Health Risks of Waste Disposal in Water: Scientific Data Versus Households' Perception in Ba-Phalaborwa Limpopo, South Africa

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Abstract

Background: There has been abundant evidence and knowledge in the literature on the health risks of waste disposal in water. Yet, households' perception of health risks is often regarded as erroneous and inferior, while scientific data, specifically water quality data, is viewed as superior and accurate.

Methods: Three hundred and eighty-four questionnaires were administered in four villages and analyzed using SPSS version 29.0 and Excel. Water samples were collected from the Ga-Selati River during the dry and wet seasons. Water quality assessment and MiniSASS were used to compare water quality indicators with the perceived health risks.

Results: The results show that variations exist between households' perception of health risks and the scientific data from the laboratory, ascertained water quality indicators. Some perception statements match with laboratory data in relation to Temperature, pH, and Electrical conductivity (EC), Total Suspended Solid (TSS), Chemical Oxygen Demand (COD), Dissolved oxygen (DO), Turbidity, Nitrates, Phosphorus and Bioindicators.

Conclusion: Our study highlights the need for a dialogue between households and researchers to develop new strategies to prevent the risks associated with waste disposal in water.

Keywords: Health risks, waste disposal, perception, quality indicators, South Africa

Introduction

One of the biggest sources of environmental damage is widely known as illegal dumping (Yi et al., 2020). Illegal or indiscriminate dumping is also known as fly tipping (or fly dumping), open dumping, or midnight dumping (Niyobuhungiro & Schenck, 2022). According to a common definition used by many scholars (Bangani et al., 2023; Yi et al., 2020 & Yuan et al., 2023), illegal dumping alludes to the disposal of waste in a restricted area and individuals with no license, dumping waste on sites contrary to properly disposing at a landfill site or using an authorized rubbish dump.

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Waste is often abandoned in vacant, unoccupied, or open areas: forests, water bodies, sidewalks, fence lines, creeks, and streets (Aslam et al., 2022; Jourbert, 2021; Shammi et al., 2023; United States Environmental Protection Agency, 2020; & Brandt, 2017). This is done to avoid the time and effort imperative for lawful dumping (Tomita et al., 2020).

Dumping wastes in water bodies causes a sudden shift in pH (Bhat et al., 2022). The diversity and density of biota decrease due to acidic pH in water, which stresses their physiological mechanisms and ultimately lowers reproduction rates (Yang & Xu, 2022). Bhat et al. (2022) also stated that biotic and chemical activities are influenced by any alteration in water pH. Acidic pH is considered inappropriate for the survival of freshwater fishes and bottom-dwelling invertebrates (Abubakar et al., 2022). The alteration of pH, particularly when it originates from waste disposal, is not suitable for the aquatic ecosystem. As a result of the high pollution load, the expeditious growth of algae removes CO_2 from water bodies during photosynthesis, which then escalates the pH in water (Rajagukguk & Nabilah, 2021). This eventually affects the quality of water. Therefore, water becomes unsuitable for domestic use, consumption, agricultural and industrial use (Bhat et al., 2022).

Disposing waste in water leads to a higher salt concentration, increasing the Total Suspended Solids (TSS) level (Gqomfa et al., 2022). The presence of suspended solids like plastic items, cardboard, paper, polythene, fruits, and vegetables alters the physical structure of water bodies, changes temperature, and reduces light penetration, ultimately diminishing the capacity of natural water bodies (Hameed et al., 2020). All materials, both biodegradable and non-biodegradable, found in water bodies are classified as suspended solids (Bhat et al., 2022). The suspended solid concentration below 25 mg/L will not affect fish and other aquatic species (Bailey et al., 2022). However, exceeding the permissible limits of TSS primarily impacts the O_2 intake capacity of fish, which can harm their gills and eventually lead to their death (Pierce et al., 2020). Dissolved Oxygen (DO) levels indicate the ability to support aquatic life (Bailey et al., 2022). Waste disposal in freshwater decreases DO levels, and the lack of DO results in a foul odor in water bodies (Bhat et al., 2022).

Disposing of waste into aquatic ecosystems is a common practice in Ba-Phalaborwa Local Municipality and thus threatens the habitat of aquatic species. People carelessly dispose of their waste in the water, which adversely impacts the river's water quality and further leads to the disease spreading of pathogens and toxins. The legislation, National Environmental Management Waste Act (NEMWA) 59 of 2008, intends to revamp waste management procedures while preventing ecological damage and pollution. This legislation guarantees and encourages municipalities to provide efficient waste services. In Ba-Phalaborwa Local Municipality, this regulation is not enforced as communities do not receive regular waste services and adequate bins for disposal. As such, illegal dumping is rampant in many places, including in water.

Research Problem

Illegal waste dumping in water is a growing problem that has received little attention in Southern Africa (Gutberlet et al., 2020). According to Triassi et al. (2021), the proliferation of cities from both developing and developed countries is equally affected by poor solid waste management as an escalating environmental hazard. Waste disposal intentions are also experienced in other BRICS (Brazil, Russia, India, China, and South Africa) countries, as they do not have proper prevention strategies to address this problem (Bukova et al., 2019; Brown & Sako, 2019). Illegal dumping is evidently a global issue, affecting the C40 municipalities (Chen et al., 2021; Amasuomo & Baird, 2020).

By 2050, the expected urban population growth will increase by 90% (Abubakar et al., 2022). According to Somani (2023), approximately 70% of the global population is predicted to reside in urban areas by 2024, increasing to 9.3 billion by 2050. As a result, the amount of municipal solid waste (MSW) generated annually is expected to grow due to industrialization and urbanization (Gherhes et al., 2022). Thus, it is crucial for households to properly dispose of waste to minimize harmful outcomes on public health.

Bangani et al. (2023) identified poor solid waste management practices such as inadequate systems, irregular collection, uncontrolled landfilling, and open burning as significant contributors to waste-related consequences. Indiscriminate dumping in water bodies, linked to weak SWM, is prevalent in countries like Zimbabwe, Pakistan, Nigeria, India, South Africa, and Nepal (Dehghani et al., 2021). This leads to disease spread by flies, rodents, and insects, causing vector- and water-borne illnesses, blocked drains and sewers, leachates, foul odor, suffocation of aquatic animals due to plastic, and greenhouse gas emissions (Siddiqua et al., 2022; Li, 2023; Somani, 2023).

With improved living standards, households' waste disposal practices increasingly affect solid waste management (Yoada et al., 2022). Disposing of waste in water remains common in rural and remote areas, exacerbated by limited infrastructure like roadside skip bins in urban areas (Fadhullah et al., 2022). A lack of land for proper disposal has increased illegal dumping (Venkateswaran et al., 2023). Current landfill-based MSW strategies are unsustainable (Rodseth et al., 2020). The Ba-Phalaborwa landfill has reached capacity, lacking sorting, separation, and leachate management. As a result, communities have resorted to unauthorized dumping, including in water bodies. This behavior is linked to the 'Not In My Backyard' (NIMBY) attitude and the absence of designated landfill sites (Fadhullah et al., 2022).

Ge and Liu (2022) argued that knowledge shapes individuals' environmental behavior and perceptions. Islam et al. (2021) found that knowledge of the harmful effects of water-borne waste significantly influences proper disposal practices. As knowledge increases, motivation to adopt waste minimization and recycling behaviors also rise (Azodo, 2019; Wu et al., 2022). Inadequate knowledge leads to low perception, intention, and attitude regarding waste disposal in water (Rasheed et al., 2022). Akmal and Jamil (2023) noted that household decisions are driven by what they know, confirming the strong relationship between knowledge and behavioral intention (Sakollawat et al., 2022). This study seeks to evaluate water quality based on the types of waste disposed of into nearby water bodies, comparing scientific water quality assessments with households' perceived impacts. Given these concerns, it is important to assess knowledge, perception, and behavioral intention regarding the effects of waste disposal in Ba-Phalaborwa Local Municipality.

Research Objectives

This study is guided by the following objectives:

1. To explore community attitudes, perceptions and practices on waste disposal in water.
2. To examine environmental health, human health and social risks associated with waste disposal in water.
3. To compare perceived environmental, health and social risks with water quality indices.

Methodology

Study Setting

This study was conducted at Ba-Phalaborwa Local Municipality (Category B), which was previously known as Phalaborwa Municipality. It is situated on 23º 57 16.47" S, 31º01' 40.93" E of the North-Eastern part of South Africa in Limpopo Province under the Mopani District. Additionally, it is one of the five local municipalities in Mopani District, with a total population of 150,637, comprising approximately 41,115 households (Statistics South Africa [Stats SA], 2022).

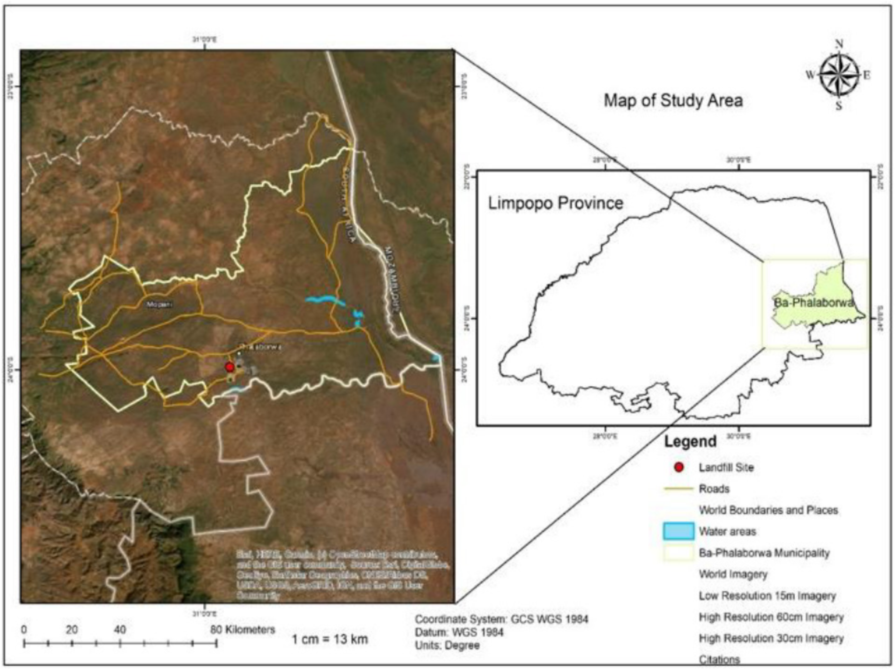
The geographical area of Ba-Phalaborwa Local Municipality is approximately 7,462 km², encompassing a vast expanse of private farms and tribal land, including Selwane, Boelane, Majeje, Maseke, Makhushane, and Mashishimale Traditional Authority. The economic growth of Ba-Phalaborwa Local Municipality is constantly improving due to the development of mining, tourism, agriculture, agro-processing, manufacturing, retail, and sports, thus providing quality socio-economic infrastructure. Ba-Phalaborwa Local Municipality has a total of 58.6% of people living in poverty (IDP, 2022).

Waste management services are provided to 22,94 out of a total of 41,115 households (IDP, 2022). There is a backlog of 18,174 households without waste management services. The shortfall is that parts of urban areas and townships are serviced weekly, whereas rural areas are serviced less frequently. As a result, there is only one operating licensed landfill site in Ba-Phalaborwa Local Municipality.

This study area (Figure 1) was selected based on observations of waste management practices and the rapid increase in waste disposal in water bodies within the municipality. According to Statistics South Africa [Stats SA] (2022), the weekly refuse removal rate is only 48.8% throughout the municipality. This denotes that a substantial part of the municipality resorts to its own waste management strategies, such as illegal dumping in water. This study investigated households' knowledge, perception, and behavioral intention regarding the effects of waste disposal on water quality.

Figure 1

Map of the Study Area



Research Design and Method

This study employed a descriptive research design to examine quantitative data about the communities within the Ba-Phalaborwa Local Municipality. This design assisted in estimating the prevalence and incidence of waste disposal in water and quantified communities' knowledge, perception, behavioral intention, and risks associated with waste disposal in water.

Research Participants and Sampling Procedure

For this study, four villages out of seven were purposively sampled because waste disposal in water is prevalent in these communities. Based on the census conducted in 2022, the total population of Mashishimale, Maseke, Boelane, and Makhushane villages is 29,171, with 7,905 households. A systematic sampling method was used to select individuals who are at least eighteen years old, residents of the study area, and have signed the informed consent form.

Cochran's formula was utilized to calculate an ideal sample size for larger populations, with the estimated percentage of the attributes found in the population and the specified desired confidence and precision level (Sullivan, 2019). For the purpose of this study, four (4) villages were purposively sampled because waste disposal in water is prevalent in these communities, and 384 households were further divided by the number of communities (4), such that 96 households were interviewed per community.

Instrument and Data Collection Procedure

Data for this study were acquired from a household survey using a self-designed questionnaire and laboratory-based water quality assessment. The questionnaire covered socio-economic characteristics and perceptions of environmental, health, and social risks associated with waste disposal in water, using a 3-point scale. The initial questionnaire in English was translated into Sepedi and then given to a household member who is a permanent resident aged 18 or older.

The questionnaire was also validated by a waste management and water quality expert before the actual data collection. Additionally, a pilot study involved 30 participants from the local residents who were excluded from the final sample size. The Cronbach's Alpha analysis resulted in a reliability coefficient of 0.70 for all items in the questionnaire, which, as Saari et al. (2023) noted, indicates that the questionnaire was valid.

Water Quality Assessment

Water quality data were obtained from three sampling sites in the Ga-Selati River. Global Positioning System (GPS) coordinates were collected from the sampled site and later coded using Quantum Geographic Information System (QGIS) to map waste disposal in water. Three water samples were collected at an interval of approximately 100 meters from one another in 2-litre plastic bottles that were pre-cleaned and well-rinsed. The sampled water was sealed and secured with proper labeling, avoided aeration, preserved, and carefully transported to the laboratory for physical and chemical analysis. Water samples were collected during the dry and rainy seasons to account for the variance due to seasonality. This study identified six key indicators of water quality: dissolved oxygen, turbidity and total suspended sediments (TSS), pH level, water temperature, nitrates and phosphates, and bioindicators.

Water temperature was determined using the Hanna Probe Instrument to assess physical properties and quality. The odor, color, and turbidity of the water were evaluated through observational comparisons. Bioindicators, specifically the visibility of macroinvertebrates, were assessed using mini stream assessment scoring system (miniSASS) at the sampled sites. Regarding chemical analysis and quality, water samples collected from each sampling site during both rainy and dry seasons were transported to the laboratory for further examination. These water samples were tested and measured three times to ensure the reliability of the results. To further ensure the validity of the water quality data, quality assurance protocols, quality control measures, and standard methods were adhered to, as outlined by Ji et al. (2022). In addition, the researchers followed the health and safety protocols by wearing gloves and a mask during collection, handling, and transport to the laboratory, as recommended by the Department of Water and Sanitation (2023) and WHO (2022).

Ethical Consideration

An ethical clearance certificate from the University of KwaZulu-Natal (UKZN) Humanities and Social Sciences Research Ethics Committee (HSSREC) was obtained. Permission was obtained from the municipality, the department of health, and local authorities to conduct the research study. Likewise, respondents for the study filled out informed consent forms before participating.

Data Analysis

Data were analyzed with the Statistical Package for Social Sciences (IBM SPSS Version 21). A t-test was conducted to assess whether the water samples from each location and season differed, using a significance level of 99% (Gangoo et al., 2023). Probit regression was used to determine factors influencing environmental, health, and social risks. Perceived risks were operationalized as a dichotomous variable.

Water Quality Analysis

The procedure for assessing water quality involved recording nitrate levels using the HACH LICO 690. The analysis of Chemical Oxygen Demand (COD) in all samples was conducted using the DRB200 and HACH LICO 690 instruments. Measurements of phosphorus pentoxide and orthophosphate, in the forms of PO43- and P2O5, as well as Total Suspended Solids (TSS), were also recorded using the HACH LICO 690. Turbidity was measured with the HACH 2100Q instrument, which was calibrated and verified for a 3-point calibration prior to testing the samples. The HQ40d instrument was employed to measure electrical conductivity, dissolved oxygen, and pH, while water temperatures were recorded using the Hanna Probe Instrument.

Results and Discussion

Socio-economic Profile of the Respondents

Table 1 shows the socio-economic characteristics of the respondents, encompassing variables such as gender, age, educational attainment, employment status, and income level. A significant proportion (66.6%) of the respondents were female, while 33.4% were male. This gender disparity may be attributed to the tendency of men to migrate to urban areas in pursuit of employment opportunities and higher income, leaving their spouses behind.

This observation aligns with the municipal gender distribution reported by Statistics South Africa [Stats SA] (2022), which indicates a higher female population (51.5%) compared to males (48.5%) in the Ba-Phalaborwa Local Municipality. Furthermore, the Integrated Development Plan (IDP) for 2024-2025 corroborates that female residents outnumber males. These findings are consistent with the studies by Viljoen et al. (2021), Manga et al. (2019), Fikadu et al. (2022), and Ayeleru et al. (2023), which also report a predominance of female respondents in the Ba-Phalaborwa Local Municipality.

Table 1

Socio-economic Characteristics of Respondents

Variables	Options	Frequency	Percentages
Gender	Male	128	33.4
	Female	255	66.6
Age	18 – 34 years	185	48.3
	35 – 64 years	136	35.5
	65 years or older	62	16.2
Education level	Primary school	102	26.6
	Secondary school	201	52.5
	Tertiary qualification	7	1.8
	None	73	19.1
Employment status	Unemployed	241	62.9
	Working full time	31	8.1
	Working part time	25	6.5
	Contract worker	29	7.6
	Entrepreneur	24	6.3
	Retired	22	5.7
	Student	11	2.9
Income level	Less than 5000	109	28.5
	5000 – 10 000	14	3.7
	10 000 – 20 000	5	1.3
	More than 20,000	9	2.3
	None	246	64.2

Table 1 also indicates that most respondents (48.3%) were within the 18-34 age group, whereas those aged 65 years or older constituted the smallest proportion (16.2%). These findings align with the studies of Ziblim and Bowan (2020), Alemu and Estifanos (2022), and Thakur and Onwubu (2024), which also observed that most respondents were aged between 18-35, with fewer individuals aged 50 years and above.

Regarding educational attainment, most respondents (52.5%) had completed secondary education, while only 1.8% possessed tertiary qualifications. This suggests that the residents of the sampled villages in Ba-Phalaborwa Local Municipality may generally have lower educational levels, which could significantly influence waste disposal behaviors in water. Similar findings have been reported by Akmal and Jamil (2023), Sekgobela and Semenya (2023), and Akeju and Omotoso (2023), who noted that the majority of respondents had secondary education as their highest qualification.

Regarding the respondents' employment status, the majority (62.9%) were unemployed, while only 2.9% were students. The findings align with those of Haywood et al. (2021) and Kala et al. (2020), who reported that unemployed households exceeded 90%. Conversely, Chikowore (2021) found that most respondents were self-employed. Additionally, 64.2% of respondents reported having no monthly income, whereas 1.3% earned between R10,000 and R20,000. This could be attributed to the participants residing in low-income areas. The results are consistent with the studies by Ngalo and Thondhlana (2023) and Kalonde et al. (2023), which indicate that most respondents were unemployed and relied on pensions, social welfare grants, and businesses such as crop and livestock farming.

Results on Water Quality Parameters

This section compares perceived environmental, health and social risks with water quality indices. The results on water quality parameters covered the quality indicators on Water temperature, pH, and Electrical conductivity (EC), Total Suspended Solid (TSS), Chemical Oxygen Demand (COD), Dissolved oxygen (DO), Turbidity, Nitrates, Phosphorus and Bioindicators.

Water Temperature

Table 2 shows the results of water temperatures at all three sampling points in the dry and wet seasons. Sample A1 had the highest water temperature of 39.9ºC in the dry season, while sample C2 had the lowest water temperature of 22.2ºC in the wet season. The results show that the average water temperatures of different sampling points in different seasons were roughly the same mean. In the dry season, water temperatures had a difference of 0.1ºC as compared to the wet season, with a difference of 0.2ºC. This shows that water temperatures slightly increased at each sampling point. The slight difference in water could be associated with the samples being taken at different times. The results clearly indicate that water temperatures were generally high in summer and low in winter. The recorded water temperatures in the dry season were above the permissible limit of below 25ºC for no risk detection as recommended by WHO, while in the wet seasons, the water temperatures were below the permissible limit. This shows that during the dry season, water quality is not suitable for domestic use compared to the wet season.

Table 2

Water Quality Parameters in Dry and Wet Seasons.

Water parameters	Units	Dry season Sample A1	Dry season Sample B1	Dry season Sample C1	Wet season Sample A2	Wet season Sample B2	Wet season Sample C2
Dissolved oxygen	mg/L	0.4	1.0	2.2	2.5	2.8	3.1
Turbidity	NTU	65.4	356	2.35	82.2	89.0	1.40
Total Suspended Solids	mg/L	29	95	9	50	14	12
pH	$-\log[H^+]$	10.56	9.72	9.25	7.04	7.39	7.48
Nitrates	mg/L	12.6	2.3	1.1	4.7	2.1	1.8
Orthophosphate	mg/L	30.8	84.3	2.7	30.4	4.3	3.8
Phosphorus Pentoxide	mg/L	26.0	12.3	2.0	27.8	3.3	3.3
Electrical Conductivity	µS/cm	2860	1933	1116	2680	1197	1175
Water temperature	ºC	39.9	39.8	39.7	22.6	22.8	22.4
Chemical Oxygen Demand	mg/L	413	1310	47	434	63	51

Waste disposal in water led to the highest temperatures in summer and the lowest in winter. Improper waste disposal in water and the exacerbation of temperature in the dry season is associated with the excessive breeding of mosquitoes, and their population thrives more in hot and dry seasons. Polluted water becomes a breeding ground for vector-borne diseases, most commonly malaria. Gqomfa *et al*. (2022) revealed that residents suffered from malaria and skin diseases due to the negative effects of breeding vectors in polluted water. Roughly 57.3% of households suffered from skin diseases, followed by 33.6% with diarrhea as the symptom of malaria. Bangani *et al*. (2023) and Perkumiene *et al*. (2023) also agree that mosquitoes like warm and stagnant water. They settle in waste tire plastics and multiply 100 times faster than usual. Thus, exposed communities to mosquito-borne diseases that have viruses such as Malaria, Zika Virus, Dengue, Chikungunya Virus, and West Nile Virus. Therefore, high temperatures in a polluted river led to human health risks such as malaria.

pH

The analysis of pH results in the dry and wet seasons from all three sampled points is shown in Table 2 above. Sample A1 had the highest pH level of 10.56, while sample A2 had the lowest pH level of 7.04. The pH level of all the sampled sites in the dry season fell within the range of 9.5 – 10.5, while the pH level of the sampled sites in the wet season fell within the range of 7 – 7.5. The recorded pH of sampled water in the wet season fell within the WHO guidelines of an ideal pH range of 6.5 – 8.5 for drinking, domestic use, and irrigation purposes, and recreational use, while the sampled water in the dry season was above the recommended pH range. The highest pH levels were recorded in the dry season and the lowest in the wet season. Based on the pH results, the sampled water in the dry season was alkaline, while the water collected in the wet season was neutral and pure.

The results show that high levels of pH (10.56) in the dry season constitute severe irritation of mucous membranes; skin and eyes are irritated, burnt, dry, or itchy. The water had an extremely sour and soapy taste, an unpleasant and foul smell, and severe rinsing problems during laundry. The lives of bacteria associated with these human health risks are influenced by the high levels of pH. The results are similar to those of Saalidong *et al*. (2022) that very high pH levels led to water having an unpleasant smell and alkaline taste, households were exposed to water with high pH levels and suffered from extreme diarrhea; skin-contact diseases such as skin and eye irritation and mucous membrane.

Electrical Conductivity (EC)

The highest electrical conductivity level was recorded in sample A1 at 2860 µS/cm, while sample C1 had the lowest recording of electrical conductivity at 1116 µS/cm. Samples A1, B1 and A2 were outliers with the highest levels of electrical conductivity, whereas the rest of the sampled points were approximately clustered with the same mean. The electrical conductivity both in the dry and wet seasons was over 1000 µS/cm. According to the WHO standards, the electrical conductivity levels should not exceed 400 µS/cm for human consumption and irrigation. In addition, the electrical conductivity of freshwater should range between 150 and 500 µS/cm to sustain diverse aquatic life (Gqomfa *et al*., 2022). However, all the sampled points in both the dry and wet seasons exceeded the permissible limit.

High levels of electrical conductivity constitute to a risk of dehydration if ingested. Madilonga *et al*. (2021) also agree that high concentrations of electrical conductivity in water have non-carcinogenic potential risks. However, humans exposed to water with high levels of electrical conductivity had symptoms of dehydration such as extreme thirst, irritability, confusion and drowsiness, very dry mouth, little to no urine, low blood pressure, fever and fast breathing and heart rate.

Total Suspended Solid (TSS)

The TSS results show that sample B1 had the highest level of TSS at 95 mg/L in the dry season, while sample C1 had the lowest level of TSS at 9 mg/L in the wet season. The TSS levels in the wet season slightly decreased at each sampled point, and sample A1 also had a low TSS level below the threshold. The South African water guidelines recommend that the TSS levels not exceed the permissible 100 mg/L level. The analysis of TSS showed that all the sampled points in the dry and wet seasons did not exceed the limit. However, sample B1 slightly approached the permissible limit. This may be attributed to the highest level of turbidity at 356 NTU, which could have resulted in the reduction of light penetration, visibility, and clarity of water. This led to an increase in suspended solids. High levels of TSS can cause gastrointestinal problems or even lead to death. Suspended sediments contain bacteria and algae that are harmful to human health. Lukhabi *et al*. (2023) determined that a risk of gastrointestinal illnesses was determined and high levels of TSS in drinking water affected human health and, in most cases, led to death.

Chemical Oxygen Demand (COD)

Sample B1 had the highest level of COD at 1310 mg/L during the dry season, while sample C1 recorded the lowest level of COD at 47 mg/L in the dry season. This showed that the COD recorded at sample B1 was approximately 28 times higher than that recorded at sample C1. Samples A1 and A2 had approximately the same mean of COD level. However, there was some fluctuation and decrease in samples C1, B2 and C2 as they are clustered around the same mean. Moreover, the level of COD fluctuates greatly during the dry season (Samples A1, B1, and C1). The wet season had the lowest levels of COD in all the sampled points, as compared to the dry season, with only sample C1 at 47 mg/L. Low COD in surface water supports aquatic species and human beings. High levels of COD indicate high levels of pollution (Tabraiz *et al*., 2023).

According to the South African water guidelines, COD levels should not exceed 75 mg/L. The high levels of COD at samples A1, B1, and A2 indicate that the river was highly polluted compared to the low levels of COD at samples C1, B2 and C2. COD is a vital pollution indicator that analyses the high occurrence of cancer in polluted water. High levels of COD in samples A1, B1 and A2 are associated with carcinogenic diseases. Wang *et al*. (2023) also agree that high levels of COD led to carcinogenic effects and the highest incidence of kidney and liver cancer; esophageal cancer; followed by breast, pancreatic and lung cancer and lastly colorectal cancer; bone and gallbladder cancer.

Dissolved Oxygen (DO)

Sample C2 had the highest level of DO at 3.1 mg/L in the wet season, while sample A1 had the lowest level of DO at 0.4 mg/L in the dry season. The difference in DO levels between sample C2 and A1 was very high, with sample C2 being 8 times higher than that of sample A1. The rest of the sample points had not much difference in DO levels between the dry and wet seasons. There was a slight increase in DO levels in each sample point. The recorded DO levels of sampled water in both dry and wet seasons did not fall within the range of 6.5 – 8 mg/L or between 80% - 120% as recommended by WHO. The DO levels in all the sampled points were less than 5 mg/L and did not reach the permissible limit, which is ideal for sustaining a healthy life in the aquatic ecosystem.

Thus, the aquatic life was at risk in the three sample sites during the dry and wet seasons. Low concentrations of DO levels in both dry and wet seasons are associated with human health risks such as cardiovascular diseases, bladder cancer, reproductive problems, and low DO levels lead to bad odor, which causes loss of appetite, headache, irritation of the nose and throat. Giri *et al*. (2022) also noticed that the deterioration of the Bagmati River had bacterial contamination with low dissolved oxygen and high organic load. The water was unsuitable for drinking and domestic use as it was associated with human health risks like cardiovascular diseases carcinogenic risks of bladder cancer, which led to reproductive problems. The reduction of DO levels leads to a bad odor. The results concur with those of Fadhullah *et al*. (2022). Households residing near a polluted river complained about a foul odor, leading to health risks such as headache and nose and throat irritation.

Turbidity

The turbidity results for three sample sites in both dry and wet seasons showed that sample B1 had the highest turbidity level at 356 NTU in the dry season, while the lowest level was sample C2 at 1.40 NTU in the wet season. Samples A1, B1, A2, and B2 had very high levels of turbidity compared to samples C1 and C2. The levels of turbidity gradually decrease at samples C1 and C2, meaning the low levels of TSS are attributed to low levels of turbidity. According to the WHO water quality guidelines, samples A1, B1, A2 and B2 have exceeded the standard limit of not more than 5 NTU or ideally below 1 NTU. In contrast, samples C1 and C2 fell within the permissible limit as recommended by WHO.

High turbid water has human health risks if ingested. The study results show that high levels of turbidity interfere with water disinfection for drinking and domestic use, which is attributed to human health risks such as diarrhea, nausea, stomach cramps and severe headaches. Elderly, infants and people with weak immune systems may be at increased health risk. Similarly, Nawaz *et al*. (2023) highly turbid water was not safe for drinking and other domestic purposes as it was associated with headaches, diarrhea and stomach cramps. The findings also concur with those of Mann *et al*. (2022) that drinking water with high levels of turbidity led to acute Gastrointestinal (GI) illnesses, and the symptoms were bloody diarrhea, vomiting and nausea, pain and stomach cramps, headache and occasional muscle aches and low-grade fever.

Nitrates

The analysis of nitrate results showed that sample A1 had the highest level of nitrate at 12.6 mg/L, while sample C1 had the lowest level of nitrate at 1.1 mg/L. The rest of the sample points showed a slight decrease in the nitrate level in both the dry and wet seasons. The WHO standards of nitrate concentrations in drinking water from surface water should not exceed 10 mg/L. The nitrate levels at all three sampling sites in both dry and wet seasons did not exceed the recommended limit, excluding sample A1 at 12.6 mg/L.

The results show that high levels of nitrates constitute excess heart rate; weakness; fatigue; nausea; headache or dizziness, and the skin turns grey or blueish in color as a result of methemoglonaemia or baby blue syndrome in children and if the child survives, it may cause mental retardation. Similarly, Meride and Ayenew (2022) also agree that blue baby syndrome was common in infants as one of the diseases caused by high concentrations of nitrates in drinking water. Moreover, low levels of nitrates are associated with colorectal cancer. Grout *et al*. (2023), Chambers *et al*. (2022), and Luvhimbi *et al*. (2022) noticed that the risk of colorectal cancer increases when humans consume water with lower concentrations of nitrate than the current water standards for drinking.

Phosphorus

Sample B1 had the highest level of orthophosphate at 84.3 mg/L, while sample C1 had the lowest level of orthophosphate at 2.7 mg/L during the dry season. There was a rapid decrease in orthophosphate levels at samples B2 and C2 during the wet season, which indicates that these samples were concentrated around the same mean. Samples A1 and A2 did not show much difference. A fluctuation in orthophosphate levels was observed during the dry season. Sample B1 had a higher level compared to the rest of the sample points. This could have been influenced by the higher levels of turbidity, TSS and COD. The highest level of phosphorus pentoxide recorded was sample A2 at 27.8 mg/L in the wet season, while the lowest level was sample C1 at 2.0 mg/L in the dry season. There was a decrease in phosphorus pentoxide levels during the dry season. Samples B2 and C2 recorded the same amount of phosphorus pentoxide during the wet season. There was a slight difference of 1.8 mg/L from samples A1 and A2. According to WHO, the phosphate content should range from 0.08 – 0.10 mg/L or be ≤1 mg/L. All three sampled sites during the dry and wet seasons have high nutrient content and exceeded the recommended limit of phosphate in water.

High levels of phosphorus constitute an increased risk of stroke, heart attack, and death. Others include hyperthyroidism, vomiting, diarrhea and reduction in bone strength. Moreover, high levels of phosphorus lead to high infant mortality due to diarrheal diseases. Isiuku and Enyoh (2020) also agree that water intake with high phosphorus levels indicates non-carcinogenic risk with a high risk of stroke, heart attack, hyperthyroidism, and infant mortality.

Bio-Indicators of Water in Dry and Wet Seasons

This section examines the presence and abundance of macroinvertebrate taxa as indicators of water quality across dry and wet seasons using MiniSASS as a biomonitoring tool. These findings, derived from the MiniSASS assessment, support laboratory-based water quality analysis, offering a holistic understanding of the ecological status of the river. Table

3 shows the results of bioindicators using the MiniSASS score sheet. Both dry and wet seasons fell within the range of <4.8 - <5.3 river ecological category, with a 2.5 score in the dry season and a 0 score in the wet season. This category indicates very poor conditions, and that the river's water quality was critically and seriously modified by waste disposal.

Based on the score, the river had a high diversity of macroinvertebrates during the dry season and had no diversity of macroinvertebrates in the wet season. This could have been influenced by the different temperatures. The river was seriously and severely polluted during the dry season and moderately polluted during the wet season. The most abundant taxa during the dry season were Oligochaetes worms, also known as aquatic earthworms. Sowa and Krodkiewska (2020) Oligochaetes successfully inhabit highly polluted water as they are resistant to oxygen deficits (anaerobic conditions) and can survive during the dry season and under severe nutrient pollution. Therefore, the findings concur with those of Sowa and Krodkiewska (2020) that Oligochaetes, as pollution-tolerant organisms, detect the ecological status of a river and the presence of pollution; their diversity and abundance signify the severe extent of pollution and poor river ecological status.

Table 3

MiniSASS Score Sheet of Dry and Wet Season.

Groups	Sensitivity score (Dry season)	Sensitivity score (Wet season)
Flat worms	3	3
Worms	2	2
Leeches	2	2
Crabs or shrimps	6	6
Stoneflies	17	17
Minnow mayflies	5	5
Other mayflies	11	11
Damselflies	4	4
Dragonflies	6	6
Bugs or beetles	5	5
Caddisflies (cased or uncased)	9	9
True flies	2	2
Snails	4	4
Total Score	5	0
Number of Groups	2	0
Average Score	2.5	0

Average Score = Total Score / Number of groups

Comparison of Households' Perceptions on Risks Associated with Waste Disposal in Water

This section addresses the third objective by comparing the perceived risks associated with waste disposal in water. The results of the comparison of households' perceptions of risks and laboratory analysis of water quality indicators data associated with waste disposal in water (Table 4). The perception of environmental, health, and social risks of waste disposal in water was sometimes in agreement with the trends highlighted by the analysis of laboratory data, either separately or combined. In terms of perception on risks, some perception statements match with laboratory data in relation to Water temperature, pH, Electrical conductivity (EC), Total Suspended Solids (TSS), Chemical Oxygen Demand (COD), Dissolved oxygen (DO), Turbidity, Nitrates, Phosphorus and Bioindicators.

Table 4 indicates that more than 50% of the respondents perceived that environmental risks would results from waste disposal in water in terms of aquatic organisms cannot survive with less dissolved oxygen, less dissolved oxygen leads to the death & decomposition of aquatic plants and animals, waste disposed decreases the amount of dissolved oxygen, excessive algae growth decreases the amount of dissolved oxygen, low concentrations of dissolved oxygen affect photosynthesis, respiration, and aeration, decomposition of aquatic species release nutrients in water such as carbon and nitrogen, polluted water contain nitrates and phosphates toxic to aquatic animals and life, increased levels of nitrates & phosphates endangers the surrounding plants and animals, disposal of heavy materials & waste leads to high turbidity, cloudy surface water, high turbidity reduces the dispersion of sunlight for aquatic ecosystem.

Similarly, more than half of the households perceived that health risks would occur from waste disposal in water in relation to low levels of nitrates in water leads to colorectal cancer, drinking water with high levels of nitrates leads to excess heart rate, weakness, fatigue, drinking water with high levels of nitrates turns the skin grey or blueish in color, excessive amount of nitrates leads to methemoglonaemia or baby blue syndrome, drinking water with less dissolved oxygen causes bladder cancer reproductive problems, excessive mosquitoes due to high water temperatures of polluted water leads to malaria, high levels of phosphorus leads to increased risk of stroke, heart attack or death, high levels of phosphorus leads to hyperthyroidism, vomiting, diarrhea, weak bone, untreated water with Chemical Demand Oxygen (COD) leads to cancer-related diseases, children under five die due to diarrheal diseases related to high levels of phosphorus, high levels of total suspended solids cause gastrointestinal problem & lead to death, high pH level causes skin irritation, dry or itchy and severe mucous membrane. For the social risks, more than 50 percent of the households perceived that waste disposal in water, would constitute risks in the areas of low pH in water causes a sour and soapy taste leads to dislikeness in residential areas, waste disposed in water create bad odor, waste in water leads to the surrounding community experiencing a foul smell, pollution hinder water sports and recreation activities such as fishing, swimming, and children drown in the polluted river due to poor turbidity. The laboratory data confirmed the perception of different risks by the households.

Table 4

Comparison of Households' Perceptions of Risks and Laboratory Analysis of Water Quality Indicators Data Associated with Waste Disposal in Water.

	Perception rate of households (individual surveys)			**Analysis of water quality parameters**	**Agreement between perception & laboratory data**
Risks identified by households	Environmental	Health	Social		
Aquatic organisms cannot survive with less dissolved oxygen.	>50%	*< 50%*	*< 50%*	DO+	Yes_E
Less dissolved oxygen leads to the death & decomposition of aquatic plants and animals.	>50%	*< 50%*	*< 50%*	DO+	Yes_E
Waste disposed decreases the amount of dissolved oxygen.	>50%	*< 50%*	*< 50%*	DO+	Yes_E
Excessive algae growth decreases the amount of dissolved oxygen.	>50%	*< 50%*	*< 50%*	DO+	Yes_E
Low concentrations of dissolved oxygen affect photosynthesis, respiration, and aeration.	>50%	*< 50%*	*< 50%*	DO+	Yes_E
Decomposition of aquatic species release nutrients in water such as carbon and nitrogen.	>50%	*< 50%*	*< 50%*	NO_3-+	Yes_E
Polluted water contains nitrates and phosphates toxic to aquatic animals and life.	>50%	*< 50%*	*< 50%*	NO_3- & PO_4^{3-}+	Yes_E
Increased levels of nitrates & phosphates endanger the surrounding plants and animals.	>50%	*< 50%*	*< 50%*	NO_3- & PO_4^{3-}+	Yes_E
Disposal of heavy materials & waste leads to high turbidity, cloudy surface water.	>50%	*< 50%*	*< 50%*	Turbidity+	Yes_E
High turbidity reduces the dispersion of sunlight for aquatic ecosystems.	>50%	*< 50%*	*< 50%*	Turbidity+	Yes_E
High levels of turbidity lead to gastrointestinal illness, diarrheal, and headaches.	*< 50%*	>50%	*< 50%*	Turbidity+	Yes_H
High levels of Electrical Conductivity lead to the risk of dehydration.	*< 50%*	>50%	*< 50%*	EC+	Yes_H
Disposal of waste increases water temperatures.	>50%	*< 50%*	*< 50%*	Water temp+	Yes_E
Excessive nitrogen and phosphorus lead to the high accumulation of algae.	>50%	*< 50%*	*< 50%*	NO_3- & PO_4^{3-}+	Yes_E
High levels of nitrates and phosphates	>50%	*< 50%*	*< 50%*	NO_3- & PO_4^{3-}+	Yes_E

	Perception rate of households (individual surveys)			**Analysis of water quality parameters**	**Agreement between perception & laboratory data**
depletes food resources.					
High levels of nitrates and phosphates decreases oxygen for aquatic life.	>50%	*< 50%*	*< 50%*	NO_3- & PO_4^{3-}+	Yes$_E$
Nitrates and phosphates leach into the ground and contaminate of groundwater.	>50%	*< 50%*	*< 50%*	NO_3- & PO_4^{3-}+	Yes$_E$
High turbidity increases the risk of flooding and alters proper water flow.	>50%	*< 50%*	*< 50%*	Turbidity+	Yes$_E$
Dissolved oxygen decreases due to high levels of pollutants in water.	>50%	*< 50%*	*< 50%*	DO+	Yes$_E$
High levels of nitrates & phosphates contaminate food chain in the ecosystem.	>50%	*< 50%*	*< 50%*	NO_3- & PO_4^{3-}+	Yes$_E$
High levels of nitrates and phosphates reduce organism's life span & ability to reproduce.	>50%	*< 50%*	*< 50%*	NO_3- & PO_4^{3-}+	Yes$_E$
Poor water quality due to waste disposal result from high nitrates & phosphates levels.	>50%	*< 50%*	*< 50%*	NO_3- & PO_4^{3-}+	Yes$_E$
Waste disposal in water alters characteristics of water (pH, temperature, and turbidity.	>50%	*< 50%*	*< 50%*	pH+, Water temp+ & Turbidity+	Yes$_E$
Low pH levels decrease in reproduction, growth and eventually death of aquatic species.	>50%	*< 50%*	*< 50%*	pH+	Yes$_E$
Using water with low dissolved oxygen levels in water cause cardiovascular diseases.	*< 50%*	>50%	*< 50%*	DO+	Yes$_H$
High water temperatures increase the effects of climate change.	>50%	*< 50%*	*< 50%*	Water temp+	Yes$_E$
Low levels of nitrates in water leads to colorectal cancer.	*< 50%*	>50%	*< 50%*	NO_3-+	Yes$_H$
Drinking water with high levels of nitrates leads to excess heart rate, weakness, fatigue.	*< 50%*	>50%	*< 50%*	NO_3-+	Yes$_H$
Drinking water with high levels of nitrates turns the skin grey or blueish in color.	*< 50%*	>50%	*< 50%*	NO_3-+	Yes$_H$
Excessive amounts of nitrates lead to methemoglonaemia or baby blue syndrome	*< 50%*	>50%	*< 50%*	NO_3-+	Yes$_H$
Drinking water with less dissolved oxygen causes bladder cancer reproductive problems.	*< 50%*	>50%	*< 50%*	DO+	Yes$_H$
Excessive mosquitoes due to high water temperatures of polluted water lead to malaria.	*< 50%*	>50%	*< 50%*	Water temp+	Yes$_H$
High levels of phosphorus lead to increased	*< 50%*	>50%	*< 50%*	PO_4^{3-}+	Yes$_H$

	Perception rate of households (individual surveys)			**Analysis of water quality parameters**	**Agreement between perception & laboratory data**
risk of stroke, heart attack or death.					
High levels of phosphorus lead to hyperthyroidism, vomiting, diarrhea, weak bone.	*< 50%*	>50%	*< 50%*	PO_4^{3-}+	Yes$_H$
Untreated water with Chemical Demand Oxygen (COD) leads to cancer-related diseases.	*< 50%*	>50%	*< 50%*	COD+	Yes$_H$
Children under five die due to diarrheal diseases related to high levels of phosphorus.	*< 50%*	>50%	*< 50%*	PO_4^{3-}+	Yes$_H$
High levels of total suspended solids cause gastrointestinal problem & lead to death.	*< 50%*	>50%	*< 50%*	TSS+	Yes$_H$
High pH level causes skin irritation, dry or itchy and severe mucous membrane.	*< 50%*	>50%	*< 50%*	pH+	Yes$_H$
Low levels of dissolved oxygen cause bad odor, appetite loss, nose and throat irritation.	*< 50%*	>50%	*< 50%*	DO+	Yes$_H$
Low pH in water causes a sour and soapy taste leads to dislikeness of residential area.	*< 50%*	*< 50%*	>50%	pH+	Yes$_S$
Waste disposed in water create bad odor.	*< 50%*	*< 50%*	>50%	pH+	Yes$_S$
Waste in water leads to the surrounding community experiencing a foul smell.	*< 50%*	*< 50%*	>50%	pH+	Yes$_S$
Pollution hinders water sports and recreation activities such as fishing, swimming.	*< 50%*	*< 50%*	>50%	pH+	Yes$_S$
Children drown in the polluted river due to poor turbidity.	*< 50%*	*< 50%*	>50%	Turbidity+	Yes$_S$

Probit Regression Analysis

Table 5 presents the results of the Probit regression analysis of the determinants of households' attitudes and perceived risks of waste disposal in water. All the models are well fitted with Chi-Square values of 2.352E+77 (Attitude), 559.57, and (perceived risks), 1.458E+49 at $p < 0.001$. The factors influencing households' attitude on waste disposal in water are perceived risks ($t = -17$, $p < 0.01$), know and aware ($t = -8.125$, $p < 0.01$), age ($t = 10.449$, $p < 0.01$), gender ($t = -22.918$, $p < 0.01$), employment status ($t = -15.396$, $p < 0.01$), income level ($t = 9.145$, $p < 0.01$), hazardous waste ($t = 5.528$, $p < 0.01$), construction waste ($t = 14.010$, $p < 0.01$), chemical waste ($t = -13.245$, $p < 0.01$), electronic waste ($t = -3.296$, $p < 0.01$), agricultural waste ($t = 2.492$, $p < 0.05$), garden waste ($t = 10.887$, $p < 0.01$), monthly payment ($t = 6.3$, $p < 0.01$), waste compaction ($t = -5.347$, $p < 0.01$), biogas generation ($t = 6.995$, $p < 0.01$), composting ($t = 21.706$, $p < 0.01$), vermicomposting ($t = -22.270$, $p < 0.01$), waste disposal in water ($t = -7.392$, $p < 0.01$), skip bin ($t = 3.896$, $p < 0.01$), municipal collection

($t = 3.044$, $p < 0.01$), satisfactory level ($t = -3.667$, $p < 0.01$) and intercept ($t = -3$, $p < 0.01$).

The results with negative values show an inverse relationship between attitude and independent variables and the perceived risks, knowledge and awareness as dependent variables. The findings agree with Omotayo *et al*. (2023), who found that income level significantly influences households' waste disposal preferences. Households with lower incomes tend not to pay for their monthly waste disposal payments. As a result, the municipality does not render waste collection services, leading to residents being unsatisfied with the municipal waste removal system and further developing their waste disposal preferences.

The factors influencing households' perceived risks are knowledge and awareness ($t = -26.8$, $p < 0.01$), age ($t = -2.669$, $p < 0.05$), gender ($t = 5.578$, $p < 0.01$), income level ($t = 7.352$, $p < 0.01$), biodegradable waste ($t = -9.077$, $p < 0.01$), hazardous waste ($t = -4.251$, $p < 0.01$), construction waste ($t = 14.00$, $p < 0.01$), electronic waste ($t = -13.522$, $p < 0.01$), agricultural waste ($t = -14.084$,$p < 0.01$), monthly payment ($t = 4.645$, $p < 0.01$), landfill ($t = 7.511$, $p < 0.01$), incineration ($t = 4.473$, $p < 0.01$), waste compaction ($t = -3.506$, $p < 0.01$), biogas generation ($t = 9.332$, $p < 0.01$), composting ($t = 6.054$, $p < 0.01$), vermicomposting ($t = -3.285$, $p < 0.01$), open spaces ($t = 2.459$, $p < 0.05$), skip bin ($t = 13.456$, $p < 0.01$), municipal collection ($t = 4.928$, $p < 0.01$), satisfactory level ($t = -3.019$, $p < 0.01$) and intercept ($t = -3.591$, $p < 0.01$). The results show an inverse relationship between the perceived risks as an independent variable and knowledge and awareness as dependent variables. There is a statistically significant association between perceived risks and households' level of knowledge. The findings in this study agree with Tomita *et al*. (2020), Omang *et al*. (2021), and Smith (2020) as households' exposure to the perceived risks increases their level of knowledge and awareness.

Table 5

Probit Regression Analysis of the Determinants of Households' Attitude and Perceived Risks of Waste Disposal in Water

Parameter	Attitude	Perceived risks
attitude		.016(.016)
Perceived risks	-.153 (.009) ***	
Knowledge & awareness	-.130(.016) ***	-.134(.005) ***
Age	1.139(.109) ***	-.291 (.109) **
Gender	-3.919(.171) ***	.714(.128) ***
Education Level	.077(.091)	.110(.088)
Employment Status	-.816(.053) ***	-.020(.041)
Income Level	1.262(.138) ***	.647(.088) ***
Biodegradable waste	-.302(.226)	-1.779(.196) ***
Hazardous waste	1.067(.193) ***	-.795(.187) ***
Household hazardous waste	.044(.187)	.200(.164)
Construction waste	2.676(.191) ***	2.548(.182) ***
Chemical waste	-2.437(.184) ***	.242(.172)
Electronic waste	-.923(.280) ***	-2.975(.220) ***
Agricultural waste	.770(.309) **	-2.676(.190) ***
Garden waste	8.557(.786) ***	.426(.360)
General waste	.041(.587)	1.456(2.350)
Monthly Payment	.693(.110) ***	.367(.079) ***
Landfill	-.270(.350)	2.133(.284) ***
Incineration	.186(.143)	.671(.150) ***
Waste compaction	-.941(.176) ***	-.575(.164) ***
Biogas generation	1.532(.219) ***	1.885(.202) ***
Composting	4.732(.218) ***	1.447(.239) ***
Vermicomposting	-4.944(.222) ***	-.795(.242) ***
Illegal disposing in water	-1.375(.186) ***	.233(.165)
Illegal disposing in open spaces	-.011(.151)	.418(.170) **
Skip bin	.600(.154) ***	1.978(.147) ***
Municipal collection	.481(.158) ***	.680(.138) ***
Satisfactory level with services	-1.632(.445) ***	-.895(.297) ***
Intercept	-6.303(2.101) ***	-3.20(.891) ***
Chi-Square	2.352E+77	1.458E+49
df	354	354
Sig.	.000	.000

Conclusion

Socio-economic characteristics such as gender, age, education level, employment status and income level influenced the determinants of probit regression analysis on knowledge and awareness, attitude and perceived risks. Gender had an influence on households' level of knowledge and awareness, as women were closely engaged with waste management. Therefore, the majority of women were more knowledgeable about issues of improper waste management than men. Age had an influence on households' level of attitude as elderly people were more willing to practice waste separation activities than young people. Employment status had a significant association with proper waste management. Lack of education contributed to high unemployment rates, which further influenced one's personal development and the development of the municipality in general.

Furthermore, employment status influenced households' level of knowledge and awareness, leading to water quality deterioration. Income level had a significant influence on households' waste disposal preferences. Households with lower income levels tend not to pay for their monthly waste disposal payments.

Households' exposure to the perceived risks increased their knowledge and awareness of risks associated with waste disposal in water. The analysis revealed a significant correlation between households' perception of the identified environmental, health and social risks. The results indicated that households demonstrated a good perception of the identified risks. Additionally, the majority of the respondents experienced those risks. Hence, they were knowledgeable and conscious of the impacts. Households' perceptions of the environmental, health and social risks associated with waste disposal in water were examined, and water quality parameters were analyzed and correlated with households' perceptions. Respondents perceived that waste disposal in water affected aquatic plants, animals, and the surrounding environment, led to short- and long-term diseases, and also experienced foul smells and hindrances in water sports and recreational activities. Both the households' perceptions and water quality parameters correlate, as water quality assessments confirm the associated risks. The congruence of households' perceptions and laboratory data points needs to be explored to identify common strategies to manage health risks related to waste disposal in water.

Limitations of the Study

This study provided valuable insights into water quality and community perceptions in four villages along the Ga-Selati River within the Ba-Phalaborwa Local Municipality, certain limitations must be acknowledged. The sampling method was limited to only four villages, which may not fully represent communities residing along the river's tributaries that may also be affected. Expanding the sample size and geographic scope to include more villages and additional sites along the Ga-Selati River and its tributaries.

Conflict of interests- The authors declare no conflict of interest

Data availability – The primary data collected for this study will be made available upon request

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