DISSERTATION

THE SPATIAL ANALYSIS OF ASSALAYA SUGARCANE FACTORY WASTEWATER IN ASSALAYA DISTRICT, SUDAN: ITS CONSEQUENCE ON WATER QUALITY AND HUMAN HEALTH

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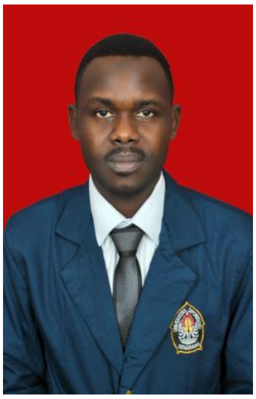

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<u>Publications</u>

Journal Publication

- Physical Wastewater From Assalaya Sugarcane Factory: reality and perception, International Journal of education science, Issue: 2339-1276; e-ISSN: 2089-4392, nationally accredited decree of the Ministry of Research, Technology, and higher education No 2/E/KPT/2015, SCOPUS INDEXED Q3 SCIMAGOJR. Published in September 2019.

Conference Publications

- The Role of Spatial Analysis in Detecting the Consequence of the Factory Sites : Case Study of Assalaya Factory-Sudan, Issue E3S Web Conf, Volume 31, 2018, The 2nd International Conference on Energy, Environmental and Information System (ICENIS 2017), Article Number 12004, Section: Health, Safety and Environment Information Systems, DOI: https://doi.org/10.1051/e3sconf/20183112004 Published online 21 February 2018
- Analysis of Management System of Solid Waste: Cases Study at Hasanuddin University (Unhas), Advanced Science Letters, Volume 23, Number 3, March 2017, The 1st International Conference on Energy, Environmental and Information System (ICENIS 2018), pp. 2336-2339(4), Publisher: American Scientific Publishers: DOI: https://doi.org/10.1166/asl.2017.8756.

Under Publication:

- Analysis of the Production Materials input of Assalaya Sugarcane Factory and its Role in the Wastewater Generation.
- The Variations of Chemical Features of the Wastewater from the Sugarcane factory

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STATEMENT

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LIST OF ABBREVIATIONS

$\mu g/m^3$	Microgram per Meter Cubic
Bé°	Baume
BOD	Biological Oxygen Demand
C	Carbon
$Ca\ HCO_3$	Calcium Bicarbonate
Ca_3	Carbonic Anhydrase-3
$CaCO_3$	Calcium Carbonate
CaO	Calcium Oxide
CD	Crop Days
CFA	Cooperative Framework Agreement
CFA	The Cooperative Framework Agreement
CKD	Chronic Kidney Disease
Cl^-	Chloride
CLTSC	Central Laboratory for the Technical Services & Calibration
Cm	Centimeter
CO_2	Carbon Dioxide
COD	Chemical Oxygen Demand
CPI	Comprehensive Pollution Index
DEM	Digital Elevation Model
DIC	Dissolved Inorganic Carbon
DIN	Dissolved Inorganic Nitrogen
DM^3	Density Meter
DO	Dissolved Oxygen
DOC	Dissolved Organic Carbon
DRC	Democratic Republic of the Congo
DT	Downtime
EDTA	Ethylene Diamine Tetra Acetate
FAS	Ferro Ammonium Sulphate
FWQ	Fair Water Quality
FWEP	Freshwater Eutrophication Potential
FWEP	Freshwater Eutrophication Potential
PWQ	Poor Water Quality
GIS	Geographical Information System
GPS	Global Position System
HCl	Hydrochloric Acid
HCO_3	Bicarbonate
IDW	Inverse Distance Weighting
IO	Input and Output
Km	Kilometer

LIFS	Laser-induced Fluorescence Spectroscopy
M	Meter
MWQ	Medium Water Quality
M&E	Monitoring and Evaluation
MEP	Marine Eutrophication Potential
Mg HCO_3	Magnesium Hydrogen Carbonate
$Mg(OH)_2$	Magnesium Hydroxide
Na	Natrium
N.A	Not Acceptable
NH_3	Ammonia
NH_3N	Nitrogen-ammonia
NO_2	Nitrogen Dioxide
NO_3	Nitrate
NTU	Nephelometric Turbidity Units
CEPI	Comprehensive Pollution Index
PAHs	Polycyclic Aromatic Hydrocarbons
pH	Potential of Hydrogen
PM	Particular Matter
PO4	Phosphate
FWQ	Fair Water Quality
RP	Reactive Phosphorus
RS	Remote Sensing
RSC	Residual Sodium Carbonate
SAR	Sodium Adsorption Ratio
SO_4	Sulphate
SPSS	Statistical Program for Social Science
SSA	Sudanese Survey Authority
SSC	Sudanese Sugar Company
SSP	Soluble Sodium Percent
TCU	Calcium Carbonate
TDS	Total Dissolved Solids
TEA	Triethylamine
TP	Total Phosphorus
TSWW	Treatment System of Wastewater
TSS	Total Suspended Solids
UNO	United Nation Organization
WHO	World Health Organization
WHO	True Color Unit
Wi	Q- value
WQI	Weighing Factor

WWTP	Wastewater Treatment Plant
Zn	Zinc

GLOSSARY

Physiochemical concentration in water concentration in water:	An alteration of physical and chemical of water or variations in the water characteristics which influenced by wastewater.
Spatial Analysis:	A technology that use to identify the distribution of phenomena on the Earth surface with the appropriate manner by environmental components; also to predict the behavior of those phenomena in the future.
Interpolation Analysis:	Predicting values for cells in a raster from a limited number of sample data points. It can be used to predict unknown values for any geographic data point.
Remote Sensing:	A technology to process the image of earth from space, with distinct features, the clarity of the object rely on the resolution and the satellite quality. The satellite image will be processed by using the GIS program.
Geographical information system (GIS):	a software that assesses the data with positions on the Earth surface
Digital Elevation Model (DEM):	Suitable to exhibit the continuous change of the Earth's topography. It is the primary data source for terrain analysis and spatial applications.
Bio-accumulation:	Also known as Bio concentration. The accumulation of substances, such as pesticides, or other chemicals in an organism. It happens when an organism absorbs a substance faster, and the substance is lost by catabolism and excretion.
Bio-magnification:	Also known as bio amplification or biological

	magnification. It is a concentration of a substance in organisms as a result of ingesting another organism with higher levels of compounds like toxic.
Dermatitis:	Is a skin condition when it turns red, swollen, and sore, sometimes with small blisters; because of direct irritation by an external agent or an allergic reaction.
Downtime:	The time of factory stop working
Crop days:	The working period of the factory
Imbibition/ Maceration:	Adding water to sugar juices to reach the production amount of sugar.
Water quality index (WQI):	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.
Factory symbiosis principle:	Using the output materials as the new input elements

SUMMARY

Most sugar mills without proper management frequently utilize hazardous materials without supervision. Wastewater containing toxic elements from the Sugar production process can harm the environment, such as degrading the quality of freshwater and causing additional adverse externalities (Sahu et al., 2017).

Sugar factory customarily aims to advance the economic sector, yet it usually holds an unwanted impact on water quality. The entire process of human life demands clean water, from producing food toward economic development; moreover, many cities in the world experience water shortages, whereas 40% of the world's food stock depends on irrigation (Halder & Islam, 2015).

This study investigates wastewater from the Assalaya sugar factory in Assalaya District, Sudan, and examines how it impacts water quality and human health; this sugar factory is the one and only *Sudanese Sugar Factory* (*SSC)*. As a result of inappropriate practices and the absence of efficient management, wastewater can modify the quality of freshwater. The drainage channel scheme reflects this unfavorable practice; the waste directly flowed into the river when most Sudanese people used the river as the primary source of drinking water. Therefore, this study discusses the impact of factory production activities on water quality in concentrated areas. Stakeholders and society are expected to take appropriate response as a mitigation action concerning such risks. The results of this study were gathered using qualitative and quantitative methods as described below:

The methods of the first purpose evaluate the input materials, which include raw and chemical substances. Raw materials comprise of cane and water, and chemical encompasses Ca, PO_4, Na, and Cl. Regarding the raw materials of cane, the study obtains

the annual cane production data from the SSC report. Water report are achieved through the interview with technical responses in the factory; they declare that 73% of water usage is gotten from the cane. Concerning the chemical input, the data from the SSC report said that it was amounted to 928 ton/year. The study estimates the amount of wastewater generation from three kinds of inputs, such as cane, water, and chemical materials; from every 1 ton of Sugar production, there are 1.000 liters of wastewater

The methods of the second objective are done by the physiochemical examination towards 20 units of water samples; 50 m from the upstream and 50 m - 250 m from the downstream, samples were also collected from other places around the river to recognize the number of pollution in different locations. This study examined five physical parameters and 12 chemical parameters. Physical parameters consist of TDS at 22.6 ^{0}C, turbidity, odor, color, and TSS. Chemical parameters consist of pH at 21.1^{0}C, Total Hardness, Total Alkalinity, Ammonia (NH_3), Calcium (Ca), Phosphate (PO_4), Biological Oxygen Demand (BOD), Chemical Oxygen Demand (COD), Chloride (Cl), Nitrate (NO_3), Nitrite (NO2), and Sodium. The study corresponded with the Sudanese Standard Metrological Organization (SSMO), and a Water Quality Index (WQI) calculation is also conducted.

The method of the third aim are; the study uses IDW interpolation spatial analysis using GIS software to understand the distribution of the affected area; in this case, chemicals are used as data input. The principle of interpolation is to predict the value of several locations based on limited data, and the value is used to predict areas of unknown amounts. In this study, IDW (inverse distance weighting) WGS_1984_UTM_Zone_30N is a coordinate system used as an interpolation technique.

In understanding the spatial distribution of various chemical variables, IDW focuses on a range of values whose concentrations are distributed at ground level. In general, chemical inputs that have been mapped in this study are Calcium (Ca), Phosphate (PO4), Sodium (Na), and Chloride (Cl). Interpolation techniques using spatial analysis have successfully identified the density and distribution of hazards by using parameters at the most expected station, this has a vital role in detecting pollution around the affected area with estimated external locations.

The method of the last purpose are; examines through three steps: first, by analyzing the waterborne diseases data from the Federal Health Ministry; second, by analyzing Assalaya hospital data from the reports and personal interviews in the Assalaya hospital (to understand the common diseases in the villages around the factory); and finally, by analyzing the study questionnaire arbitrated by supervisors, Federal Health Ministry and other assistants from Omdurman Islamic University. The questionnaire was distributed into ten villages around the factory, for understanding the community perception about the water quality and wastewater diseases. Due to water quality degradation is disastrous to human health, plus the majority of the people are very dependent on White Nile River waterways as the primary source of drinking water. Some communities used a river that has not been drained by factory waste; on the other hand, some residents used drains that have been polluted by harmful factory waste. Good human health is commonly reflected in physical, mental, and social well-being; not easily attacked by diseases and accompanied with high immune system (Munawer, 2017).

In this purpose the study focuses on diseases and symptoms caused by factory wastewater on human health both directly and indirectly. Laboratory analysis proves that there are changes in the physiochemical characteristics of water in the study area. Since 1979, the factory wastewater discharged into the Nile contains a large number of hazardous compounds, and directly affects human health and spreads various types of diseases. Beside the study use IDW interpolation of the WQI to find the impact on the human health

The result of the first objective are: through the analysis, it was found that wastewater produced in 2018 was 455.764.180 liters/year or 14.45219 liters/second. Wastewater was only collected by the factory in three ponds with a total volume of 587810 m^3; after that, the waste connected to a freshwater channel to be discharged directly to the White Nile River. Throughout 2018, the wastewater accumulation was 455.764.180 liters/year, and the pool volume was 587.810.000 liters/year. However, the Assalaya sugar factory has no proper remedy for wastewater; furthermore, it directly harms freshwater.

The findings of the second purpose are: the physiochemical analysis showed that the water had problems such as turbidity, TSS, TDS, color, concentrated odor, and most of the samples were below the standard guidelines recommended by SSMO. Chemically, most parameters met the SSMO standard, except pH, BOD, COD, and PO4. For this reason, the water quality index in the study area is medium water quality (MWQ).

The results of the third aim stated that pollution is classified into five classes, namely areas with very high concentration, high concentration, moderate concentration, low concentration, and very low concentration.

The findings of the last aim confirmed data from the Sudanese Federal Ministry of Health regarding waterborne diseases in a country crossed by the Nile due caused by

Assalaya sugar mills. As shown in figure (5.25), research shows that there are various types of diseases associated with water pollution, such as dysentery, cholera, and typhus; moreover, the deficiency of clean water causes microorganisms and parasites contained in the water to worsen the level of cleanliness of the community.

Based on data obtained through interviews with respondents and reports at Assalaya Hospital in 2018, the data of waste waterborne reported in hospitals table (5.13) are varied. Wastewater has a considerable role in causing several diseases, and all hospital staff confirms that the disease that is closely related to the low water quality due to factory waste. Some diseases report such as Malaria with a total of 8331 patients, 2047 urological diseases, 651 infections, 1075 diabetes, 914 blood pressure, 1538 pneumonia, 717 blood flow, 589 eye inflammation, 894 common symptoms, 92 digestive symptoms, 3 typhus, 3 diarrhea, 1 gastritis, 60 allergies, 50 breathing, 1 kidney inflammation, 1 food poisoning, 1 asthma, and 1155 jaundice.

Concerning diseases caused by wastewater in the study area, questionnaires were distributed in 10 villages such as Alhajalij Almadrasajanob, Alhajalij Almadrasat Shamal, Alsalam Alkambu, Alfirdaws Tayibah, Alsharifya, Aldankuj, Hajar Assalaya Alum, Hajar Assalaya Alsharifia, Assalaya Gharb, Alsalam Alkambu, Alfirdaws Tayibah, Alsharifya, Aldankuj, Hajar Assalaya Alum, Hajar Assalaya Alsharifia, Assalaya Gharb, and Aljeara. The results showed that residents in the study area suffered many illnesses due to factory waste. As the data presented in figure (5.34), 7.8% of respondents suffer Renal Failure, (11.29%) Stones, (8.02%) Jaundice, (6.8%) Poisoning, (16.46%) Diarrhea, (5.52%) Allergy, (5.3%) Permanent Allergy, (12.1%) Helicobacter pylori, (3.38%) Typhoid, and (12.29%) as Bilharzia

From figure (6.34), the diseases transmitted through wastewater based on community perception have increased dramatically; therefore, government and factory authorities should provide excellent medical health services. Based on the results of the questionnaire, the study found that 165 communities did not have health services, while 117 communities had health services in four health institutions. This study found that poor physiochemistry as shown in tables (5.7) and (5.8), and is the leading performer causing a large number of diseases.

While the results of WQI towards health impact in the study found that 35.12% of the communities are living within PWQ, in Alsalam Alkambu village, is located near to the factory outlet. MWQ represents 26.08% of the total residences, it is located in the middle between the factory outlet, before the discharging zone, and also prior and after the mouth of wastewater in White Nile River. As much as 38.75% of the communities are living under FWQ, those who have other kind of drinking sources in Alhajalij Almadrasajanob and Alhajalij Almadrasat Shamal, as indicated in Figure 5.33.

The general conclusions are:

Through the evaluation of the production process which includes chemical substances and raw materials, the study calculates the wastewater disposal in 2018 were 455.764.180 liters. The total waste could be appropriately accommodated as the capacity of three (3) ponds is 587.810.000 liters/year. The factory has been mixing wastewater with freshwater channels using a suction generator for such a long time, resulting in the degradation of quality water as seen through its physiochemical features.

From the physiochemical analysis, the wastewater has problems upon water quality, turbidity, TSS, TDS, color, concentrated odor, and most of the samples are below the standard guidelines recommended by SSMO. Chemically, most of the parameters do meet SSMO standards, except pH, BOD, COD, and PO4. For this reason, the study area has only three types of water index are; MWQ, FWQ and PWQ.

The IDW interpolation of spatial analysis succeeded in identifying the density and distribution of hazard without recorded data by using known parameter at nearby stations.

Water in the study area is indicated to be hazardous to human health. Several diseases such as diarrhea, stones, kidney failure, bilharzia, allergies, inflammation of malaria, and urine are quickly spread. Due to economic constraints, residents find it difficult to treat water in the right way.

The general recommendations are;

Promoting biological treatment in three ponds exclusively. The first pond must be treated ideally, later drain the water into the second and third ponds using an aerobic engine to supply oxygen and reduce pollutants. The factory should use treated wastewater for further projects. In light of the above, the factory promotes the sustainability principle by using the output as a further production input, and the study suggests that its better if the factory implement the optimal system of wastewater management as in Sragi sugarcane which includes equalization, neutralization, sedimentation, an anaerobic and aerobic treatment which using in the process of the evaporator the condensation

Affirming the environmental water policy and management around the river by the government. Factories must proceed to support transformation such as Green Environment and Green Economy; and must also be familiar with the sustainability concept towards the social, economic, and ecological sectors.

Government authorities must find concrete solutions for the community in the affected area. The factory must have social responsibility by providing clean water, closing the waste canal, and promoting the concept of sustainability. Communities who live in danger zones should be relocated to a safe shelter.

The factory should perform the principle of humanity in health assistance by providing medications, hospital services, and be responsible for hosting clean water management facilities.

RINGKASAN

Sebagian besar pabrik gula tanpa manajemen yang baik sering menggunakan bahan berbahaya tanpa pengawasan. Air limbah yang mengandung bahan beracun dari hasil proses produksi gula dapat merusak lingkungan, menurunkan kualitas air tawar, dan menyebabkan kerugian negatif lainnya (Sahu et al., 2017).

Pabrik gula bermanfaat untuk memajukan sektor ekonomi, namun di sisi lain juga menyebabkan dampak yang tidak diinginkan terhadap kualitas air. Manusia membutuhkan air bersih untuk berbagai aktivitas mulai dari memproduksi makanan hingga pembangunan ekonomi; di sisi lain, banyak kota besar di dunia mengalami kekurangan air padahal 40% dari persediaan makanan dunia bergantung pada saluran irigasi (Halder & Islam, 2015).

Studi ini menyelidiki air limbah yang dibuang dari pabrik gula Assalaya, Distrik Assalaya, Sudan, dan meneliti bagaimana dampaknya terhadap kualitas air dan kesehatan manusia; pabrik gula ini adalah satu-satunya *Sudanese Sugarcane Company* (SSC). Akibat dari praktik yang tidak tepat dan tidak adanya manajemen yang efisien, air limbah dapat mengubah kualitas air tawar. Skema saluran drainase mencerminkan praktik yang tidak sehat apabila limbah langsung mengalir ke sungai, padahal sebagian besar masyarakat Sudan menggunakan sungai sebagai sumber utama air minum. Oleh karena itu, penelitian ini membahas dampak limbah dari pabrik gula Assalaya terhadap kualitas air di area penelitian. Hasil penelitian ini didapatkan dengan menggunakan metode kualitatif dan kuantitatif seperti yang dijelaskan sebagai berikut:

Metode dari tujuan pertama didapatkan dengan mengevaluasi bahan input untuk aktivitas pabrik, yang meliputi bahan mentah/baku dan bahan kimia. Bahan mentah terdiri dari tebu dan air, sedangkan bahan kimia meliputi Ca, PO_4, Na, dan Cl. Terkait angkat bahan baku tebu, penelitian ini memperoleh data produksi tebu tahunan dari laporan *SSC*. Untuk data terkait jumlah air didapatkan melalui wawancara dengan teknisi pabrik; mereka menyatakan bahwa 73% dari total penggunaan air diperoleh dari batang tebu. Mengenai input bahan kimia, data laporan *SSC* menyatakan bahwa totalnya bahan kimia yang dibutuhkan mencapai 928 ton/tahun. Studi ini memperkirakan jumlah timbulan air limbah dari tiga jenis input, yaitu batang tebu, air, dan bahan kimia; dari setiap 1 ton produksi gula, ada 1.000 liter air limbah yang dihasilkan. untuk menentukan jumlah endapan air limbah pada tahun 2018.

Metode dari tujuan kedua dilakukan dengan pemeriksaan fisiokimia air terhadap 20 unit sampel air; 50 m dari hulu dan 50-250 m dari hilir, sampel juga dikumpulkan dari tempat-tempat lain di sekitar sungai untuk mengenali jumlah polusi di lokasi yang beragam. Penelitian ini menguji lima parameter fisika dan 12 parameter kimia. Parameter fisik terdiri dari TDS pada 22,6 ^{0}C, Kekeruhan, Bau, Warna, dan *TSS* (*Total Suspended Solid*). Parameter kimia terdiri dari pH pada 21,1^{0}C, Total Kekerasan, Total Alkalinitas, *Ammonia* (NH_3), Kalsium (Ca), Fosfat (PO_4), *Biological Oxygen Demand* (*BOD*), *Chemical Oxygen Demand* (*COD*), Klorida (Cl), Nitrat (NO_3), Nitrit (NO_2), dan Sodium. Hasil dari penelitian ini dicocokkan dengan *Sudanese Standard Metrological Organization* (*SSMO*), selain itu juga dilakukan perhitungan *Water Quality Index* (*WQI*).

Metode dari tujuan ketiga adalah melakukan analisis spasial interpolasi *IDW* menggunakan perangkat lunak *GIS* untuk memahami distribusi area yang terkena dampak pencemaran; dalam hal ini, data yang dimasukkan ke dalam program aplikasi didapatkan dari jumlah bahan kimia yang digunakan oleh pabrik. Prinsip interpolasi dimaksudkan untuk memprediksi nilai di beberapa lokasi berdasarkan data yang tersedia dan terbatas, dan nilai tersebut digunakan untuk memprediksi area yang jumlahnya tidak diketahui. Dalam penelitian ini, *IDW (inverse distance weighting) WGS_1984_UTM_Zone_30N* adalah sistem koordinat yang digunakan sebagai teknik interpolasi. Dalam memahami distribusi spasial dari berbagai variabel kimia, *IDW* berfokus pada kisaran nilai yang konsentrasinya didistribusikan di permukaan tanah. Secara umum, input kimia yang telah dipetakan dalam penelitian ini adalah Kalsium (Ca), Fosfat (PO_4), Sodium (Na), dan Klorida (Cl). Teknik interpolasi menggunakan analisis spasial telah berhasil mengidentifikasi kepadatan dan distribusi bahan berbahaya dengan menggunakan berbagai parameter di stasiun yang telah ditentukan. Teknik ini memiliki peran penting dalam mendeteksi tingkat pencemaran di daerah yang mungkin terkena dampak dengan perkiraan lokasi di sekitarnya.

Metode dari tujuan terakhir adalah dengan pemeriksaan tiga data: pertama, menganalisis data penyakit yang ditularkan melalui air dari Kementrian Kesehatan Sudan; kedua, menganalisis data dari rumah sakit Assalaya, laporan penyakit, dan wawancara pribadi di rumah sakit Assalaya (untuk memahami penyakit umum di desa di sekitar pabrik); dan yang terakhir adalah menganalisis kuesioner bersama pengawas, Kementerian Kesehatan Sudan, dan perwakilan lain dari Universitas Islam Omdurman. Kuesioner disebar di 10 desa di sekitar pabrik untuk memahami persepsi masyarakat tentang kualitas air dan penyakit akibat air limbah. Degradasi kualitas air adalah bencana bagi kesehatan manusia, padahal mayoritas masyarakat sangat bergantung pada saluran air Sungai Nil Putih sebagai sumber utama air minum. Beberapa komunitas menggunakan air sungai yang belum tercemar oleh limbah pabrik, di sisi lain beberapa warga justru menggunakan saluran air yang telah tercemar oleh limbah pabrik. Kesehatan manusia yang baik umumnya tercermin atas kesejahteraan fisik, mental, dan sosial; mereka yang tidak mudah terserang penyakit dan dilengkapi dengan sistem kekebalan tubuh yang tinggi (Munawer, 2017).

Analisis laboratorium membuktikan bahwa ada perubahan karakteristik fisiokimia air di wilayah studi. Sejak 1979, air limbah pabrik yang dibuang ke sungai Nil mengandung sejumlah besar senyawa berbahaya, dan secara langsung memengaruhi kesehatan manusia dan menyebabkan berbagai jenis penyakit. Penelitian ini menggunakan interpolasi *IDW* dan *WQI* untuk memetakan persebaran dampaknya.

Hasil dari tujuan pertama adalah ditemukan bahwa air limbah yang diproduksi pada tahun 2018 adalah 455.764.180 liter/tahun atau 14,452 liter/detik. Air limbah yang dihasilkan oleh pabrik dikumpulkan di tiga kolam dengan total volume sebesar 5.788.0 m^3; setelah itu, saluran limbah tersebut dihubungkan ke saluran air tawar untuk langsung dibuang ke Sungai Nil Putih. Sepanjang tahun 2018, akumulasi air limbah adalah 455.764.180 liter/tahun, dan volume kolam adalah 587.810.000 liter/tahun. Namun, pabrik gula Assalaya tidak memiliki perlakuan khusus untuk air limbah tersebut, dan justru secara langsung merusak dan membahayakan kualitas air tawar.

Temuan dari tujuan kedua menunjukkan bahwa air tawar yang telah tercemar memiliki berbagai masalah seperti Kekeruhan, *TSS*, *TDS*, Warna, Bau, dan sebagian besar kualitas sampel berada di bawah pedoman standar yang direkomendasikan oleh *SSMO*. Secara kimia, sebagian beberapa parameter memenuhi standar *SSMO*, kecuali pada *pH*, *BOD*, *COD*, dan PO_4. Atas argumentasi ini, indeks kualitas air di wilayah studi adalah sedang atau *Medium Water Quality* (*MWQ*).

Hasil dari tujuan ketiga menyatakan bahwa tingkat pencemaran air diklasifikasikan ke dalam lima kelas, yaitu daerah dengan konsentrasi sangat tinggi, konsentrasi tinggi, konsentrasi sedang, konsentrasi rendah, dan konsentrasi sangat rendah.

Temuan tujuan terakhir didapatkan dengan validasi data bersama Kementerian Kesehatan Sudan mengenai penyakit yang ditularkan melalui air di berbagai negara yang dilintasi oleh Sungai Nil akibat limbah pabrik gula Assalaya. Seperti yang ditunjukkan pada gambar 5.25, terdapat berbagai jenis penyakit yang berhubungan dengan pencemaran air, seperti disentri, kolera, dan tifus; selain itu, minimnya air bersih telah menyebabkan mikroorganisme dan parasit semakin memperburuk sanitasi masyarakat.

Berdasarkan data yang diperoleh melalui wawancara dengan responden dan laporan Rumah Sakit Assalaya pada tahun 2018, data yang terlapor seperti pada tabel 5.13 cukup bervariasi. Air limbah memiliki peran yang cukup besar dalam menyebabkan beberapa penyakit, dan semua staf rumah sakit memastikan bahwa penyakit itu berkaitan erat dengan rendahnya kualitas air. Beberapa penyakit yang dilaporkan seperti Malaria dengan total 8.331 pasien, 2.047 penyakit urologi, 651 infeksi, 1.075 diabetes, 914 tekanan darah, 1.538 pneumonia, 717 aliran darah, 589 peradangan mata, 894 gejala umum, 92 gejala pencernaan, 3 tipus, 3 diare, 1 gastritis, 60 alergi, 50 pernapasan, 1 peradangan ginjal, 1 keracunan makanan, 1 asma, dan 1.155 penyakit kuning.

Mengenai persepsi penyakit yang disebabkan oleh air limbah di daerah penelitian, kuesioner dibagikan di 10 desa seperti Alhajalij Almadrasajanob, Alhajalij Almadrasat Shamal, Alsalam Alkambu, Alfirdaws Tayibah, Alsharifya, Aldankuj, Hajar Assalaya Alum, Hajar Assalaya Alsharifia, Alfalallar Tayibah, Alsharifya, Aldankuj, Hajar Assalaya Alum, Hajar Assalaya Alsharifia, Assalaya Gharb, dan Aljeara. Hasil penelitian menunjukkan bahwa warga di daerah penelitian menderita banyak penyakit akibat limbah pabrik. Seperti data yang disajikan pada gambar 5.34, 7,8% responden menderita Gagal Ginjal, 11,29% Kencing Batu, 8,02% Penyakit Kuning, 6,8% Keracunan, 16,46% Diare, 5,52% Alergi, 5,3 % Alergi Permanen, 12,1% *Helicobacter pylori*, 3,38% Tiroid, dan 12,29% *Bilharzia*.

Dari gambar 6.34, penyakit yang ditularkan melalui air limbah berdasarkan persepsi masyarakat telah meningkat secara drastis; oleh karena itu, pemerintah dan otoritas pabrik harus menyediakan layanan kesehatan medis yang baik. Berdasarkan hasil kuesioner, studi ini menemukan bahwa sebanyak 165 komunitas tidak memiliki layanan kesehatan, sementara 117 komunitas memiliki layanan kesehatan di empat lembaga kesehatan. Studi ini menemukan bahwa fisiokimia yang buruk seperti yang ditunjukkan pada tabel 5.7 dan 5.8 merupakan faktor utama yang menyebabkan sejumlah besar penyakit.

Sementara itu, hasil *WQI* terhadap dampak kesehatan menemukan bahwa 35,12% dari masyarakat tinggal di daerah *PWQ* (*Poor Water Quality*) yaitu di desa Alsalam Alkambu yang terletak di dekat pabrik. *MWQ* (*Medium Water Quality*) diwakili oleh 26,08%, mereka berada di tengah-tengah pabrik, sebelum daerah pembuangan, dan sebelum dan sesudah Sungai Nil Putih. Selanjutnya, sebanyak 38,75% dari masyarakat berada pada kelas *FWQ* (*Fine Water Quality*), mereka juga memiliki sumber air minum lain di daerah Alhajalij Almadrasajanob dan Alhajalij Almadrasat Shamal, seperti yang ditunjukkan dalam gambar 5.33.

Kesimpulan umum yang dapat diambil adalah:

Dari hasil evaluasi proses produksi yang meliputi bahan kimia dan bahan baku, studi ini mendapatkan jumlah air limbah yang dihasilkan pada tahun 2018 adalah sebanyak 455.764.180 liter. Total limbah yang dapat ditampung di tiga kolam adalah 587.810.000 liter/tahun. Pabrik telah lama membuang air limbah dan mencampurnya dengan saluran air tawar menggunakan generator, hal ini mengakibatkan degradasi kualitas air telah berlangsung lama dan tercermin oleh fisiokimia yang buruk.

Dari analisis fisiokimia, air limbah memiliki masalah pada Kekeruhan, *TSS*, *TDS*, Warna, Bau, dan sebagian besar sampel berada di bawah pedoman standar yang direkomendasikan oleh *SSMO*. Secara kimia, sebagian parameter memenuhi standar *SSMO*, kecuali *pH*, *BOD*, *COD*, dan PO_4. Untuk alasan ini, wilayah studi hanya memiliki tiga jenis indeks air yaitu *MWQ*, *FWQ*, dan *PWQ*.

Interpolasi *IDW* dari analisis spasial berhasil mengidentifikasi kepadatan dan distribusi bahaya dengan menggunakan parameter yang diketahui di beberapa stasiun terdekat.

Air di daerah penelitian diindikasikan berbahaya bagi kesehatan manusia. Beberapa penyakit seperti diare, batu, gagal ginjal, *bilharzia*, alergi, radang, malaria, dan urologi sangat cepat menyebar. Akibat keterbatasan ekonomi, warga merasa sulit untuk mengolah air dengan benar.

Rekomendasi umum adalah:

Mempromosikan perlakuan biologis di tiga kolam secara eksklusif. Kolam pertama harus diolah secara ideal, kemudian mengalirkan air ke kolam kedua dan ketiga menggunakan mesin aerobik untuk memasok oksigen dan mengurangi polutan. Pabrik harus menggunakan air limbah yang telah dikarantina untuk penggunaan selanjutnya. Pabrik harus mempromosikan prinsip pembangunan berkelanjutan dengan menggunakan output sebagai input produksi lebih seperti metode yang diterapkan oleh pabrik Sragi yang mencakup pemerataan, netralisasi, sedimentasi, dan perawatan anaerob dan aerobik yang digunakan dalam proses evaporator dan kondensasi.

Harus ada penegasan terkait kebijakan dan pengelolaan air lingkungan di sekitar sungai oleh pemerintah. Pabrik harus mendukung transformasi Lingkungan Hijau dan Ekonomi Hijau dan membiasakan diri dengan konsep keberlanjutan terhadap sektor sosial, ekonomi, dan ekologi.

Otoritas pemerintah harus menemukan solusi konkret bagi masyarakat di daerah yang terkena dampak. Pabrik harus memiliki tanggung jawab sosial dengan menyediakan air bersih, menutup saluran limbah, dan mempromosikan konsep lingkungan sehat. Masyarakat yang tinggal di zona berbahaya harus dipindahkan ke tempat penampungan yang aman.

Pabrik harus mengedepankan prinsip kemanusiaan, memberi bantuan kesehatan dengan menyediakan obat-obatan, menyediakan pelayanan rumah sakit, dan bertanggung jawab untuk menyediakan fasilitas pengelolaan air bersih.

ABSTRACT

Sugar production wastewater is considered as one of the most fundamental factors that influence drinking water and human health. This study aims at analyzing and evaluating the reality of Assalaya factory wastewater and its ramifications on water quality and human health.

The methodology employed for this study is laboratory analysis of the 17 physiochemicals parameters, which include 20 samples of wastewater from different locations. The physical parameters that have been analyzed are TDS, Turbidity, TSS, Odor, and Color; while the chemical parameters are pH, Total hardness, Total Alkalinity, NH_3, Ca, PO_4, BOD, COD, Cl, NO_3, NO_2, and Na. The study used the spatial analysis interpolation IDW on GIS software to understand the range of affected areas considering only on the chemical substances that have been used as the primary input to produce sugar such as Ca, Cl, Na, and PO_4. Furthermore, the study makes questionnaires to recognize the community perception about the physiochemical wastewater and the health impact within the area.

Data analysis reveals that the physiochemical water of the river has been changed proportionally by factory wastewater based on SSMO, the wastewater leads some consequences on human health presented in generating several types of disease.

The study recommends biological treatment to follow the environmental water policy and establish the final treatment near the river administered by the government instead of factory administration. The factory ought keeping abreast of global transformation in the field of production such as Eco-friendly and Green economy and be familiar with the sustainability concept.

Keywords: **Factory wastewater, IDW interpolation analysis, community perception, and health impact.**

ABSTRAK

Limbah dari produksi gula dianggap sebagai salah satu faktor utama yang memengaruhi air minum dan kesehatan manusia karena keterlibatannya oleh beberapa input, seperti bahan baku produksi dan zat kimia. Penelitian ini bertujuan untuk menganalisis dan mengevaluasi keadaan faktual air limbah dari pabrik Assalaya serta cabang masalah lainnya terhadap kualitas air dan kesehatan manusia.

Metodologi yang digunakan dalam penelitian ini adalah analisis laboratorium yang terdiri dari 17 parameter fisikokimia, mencakup 20 sampel air limbah dari lokasi yang berbeda. Parameter psikis yang dianalisis adalah TDS, Turbiditas, TSS, Bau, dan Warna; sedangkan parameter kimianya adalah pH, Total Kekerasan Total Alkalinitas, NH_3, Ca, PO_4, BOD, COD, Cl, NO_3, NO_2, dan Na. Studi ini menggunakan analisis interpolasi spasial IDW dengan bantuan perangkat lunak GIS untuk mengetahui luas area yang terkena dampak dengan mempertimbangkan zat kimia yang telah digunakan sebagai input utama dalam proses produksi gula seperti Ca, Cl, Na, dan PO_4. Selain itu, penelitian ini juga menggunakan kuesioner untuk mengetahui persepsi masyarakat tentang fisikokimia limbah dan dampaknya terhadap kesehatan di daerah tersebut.

Data analisis mengungkapkan bahwa fisikokimia air sungai telah mengalami perubahan secara proporsional yang disebabkan oleh limbah pabrik berdasarkan spesifikasi oleh SSMO. Selain itu, penelitian ini menemukan bahwa air limbah menimbulkan konsekuensi pada kesehatan manusia.

Penelitian merekomendasikan pengolahan air limbah secara biologis sangat perlu dilakukan agar tetap mengikuti kebijakan air lingkungan dan membentuk pengolahan akhir limbah di sekitar sungai berdasarkan peraturan pemerintah, bukan diatur oleh administrasi pabrik itu sendiri. Pabrik harus terus mengikuti transformasi global, selain itu juga harus akrab dengan konsep pembangunan berkelanjutan.

Kata kunci: **Air limbah pabrik, analisis interpolasi IDW, persepsi masyarakat, dan dampak kesehatan.**