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Socio-Economic and Environmental Impacts of Poor Liquid Waste Management in the Municipality of Seme-Podji in Southeast Benin

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Abstract

Poor practices in the disposal of wastewater, excreta, and rainwater constitute a major environmental problem. The methodological approach used consisted first of data collection, then data processing, and finally analysis of the results. The data were processed using Excel, SPSS, and ArcView software. The disposal method is autonomous (individual), with significant gaps in collective systems. Household liquid waste is very often discharged directly into the yard, into the street (42%), or into gutters (often designed for rainwater). The population disposes of sewage through ventilated pit latrines (45% of respondents), unventilated pit latrines (32%), suspended latrines (7%), and flush toilets (16%). The environmental impacts of poor liquid waste management include ecosystem degradation (45% of respondents), groundwater and surface water pollution (36%), and inadequate drainage and flooding (19%). Pollution threatens the biodiversity of wetlands (marshes, lagoons) and receiving water bodies (Lake Nokoué), which can affect local flora and fauna. The types of diseases linked to poor liquid waste management are malaria (39% of respondents), diarrheal diseases (23%), acute respiratory infections (16%), typhoid fever (10%), dermatoses (7%), and anemia (5%).

Keywords

Municipality of Sèmè-Podji, Liquid Waste, Socio-Economic and Environmental Impacts, Management

1. Introduction

Since gaining independence, sanitation problems have become more acute in African countries. The ever-increasing urban population, unaccompanied by urbanization plans, is one of the causes of wastewater discharge in most cities in African countries [1]. Indeed, urban sprawl is a current phenomenon. Cities are growing with the expansion of new suburbs, due to the residential mobility of populations moving from city centers to the outskirts. This urban expansion raises the issue of controlling demographic and spatial growth [2]. Urban centers are environments where various human activities (commerce, industry, education, etc.) take place and where a large population is concentrated, producing significant amounts of liquid waste. Wastewater is discharged into the environment. The issue of increasing waste of all kinds in urban centers has attracted the interest of African states, which are placing this concern at the heart of debates [3]. Rapid urbanization and population growth are driving the increasing demand for water and, consequently, the production of liquid waste in various forms. Populations generally find themselves in precarious sanitary conditions due to a lack of adequate sanitation services [4].

In developing countries, there is a failure of the sanitation system, marked by an uneven spatial distribution of the collective network, which is very often concentrated in the city center. In several cities, drainage networks only exist in modern centers and are virtually insufficient [5]. Poor practices in the disposal of wastewater, excreta, and rainwater are a major environmental problem. The lack of sanitation facilities and collective systems has forced people to resort to local sanitation solutions that do not comply with construction standards. The topographical features of the area, with its flat terrain and gentle slopes (less than 1% and rarely reaching 3%), combined with the dangerous practices of very poor local sanitation implemented by households in the city, increase environmental risks [6]. Populations are more vulnerable to environmental risks. The construction of collective sanitation facilities to which households in densely populated and precarious neighborhoods would be connected would significantly reduce households' vulnerability to these health risks [7]. Spatial and demographic dynamics go hand in hand with a lack of urban waste management services. This phenomenon gives rise to the proliferation of liquid waste and exposes local populations to so-called environmental diseases. Faced with rapid population growth and a glaring lack of sanitation infrastructure, the management of this wastewater and its impact on the population is becoming a cause for concern. Households dispose of wastewater in septic tanks, cesspools, and even in the street. These practices degrade the living environment and expose the population to diseases such as malaria, typhoid fever, diarrheal diseases, and acute respiratory infections [8]. The municipality of Sèmè-Podji is no exception to this reality. Poor liquid waste management affects the environment and the health of the population.

2. Study Area

The research area is the municipality of Sèmè-Podji, located in the department of

Ouémé in southeastern Benin. The municipality of Sèmè-Podji is located between 6˚22'30" and 6˚27'30" north latitude and between 2˚31'30" and 2˚42'0" east longitude. It is bordered to the northwest by Lake Nokoué, to the northeast by the Porto-Novo Lagoon, to the south by the Atlantic Ocean, to the east by the Federal Republic of Nigeria, and to the west by the municipality of Cotonou (**Figure 1**). The municipality of Sèmè-Podji has six (06) districts, namely: Agblangandan, Ekpè, Sèmè-Podji, Djèrègbé, Tohouè, and Aholouyèmè, covering an area of 250 km^2. The geographical location of the municipality of Sèmè-Podji contributes to human settlement and the production of liquid waste that pollutes the environment.

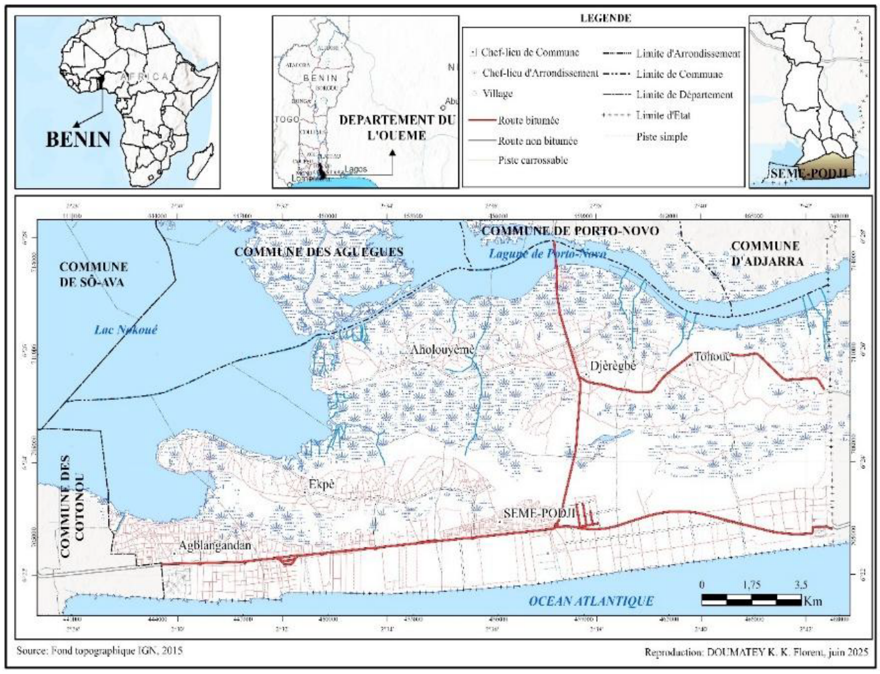


Figure 1. Geographic and administrative locations, Sèmè-Podji municipality.

3. Materials and Methods

Statistics on diseases, particularly waterborne diseases, recorded in the research area were collected from public health centers and from interviewed households. They were used for a brief analysis of the evolution of waterborne diseases in the research area. The socio-anthropological data relate to liquid waste management practices. These data are supplemented by data from a literature review and socio-sanitary surveys conducted with 288 households selected from the 37,249 households in the municipality of Sèmè-Podji, based on Schwartz's statistical protocol (2002). For this research, statistical analysis of the data was performed using descriptive statistics and statistical tests. For qualitative variable data, response frequencies were calculated, while for quantitative variables, means and standard errors were calculated. The databases thus obtained were exported to SPSS version 17.0 for tabulation.

3.1. In Situ Measurement of Physicochemical Quality and Sampling of Domestic Wastewater

Monthly measurements of physicochemical parameters, namely temperature, pH, total dissolved solids (TDS), and conductivity, were taken *in situ* between 8 a.m. and 12 p.m. at each station on a monthly basis for two years, covering both dry and rainy periods. Temperature, conductivity, and TDS were measured using a HANNA HI 99300 multimeter. pH was measured with a HANNA HI 98107 pH meter. Water samples were taken at each station and stored in sterile bottles. The bottles were labeled, stored in a cooler containing ice, and transported to the laboratory for analysis of BOD5, nitrates, nitrites, ammonium, and orthophosphates. Biochemical oxygen demand was measured using a BOD meter. Parameters such as nitrate, ammonium, and orthophosphates were measured using the cadmium reduction method, the Nessler method, and the phosVer 3 method, respectively, using a DR/6000 spectrophotometer.

3.2. Sampling and Transport of Water at Autonomous Water Stations (PEA)

Samples were taken from various water points in the two districts using 500 ml glass bottles that were washed and rinsed with distilled water. After drying, the openings of the bottles were plugged with carded cotton and wrapped in aluminum kraft paper. They were then sterilized in an autoclave. The caps were also washed, rinsed in the same way, dried, wrapped in aluminum kraft paper, and sterilized under the same conditions as the bottles. The samples were immediately sent to the laboratory. Water samples were also taken from Autonomous Water Stations (PEA). Water samples taken from four wells (04), two per district, were analyzed at the DG-Eau laboratory. This work was preceded by sampling at the wells. For the water analysis, certain water sources in the municipality were targeted based on their spatial distribution. The physical, chemical, and bacteriological analyses on which this study is based were carried out by the DG-Eau. The concentration of biological, physical, and chemical elements in the water samples was determined by measurement. The results obtained were compared with the standards in force in Benin. The different methods used and their parameters are presented in **Table 1**.

Table 1. Physicochemical and bacteriological parameters analyzed in water samples and their methods of analysis.

Parameters		Analysis methods used
Physical	- Color - Conductivity - Hardness - Temperature - Turbidity - PH	Spectrophotometry

Continued

Chemicals	- Magnesium, - Calcium, - Bicarbonates - Iron - Nitrates - Sulfates	Titrimetry
Bacteriological	- Fecal coliforms - Total coliforms	Filtration through two different membranes

Source: Fieldwork, May 2025.

The analytical methods used are titrimetry and spectrophotometry. Titrimetry was used to determine the chemical composition in terms of magnesium, calcium, and bicarbonate ions. This method involves volumetry, which consists of taking a certain volume (50 mL) of the sample (for calcium and magnesium) and 100 mL (for bicarbonate). Colorimetry is based on the change in color after titration. Spectrophotometry also involves volumetry and colorimetry, with the only difference being that the spectrophotometer reads the change in color. During this work, the focus is mainly on the physicochemical and bacteriological parameters of drinking water in the municipality of Sèmè-Podji. For fecal and total coliforms, the samples are filtered through two different membranes, under the conditions specified above, with two test samples of the water to be analyzed carefully homogenized by agitation.

3.3. Determination of the Organic Pollution Index (IPO)

Leclercq's Organic Pollution Index (IPO) (2001) was used to assess the organic load in watercourses. The IPO classifies water quality into five (05) classes. This index is obtained using the values of ammonium, BOD5, nitrites, and orthophosphates. The calculation principle is to divide the values of the four pollutants into five classes and, based on the values obtained, determine the corresponding class number for each parameter using the average data in **Table 2**. The final index is the average of the pollution classes for all parameters.

Table 2. IPO Classes and characterization of pollution levels.

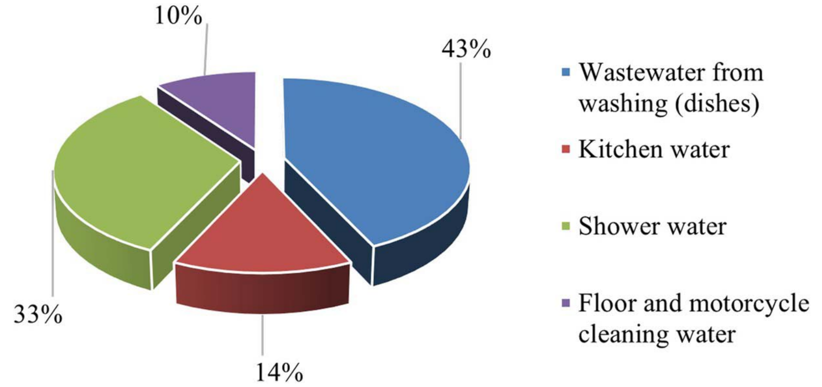
Classes	**BOD5 (mg O_2 /l)**	NH_4^+ **(mg/l)**	NO_2^- **(µg/l)**	PO_4^{3-} **(µg/l)**	**Class limits**	**Characterization of pollution**
5	< 2	< 0.1	< 5	< 15	4.6 - 5.0	None
4	2 - 5	0.1- 0.9	6 - 10	16 - 75	4.0 - 4.5	Low
3	5.1- 10	1 - 2.4	11 - 50	76 - 250	3.0 - 3.9	Moderate
2	10.1 - 15	2.5 - 6	51 - 150	251 - 900	2.0 - 2.9	Strong
1	> 15	> 6	>150	> 900	1.0 - 1.9	Very strong

Source: [9].

4. Results and Discussion

4.1. Main Sources of Liquid Waste and Frequency of Production

Liquid waste comes from several sources. Figure 2 shows the main sources of household liquid waste in the municipality of Sèmè-Podji.



Data source: Field surveys, May 2025.

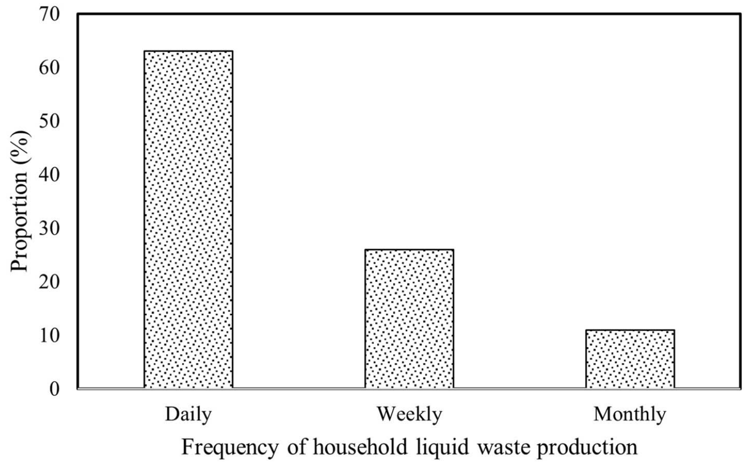
Figure 2. Main sources of liquid waste in the municipality of Sèmè-Podji.

Figure 2 shows that household liquid waste includes laundry wastewater (43% of the people surveyed), shower water (33%), kitchen water (14%), and water used to clean floors and motorcycles at home (10%). Households therefore produce more laundry wastewater (Figure 3).

Photo taken: By Doumatey, May 2025.

Figure 3. Laundry activity in Sèkandji.

Figure 3 shows a housewife doing laundry in Sèkandji. Households generally use a variety of detergents and soaps available on the local market. Without proper management, these products can contribute to water pollution. Figure 4 shows the frequency of household liquid waste production in the municipality of Sèmè-Podji.



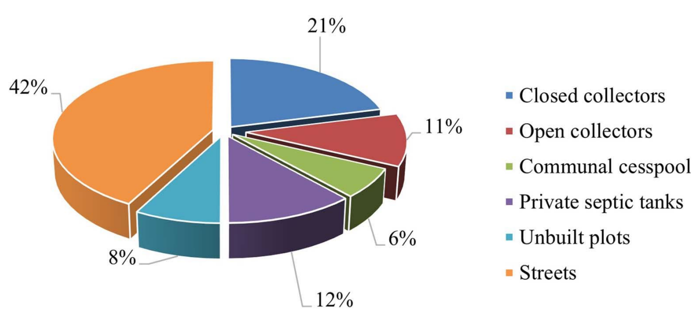
Data source: Field surveys, May 2025.

Figure 4. Frequency of liquid waste production in the municipality of Sèmè-Podji.

Liquid waste is produced daily (63% of people surveyed), weekly (26%), and monthly (11%). Kitchen and shower water is produced daily in the research area. Laundry water is produced weekly. In homes, the frequency of floor cleaning depends on several factors. Tiled or cement floors are often cleaned more frequently than dirt floors. High-traffic areas or homes located in dusty environments are cleaned more often (daily to several times a week). In addition, some families have higher standards of cleanliness than others. During the rainy season, mud requires regular cleaning. Motorcycles are a very common means of transportation in the municipality of Sèmè-Podji. How often they are cleaned also depends on usage, weather conditions, and aesthetic concerns. In general, people thoroughly clean their motorcycles and cars at home every 3 to 4 weeks. They rinse them more often, especially after driving in muddy conditions. These activities generate large amounts of liquid waste in the municipality of Sèmè-Podji.

4.2. Domestic Wastewater Disposal Methods

The population has several methods for disposing of wastewater from cooking, toilets, laundry, cleaning tiled floors, and motorcycles. Figure 5 shows the method of domestic wastewater disposal in the municipality of Sèmè-Podji.



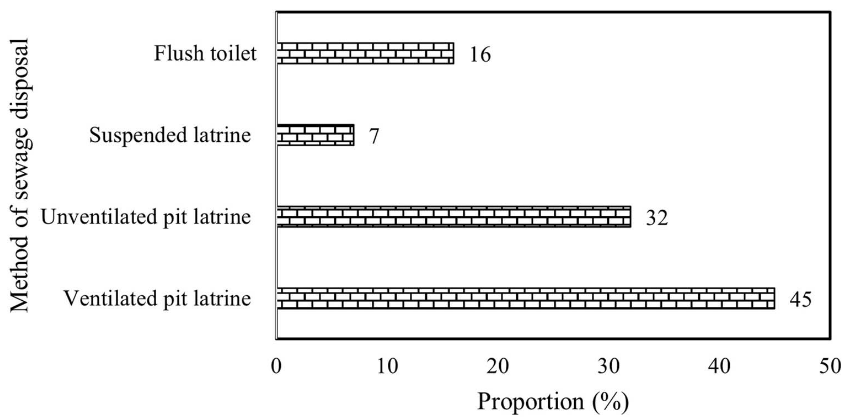
Data sources: Fieldwork, May 2025.

Figure 5. Domestic wastewater disposal methods in the municipality of Sèmè-Podji.

Analysis of Figure 5 shows that 42% of the people surveyed dispose of domestic wastewater outside in the streets, 21% discharge wastewater into closed collectors, 12% discharge directly into private septic tanks, 11% discharge into open sewers, 8% discharge onto undeveloped plots of land, and 6% discharge into communal pits. The majority of disposal methods are autonomous (individual), with significant gaps in collective systems. Liquid household waste is very often discharged directly into the yard, onto the street, or into gutters (often designed for rainwater). In addition, 34% of households have cesspools or infiltration trenches to try to dispose of gray water into the ground. However, the effectiveness of these systems is limited by the low infiltration capacity of clay soils and the shallow water table, which quickly leads to clogging and surface discharge. In the municipality of Sèmè-Podji, liquid waste is poorly disposed of. The lack of disposal infrastructure has led to poor waste management, resulting in unsanitary conditions and pollution of the population's living environment. The problem of domestic wastewater management in Sèmè-Podji stems from poor governance and a lack of action to raise public awareness. Similarly, there is no collective sanitation network. Water discharged into the environment pollutes the environment and groundwater. In fact, the population produces wastewater that is poorly managed at the end of the process. This water remains a potential hazard and provides a breeding ground for mosquitoes and other parasites. [10] notes that homes do not have adequate and appropriate sanitation systems. The population uses inappropriate methods for disposing of domestic wastewater.

4.3. Main Method of Sewage Disposal in the Municipality of Sèmè-Podji

In the municipality of Sèmè-Podji, the main method of sewage disposal (wastewater from toilets, containing feces and urine) is autonomous sanitation. Figure 6 shows the main method of sewage disposal in the municipality of Sèmè-Podji.



Data source: Fieldwork, May 2025.

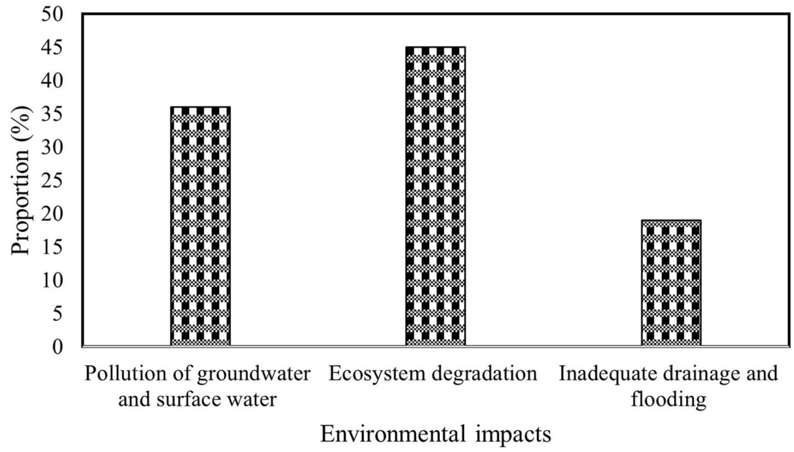
Figure 6. Main method of sewage disposal in the municipality of Sèmè-Podji.

People dispose of sewage through ventilated pit latrines (45% of those surveyed), unventilated pit latrines (32%), hanging latrines (7%), and flush toilets (16%). Ventilated pit latrines are therefore more commonly used for sewage disposal. Ventilated improved pit latrines (VIPs) have a ventilation pipe (chimney) extending from the pit to above the roof of the superstructure. This pipe is usually dark (black) to heat the air inside, creating an upward draft that draws odors from the pit to the outside and attracts flies (drawn to the light) to an insect screen placed at the top of the pipe, preventing them from leaving the pit and reproducing. The defecation hole inside the latrine is kept closed by a lid or fly screen. In addition, ventilated pit latrines are primarily designed for solid excreta and a very small amount of anal cleansing water. In urban districts (Agblangandan, Ekpè, and Sèmè-Podji), this is the most common sanitation method in households with running water and sufficient means. However, inadequate pit sizing, limited soil permeability, and proximity to the water table are recurring problems, leading to frequent emptying and a high risk of pollution. Septic tanks and cesspools struggle to function effectively when the water table is close to the surface, as infiltration is compromised and the risk of groundwater contamination is very high. Similarly, much of the soil in Sèmè-Podji is clayey or loamy, which limits the infiltration capacity of septic tank effluent, leading to overflows or very frequent emptying. Periods of heavy rain and flooding can overwhelm on-site sanitation systems, causing overflows and the spread of wastewater into the environment, with increased health risks. The performance and sustainability of these sewage disposal systems are strongly influenced by local hydrogeological conditions and the quality of their design, construction, and maintenance.

4.4. Environmental Impacts of Poor Liquid Waste Management in the Municipality of Sèmè-Podji

The environmental impacts are particularly critical due to the lagoon environment and the proximity of wetlands such as Lake Nokoué (**Figure 7**). The environmental impacts of poor liquid waste management include ecosystem degradation (45% of respondents), groundwater and surface water pollution (36%), and inadequate drainage and flooding (19%). Pollution threatens the biodiversity of wetlands (marshes, lagoons) and receiving water bodies (Lake Nokoué), which can affect local flora and fauna. The lack of adequate drainage systems, the obstruction of natural drainage channels by unregulated occupation and waste, and population growth exacerbate flooding during the rainy season. This causes water stagnation, damage to roads and infrastructure, and creates an unsanitary environment conducive to the proliferation of disease vectors.

The direct discharge of wastewater (grey water and sewage from septic tanks, which are often leaky) and contaminated floodwater into the environment leads to severe contamination of the water table (well water) by pathogens (such as E. coli and coliforms) and pollutants. Rivers, canals, and lagoons often serve as uncontrolled outlets. According to [11], cities are faced with inadequate sanitation infrastructure that does not allow for proper drainage of wastewater and rainwater. The stagnation of wastewater in the streets and the erosion of these streets by rainwater are signs of a deficient sanitation system. However, wastewater stagnating in streets, drains, ravines, and gutters, as well as sewage sludge exposed to the open air, gives off foul odors and constitutes biotopes conducive to the development of pathogens, which are vectors of several diseases.



Data source: Fieldwork, May 2025.

Figure 7. Environmental impacts of poor liquid waste management in the municipality of Sèmè-Podji.

Poor liquid waste management in the municipality of Sèmè-Podji affects the quality of drinking water, with direct consequences for the health of the population. To assess the quality of the water consumed by the populations interviewed, water samples were taken and subjected to physical, chemical, and bacteriological analyses. Several parameters were taken into account, but the most significant are color, turbidity, pH, ammonium, nitrates, nitrites, total iron, and phosphate. Table 4 shows the proportion of these parameters in the different samples taken in relation to Benin standards.

Table 4. Results of parameter analyses for the various samples in relation to Benin standards.

Parameters \ Sites	Ekpè (Dako house) Private PEA 1	Sèmè-Podji (Aloukoutoui house) Private PEA 2	Tohoué (Akoumahaou house) Private PEA 3	Aholouyèmè (Honfo house) Private PEA 4	Maximum allowable value (VMA) in Benin
Color: (uc)	81	31	09	13	15
pH	6.09	6.13	6.25	6.45	6.5 < pH < 8.5
Turbidity	18	07	03	03	05
Conductivity (µS/cm)	59	93	62	101	2000
Temperature (˚C)	27.3	28.2	29.1	28.4	-
Ammonium NH_4^+ (mg/L)	0.0984	0.0758	0.0845	0.0289	0.5
Nitrates NO_3^- (mg/L)	0.0	0.0	0.0	0.0	50
Nitrites NO_2^- (mg/L)	0.0	0.0	0	0.0	0.1

Continued

Sulfate SO_4 (mg/L)	0	0	0	0	500
Fluorides (mg/L)	0.18	0.28	0.37	0.17	1.5
Phosphates PO_4^{3-} (mg/L)	0.37	0.26	0.32	0.38	5
Iodide I^- (mg/L)	0.0	0.15	0.079	0.019	-
Total iron Fe^{2+}/Fe^{3+} (mg/L)	0.19	0.08	0.02	0.03	0.3
Chlorides Cl^- (mg/L)	18.45	24.91	24.95	22.7	250
Bicarbonate HCO_3^- (mg/L)	25.3	18.8	24.47	27.6	-
Magnesium Mg^{2+} (mg/L)	0.491	0.995	0.987	1.471	50
Calcium Ca^{2+} (mg/L)	7.684	7.278	4,868	6.516	100
Total hardness (mg/L)	67	26	18	25	500
Alkalinity (mg/L)	46	36	40	40	-

Source: DG-water and field surveys, June 2025.

An examination of the data in **Table 4** shows that the water samples have pH levels below 6.5. However, the maximum permissible value is between 6.5 and 8.5. Thus, the water samples do not comply with the drinking water quality standards in force in the Republic of Benin with regard to pH. Similarly, samples I and II have colors (81 and 31) that exceed the standard (15). This coloration is likely due to the presence of suspended particles. Sample I is turbid because its turbidity exceeds the maximum permissible value of 5. Similarly, all samples are weakly mineralized because they have low conductivity (59 to 101), whereas the standard is 2000. Thus, liquid waste is a factor in the contamination of this drinking water, which could be the cause of diarrheal diseases in the municipality of Sèmè-Podji. Several bacteriological parameters were studied. These include total coliforms, which are recognized as being germs of fecal origin; fecal coliforms; and fecal streptococci. **Table 5** shows the variation in the different bacteriological parameters studied in the water samples taken.

Table 5. Variation in the different bacteriological parameters studied in the water samples collected.

Sites Parameters	Ekpè (Dako house) Private PEA 1	Sèmè-Podji (Aloukoutoui house) Private PEA 2	Tohoué (Akoumahaou house) Private PEA 3	Aholouyèmè (Honfo house) Private PEA 4	Maximum permitted value (MPV) in Benin
Total coliforms/100 ml	367	289	375	253	10
Fecal coliforms/100 ml	52	16	68	14	0
Fecal streptococci/100 ml	0	00	31	0	0

Source: DG-water and field survey, June 2025.

Total coliform values range from 253 to 367 and fecal coliform values from 14 to 68. Therefore, the values in the samples exceed the drinking water quality standards in force in the Republic of Benin. Thus, they are all polluted by these microorganisms. The contamination of this drinking water is thought to be due to its proximity to liquid waste sites. Furthermore, the pollution of this water leads to the occurrence of waterborne diseases. Regular monitoring of the quality of this water is therefore essential. The consumption of water contaminated by sewage is a direct cause of waterborne diseases such as diarrhea, cholera, gastrointestinal infections, and skin conditions. During the frequent floods in Sèmè-Podji, the situation worsens as contaminated floodwater comes into contact with sanitary infrastructure (toilets, septic tanks) and spreads, increasing the population's exposure to pathogenic germs. Poor management of these different types of liquid waste contributes to a shortage of quality drinking water and a deterioration in public health in Sèmè-Podji. People are forced to use unsuitable water sources (unprotected wells, surface water) that are often contaminated. Despite SONEB's efforts to supply drinking water, coverage remains low in many areas, increasing residents' vulnerability to water contamination. The absence or inadequacy of adequate sanitation systems and the practice of open dumping of liquid waste in Sèmè-Podji lead to widespread contamination of water resources, posing a major challenge to access to safe drinking water and the health of the population. Flooding causes the destruction of homes, transport routes (dirt roads), and social and community infrastructure, resulting in significant repair costs for households and the community. Flooding and unsanitary conditions disrupt urban mobility and access to workplaces, education, and health facilities, leading to lower productivity and economic losses. Flood risks in the municipality of Sèmè-Podji take various forms: rainwater and river flooding. Roads, houses, neighborhoods, and entire villages are submerged by water, making roads impassable, preventing waste collection, and leading to the accumulation of debris (Figure 8).

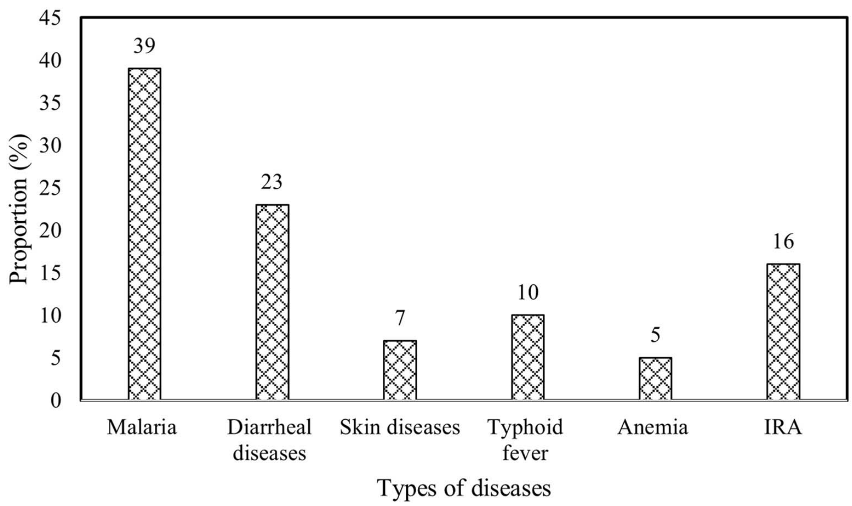
Photographs taken in Doumatey, October 2024.

Figure 8. Partial views of some flooded houses and roads in Ekpè.

Figure 8 illustrates the effects of flooding in villages in the Ekpè district. The houses are inhabited by people and are inundated by water during the heavy rainy season. Landfills and waste treatment facilities are damaged by flooding, leading to pollutant leaks and contamination risks. This causes environmental contamination and increased health risks.

4.5. Health Impacts of Poor Liquid Waste Management in the Municipality of Sèmè-Podji

Stagnant water enriched with organic matter creates favorable breeding grounds for mosquitoes (malaria vectors) and other harmful organisms responsible for diarrheal diseases. Figure 9 shows the types of diseases linked to poor liquid waste management in the municipality of Sèmè-Podji.



Source: Survey data processing, May 2025.

Figure 9. Types of diseases linked to poor liquid waste management in the municipality of Sèmè-Podji.

The types of diseases linked to poor liquid waste management in the municipality of Sèmè-Podji are malaria (39% of people selected for the survey), diarrheal diseases (23%), acute respiratory infections (16%), typhoid fever (10%), skin diseases (7%), and anemia (5%). In the research sector, cases of malaria are reported throughout the year. However, the highest number of cases is seen during the two rainy seasons, the long season from March to July and the short season from September to November. There are various modes of transmission for diarrhea. The modes of diarrheal infection are exacerbated by the existence and proliferation of risk factors for this disease. The quality of drinking water is influenced by bacteriological, physical, and chemical factors, as well as exogenous factors (liquid waste), but also by water management (collection, transport, storage, and withdrawal), which can also be a source of bacteriological, chemical, and physical pollution of drinking water. Exposure to contaminated water is a major cause of disease. Ingestion of contaminated well water and contact with floodwater promote the emergence and persistence of waterborne diseases (diarrhea, gastrointestinal infections) and vector-borne diseases such as malaria (due to the proliferation of mosquitoes in stagnant water). The rate of waterborne and fecal diseases is high, particularly affecting children and the most vulnerable populations.

5. Conclusion

At the end of this research, it should be noted that ecosystem degradation, groundwater and surface water pollution, inadequate drainage, and flooding are the environmental impacts of poor liquid waste management. Pollution threatens the biodiversity of wetlands (marshes, lagoons) and receiving water bodies (Lake Nokoué), which can affect local fauna and flora. The lack of adequate drainage systems, the obstruction of natural drainage channels by unregulated occupation and waste, and population growth exacerbate flooding during the rainy season. The rate of waterborne and fecal diseases is high, particularly affecting children and the most vulnerable populations.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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