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An assessment of water quality and the locals' perception of coastal lagoon pollution in ghana: A case study of chemu lagoon in tema

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Abstract

The Chemu lagoon is not immune to pollution through chemical waste contamination, refuse disposals, and untreated household sewage, and hence has been chosen as a case study. This paper aims to assess the lagoon's level of pollution. Chemical analysis of water samples, field observations, and a structured survey questionnaire was used to assess the state of the lagoon. The study revealed that the Chemu lagoon has inferior water quality as most of the parameters evaluated were above the acceptable standards of the United States Environmental Protection Agency (USEPA). Significant differences in concentrations of water quality parameters were established between seasons. The study found that respondents were aware of the lagoon's polluted state and attributed pollution to siltation and waste dumping. This leads to offensive odour, livelihood losses emphasising a reduction in fishing activities, and outbreaks of diseases in the area. Conclusively, stakeholders have not prioritised mitigating pollution of the lagoon. The study recommends that the Environmental Health and Waste Management Departments of the Tema Metropolitan Assembly intensify house-to-house hygiene education and sanitary inspection in the area. There should be education and sensitisation on proper waste management practices in the area.

Keywords: Chemu lagoon, Citizen science, Lagoon, Pollution, Waste management, Water quality.

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Contents

Contribution of this paper to the literature

Relevant studies on lagoons primarily focus on reporting the state of pollution and water quality and, in some instances, identifies impacts on lagoons' biodiversity by collecting water samples and specimen to investigate in laboratories. This study focuses on lagoon pollution but diversifies to study the case from a citizen science perspective to understand the respondents' perception.

1. Introduction

Lagoons are shallow coastal water bodies, entirely or partly separated from a larger body of water by a barrier, reef or other depositional features [1, 2]. Lagoons deliver services, including fisheries, flood control, fresh water, and preservation of an array of species. They also serve as critical roosting, breeding grounds, food sources, and habitats for several bird species, especially migratory ones [3, 4]. On the other hand, lagoons are extraordinarily fragile and vulnerable to natural and human-based factors [4, 5]. Natural processes and pollution from nearby urban and industrial development can easily disturb coastal lagoons [3]. The United Nations World Water Assessment Programme reiterates that river, pond, dam, ocean, and lagoon pollution is a primary global concern [6, 7]. Pollution of a water body is observed whenever a body of water is harmed as a consequence of man's addition of a substantial quantity of hazardous materials. These actions cause adverse effects such as harm to living resources and marine life, dangerous situations to public health, an impediment to coastal and maritime activities, and poor quality use of the water body (United Nations Convention of the Law of the Sea; UNCLOS). There are numerous sources of contamination, which can be classified into two categories: primary and secondary causation. Primary causes encompass effluent from homes, factories, refineries, and sewage treatment plants that discharge fluids of differing quality directly into the waterways. Contaminants that enter water bodies from soils and groundwater structures, as well as from the surrounding air of acid rain, are considered secondary sources [8].

Anthropogenic impacts contaminate a large portion of the world's water sources. Around 2 million tons of sewage, industrial, and agricultural waste are estimated to be released into the nation's bodies of water as of 2002 United Nations World Water Assessment Programme [UN WWAP] [6]; Kwadzo, et al. [9]. In Kwadzo, et al. [9], it is reported that plastic and domestic wastes are the major lagoon pollutants identified by the respondents in work conducted on the Fosu Lagoon in Ghana. These negatively influence the environment and the lifestyle of individuals who use polluted water bodies [8]. In Ghana and other less economically developed countries where population growth is mainly faster than economic development, waste treatment facilities are almost non-existent. Many people die yearly from water-borne diseases such as cholera and typhoid and from pollutants such as lead, cyanide and other metals that cause cancer and death [10]. According to United Nations Children's Fund [11] and the World Health Organization [12], one of the most effective forms of water pollution is poor sanitary conditions, which pollute water bodies globally. They believe that around 2.5 billion people worldwide cannot access enhanced hygiene. Over nine million hectares of mangroves are located around coastal lagoons, tidal estuaries and deltas along the coastal wetlands of West Africa [13].

Notwithstanding their international importance as conservation areas for global biodiversity and production efficiency, these lagoons and marshes are primarily unrestricted. Research has found over 40 coastal lagoons along Ghana's 540-kilometre shoreline, which is part of the Coast of West Africa [3]. These lagoons and their wetlands provide a unique environment and habitat for humans and numerous species of animals in Ghana [3]. Economic development and population growth have increased the pollution of these water bodies tremendously, and most often, the pollutants are chemical waste, refuse disposals, and untreated sewage from houses.

The vulnerability of coastal lagoons to pollution is counter-productive to environmental development. It is graphically illustrated in the Niger Delta, where mangroves and associated wetlands have been subjected to progressive degradation from the plethora of oil and gas mining activities in the Niger Delta and the near-shore environment [14]. The collapse of the fishing industry of the Aby Lagoon in Cote d'Ivoire in 1981 due to chemical pollution is another example [10]. Chemu lagoon is one of Ghana's worst-polluted lagoons [15]. According to Anny [16], Chemu Lagoon, which once had the prospect of being a source of sustenance, is almost depleted and is on the brink of total 'death' as a consequence of indiscriminate disposal of solid, liquid, and hazardous wastes. Chemu Lagoon, which once had the potential to be a suitable habitat for fish and serve as a valuable ecosystem and destination for migratory birds, has nearly dried up and is on the verge of 'death' due to pollution and overcrowding in its watersheds. The lagoon is presumed to be Tema's most highly contaminated body of water. For years, city officials have been conscious of the lagoons' poor condition; however, no well-defined implementation plan has been executed to save the lagoons from extermination. The Chemu lagoon in Tema New town is exposed to vehicle smoke. It is also close to the Tema oil refinery, which continuously emits smoke into the environment. Corporate Social Responsibility Movement (CSRM), a local environmental NGO, filed a writ against Tema Oil Refinery (TOR) in the Tema High Court in 2007 for purportedly contaminating the lagoon with oil and industrial wastewater from their plant [17].

Previous studies of lagoon pollution in Ghana primarily focus on Polycyclic Aromatic hydrocarbon pollution [18] and urban waste pollution Owusu Boadi and Kuitunen [19]. Biney [15] conducted water quality studies of some rivers and lagoons in Ghana, including the Chemu lagoon. Though his investigations identified Chemu lagoon as polluted, they did not consider the relevance of citizen science, what the locals perceived of the pollution and its impacts on their life. Apart from this, it is worth conducting a water quality assessment of the lagoon in recent times to mark monitoring lenses on the trends in the lagoon's pollution levels. The research will assist in deciphering why the unregulated disposal and dumping of garbage into the lagoon is exacerbating a decline in the biodiversity population in the area being studied. The research will also function as a position paper for the authorities and other intergovernmental organisations on concerns about monitoring the lagoon. The study positions that if the management policies and recommendations are followed, they will aid in the restoration of the ecosystem to a better state. The locals' income will recover if livelihood is eventually recovered in the lagoon and its watershed. Ultimately, the research will add to the existing knowledge on biodiversity protection. This paper assesses the water quality concentration of the Chemu lagoon, investigates how the local people perceive the pollution of the lagoon, and analyses the effects of the pollution on the people.

2. Water Pollution in Ghana

Water contamination challenges in Ghana are inextricably linked to the country's social, economic, and urban growth programs since independence in 1957. Following independence, most industry segments were founded throughout the country to promote the natural environment. While leveraging mineral deposits and agricultural operations in industrialisation programs, residents did not take adequate precautions to protect against the environmental cost of these programs and resource depletion [20]. Consequently, many ecological concerns are currently faced, including varying air, water, and soil pollution. The mining, mineral exploitation and processing, textile, food processing, and petroleum refining and processing factories substantially contributed to the nation's pollution. Most of Ghana's industrial establishments are concentrated in the Accra and Tema metropolitan areas, which account for less than 1% of the country's total land area. The accumulation of these industrial sectors has also resulted in increased sound, fumes, and carbon monoxide emissions, as well as urban and industrial effluents [21].

Most liquid waste from manufacturing sectors is expelled into bodies of water unmanaged. As a result, the surroundings have been devastated. The country's manufacturers also induce different types of municipal solid waste. Food processing industries, for example, produce organic solid waste; building and construction industries have metal scraps, dust particles, and asbestos tailings; textile and garment industries produce wax, cotton fluff, feints offcuts, and floor wastes. Paper cuttings, trimmings, and exposed photo and video films are produced by the paper and printing industries. Metal and metallurgical factories produce ferrous, non-ferrous metal, and other wastes [21].

The Ghanaian government, environmental regulatory bodies, and social organisations are all collaborating to address the country's ecological problem. Among the initiatives that are currently being implemented are:

- The formation of the Ministry of Local Government, Rural Development, and environment to provide policy recommendations [21].
- In 1974, the Environmental Protection Council, known as the Environmental Protection Agency, was established as the primary body to guide and regulate environmental standards.
- Development and implementation of the National Environmental Policy (NEP) and the National Environmental Action Plan (NEAP) [21].

All these measures, policies and strategies are perfect on paper, but they have failed to make significant progress in reducing the menace. Most of them are either poorly implemented or not enforced due to inadequate resources, corruption and lack of commitment to achieve a sustainable environment.

3. Materials and Methods

3.1. Study Area

Chemu Lagoon is situated to the East of Tema Community 1, as depicted in Figure 1. The lagoon is geographically marked within latitudes 5°38'59.09"N and 5°38'38.26"N and longitudes 0°0'45.95"E and 0°1'19.09"E. Tema is a coastal city located 25 kilometres east of Ghana's capital, Accra and has an area of approximately 26 km^2. It is differentiated by myriad small streams that connect a mainstream. Tema is not only Ghana's economic hub but also the location of the state's major main port and one of the most efficient shipping locations on Africa's west Coast. "Over 250 factories in the lagoon catchment, engaged in eight major areas: chemicals, textiles, food processing, engineering, paint, fish cold stores, printing and wood works" [22]. This notwithstanding, the livelihoods of many of the people in the area still revolve around agriculture. Like other coastal towns, fishing is the predominant agricultural activity around. However, few people are involved in crop farming activities, including exotic vegetables and fruits [22].

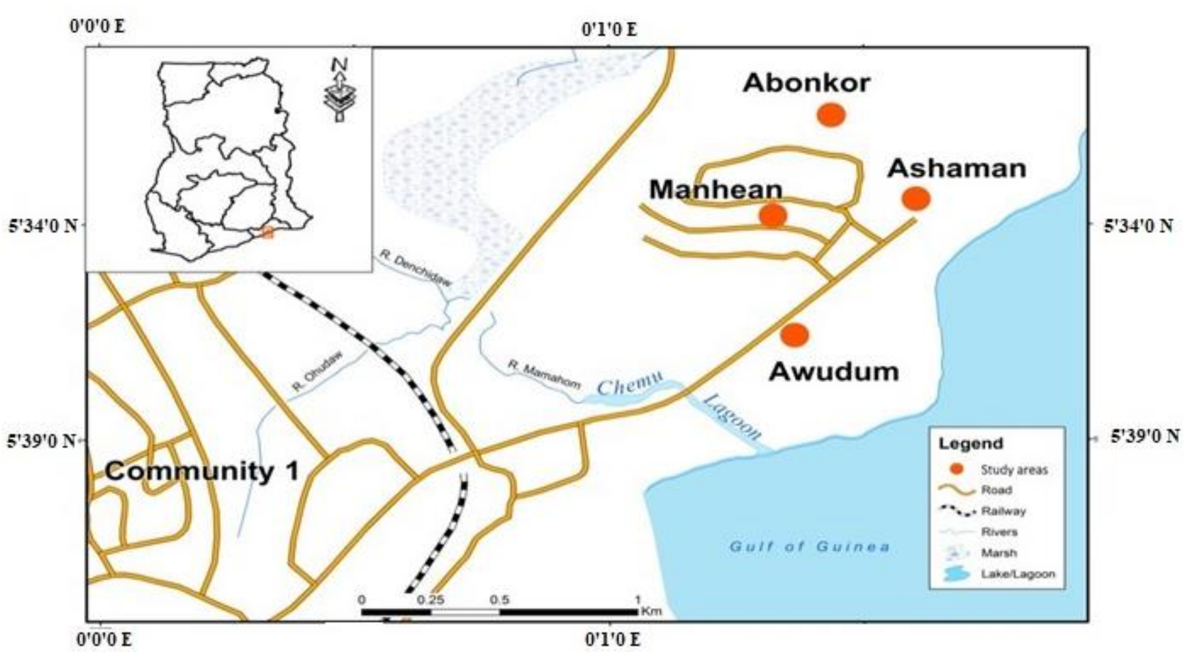

Figure 1. Map showing the study area in the regional context.

Source: Fieldwork, (2021).

3.2. Sampling, Data Collection, and Analysis

A two-pronged approach was applied in this study. Firstly, concentration analysis of sample water collected from five diverse lagoon points Figure 2 was used to assess the lagoon's composition and level of contamination. Secondly, the paper employed a descriptive survey design (comprising a structured questionnaire) to evaluate the opinion of the local people on the effects of pollution.

Water samples were collected from the lagoon to assess the level of contamination of the Chemu Lagoon. Five sampling points were determined after [23]. The samples were collected and stored in a high-density polyethene bottle. All plastic bottles for sampling were immersed in a 10% HNO_3 solution for 48 hours and were thoroughly rinsed with double-distilled water before use. The bottles were also washed with water to be sampled at each sampling point to limit contaminants. All water samples were taken at the subsurface to avoid the superficial colloidal layer, which might influence the concentration of specific parameters. Samples were put in ice chests with ice cubes to slow biological and chemical reactions and were transported to the Water Research Institute's (WRI) laboratory for analysis. Water samples from the Chemu lagoon were analysed using an Atomic Absorption Spectrophotometer.

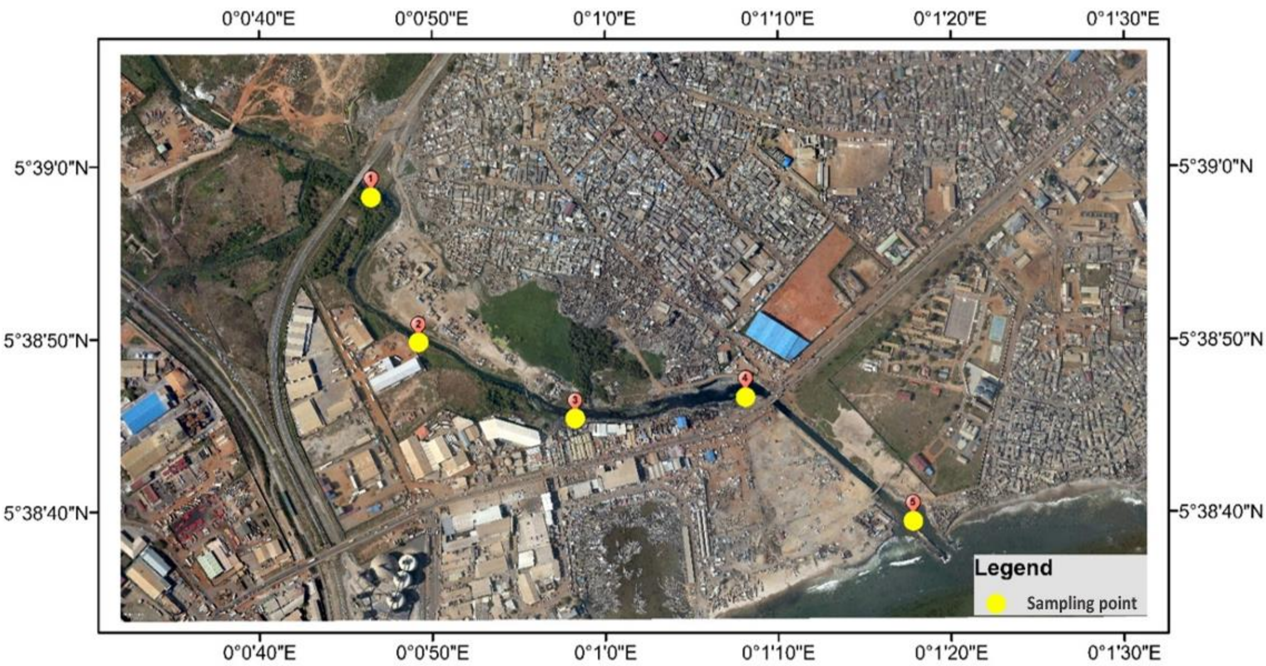

Figure 2. Water sample sites along the course of Chemu lagoon.

Source: Fieldwork, (2021).

Moreover, a descriptive survey design was used because the study sought to observe, describe, and record elements of events that take place inevitably or as a consequence of human intervention. According to Fraenkel and Wallen [24] descriptive research is gathering evidence to address research questions about the current state of a subject of investigation. Gay [25] further defined the phenomenological method as appropriate for environmental concerns exploration, appraisal or examination of behaviours, viewpoints, sociodemographic characteristics, constraints, and processes. In light of this, the descriptive survey was selected as the study's design. The estimated population of the age bracket 20 to 60 at Tema community one is 18,483, according to the Ghana Statistical Service [26] report, at a growth rate of 2.6% per annum. The sample size was determined following [27], who proposed that a sample size of 377 is ideal for a population of about 20000 persons. The study sampled 377 persons chosen purposively and was in the position to provide relevant information for the analysis. The study thus sampled adults between the ages of 20 years and 60 years old who had lived in the area for at least ten years. This sample was considered appropriate and representative of the current study.

The study's instruments featured a structured questionnaire, an interview guide, and an observation schedule. The data were processed and analysed using Statistical Package for the Social Sciences (SPSS) version 23. Descriptive statistics and inferential statistics were employed to present the data. The authors used descriptive statistics employing means of concentrations to show the research results. Inferential statistics employed paired sample t-tests to establish seasonal differences. The chemical analysis outcomes contrasted the standards for water bodies outlined by the USEPA. Although it may appear arbitrary to compare facts and social rules independently of date and utilisation, this was done by using the concentrations for studied parameters as the basis for comparison to establish the extent of pollution that the Chemu Lagoon has been experiencing for many years.

4. Results

4.1. Respondent's Sociodemographic Characteristics

The socio-economic characteristics of the surveyed residents are presented in Table 1. The distribution by gender was 64% males and 36% females. With marital status, 66% of the respondents were married, 28% were single, and 6% were divorced. Results on educational attainment found that respondents with no formal education constituted 90 (24%), and formal education in the form of Basic, Middle, Senior High School and Tertiary represented 287(76%). This shows that most of the respondents at least have tasted formal education and could have more profound knowledge and appreciation of water pollution issues in the area studied. It is believed that the level of education usually affects the littering behaviour of people. The reported age category of the respondents followed the dimension 21-30 age bracket representing 25%, 31-30 were 33%, 41-50 were 22%, with the least designated age category being those between over 60 years who made 5% of the total respondents.

Regarding years of stay in the catchment area, the results indicated that 13% of respondents had stayed there for between 1-5 years. Another 6 -10 years recorded 18.5%, with 11-15 years recording 21% of the respondents, whilst those who had lived in the area for over twenty years constituted 26%. The data presented in Table 1 showed that most respondents have stayed for a long time and are privy to the environmental injustices that have been at play in and around the lagoon. The study found that 43% of the residents earn up to 500 Cedis per month. Earnings between 501 and 1000 Cedis are for about 98 (26%), with another 117 (31%) making over 1000 Cedis on average per month. To understand the incidence of waste generation from the household level, the researchers analysed data on the household size of the respondents. The data revealed that households with 2-5 persons comprised 55% of the respondents, and households with more than 10 constituted 11.5%—persons living alone in a family consisting of 23% of the resident respondents.

Table 1. Socio-demographics characteristics of respondents.

Variable	Item	Frequency	Percentage
Gender	Male	241	64
	Female	136	36
Marital status	Single	106	28
	Married	249	66
	Divorced	23	6
Age	21 - 30 Years	94	25
	31 - 40 Years	124	33
	41 - 50 Years	83	22
	51 - 60 Years	57	15
	Above 60 years	19	5
Level of education	No formal education	90	24
	Formal education	287	76
Years of residence	1 - 5 Years	49	13
	6 -10 Years	70	18.5
	11 - 15 Years	79	21
	16 - 20 Years	81	21.5
	Over 20 Years	98	26
Mean monthly income	Up to 500 cedis	162	43
	501 – 1000	98	26
	Over 1000 Cedis	117	31
Household size	1 Person	87	23
	2 -5 Persons	207	55
	6 - 10 Persons	40	10.5
	More than 10 persons	43	11.5
Total		377	100

Note: 1 Cedis is equivalent to the average of 5.74 dollars in 2021.
Source: Fieldwork, (2021).

4.2. Seasonal Concentrations of Parameters

As shown in Table 2, the chemical analysis results express the status of Physico-chemical and heavy metals concentration of the increasingly degrading Chemu lagoon. The table shows the concentrations (mg/L) of the Physico-chemical and heavy metals parameters in water samples during the wet and dry seasons by their mean concentrations and standard deviations. The table also compares the averages for concentrations with the USEPA permissible limits for the water body. Table 2 shows the concentration of the parameters analysed during both the wet and dry seasons. As shown, the mean pH for the dry season exceeds the permissible limit according to the USEPA standards, while that for the wet season was found to be acceptable. The study also identifies that the mean concentrations or levels of turbidity, temperature, sulphate, phosphates, faecal coliforms, biological oxygen demand, zinc, manganese, lead, and cadmium exceed the USEPA limit for water bodies during either season. This expresses that the Chemu lagoon is polluted to the extent of the concentrations identified and presented in Table 2. The parameters that were below the acceptable level include ammonia and dissolved solids. In the case of ammonia, the acceptable level is 10 mg/L, but the values for the five sites were below the acceptable level; 1.82, 6.21, 2.11, 3.14 and 1.81 mg/L, respectively. According to De Lacerda [28], findings identify input pathways, including river-fed pollution, the atmosphere, and direct effluents, which are all at play in the Chemu lagoon's catchment.

There is a significant distinction between what should be considered the optimal range and the precise thresholds based on the comparisons made between the samples collected and pre-established permissible limits for the quality of water bodies laid down by the Environmental Protection Agency of the United States. It is a clear indication that the lagoon is polluted. Activities of the local people and the activities of the industries surrounding the lagoon attribute the higher pollution levels of the lagoon.

4.3. Seasonal Differences in the Concentrations of Parameters

Paired-sample t-test was conducted to explore the differences between the concentrations for parameters for the wet and dry seasons. The results of the paired-sample t-test have been presented in Table 3. As shown in the table, the study has established that no statistically significant differences exist between the wet and the dry seasons' concentrations or levels of salinity, conductivity, temperature, total dissolved solids (TDS), sulphates, phosphates, potassium, BOD, total cyanide, lead, total cadmium, and mercury. For the pH, the study found a significant increase ($t(4) = -3.434$; $p = 0.026$) in the level of the measure of acidity or alkalinity from the wet season (mean concentration [M] = 8.9; standard deviation [SD] = 0.48) to the dry season (M = 9.46; SD = 0.46). A significant effect size expressed by an eta-squared statistic of 0.75 is established for the seasonal differences in pH in the Chemu lagoon.

The results for turbidity found that the passage of time underscores differences in seasons' turbidity observations between the wet and dry seasons. Where a significant seasonal variation ($t(4) = -3.062$; $p = 0.038$) marked with an eta squared statistic of 0.7, signifying a large effect size between the wet season (M = 47.4; SD = 18.32) and the dry season (M = 61.4, SD = 9.84). The paired-sample difference in the ammonia concentration found a $t(4) = -3.048$; $p = 0.038$ with an eta squared of 0.7, connoting a large effect size. For faecal coliforms, the study has found a statistically significant increase ($t(4) = -2.834$; $p = 0.047$) in concentrations with the change from wet (M = 1905.2; SD = 645.23) to the dry (M = 2545.6; SD = 779.4) seasons.

Table 2. Means of seasonal concentrations of parameters.

Parameter	Wet season mean	SD	Dry season mean	SD	USEPA limit
pH	8.9	0.48	9.46*	0.46	6.5 to 9
Salinity	1.7	1.29	0.95	1.27	
Conductivity	5.28	3.87	7.52	12.7	
Turbidity	47.4*	18.3	61.4*	9.84	< 0.2 Nephelometric turbidity unit (NTU)
Temperature	32.7*	3.37	33.0*	1.24	< 25^{O}C
TDS	382	153	342	114	500mg/L (500ppm).
Ammonia	3	1.87	4.74	2.32	50 mg/L
Sulphates	897*	317	838*	355	250 mg/L
Phosphates	2.22*	1.28	2.37*	1.40	0.05 mg/L
Faecal coliforms	1905*	645	2545*	779	200 Colony forming unit (CFU) per 100 mL
Potassium	7.30	2.29	7.76	2.45	- -
Chromium	2.41	1.05	0.14	0.09	0.1 mg/L
Bilogical oxygen demand (BOD)	576*	448	602*	457	50 – 200 mg/L
Nickel	8.38	0.42	9.57	0.46	0.1 mg/L
Zinc	17.4*	0.66	23.3*	1.66	5 mg/L
Iron	22.9	0.95	26.6	1.75	0.3 mg/L
Benzene	36.4	11.0	46.8	13.5	0.2 mg/L
Manganese	0.72*	0.23	1.3*	0.1	0.5 mg/L
Total cyanide	1.08	0.93	1.06	0.54	0.2 mg/L
Total Arsenic	0.88	0.7	1.14	0.91	0.01 mg/L
Lead	0.48*	0.34	0.65*	0.17	0.05 mg/L
Total cadmium	0.05*	0.02	0.32*	0.23	0.003 mg/L
Mercury	0.03	0.01	0.03	0.02	0.002 mg/L

Note: *Exceed permissible limit.
Source: Fieldwork, (2021).

Table 3. Paired-sample differences in parameters' concentrations.

Pair (Wet season – dry season)	Mean difference	T	Sig.	Eta squared
pH	-0.56	-3.43	0.03*	0.75
Salinity	0.75	1.29	0.26	0.29
Conductivity	-2.24	-0.55	0.61	0.07
Turbidity	-14.0	-3.06	0.03*	0.70
Temperature	-0.32	-0.23	0.83	0.01
TDS	39.6	1.56	0.19	0.38
Ammonia	-1.79	-3.05	0.03*	0.70
Sulphates	58.4	1.21	0.29	0.27
Phosphates	-0.15	-0.74	0.50	0.12
Faecal coliforms	-640.4	-2.83	0.04*	0.67
Potassium	-0.46	-1.12	0.32	0.24
Chromium	2.27	4.78	0.00*	0.85
BOD	-26.0	-0.59	0.58	0.08
Nickel	-1.18	-4.34	0.01*	0.83
Zinc	-5.92	-10.6	0.00*	0.97
Iron	-3.69	-5.49	0.00*	0.88
Benzene	-10.4	-2.97	0.04*	0.69
Manganese	-0.58	-4.96	0.00*	0.86
Total cyanide	0.02	0.09	0.93	0.00
Total Arsenic	-0.26	-2.15	0.09*	0.54
Lead	-0.17	-1.94	0.12	0.48
Total cadmium	-0.27	-2.54	0.06	0.62
Mercury	-0.005	-0.58	0.59	0.08

Note: * Connotes a p-value is less than 0.05, which expresses a statistically significant difference in the respective parameter.
Source: Fieldwork: (2021).

An eta stared statistic of 0.67, expressing a large effect size, has been established for the seasonal differences in faecal coliforms. The only parameter to observe a decrease in concentrations as a response to seasonal change from the wet ($M = 2.41$; $SD = 1.05$) to the dry ($M = 0.14$; $SD = 0.09$) seasons. Chromium concentrations for either season are significantly varied ($t (4) = 4.779$; $p = 0.009$), with a large effect size (eta squared statistic = 0.85). For nickel, zinc, iron, benzene and manganese, the study established increases in their concentrations, which are also not confirmed by chance. Finding the most significant effect size (eta = 0.97) among all the differences shown, the case for zinc expresses a mean difference of -5.92 for a $t (4) = -10.592$; $p = 0.000$). The wet season concentration for nickel ($M = 8.38$; $SD = 0.42$) significantly increased following the passage of time, where a mean zinc concentration of 9.51 and a standard deviation of 0.46 was found for the dry season. The cases for iron, benzene, and manganese found t-values of $t (4) = -5.49$, $p = 0.005$; $t (4) = -2.97$, $p = 0.041$; and $t (4) = -4.961$, $p = 0.008$, with eta squared statistics of 0.88, 0.69, and 0.86, which all indicate large effect sizes respectively for the seasonal differences in iron, benzene, and manganese. Total Arsenic, the study also found a large effect size (eta square = 0.54) for the seasonal difference in the concentrations. This effect size is the least identified among the studied parameters. Despite this, a mean difference of -0.26 has been found for a $t (4) = -2.152$, $p = 0.098$ to express seasonal increase in total arsenic concentrations.

4.4. Residents' Perception of the Status of the Chemu Lagoon

The results from the study indicate that the residents are much aware of the pollution of the water body. About

92% said the lagoon is polluted, while only 8% believed it is not contaminated Table 4. The level of perception of the residents may go a long way to finding a lasting solution to the problems confronting them since they are aware of the extent of the problem and may advocate for alleviating the pain.

Table 4. Rating of perception by residents.

	N	Mean	SD	Skewness		Kurtosis	
Lagoon status indicator	**Statistic**	**Statistic**	**Statistic**	**Statistic**	**S. E**	**Statistic**	**S. E**
Low fish catch	200	4.76	0.43	-1.23	0.17	-0.50	0.34
Odour in the community	200	4.71	0.61	-1.95	0.17	2.49	0.34
Poor water quality	200	4.61	0.62	-1.34	0.17	0.70	0.34
Extinction of fish	200	4.76	0.43	-1.23	0.17	-0.50	0.34
Extinction of native vegetation	200	4.56	0.64	-1.16	0.17	0.22	0.34
Depth of lagoon	200	4.65	0.66	-1.65	0.17	1.33	0.34
Colour of lagoon water	200	4.65	0.50	-0.90	0.17	-0.60	0.34
Waste deposition by industries	200	4.86	0.35	-2.09	0.17	2.40	0.34

Note: 1 = Strongly disagree, 2 = Disagree, 3 = Don't know, 4 = Agree, 5 = Strongly disagree.
Source: Fieldwork: (2021).

To further interrogated the respondents on their perceptions of the Chemu lagoon. A Likert scale was developed to solicit their views on some variables. Table 4 presents the views expressed by the respondents. The first variable was waste deposition by nearby industries into the lagoon. Waste deposition by nearby enterprises was considered the most dominant variable affecting the lagoon, with mean = 4.86 (SD = 0.35), which attests to the respondents' strong agreement with the position that waste deposition by industries induces pollution of the lagoon. To establish that there has been a change in the quality of the Chemu lagoon, the study sought to evaluate the respondents' perception of the lagoon's odour. The study found a mean of 4.71, with a standard deviation of 0.61, indicating that respondents strongly agree that the lagoon brings forth offensive odour around the local communities. In analysing the ability of the lagoon to support aquatic life, the study found that some fish species in the lagoon have gone extinct. The study found a mean of 4.76 with a standard deviation of 0.43 to establish the case. To the same degree, this translates into an expression that there has been a decline in the fish catch and, consequently, lower economic returns. This backs up [29] claim that a wide range of substances such as oil, gasoline, plastics, pesticides, cleaning detergents, and solvents can endanger public health and fish and other aquatic organisms. The study also has established that the Chemu lagoon has assumed shallowness as the results express a mean of 4.65 and a standard deviation of 0.65, suggesting that the refuse deposition into the lagoon has resulted in sedimentation, leading to its shallow nature. Boateng, et al. [5], as an indication of high eutrophication, also reported the shallowness of lagoons in Ghana, predisposing the lagoons to other events such as flooding and an increase in temperature. Following the establishment of refuse deposition into the lagoon, the study investigated means of waste disposal in the study area. The survey showed that 62% of respondents either dispose of household waste into refuse containers or have agreed with a waste management entity to collect them whenever their bins are full. The remaining 38 per cent either cast their destruction at the shores of the lagoon or empty them into the drains, which as well have the potential to end up in the immediate lagoon environment. As shown in Figure 3, 45%, 34%, 4%, and 17% of residents explicitly expressed that they manage waste by disposing of it in refuse containers, on the lagoon's shores, into drains, and collecting by waste contractors, respectively. Restudy positions that it is not automatic that the case expressed here is the reflection of reality since the researchers acknowledge the room for false information shared by respondents concerning their means of waste disposal. Other things being equal, though the study's goal was presented to the respondents, some respondents would still share false information for fear of being arrested for disposing of waste in an environmentally unfriendly manner. Respondents, however, reported that many people defecate on the lagoon's shores; the faeces eventually end up in the lagoon, and consequently, the higher accumulation of faecal coliforms, especially the higher level in the wet season, and the higher concentration in the dry season.

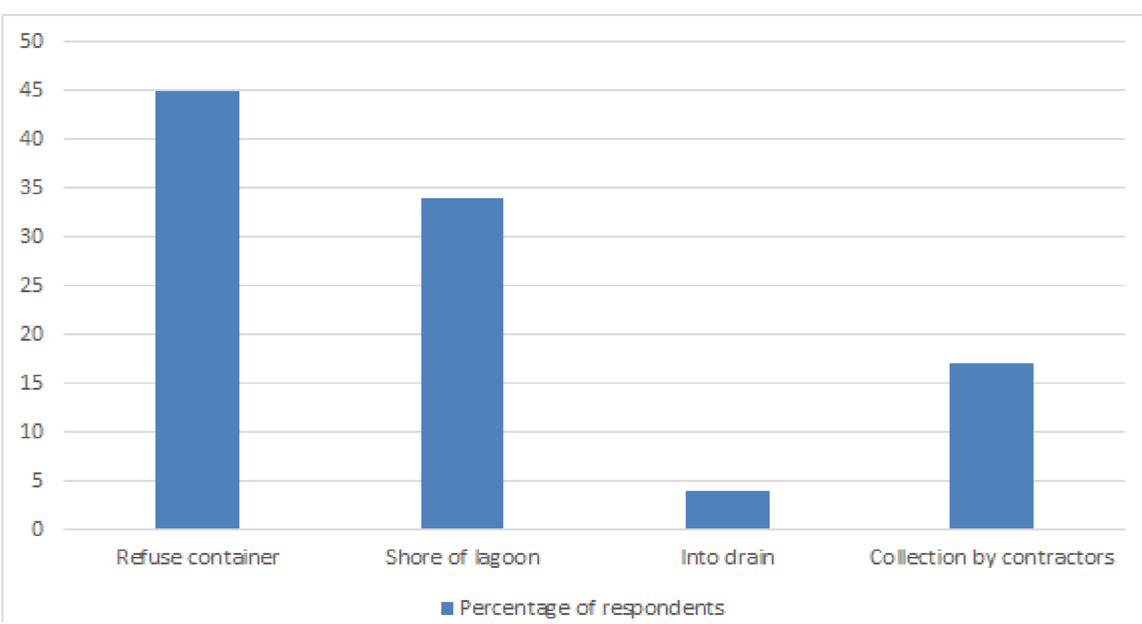

Figure 3. Disposal of solid waste in the area.

Source: Fieldwork, (2021).

Again, to further explore the level of awareness, the residents were asked why some of them fly-tip the domestic waste. Eighty-six per cent (86%) of the respondents believed that there were inadequate refuse collection points in the area, with 14.0% saying that refuse collection points in their place were adequate Table 5. These results further explain why some residents chose to dispose-off refuse indiscriminately in the study area. Figure 4 shows the unsanitary conditions at Abonkor, one of the four communities selected for the study. Refuse was found at the doorsteps of residents.

Figure 4. Insanitary conditions in a squatter settlement at Abonkor.
Source: Ghana Business News [30].

4.5. Contribution of Socio-Economic Activities to Pollution of the Chemu Lagoon

Human activities around the lagoon impinged the environment, affecting flora and fauna. The Chemu lagoon, which was once a nesting place for birds and provided boating facilities for tourists, is now polluted and almost empty. According to the study results shown in Table 5, 82% of the respondents believed that tourist operations had a detrimental effect on the lagoon. Around 18% of those polled were of the opposing opinion. The respondents espoused that the activities of the visitors contribute to waste generation. Most visitors deposed items, including polythene bags, empty cans, food items and other waste products along the lagoon, which in the long run, ended up in the lagoon—the result above shows that waste disposal facilities were not adequate. The results attest to the observation by Molina and Molina [31] that dense concentrations of the population, such as those found in large cities, or are brought together by warfare and trade, tourism, etc., are usually necessary for water-borne diseases to attain epidemic proportions through the accumulation of waste. It is also consistent with the findings of the Environmental Protection Agency [EPA] [32], which observed poor domestic sanitary conditions and illegal dumping of metropolitan solid and liquid materials as the primary prevalent challenges facing coastal regions.

Figure 5. Fishing activities in the polluted Chemu Lagoon.
Source: Fieldwork, (2021).

Results from the study, Table 5, indicate that the respondents were very much aware of the pollution of the lagoon. Ninety-two per cent (92%) of the inhabitants were aware of the lagoon being polluted, while only eight per cent (8%) were not of pollution in the lagoon's environment. The results imply that the inhabitants know about the various environmental problems in the area. This supports the view expressed by Thorne-Miller [33], who posits that people are most of the time aware that, accidentally or deliberately, the substances and materials they release into water bodies act in and on the environment. Figure 5 illustrates fishing activities ongoing in the polluted lagoon, though respondents are aware of the lagoon's status as polluted.

Figure 6. Satellite image of urban growth towards the floodplains of the Chemu Lagoon.
Source: Google Earth (2022).

Table 5 shows that (96 per cent) of participants believe that the development of squatter settlements has contributed significantly to the contamination of the lagoon. The other 4% disagreed. Personal observations by the researchers indicated that in some areas, the growth of slums had led to the discharge of untreated wastes and, consequently, led to the gradual pollution of the wetlands surrounding the lagoon where aquatic life would thrive. An observation of the lagoon shown in the satellite image in Figure 6 shows urban growth enclosing the Chemu lagoon. Surface run-off from point source pollution, such as residential and commercial sewers, can carry harmful emissions like soil particles, pesticides, and fertilisers into coastal wetlands. According to the Environmental Protection Agency [EPA] [32], the Korle, Osu Klottey, and Kpeshie Lagoons in Accra and the Fosu Lagoon in Cape Coast are all in multiple states of degeneration and environmental damage as a result of the effects of poor residential sanitation.

4.6. Health and Socio-Economic Effects of the Lagoon Pollution

Results from Table 5 indicate that 84% of the respondents believe that people fall sick frequently due to the polluted environment, while 16% shared the opposite view. Poor domestic sanitation was the most pervasive of all of the problems found around the lagoon. This environmental problem facilitates the locals' poor health, the lagoon's polluted ecological status, and the unappealing situations that impede economic and social development, such as tourism. Mulamoottil [34] stated that unsanitary environments directly or indirectly cause up to 40% of diseases reported at hospitals nearby.

Table 5. Residents' perception of the status of the Chemu lagoon.

Item	Response	Frequency	Percentage
Awareness of the Chemu Lagoon pollution	Yes	347	92
	No	30	8
Adequacy of refuse collection points in the area	Yes	53	14
	No	324	86
Pollution of Chemu Lagoon by visitors	Yes	309	82
	No	68	18
Waste disposal facilities near the lagoon	Yes	53	14
	No	324	86
Slums created around the lagoon	Yes	362	96
	No	15	4
Effects of pollution on human health	Yes	317	84
	No	60	16
Authorities organising meeting on Chemu Lagoon	Yes	79	21
	No	298	79

Source: Fieldwork, (2021).

Figure 7 shows the respondents who attributed the various diseases reported in the study area to pollution. Most (64%) respondents attributed the malaria outbreak to pollution. Again 25% of them viewed that pollution caused typhoid fever in the area. Six and five per cent (6%, & 5%) said pollution caused cholera and abdominal pains in the studied communities. The diseases mentioned above are primarily endemic in polluted and dirty environments where people defecate and dispose of waste indiscriminately. The study confirms the findings of Owusu Boadi and Kuitunen [19] from their survey of the Korle Lagoon that the presence of water does not always make communities healthier. Water carries harmful organisms or germs that cause cholera, typhoid, and diarrhoea.

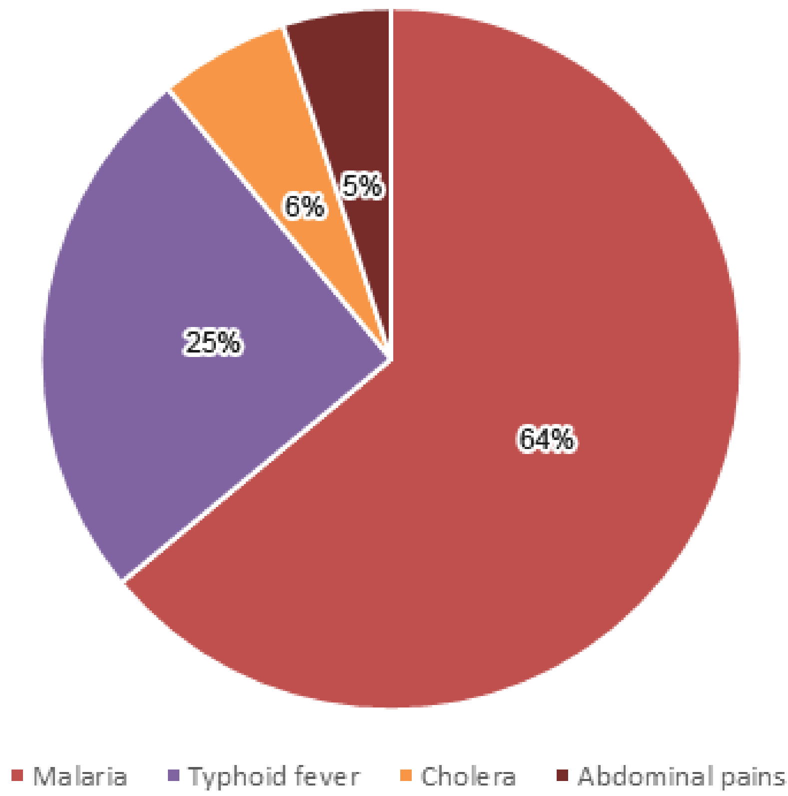

Figure 7. Health effects of pollution of the Chemu lagoon.

Source: Fieldwork, (2021).

4.7. Efforts Made by Stakeholders to Combat Pollution of the Chemu Lagoon

Though several legislations exist on coastal protection and sustainable management, there was the need to determine whether the community members had taken it upon themselves to protect the lagoon from pollution and extinction. Table 6 presents the residents' views on the attendance of the meeting to discuss the lagoon's pollution issue. From Table 6, 79% of the respondents said they had not heard about any form of meeting concerning lagoon management. About 21% said they had heard about some meetings. The findings corroborate the Environmental Protection Agency [EPA] [21] position that the authorities should enforce environmental stewardship laws in the catchment. The Ministry of Environment and Science and the Environmental Protection Agency (EPA) is projected to investigate the ecological consequences of sanitary development initiatives.

Table 6. Institutions that call meetings.

Agencies	Frequency	Percentage
Assemblyman	21	5.5
Chief	15	4.0
NGO's	43	11.5
TMA	298	79.0
Total	377	100

Source: Fieldwork, (2021).

When asked if there were institutions that organised meetings on the lagoon's pollution, 79% of the respondents said the Tema Metropolitan Authority (TMA) organises such conferences. Others (about 12%) said that some non-governmental organisations (NGOs) do that, while 21 respondents mentioned that the Assembly members of the study areas do that, as presented in Table 6. These results indicate that the lagoon's mandate on protection and sustainability is virtually in the hands of TMA and the NGOs. Consequently, the TMA must embark on serious health education in the communities. The data reinforce the Environmental Protection Agency [EPA] [32] assertion that Ghana has a diverse range of non-governmental organisations and neighbourhood entities dedicated to environmental preservation and enhancement.

The chiefs and assembly members of the selected communities are responsible for protecting and regulating the residents' activities. Still, their efforts (to preserve the lagoon) often meet challenges, including opposition from the community members who depended on the lagoon for their livelihoods. When the respondents were asked if the authorities act to protect the lagoon from pollution, 67% said that the leaders were helping in discussions to address the pollution problems and to stop the indiscriminate disposal of waste. In comparison, 33% said no authority helped.

5. Discussions

The pollution issue of Ghana's coastal lagoons was identified decades ago [6]. Admittedly, nothing has changed to this day. According to the IPCC [35]; IPCC [36], releasing untreated sewage, manufacturing, and agricultural residues contaminates most coastal lagoons in West Africa, including Ghana. Urbanisation, industrialisation, population pressures and poor waste management systems commonly cause pollution. The pollution has adversely affected the ecosystem services of the lagoons, particularly fisheries resources and migratory birds from Europe [3, 37]. The results from the water quality analysis of the Chemu lagoon showed that turbidity, temperature, sulphate, phosphates, faecal coliforms, biological oxygen demand, zinc, manganese, lead, and cadmium exceeds the USEPA's permissible limits. This finding is in line with Adu-Boahen and Boateng [23] studies on the Fosu lagoon in Ghana that revealed higher concentrations of like parameters. Similar results were recorded by Biney [15] in the Chemu Lagoon. Biney [15] found that the surface water temperature of the lagoon ranged between 22^{O}C and 36^{O}C and attributed higher water temperature to the thermal pollution originating from industrial sources. The implication is that knowledge about pollution was known to the residents, but no significant improvement has been achieved over the years. The results stand with the position of Koledoye, et al. [38], who found in their study on the Lekki lagoon that anthropogenic activities have latent health and environmental impacts that have prognosticated grave concern if not urgently mitigated. In another study [39] on the Muni Pomadze and its catchment, it was revealed that most of the Physico-chemical properties studied, temperature, TDS, conductivity, pH, salinity, and dissolved oxygen (DO) were within the acceptable limit of USEPA for freshwater resources.

According to Molina and Molina [31] the Head of the EPA in Tema, Mr Lambert Faabeluon, told the Daily Graphic that the institution and other interested parties had held a total of 12 symposiums and consultations since 1999 to probe strategies for preventing further harmful discharges into the Chemu lagoon, and to mobilise resources for the resuscitating the lagoon. Notwithstanding, hardly anything significant had come from the countless seminars and meetings held by relevant parties since 1999. The failure to progress on recovery and the lagoon's continued contamination is due to an absence of dedication by crucial parties to adopt measures and initiatives that will cease environmental damage and re-establish the lagoon.

Despite citizen science identifying that the residents are not naïve to the deteriorating quality of the lagoon, the people who, for that matter, would be interested in the welfare of the lagoon are culprits themselves, as they also contribute to the pollution of the lagoon. About 34% Figure 3 indicated that they dispose of the refuse in the lagoon and its environs. This put the residents in a compromising situation to demand changes. The local authority contributes to the problem by not providing adequate waste deposal facilities Table 5, thus forcing the residents to contribute to the pollution so that they cannot demand change because they are offenders.

This explains the reason the majority of the residents were aware of the extent of the pollution and its effects on health and socio-economic activities Table 5. Yet, they have failed to be the champions of change regarding the lagoon's pollution. The survey results from Table 6 indicate that the effort by the residents to restore the lagoon is about 10%. It is TMA and NGOs that have made the most effort. The most action should have come from the residents since they suffer from the immense pollution of the lagoon.

Because the former administration by TMA and NGOs did not produce the desired results, it is required to empower residents to direct the campaign for the rehabilitation of the Chemu Lagoon. There is a need to bring all stakeholders on board in a participatory manner under the residents' leadership to develop the Chemu lagoon restoration plan. Such a plan will not be viewed as the traditional top-down government policy; all the participating stakeholders will own it. Such ownership by the stakeholders will facilitate the successful implementation of the plan.

Regardless of the apparent connection between contamination and the development of fishery ecosystems (types of fish) and other economic interests from the Chemu Lagoon, there were insufficient patterns and attitudes on the degree of the environmental damage as well as the clear implications on local people's well-being and socio-economic existence. This paper has provided the baseline information required for action on developing a management strategy and committing to applying the existing environmental laws and policies in Ghana. The environment cannot be limited by national territorial boundaries [40]. Migratory birds that feed on the lagoon habitat could extend the impact of the pollution beyond Tema and its environs. Therefore, national, regional and international environmental pressure groups must join the call to restore Chemu and other polluted lagoons in Ghana.

The following recommendations are made in light of the findings:

- The Environmental Health Department and the Waste Management Department of the Tema Metropolitan Assembly are advised to intensify their house-to-house hygiene education and inspections in the catchment area on proper waste disposal to prevent indiscriminate defecation and flying tipping.
- The effective use of the limited facilities located along the stretch of the lagoon should be addressed. The Assembly should increase the number of waste and sanitary facilities in the catchment area.
- The Sanitation Task Force of the Tema Metropolitan Assembly should check the activities of the local people which pollute the lagoon.
- Offenders found of indiscriminate defecation and dumping of refuse should be arrested and prosecuted to serve as a deterrent.
- The Assembly should stop further slum creations and demolish the existing ones in the catchment area.
- Residents, the Tema Metropolitan Assembly, the Tema Traditional Council, local industries, and the Central Government should work together to replenish the lagoon to its natural form. The collaborative efforts would strengthen the socio-economic status functions of the residents. The Assembly should prioritise the area's development into parks and gardens to assist in restoring the polluted ecosystems.

6. Conclusions

The outcomes of water quality analyses using water samples from Chemu lagoons were significantly higher than the USEPA-recommended thresholds. This could be related to the lagoons being used as dumping grounds by most residents and the release of industrial emissions into the lagoons. Almost all the water quality parameters measured had higher values in the dry season than in the wet season. These results could be due to the evaporation of water from the lagoons' interface during the dry season, which resulted in higher concentrations in the lagoons. The level of siltation and the dumping of refuse into the lagoon hampers the free flow of water and hence encourage mosquito breeding of mosquitoes and the incidence of high malaria outbreak and other related diseases affecting the health and socio-economic lives of the people. The study concludes for informed resuscitation of the lagoon and the preservation of its ecological services, the data from this study, combined with future data, may help to monitor the Chemu lagoon. The various stakeholders are not doing enough to help combat the pollution problems in the area. It is worth noting that most respondents are unaware of any environmental law on the dumping of waste or the activities of groups forming slums along the lagoon and their further pollution. Insufficient sanitary facilities have led to indiscriminate solid waste disposal and defecation at the lagoon's banks.

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