ZIBELINE INTERNATIONAL PUBLISHING
E-ISSN: 2990-9295
CODEN: MAGACU

Malaysian Applied Geography (MAGG)

DOI: http://doi.org/10.26480/magg.01.2025.57.64

CrossMark

RESEARCH ARTICLE

WATER QUALITY DEGRADATION AND ITS IMPACT ON HEALTH OF THE RIPARIAN SLUM DWELLERS OF RIVER KARALA IN JALPAIGURI MUNICIPALITY: RESEARCH INSIGHTS

Sumit Biswas[a]*, Dipankar Das[b], Arpan Lama[a], Niranjan Barman[a] and Darshan Chandra Barman[b]

[a]Department of Geography and Applied Geography, University of North Bengal, India.
[b]Department of Geography and Applied Geography, Siliguri College, India.
**Corresponding Author Email: biswassumit712@gmail.com*

This is an open access journal distributed under the Creative Commons Attribution License CC BY 4.0, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited

ARTICLE DETAILS

Article History:

Received 06 August 2025
Revised 10 September 2025
Accepted 28 October 2025
Available online 13 November 2025

ABSTRACT

Karala river is a tributary of river Teesta which flows through the Jalpaiguri Municipality, West Bengal is facing challenges and is experiencing significant water quality degradation. This is mainly due to anthropogenic activities such as rapid urbanization and discharge of untreated sewage from the drains. Hence a study was carried out to analyze the water quality of the Karala River within the Jalpaiguri Municipality area and its impact on the health of the slum dwellers residing along river Karala. The water quality analysis was done with the help of National Sanitation Foundation's Water Quality Index (NSF-WQI) and each of the individual parameters were compared to the Bureau of Indian Standard permissible limits, and according to the classification developed by NSF as the WQI value is 49.76 which falls between 26-50 indicating not safe for direct contact and is not suitable for any type of use. The probit model analysis was used to find the effect between socioeconomic variables and the health parameters. It was found that variable educational status has significant effect on diseases related to menstrual hygiene and skin infections. The variable wealth quantile has a significant effect on skin infections, dysentery and diarrhea related diseases and lastly the variable different kinds of daily activities on the river have significant effect on diseases like menstrual hygiene, skin infections, dysentery and diarrhea.

KEYWORDS

Riparian slum dwellers, River Karala, Jalpaiguri Municipality, Water Quality Degradation, Health problems

1. INTRODUCTION

Nowadays water pollution is one of the great issues concerning urban areas. Rivers surrounding the cities are steadily going through severe contamination problems and encroachment that continuously affecting the lifelines of the cities (IWM, 2004). Rivers are getting intensely polluted by the wastewater dumping from different industries. It threatens both environmental and human health conditions (Adedin, 1997; Bhattacharya et al. 1995). The rivers of major cities of India presently diluting capabilities due to the discharge of raw sewage, garbage as well as oil spills from the surrounding factories or similar activities (McGauhey, 1968; Peavy et al. 1986). Local communities could be directly impacted by using the polluted water for bathing, washing clothes and other activities. These can be the causes of skin diseases which are directly related to high pH. Gastric ulcers and other similar problems may be detected in people for their consumption of fishes and crops (Halder et al. 2015). 1.6 billion People worldwide are facing economic water shortage and two-third people are struggling due to water scarcity problem (FAO, 2007; Mekonnen et al. 2016). And the limited water resources are under a great threat of water pollution caused by different sources like industrial sector, agricultural sector, mining, power generation etc. (UN-Water, 2001). In present situation most of the urban water bodies are contaminated without appropriate treatment (Hasan et al. 2019). Water pollution caused by anthropogenic factors has become a matter of global concern. The situation is worsening day by day in almost all rivers in the world (UNEP, 2016). Majority of the deterioration of water bodies is caused by urban activities. Basically, the sewage discharge is causing concentration of high nutrients in urban rivers (Chen, et al. 2022). The increasing pollution is creating a high concentration of ammonium in rivers through the discharge of wastewater (Tromboni et al. 2017; Moncayo et al. 2017). On the other hand, detergent from the household has led the phosphorus emissions to water resources (Xiong et al. 2020). Along with the growing population in the world, especially in urban areas, lack of infrastructural advancement and absence of sophisticated wastewater purification techniques the water quality of urban areas is deteriorating (Haddis et al. 2014; Hoven, V.D. et al. 2017; Yu, et al. 2018). The municipal and industrial wastewater contaminate the river water throughout the year whereas the surface runoff from residential and agricultural field is a seasonal phenomenon contributes to the water pollution significantly affected by the climate (Badaii et al. 2012). Land cover and land use pattern also impact upon the water pollution. The chemicals from the agricultural and household fertilizers mix with nearby water bodies by surface runoff and contaminate rivers as well as groundwater (Gasim, et al. 2018). An excess amount of such chemicals or pollutants in water bodies affects the aquatic ecosystem e.g. low concentration of dissolved oxygen, growth of algal bloom and loss of biodiversity. Water pollution led the scarcity of water supply in domestic, agricultural, industrial and other sectors (Carpenter et al. 1998). The pollutants can be both organic and inorganic. But inorganic or non-biodegradable substances like plastics create a harmful impact by accumulating on riverbed which increase toxicity over time. Other non-biodegradable pollutants come from mineral extraction, building materials, processing and packaging of items etc. (Thompson et al. 2009). Rainfall also impacts upon the water quality as it washes away wastes from industrial sites, residential areas, agricultural fields, roads etc. Due to

Quick Response Code	Access this article online	
	Website: www.magg.com.my	**DOI:** 10.26480/magg.01.2025.57.64

Cite The Article: Sumit Biswas, Dipankar Das, Arpan Lama, Niranjan Barman and Darshan Chandra Barman (2025). Water Quality Degradation And Its Impact On Health Of The Riparian Slum Dwellers Of River Karala In Jalpaiguri Municipality: Research Insights. Malaysian Applied Geography (MAGG), 3(1): 57-64.

this the pollutants like hydrocarbons, lead, and zinc end up in the rivers (Kamaruddin, et al 2015). A rapid growth of population and development of industries along with the river areas is increasing the input of effluents in the water bodies which finally degrade the overall water quality making it unfit for any type of use (Jindal et al. 2011; Sanchez et al. 2007; Suratman et al. 2009). The water quality of rivers is very sensitive to anthropogenic factors which cause variation in the quality place to place (Ahearn et al. 2005; Sharma et al. 2016). Natural determinants e.g. geology, precipitation, weathering related to urban, industrial and agricultural activities lead the spatiotemporal variation in river water quality (Hamid et el. 2019). Human beings are dependent on water to fulfill multiple needs, and this dependency alters the fundamental characteristics of water quality parameters, affects the ecosystem and ultimately the supply of abundant and clean water (Brauman et al. 2007; Biaggi, 1965; Hunter et al., 1995; Gordon et al., 2011; Vorosmarty et al., 2010; Davis et al., 2015; Grizzetti et al., 2016). The acidification, salinization, eutrophication, and bacterial concentration in water portrays the over exploitation of water bodies by human population (Kondolf 1997; Pringle 2000; Robinson et al. 2009; Smol 2010; Capon et al., 2015). The change in physical and chemical properties of water significantly affects aquatic lives. Species of aquatic environment are very sensitive in varying degrees of sedimentation, temperature, pH, dissolved oxygen, chemicals and metals present in water (Resh et al., 1993; Karr et al., 1991). Most of the cases the untreated solid and liquid wastes discharged directly in water bodies posing a serious damage on river ecology, which influence the floral and faunal lives in water as well as human health (Degefu et al., 2013). Although the rivers have self-purification capacity, human activities nowadays go to an extent that these activities are destroying almost every major aquatic ecosystem by leading the water pollution severely (Rashid et al., 2012). Hence it becomes very important to analyse the water quality of the river Karala and it its impact on the health of the slum dwellers residing along the river.

2. Methodology

For the assessment of water-borne health problems of the slum dwellers, we applied water quality index to analyse water quality of River Karala alongside a probit model used to analyze an outcome of health issues of slum dwellers.

2.1 Study Area

Jalpaiguri Municipality lies in the northern part of the West Bengal, in the foothills of the Himalayan Mountain, with a mean sea level of 89 metres. Geographically, the municipality spans from 26^{0}30’30” to 26^{0}32’52” North latitudes and 88^{0}41’52” East longitude to 88^{0}44’18” East longitudes (Hossain and Kasemi, 2024). The municipality is bounded by River Teesta in the east, Kharia and Aurobindo Gram Panchayat in the west, Paharpur gram in the north and Kharia in the south (Jalpaiguri Municipality Report, 2018). The River Karala flow through the city, entering from the north and moving towards the southeast passing though ward nos. 25, 1, 24, 4, 5, 3 and 8. Urbanization associated with economic development and modernization has led to the rapid expansion’s slums in the Jalpaiguri city. Presently, the Jalpaiguri Municipality has a total 77 slums (55 notified slums and 22 non-notified slums) and the average age of the slums is 125 years across the 25 wards.According to the Census of India (2001 and 2011), Jalpaiguri Municipality had a total population of 100348 in 2001 and 107,341 population in 2011 which further increased to 115000 in 2015. The slum households were 7748 (20.39%) out of the total households of 22063 in 2001 which increased 8880 (33.47%) households out of the total households of 27106 in 2015 (USHA, 2015). The total area under slum also increased from 3408.8 sq.km. in 2001 to 4307.5 sq. km. in 2015. The drainage network and the sanitation system of the city is very poor. The drainage network of the municipality is 339 km in total length and the length of the kaccha drain is 284 km and pucca drain is 55 km (Jalpaiguri Municipality Report, 2018).

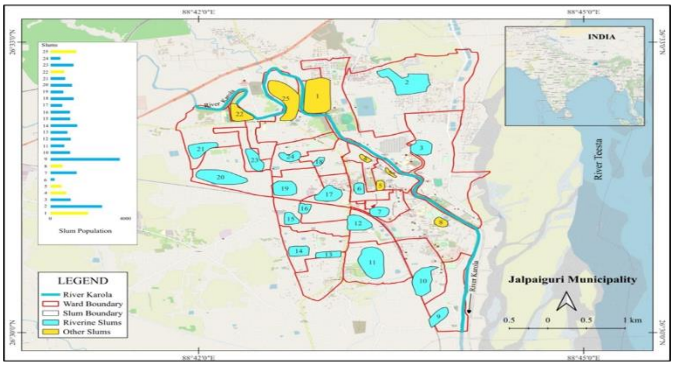


Figure 1: Location map of the study area

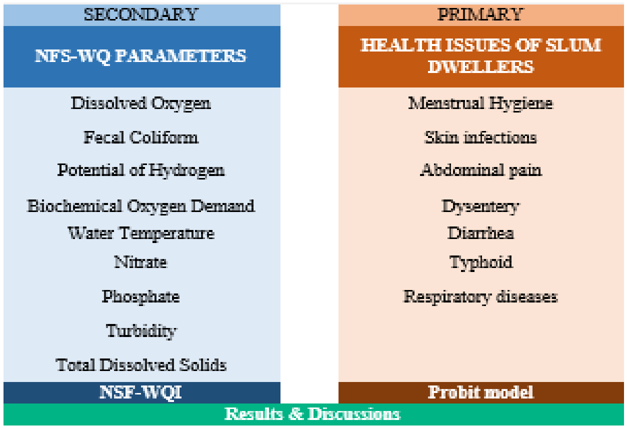


Figure 2: Framework of the present study

2.2 Water Quality Index

The most well-known and extensively used index in the world, the National Sanitation Foundation's Water Quality Index (NSF-WQI), was proposed by Brown et al. based on the Horton index. In order to streamline the reporting of overall water quality, the NSF-WQI was created in the 1970s (Horton, 1965 and Brown et al., 1970). It helps communities, governments, and non-experts evaluate the overall health of water bodies including rivers, lakes, and reservoirs by distilling complex water quality data into a single numerical value. The goal of the project is to assess surface water quality in a consistent and comprehensible manner, support public communication, environmental monitoring, and decision-making, and enable comparison of water quality over time and across different sites.Water quality for a variety of applications, including irrigation, water supply, and navigation, as well as for diverse bodies of water (lakes, reservoirs, and rivers), can be determined using this index. The nine primary water quality criteria included in the original NSF-WQI were selected for their importance to human health and the ecosystem are temperature, pH, turbidity, phosphate, nitrate, total solids, dissolved oxygen (OD), biochemical oxygen demand (BOD), and fecal coliforms—were employed in this index in accordance with the standards listed in Table 1(Misaghi et al., 2017). A statistical survey employing the DELPHI technique, created by 142 experts, states that the NSF-WQI is computed based on weights assigned to each parameter. Table 2 displays each parameter's weights (Effendi et al., 2015). Evaluating the value of each parameter using NSF-WQI the formula is given below.

$$WQI = \sum_{i=1}^{n} (Qi \; x \; Wi)$$

Where, Qi corresponds quality rating parameter i, Wi to its weight of parameter i and n is the number of parameters (considering 9)

Table1: Significance of parameters of NSF-WQI

Parameter	Symbol	Unit	Importance
Dissolved Oxygen	DO	mg/l	Shows the presence of aquatic life support.
Fecal Coliform	FC	MPN/100 ml	Shows the existence of harmful microbes.
Potential of Hydrogen	pH	-	Evaluates acidity or alkalinity

Table1 (cont): Significance of parameters of NSF-WQI

Biochemical Oxygen Demand	BOD	mg/l	Measures organic pollution
Water Temperature	T	°C	impacts oxygen solubility and organism health
Nitrate	NO_3	mg/l	Effects agricultural runoff, eutrophication
Phosphate	PO_4^{3-}	mg/l	Effects to algal blooms
Turbidity	NTU	NTU	Impacts light penetration and aquatic life
Total Dissolved Solids	TDS	mg/l	Shows the presence of dissolved/suspended materials

Table 2: Suitability of NSF-WQI

NSF-WQI Range	Water Quality Rating	General Use Suitability
0–25	Very Poor	Highly polluted; unsafe for most uses
26–50	Poor	Needs treatment; not safe for direct contact
51–70	moderate	Suitable for irrigation, recreation
71–90	Good	Suitable for all uses, minor pollution
91–100	Excellent	Ideal for drinking, recreation, aquatic life

Source: Environmental Indicators (2007), State of the Environment Report, 4:32-33

2.3 Probit Model Analysis

When the dependent variable in statistics is binary (for example, 0 or 1, success/failure, yes/no), a Probit model is a type of regression utilized. It belongs to the family of generalized linear models and is frequently used to estimate the likelihood that an observation would fall into one of two categories in the social sciences, biostatistics, and econometrics.The Probit model assumes that the latent variable model's error term has a typical normal distribution (Wooldridge, 2010 and Greene, 2012). The model's functional form is:

$$P(Y=1|X)=\Phi(X\beta)$$

where Y is a binary dependent variable (0 or 1), X is a vector of independent variables, β is a vector of coefficients to be estimated, Φ is the cumulative distribution function (or CDF) of the standard normal distribution, and. In contrast, the logistic CDF is used in the logit model.Usually, maximum likelihood estimation (MLE) is used to estimate the model. The direction of each predictor's effect is shown by the coefficients β, but not its probability magnitude. Marginal effects are calculated in order to interpret the influence of variables in terms of probability. The standard normal probability density function is denoted by ϕ(Amemiya, 1981).

$$\frac{\partial P(Y=1 \mid X)}{\partial X} = \phi(X\beta)\beta$$

The probit model has been used to assess the effects of selected factors on different health issues of riparian slum dwellers of Jalpaiguri municipality area.

4. Results

4.1 Water Quality Degradation

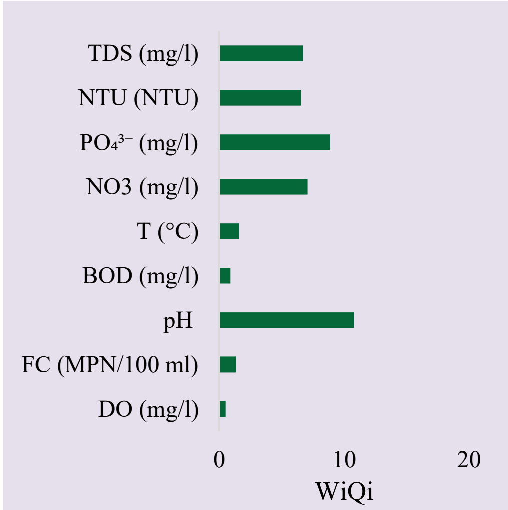
The water quality of KaralaRiver has been calculated in Table 3 following the Weighted Arithmetic Water Quality Index (NSF-WQI) method by Brown et al. 1972. The water quality parameters used in this study are

Dissolved Oxygen, Fecal Coliform, Potential of Hydrogen, Biochemical Oxygen Demand, Water Temperature, Nitrate, Phosphate, Turbidity, Total Dissolved Solidswhich were collected from the Central Pollution Control Board, 2023. While calculating it was observed that the actual values or mean concentration of these parameters are compared with the BIS standard values of permissible limit. The mean concentration value of pH in Karala River is 7.4 which is under the permissible limit of 6.5-8.5. The observed concentration of dissolved oxygen is 7.66 mg/l which is much higher than the BIS standards of 5. In case of biological oxygen demand the observed concentration is higher than the standard value. The mean concentration is 24.8 mg/l whereasthe standard value is 10 mg/l. Nitrate concentration is also very low compared to the standard concentration. The BIS standard value is 45 mg/l and the mean concentration value is only 2.1 mg/l. The observed fecal coliform is 2960 mpn/100 ml where the standard value is 0 mpn/100 ml which much higher than the standard value. Similarly, the standard for TDS is 500-2000 whereas the observed concentration is 1.76 mg/l.The phosphate content in the river is 0.059 which is lower than the BIS permissible level.After the calculation it could be identified that the WQI value of Karala River falls under the 'Suitability of NSF-WQI' category (Table 2) in of the water quality classification developed by NSF as the WQI value is 44.76 (Table 3) which belongs to 26-50 indicating not safe for direct contact which Needs immediate treatment. The water quality in Jalpaiguri Municipality is in extremely bad condition for any type of use.

The whole stretch of Karala is not polluted. The polluted portion of the river stretches from Jalpaiguri to Thakurerkamat, which is approximately 50 km in length. The Karala River pollution mainly happens due to urban activities. The dumping of waste, outfall of untreated sewages into the river is the main causes of water pollution in Karala. The river further gets polluted by the various activities of the slum dwellers. A large amount of solid waste is being dumped into the river. Also, a pile of waste could be seen along the riverbank. Mainly four drains are contributing to the pollution of the river namely Dhardhara river, Maskalaibari Crematorium Ghat, District Hospital Road, and Dinbazar drain. The Dhardharariver entersthe tributary of Karala River and it collects sewage from town area as it passes through Raikatpara, Senpara, Haspatalpara, Samajpara and then drains it into Karala River. From the above major drains12.81 MLD sewage outflows into Karala River which contributes greatly to the water contamination. Also,waste is being dumped into the river by slum dwellers(Action Plan for Rejuvenation of River Karola Jalpaiguri, West Bengal, 2020). From the FGDs it can be identified that 72.5% of people are throwing waste in the river. These wastes are both solid and liquid in nature. The solid wastes are plastics, pieces of broken or torn household items, kitchen waste and the liquid wastes are dirty water from household sewage, wastewater by washing clothes, dishes etc. From the collected data it can be observed that 56% of households using riverbank for their urination and defection and 44% said "No" to the statement. So, these excreta with a close contact with the river water making it polluted day by day.

Table 3: Weighted Arithmetic Water Quality Index (NSF-WQI)of River Karala

Parameters	Mean value	Weight (Wi)	Q-value (Qi)	WiQi
DO (mg/l)	7.66	0.17	3.1	0.527
FC (MPN/100 ml)	2960	0.15	9	1.35
pH	7.4	0.12	90	10.8
BOD (mg/l)	24.8	0.1	9	0.9
T (°C)	24.7	0.1	16	1.6
NO_3 (mg/l)	2.1	0.1	71	7.1
PO_4^{3-} (mg/l)	0.059	0.1	89	8.9
NTU (NTU)	69.4	0.08	82	6.56
TDS (mg/l)	1.76	0.08	84	6.72
Total				



4.2 Health issues of Slum dwellers

Binary regression (probit) analysis was utilized to further understand the association between the socio-economic condition of the slum dwellers and each of the health parameters like Menstrual hygiene, skin infections, abdominal pain, dysentery, diarrhea, typhoid and respiratory diseases. Only Educational Status (coefficient 2.119) and different Kind of Daily Activities on River (coefficient2.206) show statistically significant positive effects on menstrual hygiene ($p < 0.01$) and all other variables (Age, Marital Status, Caste, Religion, Wealth, Working Status) are not statistically significant ($p > 0.05$). This shows that education and daily engagement in river practices are key drivers of menstrual hygiene practices for skin infections, three variables show statistically significant effects. Educational Status (Coefficient -1.186) has a significant negative association ($p = 0.0296$), indicating that individuals with higher education are less likely to experience skin infections. Similarly, Wealth Quantile (coefficient -0.841) is negatively associated and significant ($p = 0.0403$), suggesting that individuals in higher wealth groups are at lower risk. In contrast, Different Kind of Daily Activities on River has a strong positive (Coefficient 2.122) and highly significant effect ($p < 0.001$), implying that increased exposure to river activities substantially raises the likelihood of skin infections. Other variables (Age, Marital Status, Caste, Religion, and Working Status) do not show statistically significant effects in this model. The findings highlight the protective role of education and wealth, while also emphasizing the health risks linked to environmental exposure through river-related activities.In the Probit model for abdominal pain, none of the explanatory variables show statistically significant effects. Variables such as Age, Educational Status, Marital Status, Caste, Religion, Wealth Quantile, Working Status, and Different Kind of Daily Activities on River all have p-values well above the conventional significance thresholds (e.g., $p > 0.05$). While some coefficients are positive or negative, their lack of statistical significance suggests these relationships are not strong enough to draw reliable conclusions. Therefore, based on this model, we cannot identify any clear demographic, socioeconomic, or environmental predictors of abdominal pain.In the Probit model for dysentery, two variables show statistically significant effects. Wealth Quantile (coefficient -0.519 and $p = 0.0277$), indicating that individuals with better economic status are less likely to suffer from dysentery. Conversely, Different Kind of Daily Activities on River (coefficient 0.877) has a strong and highly significant positive effect ($p = 0.0054$), suggesting that engaging in varied river-related activities increases the risk of dysentery. Other variables, including Age, Educational Status, Marital Status, Caste, Religion, and Working Status, have p-values greater than 0.05 and therefore do not significantly influence dysentery in this model.According to the findings (Wealth Quantile with p-value 0.00037) shows that wealthy families have better access to sanitation and hygiene, they are less likely to get diarrhea. On the other hand, regular activities near rivers greatly increase the risk of diarrhea, emphasizing pollution as a major contributing factor.Additionally, Different Kind of Daily Activities on River also has a significant positive impact ($p = 0.0200$), reinforcing the idea that engaging in varied river-related activities increases the risk of diarrhea, likely due to exposure to contaminated water (Table 4).

Other variables, including Age, Educational Status, Marital Status, Caste, Religion, and Working Status, have p-values above 0.05, indicating no statistically significant effect on the occurrence of diarrhea.In the Probit model for typhoid, none of the explanatory variables demonstrate statistically significant effects, as all p-values are substantially greater than the standard threshold of 0.05. This includes Age, Educational Status, Marital Status, Caste, Religion, Wealth Quantile, Working Status, and Different Kind of Daily Activities on River. This shows that there is no association between the socio-economic variables and health parameter typhoid. In the Probit model for respiratory diseases, none of the explanatory variables exhibit statistically significant effects, as all the p-values exceed the conventional significance threshold of 0.05. hence there is no strong evidence to link them to the likelihood of respiratory diseases in this model.

Table 4: Probit model analysis results.

Variables	Menstrual Hygiene			Skin Infections			Abdominal Pain			Dysentery		
	Coefficient	Standard Error	P-Value	Coefficient	Standard Error	P-Value	Coefficient	Standard Error	P-Value	Coefficient	Standard Error	P-Value
Age	-0.101855753	0.0563443	0.070647	-0.04845	0.049865279	0.331214	0.0270301	0.042216	0.521994	-0.0042854	0.033664	0.898703
Educational Status	**-2.119867715****	0.7500441	0.004709	**-1.18603***	0.545315597	0.029634	-0.0470263	0.550745	0.931954	0.18882487	0.416403	0.650213
Marital Status	-0.836605807	0.8703099	0.336415	-0.03547	0.756991247	0.962627	-0.5334386	0.613465	0.384546	0.2744375	0.473529	0.562213
Caste	-0.618974056	0.4442914	0.163568	0.21782	0.517156412	0.673618	0.2326989	0.340005	0.493724	0.15897318	0.286188	0.578562

Table 4 (cont): Probit model analysis results.

Religion	1.010234012	0.6380111	0.113328	-0.48615	0.701338963	0.488199	-0.2664679	0.493831	0.589477	-0.221849	0.399219	0.578411
Wealth Quantile	-0.348931876	0.3830513	0.362334	**-0.84163***	0.410366699	0.040275	-0.3604176	0.318257	0.257436	**-0.5193266***	0.235916	0.027714
Working Status	-0.188607136	0.8710949	0.828585	1.589326	1.141249009	0.163735	0.4672436	0.636583	0.462957	0.48773207	0.569268	0.391572
Different kind of Daily Activities on River	**2.206431214****	0.5728326	0.000117	**2.122627****	0.452114808	0	0.7882553	0.653246	0.227557	**0.87743812****	0.315127	0.005363
Variables	**Diarrhea**			**Typhoid**			**Respiratory Diseases**					
	Coefficient	**Standard Error**	**P-Value**	**Coefficient**	**Standard Error**	**P-Value**	**Coefficient**	**Standard Error**	**P-Value**			
Age	-0.0126281	0.04153	0.76107	0.1324743	0.190806	0.487503	0.3910646	0.272198	0.150805			
Educational Status	0.1228562	0.53926	0.819783	14.782109	560.0616	0.978943	4.7568643	3.985736	0.232685			
Marital Status	-0.0730541	0.56666	0.897421	19.315376	3690.951	0.995825	2.0762587	3.854568	0.590129			
Caste	0.2605877	0.376946	0.489369	55.741233	1386.914	0.967941	-0.853362	2033.234	0.999665			
Religion	-0.2754899	0.504096	0.58472	-44.732258	1825.38	0.980449	18.757747	2033.235	0.992639			
Wealth Quantile	**-1.2825912****	0.360268	0.000371	-27.001732	780.6838	0.972409	1.4186657	1.237005	0.251441			
Working Status	0.2587451	0.69228	0.708584	84.183606	2155.644	0.968848	-15.25929	3346.997	0.996362			
Different kind of Daily Activities on River	**2.3921343***	1.028457	0.020022	43.875955	1650.654	0.978794	-1.507481	1.508544	0.317652			

5. Discussions

All the parameters show varied concentration and differ from place to place. Several biological and anthropogenic factors influence the pH of water bodies (Hamid et al., 2019). Depending on the wastewater from the industrial discharge the pH of water varies greatly. The lead battery manufacturing industries, liquid effluents containing sulfuric and nitric acid, alcohol distillery contributes to the acid concentration in the water bodies. On the other hand, the waste water from the agricultural fields, different factories like plastic cup manufacturing industries, soap and detergent industries release a high number of alkaline effluents. In the context of biological factors, the photosynthesis process releases oxygen which increases pH; respiration process consumes oxygen and lowers pH (Cronin et al., 2007). As there are no significant industries but agricultural fields alongside the River Karala, the pH of this river water is (7.4), which is under the ideal range of 6.5 to 8.5. This phenomenon could be traced to the total amount of coliform present in River Karala. Moreover, consuming oxygen lowers pH so the high number of coliforms in Karala River can be the cause of low alkaline nature of the water. In any aquatic ecosystem the level of dissolved oxygen plays a crucial role and has great importance for survival of aquatic lives (O'Boyle et al. 2009; Wetzel and Likens 2000; Allan and Castillo 2007). DO concentration is inversely related to temperature and salinity. It directly related to the high amount of rainfall (Hynes, 1960; United States Environmental Protection Agency). Karala River is situated in tropical climatic zone which receives an ample amount of rainfall during monsoon; also, the salinity is lower in level which increases the DO of the river. Higher BOD indicates high number of organic pollutants present in water body coming from domestic wastewater (Saifulla et al. 2016). The mean concentrated value of BOD for Karala River is higher than the standard value which implies highnumber of organic pollutants in this river. A low concentration of nitrate in water bodies can be due to absence agricultural fields, concentrated animal farming, noindustrial waste and leachates from solid waste landfills (Manassaram et al. 2006; Boyer et al. 2002; Edwards et al., 2000; Goller et al., 2006). A low concentration of nitrates could be identified in this river correlated with presence of agricultural and industrial activities. A very high level of total coliform concentration could be observed in the river water. Coliform bacteria come from the same source of pathogenic organisms and water pollution caused by coliform contamination is a serious issue due to the potential contracting diseases from pathogens. The contamination of these bacteria in the water is related to the human and animal excreta (Department of Health, New York State, year). As the banks of River Karala are used for open defection by the slum dwellers the water may get infected by those bacteria. Conductivity is a measure of the concentration of the charged ions viz. salts, calcium, potassium, chloride, sulphate, nitrate etc.Geology of the catchment area, soil type, rock weathering, and water temperature are the prominent natural controls of conductivity in water (Cunningham et al. 2010; Olson, 2012). The concentration of charged chemical ions can also be included through various anthropogenic activities like downfall of sewages, road runoff, agriculture and urban landuse pattern etc. (Berner and Berner, 1987; Wang and Yin, 1997; Gray, 2004). The high intensity of conductivity in Karala River is related with the outfall of a number of untreated drains from Jalpaiguri Municipality and urban runoff. Due to their day-to-day life interaction with the river the slum area people are facing hygieneand skin diseases related health problems. The probit regression also shows that educational status and daily river activities significantly influence the menstrual hygiene. For skin infections, higher education and wealth reduce risk, while river activities increase it. Dysentery is negatively linked to wealth but positively linked to river exposure. No significant predictors were found for abdominal pain, typhoid and respiratory diseases.

6. Conclusion

Water quality degradation of River Karala is a major concerning issue. Numerous reasons are behind the pollution of River Karala in Jalpaiguri Municipality which were discussed in above sections. Rapid urbanization, lack of space to dispose wastes, drain water falling in to the river without treatment, activities of slum people turned the river into a drain. It negatively impacts upon the environment and also the people dependent on it. Hence authorities and people should jointly take upon action plans for reviving the river and spread awareness among the people by which the harmful effects of the river could be abolished. These would help to ensure good health of the Karala River essential for water security, food security and ecological sustainability of the river. Moreover, steps like development of waste water treatment infrastructures and community-based awareness among the local people could help in sustaining the river water quality.

References

Abedin, M., 1997.Health and Population Sector: An Overview and Vision, in Logical Framework (Log-Frame) Workshop for the Fifth Health and Population Programme (HAPP-5), Pp. 23–25.

Abrahao, R., Carvalho, M., Junior, W.R., Machado, T.T.V., Gadelha, C.D.M., Hernandez, M.S.M., 2007. Use of index analysis to evaluate the water quality of a stream receiving industrial effluents. Water Sa 33(4). Doi: https://doi.org/10.4314/wsa.v33i4.5294

Akhtar, N., Ishak, M., Bhawani, S., Umar, K., 2021. Various Natural and Anthropogenic Factors Responsible for Water Quality Degradation: A Review, Molecular Diversity Preservation International, Volume-13, Issue-19, 2660.

Allan, J.D., and Castillo, M.M., 2007. Stream Ecology: Structure and Function of Running Water. Cabidigitallibrary.org.

Amemiya, T., 1981. Qualitative Response Models: A Survey. Journal of Economic Literature, 19(4), Pp. 1483–1536.

Anonna, T.A., Ahmed, Z., Karim, M.M., Xie, Z., Zhang, F. and Gandara, J.S., 2021. Water Quality Assessment for Drinking and Irrigation Purposes in Mahananda River Basin of Bangladesh. Earth System and Environment. Doi: https://doi.org/10.1007/s41748-021-00274-x.

Badaii, F.A., Gasim, M.B., and Mokhtar, M., 2012. Water Pollution Study based on the Physico-Chemical and Microbiological Parameters of the Semenyih River, Selangor, Malaysia. Cabidigitallibrary.org 15(4): Pp. 318-334. Doi: https://doi.org/10.5555/arwg.15. 4. hn3076665801k728

Berner, E.K., and Berner, R.A., 1987. The global water cycle. Prentice-Hall, Englewood Cliffs.

Bhattacharya, D., Kabir, B., and Ali, K., 1995. Industrial Growth and Pollution in Bangladesh: A sectoral Analysis," in Symposium on, Environment and Sustainable Development with Special Reference to Bangladesh", North South University, Dhaka.

Biaggi, N., 1965. Puerto Rico's Water Pollution Image. Water Pollution Control Federation 37(3): Pp. 381-391. Doi: http://www.jstor.com/stable/25035256.

BIS Standards for the Drinking Water: A complete Overview. https://corpbiz.io/learning/bis-standards for-the-drinking-water/

Boyer, E.W., Goodale, C.L., Jaworski, N.A. and Howarth, R.W., 2002. Anthropogenic Nitrogen Sources and Relationships to Riverine Nitrogen Export in the Northeastern U.S.A. Biogeochemistry 57/58: 137-169. Doi: https://www.jstor.org/stable/1469687.

Brauman, K.A., Daily, G.C., Duarte, T.K., Mooney, H.A., 2007. The Nature and Value of Ecosystem Services: An Overview Highlighting Hydrologic Services. Annual Review of Environment and Resources 32: Pp. 67-98. Doi: 1543-5938/07/1121-0067$20.00.

Brown, R. M., McClelland, N. I., Deininger, R. A., and Tozer, R. G., 1970. A water quality index-do we dare. Water and sewage works, 117(10).

Brown, R.M., McClelland, N.I., Deininger, R.A. and Tozer, R.G., 1970. A Water Quality Index- Do We Dare? Water and Sewage.

Capon. S.J., Lynch, A.J., Bond, N., Chessman, B.C., Devis, J., Davidson, N., Finlayson, M., Gell, P.A., Hohnberg, D., Humphrey, C., Kingsford, R.T., Nielsen, D., Thomson, J.R., Ward, K., Nally, R.M., 2015. Regime shifts, thresholds and multiple stable states in freshwater ecosystems; a critical appraisal of the evidence. Science of the Total Environment. Doihttp://dx.doi.org/10.1016/j.scitotenv.2015.02.045.

Carpenter, S.R., Caraco, N.F., Correll, D.L., Hoearth, R.W., Sharpley, A.N. and Smith, V.H., 1998. Nonpoint Pollution of Surface Waters with Phosphorus and Nitrogen. Ecological Applications 8(3): Pp. 559-568. Doi: https://www.jstor.org/stable/2641247

Chen, S., Chen, L., Liu, X., Pan, Y., Zhou, F., Guo, J., Huang, T., Chen, F. and Shen, Z., 2022. Unexpected nitrogen flow and water quality change due to varying atmospheric deposition. 609: 127679. Doi: https://doi.org/10.1016/j.jhydrol.2022.127679

Chen, S.S., Kimirei, I.A., Yu, C., Shen, Q., and Gao, Q., 2022. Assessment of urban river water pollution with urbanization in East Africa. Environmental Science and Pollution Research 29: Pp 40812-40825. Doi: https://doi.org/10.1007/s11356-021-18082-1Choking Mahananda: How Siliguri's Waste, Water Crisis is turning on its people https://www.downtoearth.org.in/news/water/choking-mahananda-how-siliguri-s-waste-water-crisis-is-turning-on-its-people-77846

Cochran, W. G., 1977. Sampling techniques (3rd Edition). New York, USA: John Wiley and Sons.

Corin, A.A, Hoadley, A.W., Gibson, J., Breslin, N., Komou, F.K., Haldin, L. and Pedley, S., 2007. Urbanisation effects on groundwater chemical quality: findings focusing on the nitrate problem from 2 African cities reliant on on-site sanitation. Journal of Water and Health. Doi: 10.2166/wh.2007.040.

Cunningham, M.A., Menking, K.A., Gillikin, D.P., Batur, P., 2010. Influence of open space on water quality in an urban stream. Phys Geogr 31(4): Pp. 336–356. Doi: https://doi.org/10.2747/0272-3646.31.4.336

Davis, A.M., Pearson, R.G., Brodie, J.E., and Butler, B., 2017. Review and conceptual models of agricultural impacts and water quality in waterways of the Great Barrier Reef catchment area. Marine and Freshwater Research 68: Pp. 1-19. Doi: http://dx.doi.org/ 10.1071/MF15301_AC

Degefu, F., Lakew, A., Tigabu, Y., Teshome, K., 2013. The water quality degradation of upper Awash River, Ethiopia. Ethiopian Journal of Environmental Studies and Management 6(1). Doi: https://doi.org/10.4314/ejesm.v6i1.7

Edwards, M.A., Jacobs, S., and Taylor, R.J., 2000. The Blue Water Phenomenon. Journal AWWA, 92:7:72.

Effendi, H., and Wardiatno, Y., 2015. Water quality status of Ciambulawung River, Banten Province, based on pollution index and NSF-WQI. Procedia Environmental Sciences, 24, Pp. 228-237.

Ewaid, S.H., Abed, S.A., 2017. Water quality index for Al-Gharraf river, southern Iraq. Egypt. J. Aquat. Res. 2017, 43, Pp. 117–122. Doi: https://doi.org/10.1016/j.ejar.2017.03.001

FAO. 2007. Safety Evaluation on Certain Food Activities and Contaminants. World Health Organisation.

Galib, S.M., Rashid, M.A., Chaki, N., Mohsin, A., Joadder, M.A.R., 201. Seasonal variation and community structure of fishes in the Mahananda River with special reference to conservation issues. Indian Journal of Fisheries 4: 325. Doi: https://doi.org/10.17017/ jfish.v4i1.2016.139.

Ghosh, R., Bruch, A.A., Portmann, F., Bera, S., Paruya, D.K., Morthekai, P., and Ali, S.N., 2017. A modern pollen–climate dataset from the Darjeeling area, eastern Himalaya: assessing its potential for past climate reconstruction. Quaternary Science Review 174: Pp. 63-79. Doi: https://doi.org/10.1016/j.quascirev.2017.09.002

Goller R., Wilcke W., Fleischbein K., Valarezo C., Zech W., 2006. Dissolved nitrogen, phosphorus and sulfur forms in the ecosystem fluxes of a montane forest in Ecuador. Biogeochemistry 77:Pp. 57–89.

Gordon, N., Adams, J.B. Rodriguez, F.C., 2011. Water quality status and phytoplankton composition in Soetendalvlei, Voëlvlei and Waskraalsvlei, three shallow wetlands on the Agulhas Plain, South Africa. African Journal of Aquatic Science 36(1). Doi: https://doi.org/10.2989/16085914.2011.559709.

Gray, J., 2004. Conductivity analyzer and their application. In: Lehi RD (ed) Environmental instrumentation and analysis. Wiley Handbook, New York, Pp 491–510.

Greene, W. H., 2012. Econometric Analysis (7th ed.). Pearson Education.

Grizetti, B., Lanzanova, D., Liquete, C., Reynaud, A., and Cardoso, A.C., 2016. Assessing water ecosystem services for water resource management. Environmental Science and Policy 61: Pp. 194-203. Doi: https://doi.org/10.1016/j.envsci.2016.04.008

Haddis, A., Getahun, T., Mengistie, E., Jemal, A., Smets, I., van der Bruggen, B., 2014. Challenges to surface water quality in mid-sized African cities: conclusions from Awetu-Kito Rivers in Jimma, south-west Ethiopia. Water and Environment Journal 28(2): Pp. 173–182. https:// doi.org/10.1111/wej.12021.

Halder and Islam, 2015. Water Pollution and its Impact on Human Health. Journal of Environment and Human 2(1): Pp. 2373-8332. Doi: 10.15764/EH.2015.01005

Hamid, A., Bhat, S.U. and Jehangir, A., 2019. Local Determinants of Water Quality. Applied Water Science 10(24). Doi: https://doi.org/10.1007/s13201-019-1043-4

Hassan, M.K., Khan, M.R., Nesha, M.K., and Happy, M.A., 2014. Analysis of Water Quality using Chemical. Open Journal on Water Pollution and Treatment 1(2): Pp. 58-74.

Hernandez, M.S.G., Anda, J.D., Gongalez, A.G., Montes, C.Y., Pina, H.B., Palomino, P.R., and Vazquez, D.D., 2020. Assessment of the water quality of a subtropical lake using the NSF-WQI and a newly proposed ecosystem specific water quality index . Environmental Monitoring and Assessment 192: Pp. 296. Doi: https://doi.org/10.1007/s10661-020-08265-7

Horton, R. K., 1965. An index number system for rating water quality. J Water Pollut Control Fed, 37(3), Pp. 300-306.

Hoven, C.V.D., Jasawa, E.U., Merwe, B.V.D., Loubser, M., and Abia, A.L.K., 2017. The impact of various land uses on the microbial and physicochemical quality of surface water bodies in developing countries: prioritisation of water resources management areas. Environmental Processes.

Feasibility, B. W. D. B., 2004.Water Modeling (IWM), Feasibility and Mathematical Model Study of Approaching and Investigating Strategy for Rehabilitating the Buriganga Turag Shitalakhya River system and Augmentation of Dry Season Flow in the Buriganga River, 2004

Jindal, R., and Sharma, Chetan. 2011. Studies on water quality of Sutlej River around Ludhiana with reference to physicochemical parameters. Environmental Monitoring and Assessment 174: Pp. 417-425. Doi: 10.1007/s10661-010-1466-8.

Kamaruddin, A.F., Toriman, M.E., Juahir, H., Jain, S.M., Rahman, M.N.A., Kamaruddin, M.K.A. and Azid, A., 2015. Spatial Characterization and Identification Sources of Pollution using Multivariate Analysis at Terengganu River Basin, Malaysia. Science and Engineering 77(1). Doi: https://doi.org/10.11113/jt.v77.4054

Karr, J.R., 1991. Biological Integrity: A Long-Neglected Aspect of Water Resource Management. Ecological Applications 1(1): Pp. 66-84. Doi: https://www. jstor.org/ stable/1941848

Kondolf, G.M., 1997. Hungry Water: Effects of Dams and Gravel Mining on River Channels. Environmental Management 21(4): Pp. 533-551.

Lama, A., and Lama, N. D., 2025. A Spatial Assessment of Water Scarcity Using the Water Poverty Index in Darjeeling Municipality, West Bengal, India. World Water Policy. https://doi.org/10.1002/wwp2.70026

Lumb, A., Sharma, T.C., and Bibeault, J.F., 2011. A Review of Genesis and Evolution of Water Quality Index (WQI) and Some Future Directions 3: Pp. 11-24. Doi: 10.1007/s12403-011-0040-0.

Manassaram, D.M., Backer, L.C., and Moll, D.M., 2006. A Review of Nitrates in Drinking Water: Maternal Exposure and Adverse Reproductive and Developmental Outcomes. Environmental Health Perspectives 114(3): Pp.320-327. Doi: https://www.jstor. org/stable/3436672

Mandal, D.K., 2013. River Linking and Flood Management of Mahananda River Basin in West Bengal. J. Bengal Geogr.

McGauhey, P.H., 1968. Engineering Management of Water Quality.

Mekonnen, M. M., Hoekstra, A.Y., 2016. Four Billion People Facing Severe Water Scarcity. Science Advances 2(2).

Misaghi, F., Delgosha, F., Razzaghmanesh, M., and Myers, B., 2017. Introducing a water quality index for assessing water for irrigation purposes: A case study of the Ghezel Ozan River. Science of the Total Environment, 589, Pp. 107-116.

Moncayo-Estrada, R, Escalera-Gallardo, C., Arroyo-Damián, M., Campos-Campos, O., Silva-García, J.T., 2017. Nitrogen nutrients in a subtropical river: temporal variation and analysis at diferent spatial scales. Mar Freshw Res 68:Pp.1935–1949.

Mukherjee, S., Kumar, D., Nanda, A.K. and Chakraborty, R., 2013. 16S rRNA gene sequence analyses of the metagenome derived from waters of river Mahananda at Siliguri: an approach to understand bacterial diversity. Indian Journal of Biotechnology 2: Pp. 22-26.

O'Boyle, S., Wilkes, G., McDermott and Wilkes, R., 2009. Dissolved oxygen levels in estuarine and coastal waters around Ireland. Marine Pollution Bulletin 58: Pp. 1657-1663. Doi: 10.1016/j.marpolbul.2009.07.002.

Olson, J.R., 2012. The influence of geology and other environmental factors on stream water chemistry and benthic invertebrate assemblages. All Graduate Theses and Dissertations.

Parween, S., Siddique, N.A., Diganta, M.T.M., Olbert, A.I., and Uddin, M.G., 2022. Assessment of urban river water quality using modified NSF water quality index model at Siliguri city, West Bengal, India. Environmental and Sustainability Indicators 16: 100202. Doi: https://doi.org/10.1016/j.indic.2022.100202

Peavy, H., Rowe, D. G., and Tchobanoglous, G., 1986. Environmental Engineering, 1986.

Pringle, C.M., 2000. Threats to U.S. Public Lands from Cumulative Hydrologic Alterations Outside of Their Boundaries. Ecological Applications. Doi: https://www. jstor. org/stable/2641012

Ramakrishnaiah, C.R., Sadashivaiah, C. and Ranganna, G., 2009. Assessment of Water Quality Index for the Groundwater in Tumkur Taluk, Karnataka State, India. Journal of Chemistry 6(2): Pp. 523-530.

Rangarajan, D., Thattai, D., Kumar, H., Satish, N., Rustagi, R.Y.P., 2019. Evaluation of water quality index for River Mahananda West Bengal India. International Journal of Innovative Technology and Exploring Engineering 8: Pp. 1307-1309.

Rashid, I., and Romshoo, S.A., 2013. Impact of anthropogenic activities on water quality of Lidder River in Kashmir Himalayas. Environmental Monitoring and Assessment 185:Pp. 4705-4719. Doi: 10.1007/s10661-012-2898-0.

Resh V. H., and McElravy E. P., 1993. Contemporary quantitative approaches to biomonitoring using benthic macroinvertebrates. In: Freshwater Biomonitoring and Benthic Macroinvertebrates (eds D. M. Rosenberg and V. H. Resh Pp. 159–94. Chapman and Hall, New York .

Robinson, C.J., Taylor, B.M., Pearson, L., Donohue, M.O., and Harman, B., 2009. A SMART assessment of water quality partnership needs in Great Barrier Reef catchments. Australian Journal of Environmental Management 16(2). Doi: https://doi.org/10.1080/ 14486563.2009.9725222

Rocha, F.C., Andrade, E.M., and Lopes, F.B., 2015. Water quality index calculated from biological, physical and chemical attributes. Environmental Monitoring and Assessment 187: 4163. Doi: 10.1007/s10661-014-4163-1.

Saifullah, A.S.M., Kamal, A.H.M., Idris, M.H. Rajaee, A.H., Bhuiyan, M.K.A., and Haque, M.N., 2016. Inter-linkage among some physico-chemical and biological factors in the tropical mangrove estuary. Zoology and Ecology 26(2). Doi: https://doi.org/10.1080/ 21658005.2016.1148964

Shanchez, E., Colmenarejo, M.F., Vicente, J., Rubio, A., Garcia, M.G., Traviesso, L., and Borja, R., 2007. Use of the water quality index and dissolved oxygen deficit as simple indicators of watersheds pollution. Ecological Indicators 7: Pp. 315-328. Doi: http://dx.doi.org/ 10.1016/j.ecolind.2006.02.005

Sharma, S., and Chhipa, R.C., 2016. Seasonal variations of ground water quality and its agglomerates by water quality index. Global Journal of Environmental Science and Management 2(1):Pp. 79-86. Doi:

10.7508/gjesm.2016.01.009.

Shil, S., and Singh, U.K., 2019. Health risk assessment and spatial variations of dissolved heavy metals and metalloids in a tropical river basin system. Ecological Indicators 106: 105455.

Smol, J.P. 2010. The power of the past: Using sediments to track the effects of multiple stressors on lake ecosystems. Freshwater Biology 55: Pp. 43-59.

Suratman, S., Hang, H.C., Shazili, N.A.M. and Tahir, N.M., 2009. A Preliminary Study of the Distribution of Selected Trace Metals in the Besut River Basin, Terengganu, Malaysia. Bulletin of Environmental Contamination and Toxicology 82: Pp. 16-19. Doi: 10.1007/s00128-008-9507-5.

Tomas, D., Curlin, M., Maric, A.S., 2017. Assessing the surface water status in Pannonian ecoregion by the water quality index model. Ecological Indicators. Doi: http://dx.doi.org/10.1016/j.ecolind.2017.04.033

Tromboni, F., Dodds, W.K., 2017. Relationships Between Land Use and Stream Nutrient Concentrations in a Highly Urbanized Tropical Region of Brazil: Thresholds and Riparian Zones. Environmental Manangement 60: Pp. 30-40. Doi: 10.1007/s00267-017-0858-8.

UN- Water, 2001. Water Quality.

UNEP, 2016. A Snapshot of the World's Water Quality: towards a Global Assessment. United Nations Environment Programme.

Vorosmarty, C.J., McIntyre, P.B., Gessner, M.O., Dudgeon, D., Prusevich, A., Green, P., Glidden, S., Bunn, S.E., Sullivan, C.A., Liermann, C.R., Davies, P.M., 2010. Global threats to human water security and river biodiversity. Nature 467: Pp. 555-561. Doi: 10.1038/nature09440.

Wang, X., Yin, Z., 1997. Using GIS to assess the relationship between land use and water quality at a watershed level. Environ Int 23:Pp. 103–114.

Water Quality Data Year, 2014, Central Pollution Control Board, Ministry of Environment, Forest and Climate Change, Government of India. https://cpcb.nic.in/nwmp-data-2014/

Watzel, R.G., Likens, G., 2000. Limnological Analysis. Springer Science and Business Media. What is Water Quality? Florida Keys National Marine Sanctuary, National Oceanic and Atmospheric Administration.

Wooldridge, J. M., 2010. Econometric Analysis of Cross Section and Panel Data (2nd ed.). MIT Press.

Xiong, C., Guo, Z., Chen, S.S., Gao, Q., Kishe, M.A., Shen, Q., 2020. Understanding the pathway of phosphorus metabolism in urban household consumption system: a case study of Dar es Salaam. Tanzania Journal of Cleaner Production 274:Pp. 122874. https://doi. org/10.1016/j.jclepro.2020.122874.

Yu, C., Chen, S.S., Zhang, L., Gao, Q., Wang, Z., Shen, Q., 2018. Changes in water quality of the rivers discharging into Lake Tanganyika in Bujumbura. Burundi Aquatic Ecosystem Health and Management 21(2): Pp. 201–212. https://doi.org/10.1080/14634988.2017.1394772.