The Environmental Impact of the Sugar Industry Waste in Sudan

Tageldeen Saeed Tageldeen Ibrahim (tageldeen13@yahoo.com)
University of Khartoum
Tilahun Seyoum Workneh
University of KwaZulu-Natal

Research Article

Keywords: environmental impact, wastewater, pollutants, sugar industry, Sudan

Posted Date: October 14th, 2022

DOI: https://doi.org/10.21203/rs.3.rs-2121911/v1

Abstract

The purpose of this study was to investigate the impact of Sudanese sugar manufacture waste on the communities surrounding the industries. The study employed across-sectional survey approach comprising of 311 respondents living around factories areas. The selected sugar industries included; Kenana, Guneid, Halfa, Sinnar, Assalaya and White-Nile. Data were analysed by using SPSS version 19; the descriptive statistics, nonparametric statistics and logistic regression were employed. The results showed that the wastewater discharge has a significant ($P < 0.05$) effect on the community health. The respondents indicated that the waste creates suitable environment for the reproduction of parasites, off-odor development and finally contaminates the drinking water. The multinomial logistic regression model showed that the wastewater (i.e. creates off-odor and mosquito) have significant ($P < 0.05$) influences on causing health risks (i.e. malaria) to the people residing around the sugar factories areas. The study was also revealed that the lack of the sugar industry wastewater management has significantly affected the crop and animal production. The suspending particles and bagasse fly were found significantly ($P < 0.05$) caused high rate of occurrence of eye and respiratory systems diseases in the region. The health services provided by the industries were found significantly ($P < 0.05$) affected the community satisfaction. It is therefore, the study designed a framework for enhance handling the industrial waste to be adopted by the Sudanese sugar industries decision makers. The framework focused on decreasing the impact of waste to the lowest level through sufficient improvement of the management strategies.

Introduction

The environment is one of the main elements of individual and community health. Its situation of pollution considered far from satisfactory especially in the developing countries (Sahu, 2015). In Sudan pollution is rapidly increasing with an increase of urbanization and industrialization (Alim, 2012). On the other hand, the institutional and legislative frameworks are very limited and need to make pollution control measures effective. There is a lack of knowledge with regards to waste management practices in the country (Robert, 2011). The environmental management strategies have been nonexistent in industry management structure until the year 2000. The major challenges need to be identified are the impacts assessment and improve the operation of older and government-managed sugar industries (Alim, 2012). The sugar industry is one of the largest sources of industrial effluent that generates a considerable amount of wastewater including pollutant inform solid and gaseous (Sahu, 2015; Sahu, 2018). Sugar industry in Sudan discharges untreated wastewater that contains pollutants poisoning the watercourse (Alim, 2012; Anail, *et al.*, 2013). Volume of the discharged effluent varies from factory to another depending on the cane crushing capacity (Sahu, 2015). The estimated daily discharge of wastewater of the whole sugar factories in Sudan is about 150 000 m^3. Small proportion of this wastewater is used for crop irrigation but under uncertain health conditions (Aisha, 2007). Also, there is a reasonable amount of waste resulted from sugar manufacture such as filter cake and vinasse (Oboody, 2016). These pollutants have the harm effect on the human and the surrounding ecosystem (Oboody, 2016 and Sahu 2018). However, the wastewater discharged into open fields has its impact on the environment and the community residing around the industries. Also, contamination such as acidification and heating for the river water will appear which could cause health risks (Günter, et al., 2007). This issue needs to be solved for all sugar industries in Sudan. Therefore, analyzing the environmental aspects must be carried out through identifying the impacts of this effluent on the community living around the selected sugar industries.

In addition, Bagasse is one of the wastes from the sugar industry and used for steaming the boiler of the factory (Sahu, 2018). It combusted during the sugar processing and produces ash that affect the human health (Mohamed and Samah, 2011; Le Blond, et al., 2017). Roughly 11 284 ton of residual ash is produced annually from the sugar factories in Sudan (Cordiero et al., 2004). The impact of the Sudanese sugar industry pollutant needs to be studied and solutions should be found. The authorities concern about the highly cost of the waste treatment (Oboody, 2016). However, there is a lack of sufficient data on waste treatment and its impact on the community residing around these sugar factories. This makes the procedures of identify the adverse effects of the waste and then find proper solutions are accordingly difficult (Abid, 2008). Moreover, sugar industries are producing large amount of gases (carbon and others) that affect the animal, plant and human health. The dust storms produced during the cane harvesting is also affect the communities residing around the factories. The sugar industries in Sudan are a source of noise due to the various operations and heavy machinery taking part during the production process (Abid, 2008). From environmental aspect the industry facing problems related to the pollutants because of mismanagement and industrial standardization (Sahu, 2018). However, there was no clear method so far examined the adverse effects of sugar manufacture pollutants on the community residing around the

selected sugar industries in Sudan. Therefore, its necessary to study the impact on the environment of the community surrounding the factories areas.

Waste management strategies are significantly different between the countries so as it remains to be a prominent issue to achieve a certain objective. A good designed framework can steer managers address the waste issue in a cost-effective and timely manner. It can spur the enhancements of existing plans or aid in the design of new ones (Davidson, 2011). A variety of approaches have been developed to tackle the waste problem such as the integrated waste management (IWM) which combining a range of techniques, technologies and management programs to achieve specific objectives and goals. Systems analysis provides useful information to define, evaluate and adapt waste management systems (Pires et al, 2010). The sugar waste could be used as raw materials as source for energy and environmentally friendly products (Evgeniya, *et al*., 2017). The aim of this study is to evaluate the impact of the waste on the environment and the community around the selected industries in Sudan. The study also aims to create a framework for handling the industrial waste integrally that spur the decision makers towards enhancing the environment of the sugar industry in Sudan.

Research Methods

Study areas

This study was carried out in different locations around six sugar industries in Sudan between March 2017 and July 2017. The selected sugar industries are Guneid, Halfa, Sennar, Assalaya, Kenana and White Nile. Kenana (Fig. 1), White Nile and Assalaya industries are from White Nile State. While Guneid is from Gazeira State, Sinnar is from Sinnar State and Halfa is from Kassala State (Fig. 1). Guneid is located between longitude and latitude; 14°51.55 N 33°15.62 E, Halfa location is roughly between 15°28 N 35°34.3 E, Sinnar 13°45.3 N 33°28.5 E, Assalaya 13°15.434 N 32°44.745 E, White Nile 14°4.30 N 32°28.21 E and Kenana is between 13°4.5 N 32°55.6667 E.

Figure 1

Data collection

This study was a cross-sectional survey which employed self-administered semi-structured questionnaires. The questionnaire was developed, evaluated by experts and colleagues and pretested by respondents and experts to avoid ambiguity and refine categories. The survey questions used a three-point Likert Scale for agreeing or disagreeing and neutral. The degree of complaints was set to four levels (i.e. no complain, low, medium and high) to measure the effect of the stated pollutants on the surrounding community. The targeted population were the families who are living in campuses and villages close to the selected industries. The samples of this study comprised of 377 respondents (families) selected randomly by lottery method from the selected residential areas around the industries. The number of samples has been determined using the Eq. (1) as it showed below (Taro, 1967). The questionnaire was divided into nine main questions.

$$n = \frac{N}{1 + N(e)^2}$$

1

Where: n = sample size, N = population size, e = 0.5, 0.3, 0.7

Sampling techniques

The random sample technique was used for this study and the sample unit was the respondent's family so as to be much representative (Mengistua, et al., 2016). Questionnaires were distributed randomly to the families who are living around within a diameter of 20 kilometers of the selected industries. The questionnaire was carried out to be filled by all the family members. The main reason for selecting respondents settled around the industries was to allow very detailed insights and acquire clear-cut information about the raised issues in the questionnaire.

Data analyses

The statistical package for social science (SPSS) was used to analyze the obtained data from the questionnaires. SPSS 19 is a common computer application to supports statistical analysis of survey data. The descriptive statistics included: percentages, means, standard deviation and standard error. Nonparametric statistics encompassed Mann-Whitney test and chi-square test were used to compare mean values of variables and to identify the significant differences. Furthermore, multinomial logistic regression was employed to find out the important factors influencing the surrounding environment. Multinomial logistic regression is a probability estimation model used when the dependent variable is more than two categories (i.e. agree disagree and neutral) and the independent variable is categorical or continuous (John, et al., 2017). Table 1 shows the dependent and independent variables that associated with influencing the environment and their definitions.

If Y is the dependent variable, it can take values of either 1, 2 or 3.

Yi = 1 if the respondent i agree with the raised question

Yi = 2 if disagree

Yi = 3 if neutral

Hence, the multinomial logistic regression model for estimating the influence of wastewater on the community health is as follows:

$$ln\left[\frac{\rho_h}{\rho_j}\right] = \beta_{0h} + \beta_{1h}x_1 + \beta_{2h}x_2 + \cdots + \beta_{kh}x_k$$

1

Where:

ln = the log of the odd ratio

P = the probability of community health effect

j = the number of categories (3)

h = 1 to j -1

β = a constant

β_1, β_2 and β_k = the estimated parameters corresponding to each predictor

X_1, X_2 and X_k = the explanatory variables (predictors)

k = the number of predictors

To compare the probability of one of the categories, odds ratios are all compared to the reference outcome by using the following equations:

$$ln\left[\frac{\rho_1}{\rho_3}\right] = \beta_{01} + \beta_{11}x_1 + \beta_{21}x_2 + \cdots + \beta_{k1}x_k$$

2

$$ln\left[\frac{\rho_2}{\rho_3}\right] = \beta_{02} + \beta_{12}x_1 + \beta_{22}x_2 + \cdots + \beta_{k2}x_k$$

3

Equation 2 represents the probability of respondents agree (P_1) with compare to neutral (P_3) to the issue of health risks caused by wastewater. Eq. 3 illustrates comparison the probability of disagree category (P_2) to the neutral (P_3) category (Grace-Martin, 2018).

Table 1
variables influencing the surrounding environment of the Sudanese sugar factories and their descriptions

Variable	Description	Type
Wastewater creates off-odor	Agree = 1, Disagree = 2 and Neutral = 3	Nominal
Wastewater creates mosquito		
Wastewater mixes with water source		
*People health (i.e. Malaria)		
Particulates contaminate the air		
Particulates pollute the flours and clothes		
Invisibility due to smoke clouds		
*Health risks to human	Stomach ache = 1, Vomiting = 2, Diarrhea = 3 and Other = 4	Nominal
*The infection (Eye disease, Heart attack, Respiratory disease, Asthma, Chronic bronchitis and Irregular heartbeat)	Yes = 1 and No = 2	Ordinal (Binary)
*Disease cases among the animals		
*Death cases among the animals		
*Risk to crop		
*People complain	High = 1, Medium = 2, Low = 3 and No complain = 4	Ordinal
* = Dependent variable.		

Results And Discussion

The effect of wastewater on people residing around the industries

The descriptive statistics of the variables that were expected to associate with the effect of wastewater on the surrounding community were displayed in Table 2. The wastewater was found to have statistically significant ($P < 0.05$) mean differences in creation off-odor, mosquito, and mix with the water source and cause health risks (i.e. malaria). The non-parametric statistics showed that the creation of parasites and off-odor due to wastewater were significantly ($P < 0.01$) affected the human health. Whereas, the wastewater was significantly ($P < 0.05$) contaminates the water source that used for drinking purpose. In a study conducted in the Assalaya, water related disease (i.e. vomiting, diarrhea and allergic) were observed among the community used the surplus irrigation canals that affect by the factory effluences (Ahmed, et al., 2017). This might be due to the lack of health awareness of the villages around the sugar industries. It might be also because of the fact that most of the sugar industries in the country are located nearby Nile that increases the chances of water source contamination. This went with the findings of Hind (2015) who concluded the simple undeveloped life style of the communities living around the industry, that may have endangered their health. It also concurs with Elhag (2010) who indicated that the lack of awareness of the impact of pollution is one of the problems facing the sugar industry in Sudan.

Moreover, the respondents' complaints were found to have significant ($P < 0.05$) mean differences in off-odor, mosquito and health risk caused by the wastewater as it showed in Table 2. The surrounding communities are suffering from pollutants which may have harmed the health. The main reason behind this might be due to the insufficient treatment of sugar industrial effluents. This concurs with the findings of (Mohamed, et al., 2017, Alnail, et al., 2013; Pradeep and Omprakash, 2017). The studies were indicated that the pollution of waterbodies was due to the sugar industry waste disposals when discharged without treatment. Hence, that could lead to affect the water quality and the ecology system. Oboody, 2016 and Alnail, et al., 2013 were also observed the creation of the insects, parasites and off-odors in the stagnated wastewater of the sugar industries. However, the authorities in the country should find effective means for sugar industry wastewater treatment.

Impact of wastewater on animal production

Some of the respondents 134 (43%) enrolled in activities such as animal and crop production. The water sources used are cane irrigation drainage canals, wastewater streams, Nile, water tanks, Wells, Lakes and cane irrigation canals. The wastewater was used by 3.1% with compare to another available water source. The water source was found to have statistically significant ($P < 0.05$) mean differences in animal production. health sickness symptoms on some animals were observed. Also, animal death cases were funded as 90 (30%) of 205 of the respondents stated that as it showed in Table 2. In a study conducted in Pakistan, animals suffered different diseases and, in some cases, death was recorded due to consumption of sugar industry effluents discharged in to drains nearness of the villages (Qureshi, et al., 2015). The descriptive statistics revealed that the wastewater was have significant ($P < 0.05$) mean differences in animal production. The non-parametric statistics showed the significant ($P < 0.05$) effect of wastewater to the animal health with compare to other water sources (i.e. cane irrigation cannal). On the other hand, chemicals that included in the wastewater might have health risks for the animals. This concurs with other researchers who analyzed the wastewater resulted from the sugar industry locally and globally and found that the chemical oxygen demand (COD) was extremely high resulting contamination to the water (Reddy, et al., 2014; Oboody, 2016; Asmah, 2017). It also went with (Mohamed, et al., 2017) findings, who concluded that the wastewater from the Assalaya sugar factory caused a threat to the agricultural environment and the superiority of animals.

Impact of wastewater on crop production

Crops like vegetables, cereals and fruits were planted in small scale farms (0.4 ha). Vegetables were the main cultivated crop (69%), with compare to the others by 28% and 3% for cereals and fruit trees, respectively. Of the total 177 respondents, 44 (25%) were used the wastewater for crop irrigation without pretreatments, whereas, 133 (75%) were used sedimentation pans. The wastewater pre-treatment (i.e. sedimentation pan) was found to have statistically significant ($P < 0.01$) mean differences in crop production. Whereas, the non-parametric statistics revealed insignificant difference ($P > 0.05$) in the effect of using pre-treated wastewater for crop irrigation on human health with compare to the nontreated wastewater. There could be many reasons of utilization the waste water for crop irrigation; firstly, it may due to the proximity of the streams from to the fields. Secondly, it could also might be due to the lack of availability of alternative water source for irrigation. This concurs with (Saranraj and Stella, 2014) who were concluded that the sugar mill effluent was used for plant irrigation in India due to the lack of water sources. On the other hand, there is a consensus that wastewater is enriched with the nutrient elements. The present finding showed that the health risk is non-considered aspect among the producers. However, the wastewater was found to have significant ($P < 0.05$) mean differences in causing risks to crop. Consumption vegetables that irrigated with untreated wastewater was found significantly ($P < 0.01$) increased the susceptibility of infection with disease (i.e. stomach ache and diarrhea). In a study conducted by Aisha (2007), the uncertainty of healthy consume of crop irrigated with sugar manufacture effluent was concluded. However, sugar manufacture effluent could be used for crop irrigation in a very restricted condition, when appropriate dilution took place (Vinod, 2014). The risks might be due to the accumulated chemicals such as heavy metals that consequently affected the human health. This goes with the same line of researchers (Vinod, 2014; Reddy, et al., 2014; Sahu, 2015, Alnail, et al., 2013) who indicated that the untreated sugar industry effluents were found to have a significant proportion of chemicals that contaminate land, water, crop and air. Thus, it may have led to negatively effect on water quality for drinking and irrigation purposes. Another a study conducted in India, occurrence of human health risk due to the long-term usage of contaminated sugarcane irrigated with industrial effluents, were observed in rural areas (Bhawna, et al., 2016).

Table 2
Descriptive statistics of the variables illustrating the environmental impact of sugar wastes

Variables	N	Agree (%)	Disagree (%)	Neutral (%)	Mean	S.D.	S.E.	Sig.
Wastewater creates off-odor	311	196 (63)	87 (28)	28 (9)	1.43	.628	.036	.000
Wastewater creates mosquito	311	209 (67.2)	77 (24.8)	25 (8)	1.40	.608	.035	.000
Wastewater contaminates water	311	121 (38.9)	160 (51.4)	30 (9.6)	1.44	.634	.036	.000
*People health (malaria)	311	206 (66.2)	70 (22.5)	35 (11.3)	1.45	.689	.039	.000
Particulates contaminate the air	305	260 (83.6)	34 (10.9)	11 (3.5)	1.18	.47	.027	.000
Particulates dirt the flours and clothes	305	278 (89.4)	21 (6.8)	6 (1.9)	1.11	.369	.021	.000
Invisibility due to smoke clouds	305	236 (75.9)	49 (15.8)	20 (6.4)	1.29	.582	.033	.000
Loud-sounds	305	204 (65.6)	70 (22.5)	31 (10)	1.43	.671	.038	.000

	N	Stomach ache (%)	Vomiting (%)	Diarrhea (%)	Other (%)	Mean	S.D.	S.E.	Sig.
*Health risks to human	108	38 (12.2)	3 (1)	54 (17.4)	13 (4.2)	2.39	1.09	.105	.000

* Infection:	N	Male (%)	Female (%)	Mean	S.D.	S.E.	Sig.
Eye disease	125	82 (26.4)	43 (13.8)	1.34	.477	.043	.000
Heart attach	10	6 (1.9)	4 (1.3)	1.40	.516	.163	.527
Respiratory disease	62	40 (12.9)	22 (7.1)	1.35	.482	.061	.022
Asthma	40	30 (9.6)	10 (3.2)	1.25	.439	.069	.002
Chronic bronchitis	65	42 (13.5)	23 (7.4)	1.35	.482	.060	.018
Irregular heartbeat	18	13 (4.2)	5 (1.6)	1.28	.461	.109	.059

	N	Yes (%)	No (%)	Mean	S.D.	S.E.	Sig.
*Diseases to animals	204	90 (28.9)	114 (36.7)	1.56	.498	.035	.093
* Animal Death cases	205	94 (30.2)	111 (35.7)	1.54	.499	.035	.235
*Risk to crop	206	124 (39.9)	82 (26.4)	1.40	.491	.034	.003

* Dependent variables

Variables	N	Agree (%)	Disagree (%)		Neutral (%)	Mean	S.D.	S.E.	Sig.
Variables	N	High (%)	Medium (%)	Low (%)	No (%)	Mean	S. D.	S.E.	Sig.
Off-odor	309	137 (44.1)	60 (19.3)	42 (13.5)	70 (22.5)	2.15	1.212	.069	.000
Mosquito	309	194 (62.4)	61 (19.6)	36 (11.6)	18 (5.8)	1.61	.908	.052	.000
Fly	309	148 (47.6)	83 (26.7)	48 (15.4)	30 (9.6)	1.87	1.005	.057	.000
Cane burning particles	309	193 (62.1)	74 (23.8)	29 (9.3)	13 (4.2)	1.55	.830	.047	.000
Bagasse particles	309	155 (49.8)	67 (21.5)	46 (14.8)	41 (13.2)	1.91	1.085	.062	.000
* Dependent variables									

Figure 2

Figure 3

Figure 4

Impact of pollutants on community around the industries

Sugar industries in Sudan were found releasing huge quantities of pollutants (i.e. organic particles, noises and smoke clouds) during the processing operation. People were suffered from the massively spreading of organic pollutants and particles as it showed in Fig. 5. The descriptive statistics showed that the pollutants were significantly ($P < 0.01$) contaminated the air and polluted clothes and floors of the community surrounding the sugar industries. The nonparametric statistics revealed that the respondents were significantly ($P < 0.05$) suffered from the suspending particles resulted from cane and bagasse burning. This could be because of the lack of pollution measures for the sugar industry sector in the country. It was reported (TIFAC, 2019) that the air pollution control equipment installation is the governor for pollutants (i.e. ash) fully escape into the atmosphere through the chimney. The loud sounds due to the operations taking place over the sugar processing season, was found significantly ($P < 0.05$) affected the people living in the vicinity villages Table 2. This might be due to the proximity of the factories (i.e. one km in average) to the villages. Moreover, it was observed that pollutants were massively released from the chimneys of the sugar factories. The nonparametric statistics declared that the factories depreciation and old practices approaches in the sugar industries in Sudan were significantly ($P < 0.01$) increased the sufferings of the vicinity villages from the off-odor and parasites (i.e. mosquitoes and fly). This concurs with engineers (Yosuf, 2017 and Yassir 2017) who stated that the publicly owned factories in the country were depreciated and found to have no updated technology which may have affected the surrounding environment. It also went with the same line of TIFAC (2019), the report stated a reduction in visibility in the surrounding areas of the sugar mill because of massive release of pollutants into the air. The present findings indicated that there were more aspects (i.e. noise pollution) that affected the community in the factories surrounding areas. However, the effect of pollutants resulted from sugar manufacture are inevitable (Wada, et al., 2017), but it could be minimized. For instant, villages should be kept far away from the industries areas. Also, the authorities must embark in a rehabilitation program with improve the performance of industries chimneys so as to reduce the effects of emission.

Figure 5

Health effects of pollutants on the community around the industries

The responses to the health questions were relatively low with compare to the targeted population. Out of total of 311, 151 (48%) of the respondents were dealt with the questions related to the health issue. This might be firstly due to the sensitivity of the issue which is rarely irritated in this particular society to avoid conflicts with the authorities. Secondly, it might be because of the lack of the health awareness among the community around the industries. This concurs with Hind (2015) how stated the simplicity of the

community around one of the sugar in factories in the country (i.e. the Kenana). Accordingly, this might made people reluctant to respond to questions deal with both environment and health issues. However, the authorities should take effective tools to deal with this issue in a transparent manner in order to develop a viable solution towards mitigate the health risks which might cause by the industry pollutants.

The pollutants were caused diseases such as eye allergy and infection, chronic bronchitis, respiratory system infections, asthmas, irregular heartbeat and heart attacks to 125 (82.7%), 65 (43%), 62 (41%), 40 (26.5%), 18 (12%) and 10 (6.6%) of the respondents, respectively (Fig. 6). Eye diseases (i.e. allergy and infection) were found to have a high significant ($P < 0.01$) mean difference in community health. Also, respiratory diseases (i.e. asthma and chronic bronchitis) were found to have significant ($P < 0.05$) mean differences widespread midst the residences Table 2. Paula, et al. (2017) found that people who residing close to the cane burning area in Brazil were significantly susceptible to cardiovascular morbidity. The study was estimated the effect of exposure to air pollutants on people in one disease (i.e. cardiovascular), as an evidence for the health risk due to sugar manufacture pollutants. The present findings revealed that the impact of the sugar manufacture pollutants on human health could cause wide range of diseases for those who are living around the industries. It is reportedly (Qureshi, 2015) that wastes discharged by sugar mills in Pakistan were found to cause asthma and various skin diseases. In a study conducted in India, dizziness and physiological effects such as irritation in the eye, nose, throat and lungs were recorded on people living in the surrounding areas of the sugar mills (TIFAC, 2019).

Figure 6

Figure 7

Figure 8

Industry participations to the community

The sugar industries in Sudan were found providing services (i.e. hospitals accessibility, medical aid, availability of qualified staff and scheduled prevention rotations) to the community. The hospitals were found to have a statistically significant ($P < 0.05$) mean difference in closeness to the villages. The availability of doctors and medical team in the hospitals were significantly ($P < 0.01$) affecting people satisfaction. The regular prevention works (i.e. pesticides spray for parasites) were significant ($P < 0.05$) in people satisfaction (Fig. 9). In a study conducted in South Africa, there were some cases of medication shortages in the hospitals of the surrounding community. It reported that there was dissatisfaction of health services due to shortages of doctors and the required medical equipment (Takalani, 2013). This might be due to the lack of the scientific background among the society on the healthy environment. It could be also because of the authorities' ignorance to the issue of community health and their surrounding environment. The survey results showed that there were no centers for monitoring the effect of sugar manufacture wastes on human health. This concurs with a study conducted in the Halfa sugar factory by Elhag (2010). It concluded that there was a lack of awareness from the side of sugar industry authorities toward its wastes impact on both the environment and human health.

Figure 9

Issues should be taken in consideration

It was revealed that there were serious issues threating both the environment and health of the community surrounding the selected industries. Out of 300, the majority 268 (89%) of respondents were agreed to find means for sufficient manage and protect the community from the sugar industry wastes. People responses were found to have significant ($P < 0.01$) mean differences in the importance of protection the community from the effluents, improving the air and water quality, enhance the waste management and the surrounding environment (Fig. 10). This might be due to the old practices that have been followed since inaugurations the majority of the sugar industries in the country. The conventional approach of the sugar production in Sudan seemed to focuses on the economic benefits rather than the environmental impact. In a study conducted by Elhag (2010), it concluded that the sugar industry in Sudan was facing problems related to the environmental aspect due to its old follows. However, the sugar industry's authorities should undertake effective means that would have decrease the environmental impact on the community surrounding the industries. It reportedly (Günter, et al., 2007) that the sugar cane industries in Brazil must use waste reducing technologies and water cycling processes in order to protect the region's environment and water resources.

Figure 10

Factors Influencing The Community Health

The multinomial logistic regression model was conducted to identify the main factors influencing the community health (i.e. malaria). The results of the analysis showed that the model was good fitted with the observed data set. A statistically significant improvement in fit about the model was found, where chi-square = 247.12, df = 32 and $p < 0.001$. The Pseudo R-Square (i.e. Cox and Snell R-squared, Nagelkerke R-squared and McFadden R-square) values, which merely mimic the R-squared value in linear regression (Pallant, 2011) were 0.55, 0.66 and 0.46, respectively. The McFadden R-Square is often reported in the researches. The McFadden R-Square value was 0.46 which indicated the good of fit to the data and supporting the quality of the model.

Eight independent variables were included in the multinomial logistic regression test to define their effect on people heath. Wastewater creates off-odor and wastewater creates mosquito were found to have significant ($P < 0.05$) influences on causing health risks (i.e. malaria) to the people residing around the sugar factories areas. The distance of wastewater streams from the villages, the flow season, the mix with the water source, the water source contamination, creation swamps and fly were found to be statistically insignificant ($P > 0.05$) predictors Table 3. The results of the analysis revealed that the untreated wastewater resulted from sugar industry in Sudan is encouraging create off-odors and parasites (i.e. mosquitoes). Hence, its critically essential in affecting the surrounding environment and people health. Many studies (Mohamed, et al, 2017; Ahmed, et al, 2017; Sahu, 2019) indicated the rationale behind the untreated sugar industry wastewater and creation of parasites (i.e. mosquitoes) that cause different diseases. However, sugar industry wastewater has major effect on the surrounding community and areas unless it well treated.

Table 3
Multinomial logistic regression model results for the effect of wastewater on the community heath

I have had malaria several times	Parameter Estimate	Standard Error	Wald	P-Value	Odd Ratio
Wastewater stream is close (agree = 1)	0.528	1.419	0.139	0.710	1.696
Wastewater flow all the year (agree = 1)	1.033	0.956	1.168	0.280	2.810
Wastewater mix with water body (agree = 1)	1.664	1.036	2.580	0.108	5.280
Wastewater contaminates waterbody (agree = 1)	1.118	0.972	1.323	0.250	3.058
Wastewater creates swamps (agree = 1)	0.085	0.898	0.009	0.925	1.089
Wastewater creates off-odor (agree = 1)	0.436	0.869	0.251	0.616	1.546
Wastewater creates flies (agree = 1)	1.503	0.713	4.449	0.035*	4.495
Wastewater creates mosquitoes (agree = 1)	2.534	0.813	9.712	0.002**	12.61
Constant	− 3.911	1.603	5.950	0.015	0.021
Wastewater stream is close (disagree = 2)	− 1.271	1.499	0.719	0.397	0.281
Wastewater flow all the year (disagree = 2)	0.630	1.343	0.220	0.639	1.877
Wastewater mix with water body (disagree = 2)	2.074	1.242	2.790	0.095	7.956
Wastewater contaminates waterbody (disagree = 2)	− 0.653	1.226	0.284	0.594	0.520
Wastewater creates swamps (disagree = 2)	− 0.834	1.114	0.560	0.454	0.434
Wastewater creates off-odor (disagree = 2)	1.131	1.150	0.969	0.325	3.100
Wastewater creates flies (disagree = 2)	0.862	0.986	0.764	0.382	2.367
Wastewater creates mosquitoes (disagree = 2)	1.094	1.058	1.069	0.301	2.986
Constant	− 2.799	1.677	2.786	0.095	0.061

*and ** Significant at $P < 0.01$ and $P < 0.05$, respectively. -2 log likelihood = 221.351; Chi-square = 247.117 and p = 0.000. Pseudo R-Square (Cox and Snell, Nagelkerke and McFadden) = 0.548, 0.669 and 0.465, respectively.

Wastewater creates flies

The flies created by the sugar industry wastewater was found to have positive and statistically significant ($P < 0.05$) relation with the endangered of the community health. The wastewater creates flies appeared to have more likely to affect the health of the people surrounding the sugar factories areas. More flies created by the wastewater are more likely to fall in the agree category than in fall the disagree or natural categories. The probability of respondents agrees to the issue of health risks appeared more likely to increases by a factor of 4.5 as the level of creation flies increases by one more time. This seems to indicate that the sugar industry wastewater in Sudan is discharged without treatment that mediates the reproduction of parasites. The result is supported with the findings of studies conducted in Sudan on analysis the wastewater of the Assalaya sugar factory (Mohamed, et al, 2017; Ahmed, et al, 2017). It also went with same line of the findings of a study conducted in Ethiopia on treatment of sugar industry wastewater with ferrous material (Sahu, 2019).

Wastewater creates mosquitoes

The sugar industry wastewater was found to have positive predictor and highly significant ($P < 0.01$) indicator to create mosquitoes and affect the health of the surrounding community. The probability of the reproduction of mosquito in the sugar manufacture wastewater was more likely supported by the respondents than to fall in other categories (i.e. disagree and neutral). Accordingly, this means that the more increase of the wastewater the more median of diseases (i.e. mosquitoes) created. Hence, increases the probability of endangered the health of the surrounding community by a factor of 12.6. This result revealed that the sugar industry wastewater in Sudan is the main contributor to the creation of mosquitoes. This concurs with a study stated that the sugar industry untreated wastewater in Ethiopia is a source of mosquito (Sahu, 2019).

A Prospective Frame Work To Handling The Sugar Manufacture Wastes In Sudan

The community surrounding the selected sugar industries in Sudan is facing unavoidable contaminants. These contaminants could be minimized to the lowest levels by sustaining sufficient tools to manage the waste. Hence, the environmental impacts could be mitigated. Therefore, this study designed an integrated framework to conserve the bionetwork of sugar industry in the country. The framework is based on collaborative efforts from both the sugar industries and the society around to better waste management.

The concept of this framework depends on the industrial ecology which focuses on integrating and adapting technologies to sustain a better management for sugar manufacture waste (Davidson, 2011). Based on this context, the prospective industrial waste handling framework for the selected sugar industries aims to (1) maximize reuse and recycling of the waste resulting from sugar manufacture, (2) support decision makers towards achieve sustainable sugar production and (3) achieve zero waste for sugar industry in Sudan. The above-mentioned goals can be achieved by introduce new technologies to use the sugar manufacture waste as raw materials to produce ecofriendly products. For instance, wastewater treatment plant and the idea of cane green harvesting will contribute to minimize the impacts of pollution on the society around the industries. The existing practices of treating sugar by-products and waste are not environmentally friendly. The surplus bagasse, filter cake, wastewater and vinasse are improperly managed. Filter cake and bagasse ash and wastewater are produce pollutants such as suspending particles, off-odors and parasites. The pollutants are causing health risks to the human and animal in surrounding areas (Fig. 11). However, it is obviously clear that there is no collaborative work between the industries' authorities, the environmental aspects and the social part in order to maintain a sustainable sugar industry bionetwork in Sudan.

The prospective strategy is to target specific by-products and waste to be used as raw materials to produce ecofriendly products (Fig. 12). The surplus bagasse could be used to produce papers. The wastewater could be recycled and reused. Vinasse with filter cake could be used to produce fertilizers such as potassium and phosphate (Prado et al, 2013, Nakhla, 2014 and Evgeniya, *et al*., 2017). Also, increase the efficiency of the on process treatment plants such as wastewater recycling program as (Oboody, 2016). Moreover, sustain effective bodies to work integrally with industrial, social and environmental sides to conserve the bionetwork of the sugar industry. Embark on create institutions responsible for implementation the extensive environment, pollution and waste management legislations. Collecting information about pollution and waste monitoring are essential for the implementation of pollution reduction measures. Sharing information is important element to create awareness about the issue of the effect of waste on human health. This framework was the first of its kind for the case of Sudanese sugar factories with the approach to steer the decision makers to reduce the environmental impact of sugar manufacture waste and pollutants. This will enable gain better

understanding of the relationship between pollution, waste management and the healthy life that the surrounding community are need to live.

Figure 11

Figure 12

Conclusion

The identified Sudanese sugar factories have problems in the waste that affect the community and the surrounding environment. The wastewater was significantly ($P < 0.05$) created off-odor, mosquito, mixed with the water source and caused health risk. It was also significantly ($P < 0.05$) affected the crop and animal production. The appearance of diseases and death cases was observed in some animals and plants that use the wastewater. The sugar industry pollutants (i.e. suspending particles, and smoke clouds) were significantly ($P < 0.05$) caused eye disease and respiratory system infections. The majority of respondents (85%) agreed with that the sugar manufacture waste is need to be effectively managed and the quality of water and air needs to be improved. However, the availability of doctors and medical team in the hospitals were significantly ($P < 0.01$) affecting people satisfaction. Therefore, major reforms are required to manage the sugar manufacture waste in order to put an end to the environmental impacts. The study was designed a framework to enhance handling the sugar industrial waste. The framework will positively reflect on the environment of the community residing around the sugar industries in Sudan. It will spur the decision makers toward enhance the bionetwork of sugar industry in the country.

Declarations

Competing interests: The authors declare that they have no known competing financial interests or personal relationships which have, or could be perceived to have, influenced the work reported in this article.

Availability of data and materials: Data and materials of this study are available if needed for further review.

Authors' contributions: I (Tageldeen Saeed Tageldeen Ibrahim) developed and evaluated the questionnaire and collected data from 377 respondents living in the vicinity of the six selected sugar factories in Sudan. I employed the multinomial regression analysis to establish a unique relationship between the identified factors that influenced the surrounding environment. I generated and discussed the results in this paper. Prof. Tilahun Workneh, provided guidance and revision, and proofread the article prior to submission in journal of environmental monitoring and assessment.

Funding: No funding was obtained for this study.

References

1. Ahmed, M. K., Harounm M. A., Mahyoub, J. A., Al-Solami, H. M. & Ghramh, H. A. (2017). Environmental impacts of the liquid waste from Assalaya sugar factory in Rabek locality, White Nile State, Sudan, *International Journal of Environment, Agriculture and Biotechnology (IJEAB)*, 2 (4): 1493-1504.
2. Abid, A. A. (2008). Economic impact of air pollution by sugar industry in the White Nile state, Sudan, Unpublished MScEng Dissertation, University of Khartoum, Khartoum, Sudan.
3. Aisha, M. M. (2007). Impacts of sugar industry waste water on some vegetable crops production. Unpublished MScEng Dissertation, University of Khartoum, Sudan.
4. Alim, EA. (2012). Assessment the liquid and solid wastes from Guneid sugar factory. Unpublished MScEng Dissertation, University of Khartoum, Khartoum, Sudan.
5. Alnail, M., Kabenge, M., Li, J., Zhu, M., Abubaker, A. & Magzoub, A. (2013). Pollution control on river Nile in the White Nile state sugar hub of Sudan. *Environmental Science and Technology*, 47 (2013): 12628–12629.
6. Asmah, M. (2017). Analysis the wastewater resulted from sugar processing in Kenana sugar industry lagoon, Report No. 17. Department of Quality Control, Kenana, Sudan.

7. Bhawna, P., Surindra, S. & Vineet, S. (2016). Accumulation and health risk of heavy metals in sugarcane irrigated with industrial effluent in some rural areas of Uttarakhand, India, *Process Safety and Environmental Protection*, 102 (Part B): 655 – 666.
8. Cordiero, G. C., Romildo, F., Eduardo, F. & Cristiano, O. (2004). Influence of mechanical grinding on the pozzolanic activity of residual sugarcane bagasse ash. In: eds. Toledo Filho, RD. *Proceeding of Conference on the Use of Recycled Materials in the Buildings and structures*, 1-10, Barcelona, Spain.
9. Davidson, G. (2011). Waste Management Practices: Literature Review, Dalhousie University - Office of Sustainability, Nova Scotia, Canada.
10. Evgeniya, G, S., & Olga, I. S. (2017). Comparing the environmental impact of disposal methods of sugar production waste by simulation modeling, *Energy Procedia*, 113 (2017): 224 – 230.
11. Elhag, I. A. (2010). Study on cleaner production opportunities in the sugar industry in Sudan, Unpublished MScEng dissertation, Engineering Research and Industrial Technology Council, Sudan Academy of Science and Technology, Sudan.
12. Fatima, A. E. (2017). GIS research group, Ministry of environment and architectural planning. Khartoum, Sudan.
13. Grace-Martin, K. (2018). Binary, ordinal, and multinomial logistic regression for categorical outcomes. [Internet]. The Analysis Factor, New York, USA. Available from: http://TheAnalysisFactor.com. [Accessed: 01 January 2018].
14. Günter, G., Jan, K., Maria, S., Hendryk, R., Suzana, M. & Joana, A. (2007). Sugar cane industry as a source of water pollution – case study on the situation in ipojuca river, Pernambuco, Brazil. *Water Air Soil Pollut,* 180 (2007): 261–269.
15. Hind, B. A. (2015). The effect of Kenena sugar company on community livelihood: a case of altogaba village, White Nile state, Sudan. *International Journal of Research in Humanities and Social Studies,* 2 (3): 19-29.
16. John J., Soko S., Yu, C. & Aurelia K. (2017). STEM Aspiration: The influence of social capital and chilly climate on female community college students, *Community College Journal of Research and Practice*, 41:4-5, 253-266.
17. Le Blond, J. S., Woskie, S., Horwell, C. J. & Williamson, B. J. (2017). Particulate matter produced during commercial sugarcane harvesting and processing: A respiratory health hazard. *Atmospheric Environment,* 149 (2017): 34 – 46.
18. Mengistua, M. G., Simanea, B., Esheteb, G. & Workneh, T. S. (2016). Factors affecting households' decisions in biogas technology adoption, the case of Ofla and Mecha Districts, Northern Ethiopia, *Renewable Energy,* 93 (2016): 215-227.
19. Mohamed, Y. A., Wahab, H. A., Khalifa, S. A., Yahia D. & Mansour, F. (2017). Wastewater analysis of Assalaya sugar factory. *International Journal of Trend in Research and Development,* 4(6): 21-24.
20. Mohamed, E. S. & Samah, M. F. (2011). The use of sugarcane bagasse ash as an alternative local pozzolanic material: study of chemical composition. *Journal of Science Vision,* 16 (17): 65-70.
21. Nakhla. D. A. (2014). Achieving the environmental sustainability of sugarcane industry in Egypt: An application of life cycle assessment, Unpublished PhD Dissertation, The American University, Cairo, Egypt.
22. Oboody, F. A. (2016). Evaluation of biogas productivity from vinasse, waste water and filter mud in Kenana sugar scheme. *International Journal of Current Microbiology and Applied Science*, 5 (4): 117-126.
23. Pallant, J. (2011). *SPSS survival manual: A step by step guide to data analysis using SPSS* (4th ed.). Allen & Unwin, Crows Nest, Australia.
24. Paula, R. S. P., Alfésio, L. F. B., Ercy, M. C. R., Ariadna, F. O., Christian, R. O., Aline, D. F. & Dionei, R. (2017). Effects of air pollution caused by sugarcane burning in Western São Paulo on the cardiovascular system. *Rev Saúde Pública,* 2017; 51:13.
25. Pradeep, K. P. & Omprakash, S. (2017). Quality and management of wastewater in sugar industry. *Applied Water Science*, 7 (1): 461-468.
26. Prado, R. D., Caione, G. & Campos, N. S. (2013). Filter Cake and Vinasse as Fertilizers Contributing to Conservation Agriculture. *Applied and Environmental Soil Science*, 2013: 1-8.
27. Qureshi, A. l., Mahessar, A. A., Leghari, A. E., Lashari, B. K. & Mari, F. M. (2015). Impact of releasing wastewater of sugar industries into drainage system of LBOD, Sindh, Pakistan. *International Journal of Environmental Science and Development*, 6 (5): 381-386.
28. Reddy, A. V. K., Prasad, M.P. D., Sujatha, V., & Sridevi, V. (2014). A review on treatment of sugar industry effluents by up flow anaerobic sludge blanket reactor. *Journal on Future Engineering and Technology*, 9(3): 31-37.
29. Robert, C. (2011). Assessment of carbon emission reductions in Africa from improved waste management, Unpublished PhDEng Dissertation, School of Engineering, University of KwaZulu-Natal, Durban, South Africa.

30. Sahu, O. P. (2019). Electro-oxidation and chemical oxidation treatment of sugar industry wastewater with ferrous material: An investigation of physicochemical characteristic of sludge. *South African Journal of Chemical Engineering*, 28 (2019): 26-38.
31. Sahu, O. P. (2018). Assessment of sugarcane industry: Suitability for production, consumption, and utilization. *Annals of Agrarian Science,* 16 (2018): 389–395.
32. Sahu, O. P. 2015. The characteristics, effects, and treatment of wastewater in sugarcane industry. *Water Quality, Exposure and Health*, 7 (3): 435–444.
33. Saranraj, P. and Stella, D. 2014. Impact of sugar mill effluent to environment and bioremediation: A review. *World Applied Sciences Journal,* 30 (3): 299-316.
34. Takalani, M. N. (2013). Social impact assessment of sugar production operations in South Africa: a social life cycle assessment perspective. Unpublished MScEng Dissertation, Faculty of Engineering and Build Environment, The University of Johannesburg, Johannesburg, RSA.
35. Taro, y. (1967). *Statistical Analysis, Introductory Analysis*, 2nd Edition. Harper and Row, New York, USA.
36. Technology Information Forecasting and Assessment Council (TIFAC). (2019). *Pollution control technologies for sugar industry*, Report No: TMS102. Foods and Agriculture: Sugar Technology, New Delhi, India.
37. Vinod, k. (2014). Sugar mill effluent utilization in the cultivation of maize (Zea mays L.) in two seasons, *Journal of Waste Management*, 2014: 1-12.
38. Wada, A. C., Abo-Elwafa, A., Salaudeen M. T., Bello . Y. & Kwon-Ndung E. H. (2017). Sugar cane production problems in Nigeria and some northern African countries. *Direct Research Journal of Agriculture and Food Science*, 5 (3): 141-160.
39. Yassir, B. H. (2017). Personal communication, Department of Quality Control, Assalaya Sugar Industry, Assalaya, Sudan, 08 June 2017.
40. Yosuf, M. A. (2017). Personal communication, Department of Quality Control, Guneid Sugar Industry, Guneid, Sudan, 23 May 2017.

Figures

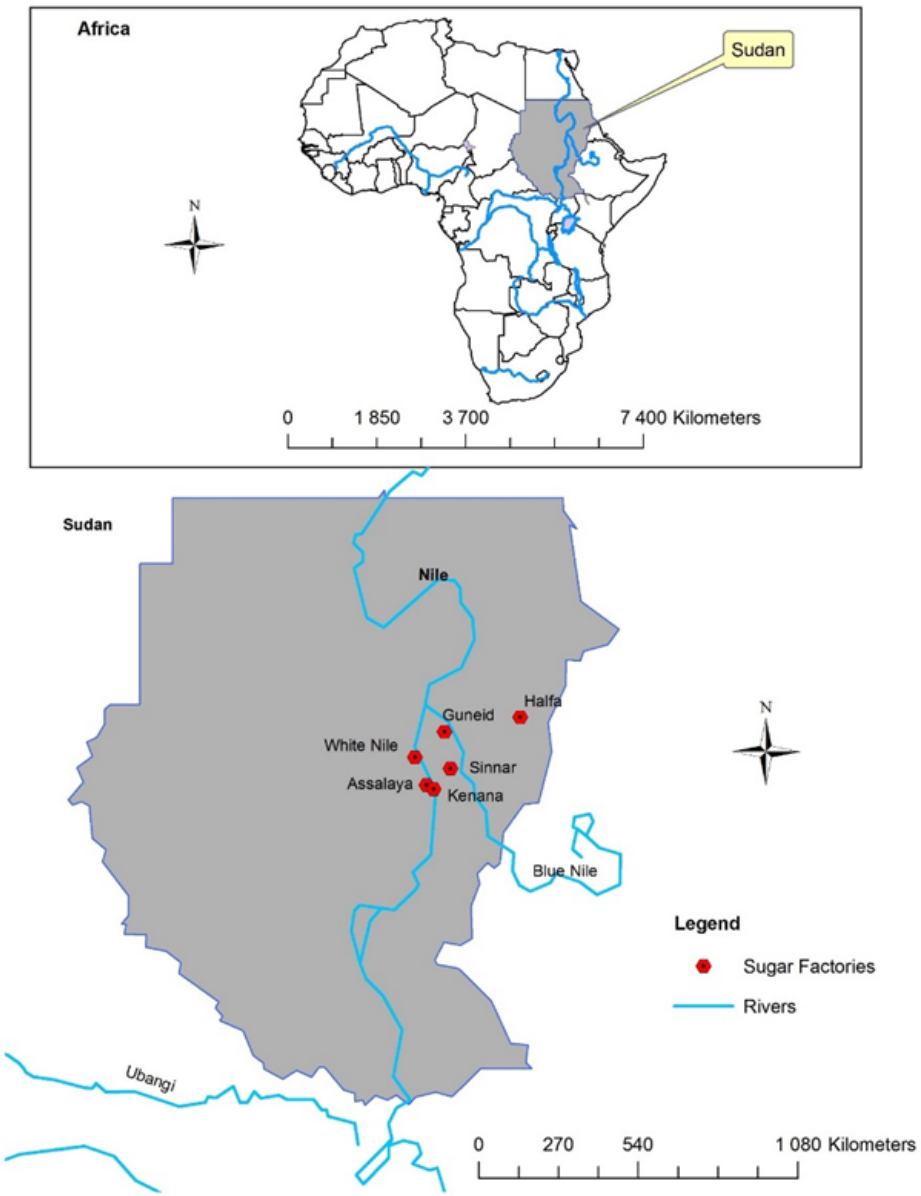

Figure 1

Sugar factories in Sudan (Fatima 2017)

Figure 2

Releasing wastewater into open fields in the Assalaya sugar industry

Figure 3

Wastewater creates parasites in the Sennar sugar industry

Figure 4

Crop and animal production affected by wastewater in the Kenana sugar industry

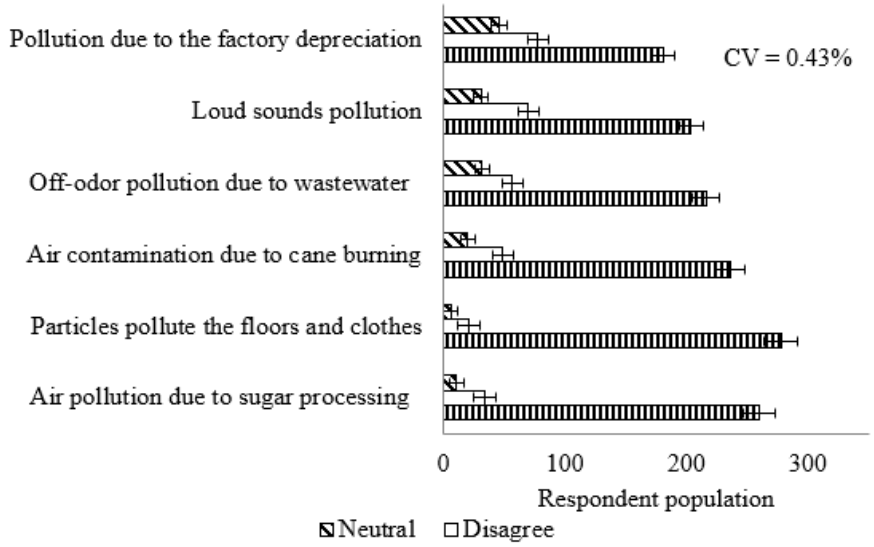

Figure 5

People sufferings from pollutants in their environment

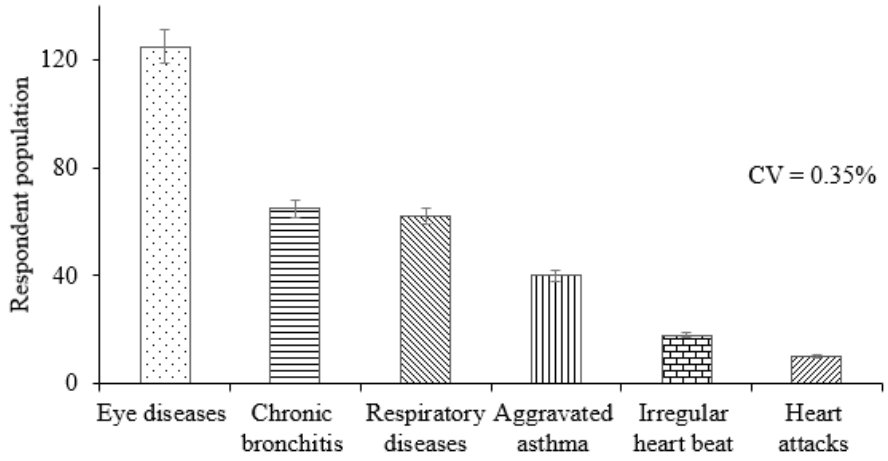

Figure 6

Diseases caused by sugar manufacturing waste

Figure 7

Emissions from bagasse and filter cakes in the Kenana industry

Figure 8

Bagasse and filter cake ash in the Kenana industry

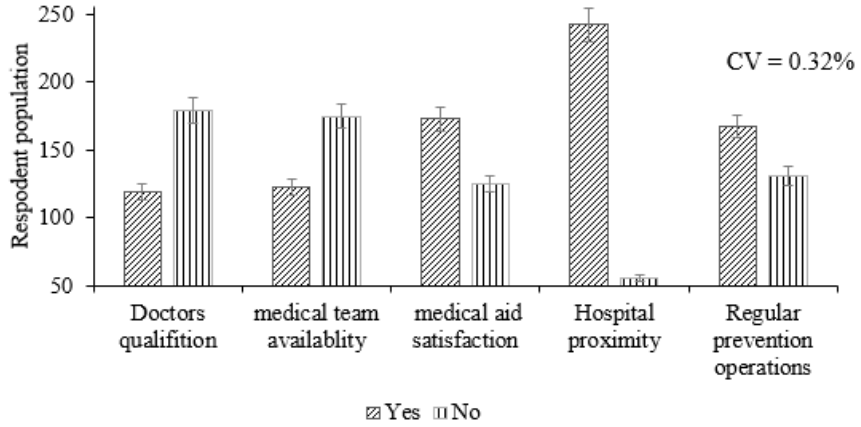

Figure 9

The satisfaction of the population with health services.

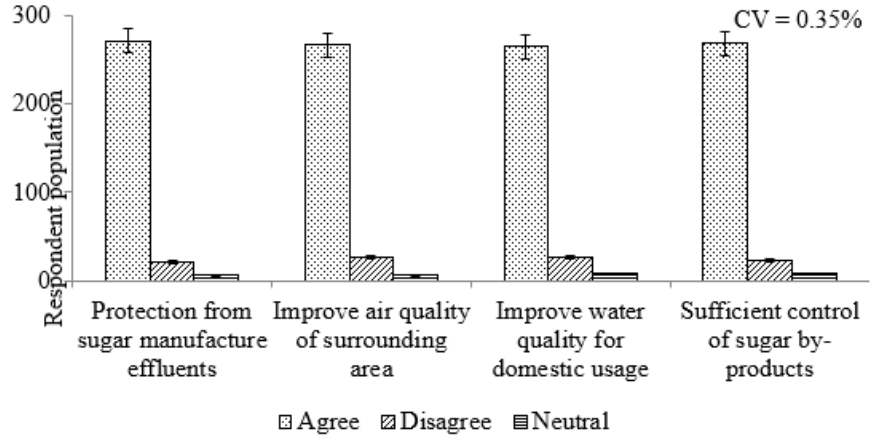

Figure 10

Responses to the important issues that should be considered

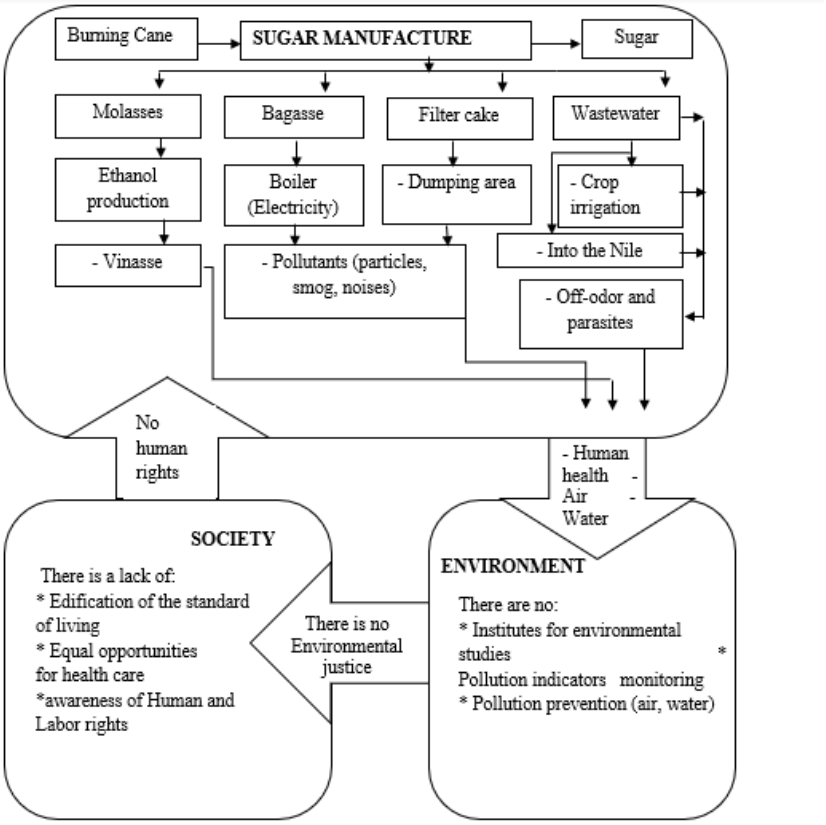

Figure 11

The existing sugar waste management system

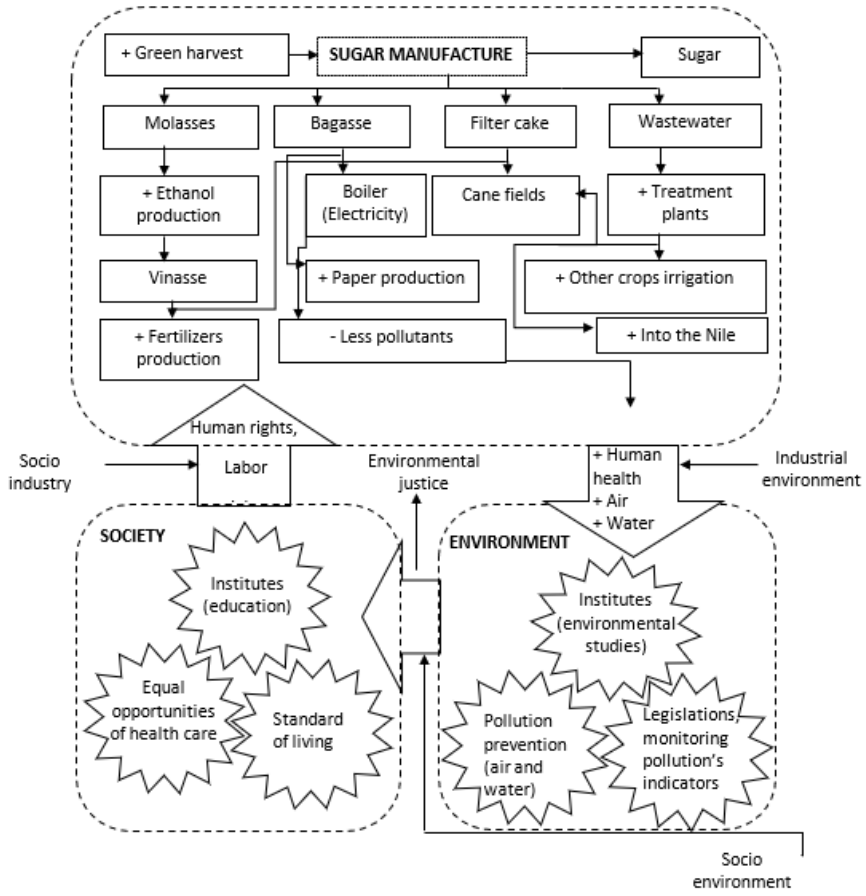

Figure 12

The prospective framework for the sugar waste management

Where: [-] = Negative impact on the environment, [+] = Positive impact on the environment