) in waters of the lake Ichkeul	The heavy metal evaluation index (HEI) show high pollution located at the mouths of water and an increase of heavy metal concentrations
Azzoni et al. (**2016)**	A Spatial Difference-in-Differences Analysis of the Impact of Sugarcane on Respiratory Diseases	This method is an addition to the Spatial Econometrics literature, as it includes spatial effects on treated and untreated regions so that the effects on both producing and surrounding non-producing regions can be estimated appropriately	The results indicate that the effects on the producing regions are 78% larger if the effects on the surrounding areas were ignored. Moreover, the effects on the surrounding areas, typically ignored in other studies, are relevant, and almost as large as the effects on the producing areas
Alejandra **Ingaramo**a **(2009)**	Water and wastewater eco-efficiency indicators for sugarcane industry	The study evaluates the environmental impacts of sugarcane wastewater on WIN, which indicates the efficiency of water use, and EIN1 and EIN2, which quantify Chemical oxygen demand of wastewater	Three new indices for sugarcane plants are introduced in this work: WIN, which indicates the efficiency of water use, and EIN1 and EIN2, which quantify Chemical Oxygen Demand of wastewater
Filoso et al. (**2015)**	Reassess the environmental impacts of sugarcane ethanol production in Brazil to meet sustainability goals	The study evaluates the environmental impacts of sugarcane agriculture and ethanol production by different methods. The study focused on the evaluation of the impacts on water, atmosphere, and soils	The study found that the environmental impacts of sugarcane ethanol in Brazil advanced with regards to soil degradation, nitrogen dynamics, and soil carbon stocks. However, more information is still needed about the impacts of the increasing use of pesticides, herbicides, and fertilizers in sugarcane agriculture
Márcio et al. (**2016)**	Soil carbon changes in areas are undergoing an	Evaluate C and N dynamics in land-use	The increase of C stocks in areas converted from

Author Names	Topics	Methodology	Result
	expansion of sugarcane into pastures in South-Central Brazil	change (LUC) sequence in sugarcane expansion areas (native vegetation to pasture to sugarcane). The sample size selected is the top 1 m soil layer	pasture to sugarcane cultivation was 1.97 Mg ha_1 yr_1, in contrast to the conversion of native vegetation to pasture, which decreased soil C stocks by 1.01 Mg ha_1 yr_1 for 0–1.0 m of the soil layer
Oliveira et al. (2017)	Changes in quantity and quality of soil carbon due to the land-use conversion to sugarcane (Saccharum officinarum) plantation in southern Brazil	The study analyzes the soil sample collected from different levels: 1-m depth (0–10,10– 20, 20–60 cm), (60–100 cm), the equivalent layers of (0–20 cm), and (0–100 cm), were obtained for each paired area	Regarding the conversion from annual crops to sugarcane, there was no difference in soil C stock among land uses at any soil depths. Overall, conversions of perennial tree crops (e.g., coffee and citrus) into sugarcane increased the ramification levels of SOM in subsoil, except when sugarcane replaced pasture
Rivers et al. (2017)	The impact of irrigation-based sugarcane cultivation on the Chiredzi and Runde Riversquality, Zimbabwe	An assessment of the water quality with physical-chemical variables	The results showed that the wetland was deficient. Water quality sites were characterized by a high diversity of pollution sensitive macroinvertebrate taxa, while the irrigation impacted sites were characterized and dominated by pollution tolerant taxa
Mthimkhulu et al. (2016)	The effect of 72 years of sugarcane residues and fertilizer management on soil physiochemical properties	The method was an analysis of soil, where the soil samples for physiochemical and aggregate stability analysis were collected at depths of 0-10 and 10–20 cm from 24 plots. In comparison with burning, significant effects of mulching were observed	Annual fertilizer applications may lead to soil structure deterioration under sugarcane regardless of the harvesting method practiced and (ii) increasing additions of organic matter (through mulching) do not always correspond to an improvement of soil aggregate stability and related soil properties

Author Names	Topics	Methodology	Result
Prasara-a & Gheewala (2015)	Sustainability of sugarcane cultivation: a case study of selected sites in north-eastern Thailand	The method analyzed the impact of sugarcane cultivation on socio-economic	Freshwater eutrophication and marine ecotoxicity. Yields, cultivation practices, and distance to the sugar mill are the key factors influencing the environmental and socio-economic impacts
Ahmed & Alam-Eldin (2015)	An assessment of mechanical versus manual harvesting of sugarcane in Sudan – The case of Sennar Sugar Factory	Different experiments were conducted to compare between the two harvesting systems with regards to production efficiency, cost-effectiveness, cane loading efficiency, infield losses, and the effect of trash in the factory process because this paper aimed to evaluate the current sugarcane manual and mechanical harvesting systems	The results revealed that manual harvesting (8.98 SDG/ton) is more expensive than mechanical harvesting (4.9.5 SDG/ton). The wages for the cane cutting labor represents 74.14% of the total cutting cost, 46% of the total manual harvesting cost, and 18.9% of the total harvesting cost
Faibischew et al. (2012)	Burnt sugarcane harvesting: particulate matter exposure and the effects on lung function, oxidative stress, and urinary 1-hydroxypyrene	The study evaluated two respiratory symptom questionnaires, spirometry, and urinary 1-hydroxypyrene levels. This research demonstrates the exposure of sugarcane workers and inhabitants of a neighboring town to high PM 2.5 concentrations during the sugarcane harvest period	The environmental assessment was determined from PM 2.5 concentration. PM 2.5 level increased from 8 $\mu g/m^3$ during the non-harvesting period to 23.5 $\mu g/m^3$ in the town, and 61 $\mu g/m^3$ on the plantations during the harvesting period
Mugica-alvarez et al. (2015)	Emissions of PAHs derived from sugarcane burning and processing in Chiapas and Morelos México	Identifying the health risks to the neighboring population should be a significant governmental concern, leading to identification and quantification of toxic compounds, such as polycyclic aromatic hydrocarbons (PAHs) in order to establish the magnitude of the problem	The results showed that during harvest, the PM10 mass increased lightly in Chiapas on three different sources during harvesting: the combustion process in the sugar mill, sugarcane burning, and vehicular emissions

Author Names	Topics	Methodology	Result
Noorollahi et al. (2016)	Multi-criteria decision support system for wind farm site selection using GIS	This study applied GIS to determine the potential of wind energy in Markazi province in western Iran. The multiple criteria decision-making method and site selection criteria for wind resources assessment	The results were favorable for electricity production following international standards from the wind in western Iran. The results show that 28% of the study area has the capacity for installing large wind farms
Wang et al. (2016)	Selecting photovoltaic generation sites in Tibet using remote sensing and geographic analysis	Using Geographic information system (GIS) to identify the best location for the photovoltaic generation with specific criteria including solar energy distribution, local terrain, and native land cover. Several remotely sensed data were employed as input, including time series of solar radiation data, land cover data, and digital elevation model data	The results were discussed according to their distance to existing electricity substations, to evaluate the difficulty to be connected to the grid. The work highlights a method for the selection of suitable PV power generation sites and guides the construction of these stations, particularly in Tibet-like regions with poor electrical infrastructure, and harsh environmental conditions
Xu et al. (2015)	GIS-modelling based coal-fired power plant site identification and selection	Using the technology basis on a vital consideration in the site selection process and multi-criteria framework	By considering stakeholder interest and energy efficiency, this methodology provides a method for a better understanding of CPP site identification and selection to ensure sustainable development. This methodology could be used in many developing countries by making minor modifications to some parameters

1.6 Benefits of the research

The benefits of this study are manifested into contributing and protecting the environment and society from externalities that affect severely on the environment, resources, human and animals. The social must be prevented and protected from the factory consequences by several means. As we understand that sugarcane factory has an important role and contribution to the national economy; nevertheless, the study demonstrate on the consequences which are influenced by sugarcane factory. In general, the benefit of the study presented in:

- Elaborate the seriousness of factory wastewater pollutants and to take precaution from it, because its output can cause a considerable number of difficult issues such as respiratory diseases, dermatitis, skin cancer, permanent allergy, bioaccumulation, and Biomagnifications.
- To clarify that the contaminated water by different kind of pollutants that have a side effect on human health. Water-Borne diseases kill 25.000 people per day, and pathogenic organisms may cause some illnesses as Gastrointestinal tract and skin sensitivity.
- The study area is rich in resources such as livestock, wildlife, agriculture, and arable land; therefore, it is better to protect them from damage and deteriorations. Provide environmental and cultural awareness for the local community, particularly regarding river resources such as fish and other Nilotic food in order to avoid bioaccumulation and biomagnifications.
- To emphasize the importance of proper planning in selecting the appropriate location of factories using new technological means such as spatial analysis. It is a

useful contribution to prevent the dangers, disasters and hazards as well as reducing the environmental problems, and achieving economic factors.

- To clarify the importance of the economic aspect of sugarcane factories and its contribution to national income revenue.
- Providing environmental and economic concepts include eco-efficiency, carrying capacity, absorptive and assimilative capacity, industrial symbiosis, industrial metabolism, clean production, environmental management systems and auditing, clean industry, pollution standard, and sustainable development.
- To promote the establishment of wastewater treatment units accompanied by modern laboratories on the estuaries drainage, near to the water resources.

1.7 The Novelty

The novelty of the study is the analysis of the WQI. The study found that the research area located within risk zoon is extremely close to the production site (factory). There are three types of Water Quality Index, PWQ, FWQ, and MWQ, with the absence of GWI and EWQ. These indicators indicate the deterioration of the freshwater quality. Since there is a close relation between WQI and health, it can directly affect human health. By using the IDW interpolation toward these indicators, the study could found the magnitude of the impact. Overall, the index of MWQ affects 26.08% of the residents, 38.75% of the community is living under the FWQ indicator, and as much as 35.12% of the inhabitants have resided under PWQ indicator.