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Exploring Wetland Health and its Contributions to the Community Well-being Entities: Perspectives from the Rudrasagar Lake area, Tripura

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Abstract : *This study is a comprehensive approach and framework that examines the perception of villagers about Rudrasagar Lake water and analyses their health conditions. Through a combination of extensive field surveys and interviews, the study explores the divergent perceptions regarding recent water quality and changes in the quality among different group of people. The questionnaire was calculated using 5-point Likert scale ranging from 1-5. Community health status and their perceived medical services were also examined in this current research. Statistical methodologies such as Gibbs' ternary diagrams, Venn diagrams, and Pearson's correlation analysis were employed for aggregating the field data. In terms of health assessment, this study discusses the correlation between lake water quality and different health risks, including gastrointestinal diseases and skin irritations. Hall's satisfaction index was employed to determine their satisfaction level regarding the lake water. The findings of this study indicated the significance of dwellers' perception as a decision-making force behind water use and recreational activities. Findings also suggested the need for effective lake management, which includes monitoring water quality and addressing public health risks. By encouraging a deeper understanding of human-environment interactions, policymakers can promote more effective strategies for the health and well-being of communities dependent on lake ecosystems.*

Key words: *Community well-being, Demographic pattern, Health status, perception of water quality, Wetland*

1. Introduction

It is globally accepted that wetlands provide diverse and valuable goods and services for human well-being (Finlayson et al., 2015; Dale and Connelly, 2012). Wetlands are often considered kidneys of the earth due to their critical services in filtering and regulating water by trapping pollutants and excess nutrients and serving in maintaining the health and balance of Earth's ecosystems and water resources (Stewart and Schriever, 2023). Additionally, they provide diverse ecosystem services. For instance; Williams and Dodd (1978) stated that wetlands provide habitat

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for diverse species, including many vulnerable, endangered, and critically endangered species. Furthermore, this statement is strongly supported by Biswas et al. (2025), who examined the crucial role of wetlands in providing ecosystem services and conserving bird diversity. It is characterised as a transition between terrestrial and aquatic ecosystems (Hammer and Bastian, 2020), which also helps in multiple functions, including weather monitoring, flood control, carbon sequestration, and groundwater recharge (Nayak and Bhusan, 2022). Finally, wetlands provide livelihood support to inhabitants as well as a recreational space (Lamsal et al., 2015). It has enormous ecological significance but is facing many challenges worldwide (Shan et al., 2021). With the shift in scientific understanding and public perception, policies have also shifted. Many policies have been formulated to preserve and protect wetlands worldwide (Kumari et al., 2020).

Understanding wetland ecosystem health requires a heterogeneous approach that incorporates several social, ecological, and economic perspectives (Aryal et al., 2021). Research on community perceptions is equally important, as well as valuable scientific insights on wetland health (Cottet et al., 2013). Local communities at the wetlands often possess invaluable knowledge regarding wetlands. Their attributes, culture, and behaviour can change wetland health, which further has an impact on people's well-being (Horwitz and Finlayson, 2011). In recent decades, wetlands have been strongly affected by anthropogenic activities such as urbanisation, increasing pollution load (Biswas et al., 2024), increasing population and unscientific extraction of resources (Melly et al., 2018). Domestics and municipal wastewater, surface run-off, and effluents from idol immersion and recreational activity are directly discharged and influx with the water bodies hampering the water quality (Neralla, 2000). Perhaps the direct use of lake water is not always safe and healthy (Zimmerman, 2001). Wetlands are directly related with the health of people living around them; even they contribute to mental and social well-being, which are positive aspects of health (McCartney et al., 2015). Human health can be defined as "Health is a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity" (WHO, 2012). Wetland health and local well-being are interrelated with each other. It identifies the disjunction that can exist between managing wetland health and human health. There is a need to resolve the potential conflict between managing wetlands for their values and managing them for positive human health outcomes (Maund et al., 2019). Management of wetlands to minimise human health risks is fraught with potential conflicts (Dale and Connelly, 2012). The physical health dimension perceived with wetlands may be a negative one, with a range of disease risks (Brownlie, 2016).

The Ramsar Convention was employed worldwide to protect wetlands as waterfowl habitats for the conservation and sustainable use of wetland resources (Kingsford et al.,2016). It was first adopted in 1971 in the Iranian city of Ramsar and designated the Cobourg Peninsula in Australia on 22nd December 1974 (WBM, 2007). Water resources management, conservation of biodiversity, socio-cultural and economic value, and legal responsibility are some of the important objectives that must be considered to implement the international interest convention. In India, 80 Ramsar sites have been designated since 1982, with a surface area of 1,332,200 Ha (https://www.ramsar.org).

Of all the Indian Ramsar sites, Rudrasagar was designated in 2005, as International Site Number 1572, located in Tripura. Seasonally inundated water bodies are used for cultivation, which leads to increased sedimentation (Uwimana et al., 2018). Land conversion, farming, agriculture and recreational activities are increasing day by day in this area (Yu et al., 2018). The lake is immensely significant to neighbouring villagers as it is intertwined directly and indirectly with their livelihood (Nabahungu and Visser, 2011). While serving as a vital source of income repository for cultural activities, it is the most essential and fundamental source of water and other natural resources (Ghosh et al., 2018). Hence, this particular area has become an area of concern in recent days for its multifaceted use. Despite this, wetland values are widely ignored and wetland destruction and degradation are widespread.

Several works have been conducted on the lake considering various aspects of the lake such as water quality (Biswas et al., 2024; Debnath et al., 2023a). But the health status of the villagers around the lake remained untouched. This current study aims to create a bridge between these gaps. The main objective of the study is to investigate the health status of the villagers and the inter-relationship of the health status with their occupational structures. This current research also aims to investigate the satisfaction level of the villagers regarding the lake water as they directly or indirectly use the water.

2. Material and methods

2.1 Description of the study area

Rudrasagar Lake is located in the Sonamura subdivision of Sepahijla district and is 55 km from Agartala, the capital of the Indian state of Tripura (Figure 1a, 1b). Geographically, the lake extends between 23°292 –23°312 north latitude and 90°182 –90°192 east longitude (Figure 1d) with a maximum length of 3.87 km and a width of 2.1 km. The study area is located at an altitude of 10-30 meters above sea level. The lake is seasonally replenished by three perennial tributaries (Noa cherra, Kemtali cherra and Durlavnarayan cherra) and drained by the Kachigang channel (Fig. 1c) on the right bank of the Gomti River. The lake is surrounded by seven Gram Panchayats (Fig. 1e) and Melaghar Municipal Corporation (MMC). Morphologically, it is a lowland area, and ecologically rich in biodiversity, which was internationally recognised as a Ramsar site in 2005. According to the 2011 census, a total of 9,051 residents live in the lake region, and most of their livelihoods depend on agriculture, fishing, and animal husbandry. The sampling villages were selected based on their dependency on lake and water sampling on account of potential sources of contamination, including animal husbandry, urban sewerages, and agricultural discharges. Based on their significance, twenty-four (24) sampling sites were considered for monitoring wetland health. A lake palace, Neermahal is situated amidst the lake, which is a famous tourist destination.

2.2 Description of the sampling areas

Gram Panchayats (GP) and municipal corporation locations were recorded with the help of GPS Garmin eTrex 30. The Geospatial mapping was prepared in ArcGIS10.8 platforms. The sampling

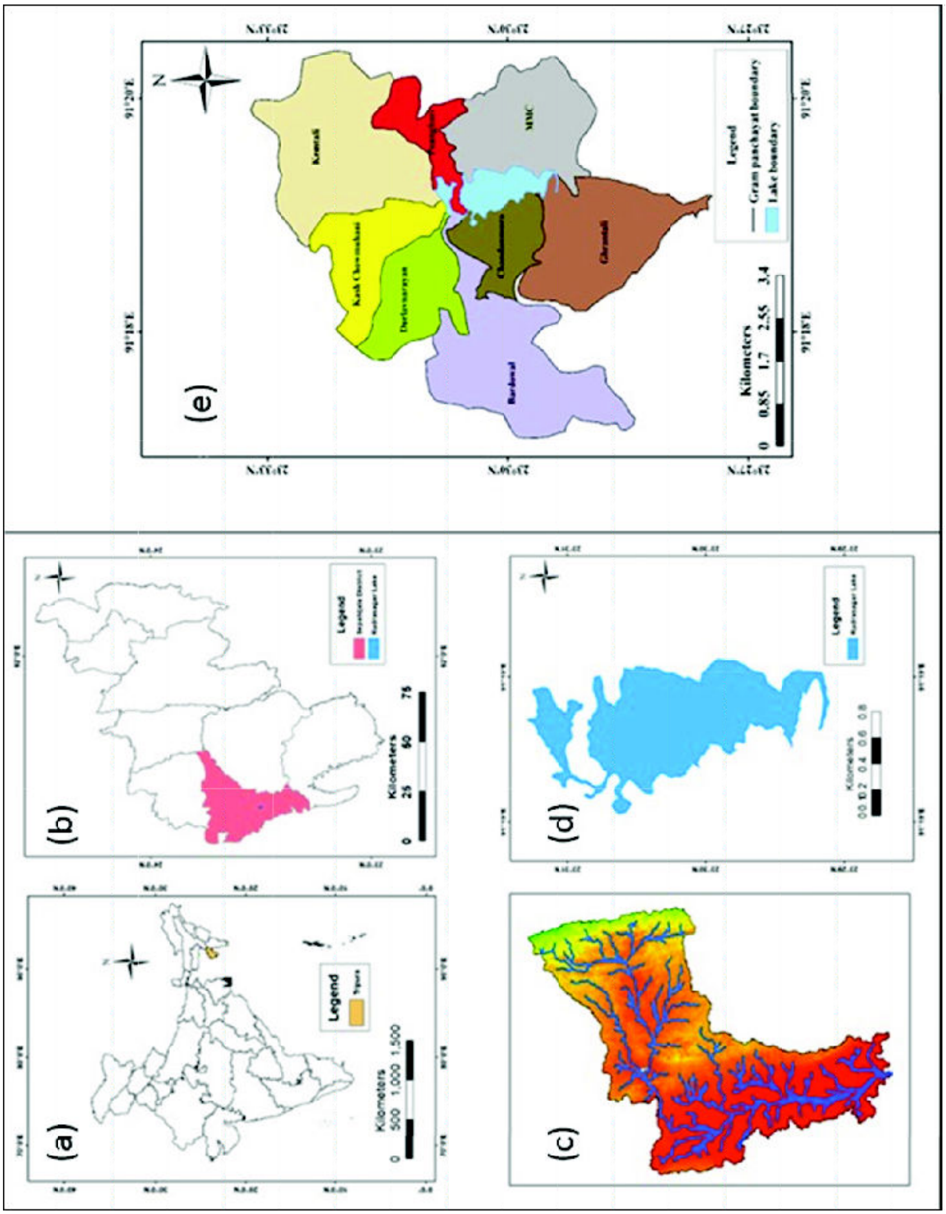

Fig. 1: Study area map (a) country map delineating the Tripura state (b) Map of Tripura and Sepahijala district which demarcating Rudrasagar Lake(c) Catchment area of the wetland (d) Areal expansion of Rudrasagar Lake and (e) Sampled areas; Gram panchayats and MMC located around the lake.

areas along with their geo-coordinates were demonstrated in Table 1. The sampling sites were selected for this study to evaluate the community well-being due to the use of wetland water for irrigation, domestic, and drinking purposes.

Table 1: Description of the study areas along with their geo-coordinates

Site No.	Name of the GP	Coordinates	RD Block	Descriptions
V1	Durlabnarayan	23°32’26"N 91°17’46"E	Nalchar	Located in the north-western side of the lake
V2	Poangbari	23°29’26"N 91°19’49"E	Nalchar	Situated at the north-eastern side of the lake. The smallest GP
V3	Chandanmura	23°30’27"N 91°18’23"E	Nalchar	Western fringe of the lake
V4	Bardowal	23°31’22"N 91°17’46"E	Nalchar	Located on the north-western side
V5	Ghrantali	23°29’31"N 91°18’21"E	Mohanbhog	It is on the south-western side of the lake
V6	Kemtali	23°31’28"N 91°19’21"E	Nalchar	Northern side of the lake. It covers the largest area
V7	Khas Chowmuhani	23.54’10"N 91.30’51"E	Nalchar	Northern side of the lake
M1	MMC*	23°29’49"N 91°19’52"E	MMC	Located at the eastern region of the Rudrasagar

*Melaghar Municipal Council is an urban area settled on the wetland catchmentSource: Data collected using GPS

All the sampled villages are predominantly dependent upon agriculture and fishing, with the villagers largely dependent on farming activities. The northern side of the lake covers the largest area and the smallest GP is situated at the north-eastern side of the lake. Only one urban centre is developed at the eastern region of the Rudrasagar Lake.

2.3 Sample design and data collection

The study was conducted in three distinct phases, which were the pre-field stage, field survey, and post-field stage (Fig. 2). In the pre-field phase, a preliminary survey was conducted to identify problem and a standard questionnaire was prepared. The questionnaire was designed into three different aspects; the first part focused on their occupation and usage of water, the second part was on community health status and disease distribution in the area, while the final part was focused on their perception regarding the water quality of the Rudrasagar wetland. Household surveys were conducted using the interview and community participatory methods during the field surveys. Stratified random sampling was followed across the survey. Older people in the house were questioned because they had better experience of the previous and current conditions of the lake. Table 2 describes the sample size used in the study. A total of 212 samples were collected from the sampling areas surrounding the lake. Five gram-panchayats and one municipality were selected as they are directly associated with the lake. Therefore, Durlabnarayan and Ghrantali GP were excluded from the current study due to their limited access and dependency to the lake area.

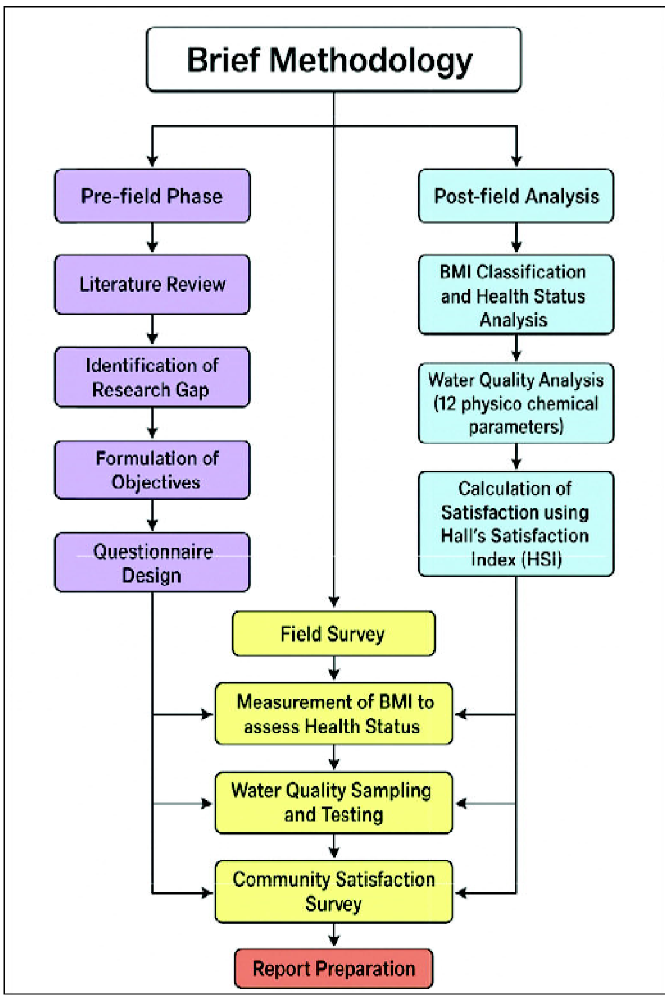

Fig. 2: Brief methodology perceived for the entire study

Table 2: Description of the sample size used in the study

GP ID	Name of the Gram Panchayats	Number of samples	Proportion of sample (%)
V2	Poangbari	40	18.87
V3	Chandanmura	34	16.04
V4	Bardowal	24	11.32
V6	Kemtali	32	15.09
V7	Khas Chowmuhani	30	14.15
M1	MMC*	52	24.53

Source: Primary field survey, V1 & V5 excluded from the survey

2.4 Determination of Occupational Structure

The ternary diagram provides some useful insights for understanding intricate relationships between the components within a given system. This equilateral triangular plot, also known as the Gibbs triangle, represents three component data sets in various fields, including chemistry, ecology, hydrology, and many more (Howarth, 1996). All three axes represent three different components of the given system, and vertices are labelled accordingly. Each point within the triangle corresponds to a specific composition, while the distance from the triangle sides indicates the relative proportion of each component. In this study, Ternary diagram is used to elucidate the occupational structure of respondents. The ternary plot is to prepare using the Rstudio. Here, to show the diversity of occupations, three broad categories have been formed. Primary occupations include agriculture, fishing, timber collection and animal husbandry as these are closely connected to the lake waters and they spend most of the day in and around the lake for their occupations. The second occupation includes labourers and housewives as they use the lake water relatively less, although the lake water is for washing dishes and clothes. Tertiary occupations included businesses, services, and students, as they are largely prevented from using the lake water for occupations.

2.5 Determination of health status

Health status was determined by Body Mass Index (BMI). A standard medical stadiometer and weighing machine were used for measuring the height and weight of the respondents respectively. Using the respondents' height and weight, BMI is calculated through the matrix method (Nuttall, 2015) using the following formula:

$$BMI = \frac{W_{ij}}{h_{ij}} \tag{1}$$

Where, W_{ij} denotes the weight of an individual in kg, and h_{ij} denotes the subject height in m. Respondents were classified into four different weight categories based on BMI values. Observed diseases were categorised into seven distinct groups (Table 3). Distribution of disease across the sampling area and was illustrated through Venn diagrams. These diagrams were used to show the commonality of the disease occurrence (Soriano et al., 2003).

Table 3: BMI indicator and Categorisation of diseases

Under weight		Normal Weight		Overweight	Obesity	
<18.5		18.5-24.9		25-29.9	>30	
Category 1	**Category 2**	**Category 3**	**Category 4**	**Category 5**	**Category 6**	**Category 7**
Skin diseases and Allergies	Diarrhea, digestive problem, gall stone	Cold, cough and fever	Blood sugar and pressure	Heart and nerve-related issues	Ear and eye problems	Dental and bone health

Source: Categorisation is done by the authors, 2024

It was used to show the contrast of the characteristics of different variables or data sets where separate circles have been used to show different types of diseases (Liu et al., 2016). There are several types of Venn diagrams and they can be formulated in many ways (Jia et al., 2021). In this study, the acquired formula for Venn diagram is defined as equation 2.

$$n\left(X \cup Y\right) = n(X) + n(Y) - n(X \cap Y) \tag{2}$$

Where, n was total number of variables, while X, Y = two sets of elements. Venn diagrams are prepared in Past Statistical Software (v.4.11).

2.6 Correlation analysis

To determine the relationship of the observed diseases with the other important variables, 2-tailed Pearson correlation coefficient matrix was utilised. The matrix included the value of the correlation coefficient r, which refers to the degree of linear correlation. The highest positive and negative correlation is determined by ±1, indicating a perfect linear relationship. A correlation analysis where $r = 0$ shows no linear correlation between the variables (failed to explain the variables by correlation analysis). Additionally, an r value exceeding ±0.75 indicates strong correlation. Linear relationship among the variables was determined using the formula:

$$r = \frac{\sum_{i=1}^{n}\left(ai - ax\right)\left(bi - bx\right)}{\sqrt{\sum_{i=1}^{n}\left(ai - ax\right)^2}\sqrt{\sum_{i=1}^{n}\left(bi - bx\right)^2}} \tag{3}$$

Where, n is the total number of variables, ai and bi are the values of the i^{th} variable, ax and bx are the mean of the variables. It was analysed in GraphPad prism (V.8.02).

2.7 Water quality analysis

Twenty-four sampling sites were selected from the wetland using Latin Square Matrix (LSM) for water quality analysis (Biswas et al., 2024). A set of 12 parameters such as temperature (Temp), pH, electrical conductivity (EC), oxidation-reduction potential (ORP), total dissolved solids (TDS), total suspended solids (TSS), biochemical oxygen demand (BOD), dissolved oxygen (DO), total alkalinity (TA), total hardness (TH), turbidity (Turb.) and total solids (TS) have been chosen to analyse the physico-chemical properties of water. Initially, at the sampling site, several parameters such as pH, temperature, conductivity, ORP were measured with a multiparameter probe and DO was measured by Winkler's method (Winkler 1888). The samples were collected and transported to the laboratory with proper preservation for further analysis. TDS, TSS, and TS were analysed following the standard protocol of the American Public Health Association (APHA 2012). BOD was also determined in Winkler's method after 72 hours of incubation of the water sample in BOD bottle at 27°C in the BOD incubator. Turbidity was analysed with nephelometer. Total alkalinity, and total hardness were measured by titrimetric method following the standard protocol. Weighted arithmetic water quality index (WAWQI) was chosen to analyse the water quality of the study area, which aggregated all the parameters into a single integer. WAWQI was calculated using the following equations:

$$\mathrm{WAWQI} = \frac{\sum_{i=1}^{n} \mathrm{WiQi}}{\sum_{i=1}^{n} \mathrm{Wi}} \tag{4}$$

where, n is the number of physico-chemical parameters; W_i and Q_i are denoted as unit weight and quality rating scale for each parameter. Quality rating (Qi) was calculated by

$$\mathrm{Qi} = \frac{\mathrm{Vi}}{\mathrm{Ci}} \times 100 \tag{5}$$

where, V_i, C_i are denoted for analysed value and standard value by WHO of the i^{th} parameter at a given sampling station respectively. Unit weightage (W_i) was computed with the equation

$$\mathrm{Wi} = \frac{\mathrm{K}}{\mathrm{Ci}} \tag{6}$$

where, k is the proportionality constant. The classification of quality is based upon 0-100 grading scale for water quality.

2.8 Satisfaction measurement

Hall's Satisfaction Index (HSI) is a metric commonly used in marketing and customer satisfaction research to measure the level of satisfaction among respondents. In the present study it has been utilised to assess the respondents' perception on the lake water, as proposed by Ajayi et al., 2015). The value of the index ranges from -1 to +1, indicating the highest level of satisfaction and dissatisfaction, respectively by the following formula:

$$SI = \frac{fs - fd}{n} \tag{7}$$

where, *fs* = number of satisfied respondents; *fd* = number of dissatisfied respondents; n = total number of respondents. After incorporating the Hall satisfaction index, the Relative Satisfaction Index (RSI) was used to measure satisfaction levels in accordance with multiple variables. The RSI provides insights into the strengths and weaknesses of water quality perceptions and their interrelation with health, which leads to employing policy development and resource allocation decisions to improve water treatment infrastructure or implement public health interventions. RSI has been calculated using the Likert method with a scale ranged from 1–5 where the minimum score shows strong dissatisfaction, while 5 for strong satisfaction.

$$RSI = \frac{5(n) + 4(n) + 3(n) + 2(n) + 1(n)}{5N} \tag{8}$$

Where, *n* denote the number of respondents while *N* is the total number of respondents.

3. Results

3.1. Hydro-chemical characteristics

Table 4 describes the statistical summary of variables of wetland water. The desirable limit of variables was considered to determine the threshold limit recommended by the World Health Organization (WHO). The threshold limit of pH in freshwater is 6.5. It was observed that all the parameters analysed in the study area were within the limits set by WHO, except TSS, alkalinity and turbidity. During the study period, pH and temperature levels range from 6.3 to 7.9 and 27.7 to 32.6, with an average value of 6.9± 0.4 and 30.9±1.4 (mean ± S.D). In the present study, the pH values of some samples were found below the desirable limits (6.5-8.5). The concentration of TDS, TSS, turbidity and EC varies from 100 to 300 mg/L, 9 to 762 mg/L, 8.32 to 119.0 NTU and 51.7 to 350.7 ìS/cm and with an average value of 158.4±68.2 mg/L, 98.2±150.6 mg/L, 36.38±35.15 NTU and 132.9±64.4 ìS/cm, respectively. The concentration of total alkalinity and Hardness range between 70.0 to 190.0 mg/L and 67.2 to 169.0 mg/L with an average of 151.0±31.0 and 98.3± 25.6 mg/L. On the other hand, in the study site, the concentrations of BOD and DO vary between 0.5 to 3.2 mg/L and 0.2 to 6.9 mg/L, respectively, with mean values of 1.7±0.9 and 1.8±1.3, respectively.

Table 4: Descriptive statistics of different hydro-chemical parameters of Rudrasagar wetland

Variables	pH	Temp	EC	ORP	TDS	TSS	Turb.	TS	BOD	DO	TA	TH
Min.	6.3	27.7	51.7	90.4	100.0	9.0	8.3	126.0	0.5	0.2	70.0	67.2
Max.	7.9	32.6	350.7	136.7	300.0	762.0	119.0	862.0	3.2	6.9	190.0	169.0
Range	1.6	4.8	299	46.3	200.0	753.0	110.7	736.0	2.7	6.7	120.0	101.8
x	6.9	30.9	132.9	116.6	158.4	98.2	36.4	259.1	1.7	1.8	151.0	98.3
σ	0.4	1.4	64.4	13.9	68.2	150.6	35.2	145.1	0.9	1.3	31.0	25.6
WHO limit	6.5-8.5	>15	<300	103.5-268.3	<500	<500	<5	<1000	<3	>5	<120	<300

*All units are mg/L except Temperature (°C), 0RP (mV), EC (uS/cm) and Turbidity (NTU), while pH is unit free

3.2. Wetland water quality

The results showed that the lake water quality was not so good. Most of the sampled locations (83.34%) were found to be unsuitable for domestic use, while only 8.33% (S6, S11), 8.33% (S23, S24) were identified as very poor and hazardous to health, respectively. WAWQI showed an average of 110.72±11.99 (mean±SD). The maximum WAWQI (147.08) was recorded at S23, while the minimum (94.85) was observed at S26 (Fig. 3). Since S23 was identified for a

Table 5: Status water quality using WAWQI

WAWQI value	Water Quality Classes	Purpose of use	Water quality status	
			No of Sampling Sites (%)	Sample site ID
0-25	Excellent	Drinking, Agriculture		
26-50	Good	Drinking, Agriculture, Pisciculture		
51-75	Poor	Agriculture, Pisciculture		
76-100	Very poor	Industry and Irrigation	2 (8.33%)	S6, S11
101-125	Unsuitable for domestic use	Industry and Irrigation	20 (83.34%)	S1, S2, S3, S4, S5, S7, S8, S9, S10, S12, S13, S14, S15, S16, S17, S18, S19, S20, S21, S22
>125	Hazardous for health	Need proper treatment before use	2 (8.33%)	S23, S24

permanent grazing site and a densely populated area with relative distance from the cremation site, it showed the highest WAWQI for mixing of untreated residential waste, charcoal, dust and other wastes from the cremation site in the water. The lake catchment area faces conversion to agricultural land and is completely devoted to paddy cultivation (Boro rice), which is a significant contributor to water quality degradation but surface run-off and infiltration processes from agricultural areas are minimal during dry season. The eastern and western sides of the wetland were highly polluted because these areas were mostly occupied by human settlements.

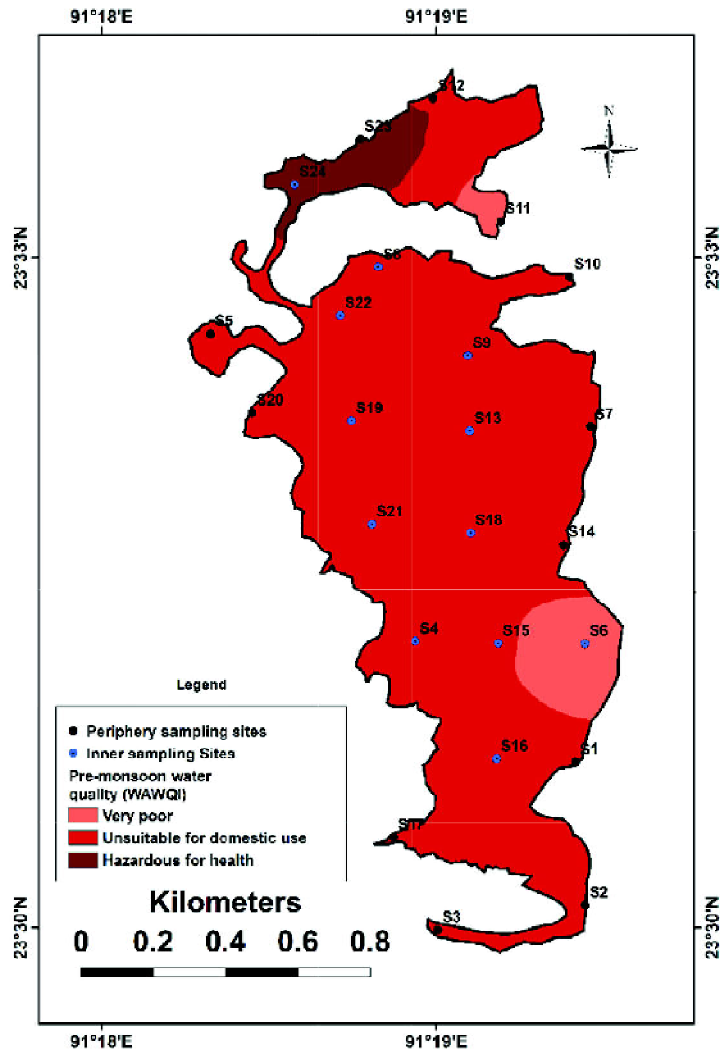

Fig. 3: Spatial variation of surface water quality of Rudrasagar Wetland

Subsequently, the polluted waste materials, household effluents with high quantities of detergent and small markets regularly produce large amounts of solid waste and release into the wetland, and as a result, the wetland water is severely polluted (Debnath et al., 2023b). Biswas et al. (2025) investigated the habitat suitability of avian species in correspondence with anthropogenic activities around the study area and suggested that anthropogenic pressures have tremendously disrupted wetland ecosystems, particularly the aggregation and assemblage of avian species. Therefore, the government should take immediate action to rejuvenate the wetland for the future.

3.3. Occupational structure

A ternary diagram was prepared to show the occupational structure of Rudrasagar adjacent regions. It was evident from the survey that most of the respondents in MMC were involved in tertiary professions where services and business were predominant over others (Table 6, Fig. 4).

Table 6: Proportion of economic activity of the sampled area

Sample village	Primary activity (%)	Secondary activity (%)	Tertiary activity (%)
V2	61.76	8.82	29.41
V3	52.94	17.65	29.41
V4	78.05	12.20	9.76
V6	61.36	27.27	11.36
V7	72.72	18.18	9.09
M1	13.16	36.84	50.50

*Source: Field survey, * V1 &V5 is excluded from the survey.*

Bardwal has shown the highest number of respondents involved in agriculture and fishing (>70%). Involvement in agriculture and fishing makes them more prone to waterborne diseases due to their direct contact with lake water. On the other hand, respondents who are associated with services or businesses are comparatively less prone to waterborne diseases. Figure 3 depicts a ternary plot of the occupational composition in six studied regions. The three axes correspond to the percentage of the population with primary occupations (mainly fishing, agriculture, and animal husbandry), secondary occupations (labour, housewife), and tertiary occupations (business, service, students). The colour dots denoted the total population, and bigger dots correspond to bigger populations. The contour lines (shaded grey) indicated the density or the concentration of particular occupation patterns across the regions.

3.4 Determination of health status

BMI is used to get an overview about the overall fitness of people residing there. By following the Body Mass Index Chart, most of the respondents (58.96%) come under the healthy

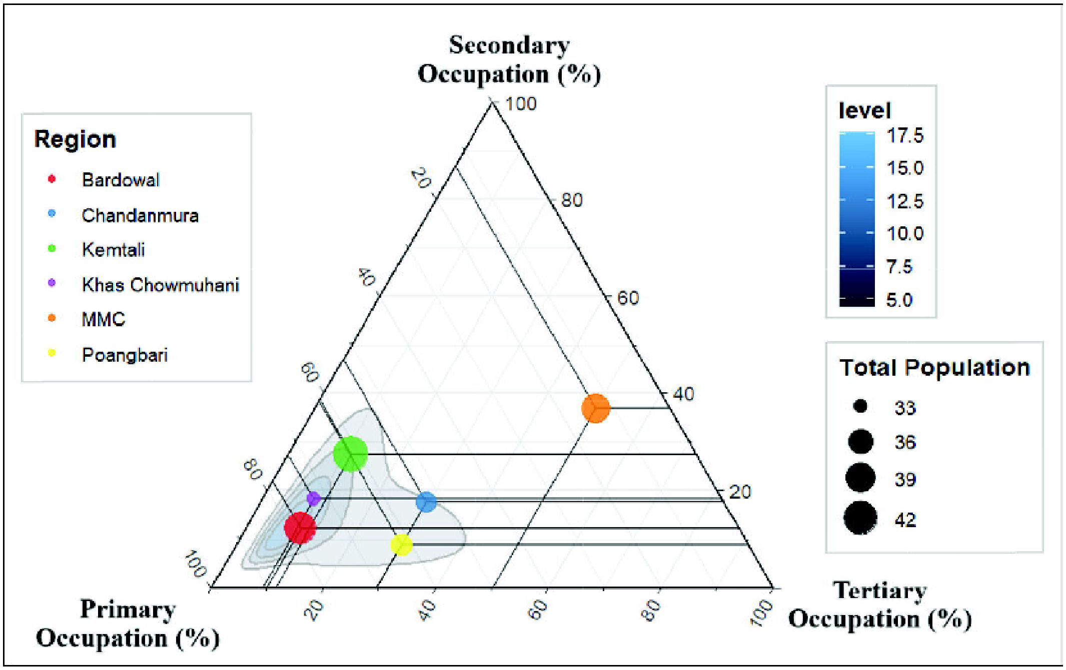

Fig. 4: Ternary diagram showing the Occupational Structure of respondents

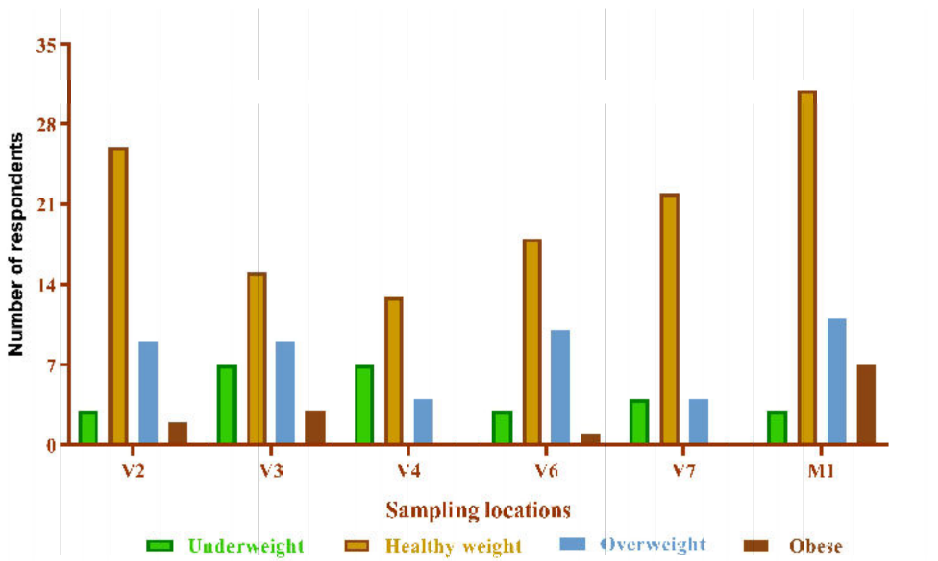

Fig. 5: BMI distributions in the sampling locations

weight category out of the total surveyed respondents (Fig. 5), which is obviously a good indicator as it is not associated with an increased health risk in terms of weight and height-related diseases. About 22.17% of respondents come under the overweight category.

Due to their daily unhealthy life style practices. Very few (6%) of respondents suffer from obesity, Melaghar mainly leads in this case while 12.73% of respondents suffer from underweight, which is slightly high and indicates lack of proper nutrition and healthy food. This could be attributed to the unhealthy food and an undisciplined lifestyle. Obesity and being underweight can lead to some serious health issues, such as low immunity and infertility and can affect mental health as well.

3.5 Distribution of diseases

Venn diagrams (Fig. 6) illustrate the distribution of diseases across different categories in the sample villages labelled V2, V3, V4, V6, V7, and M1. Each diagram represents the overlap of disease categories, showing how certain categories are present together within the same village.

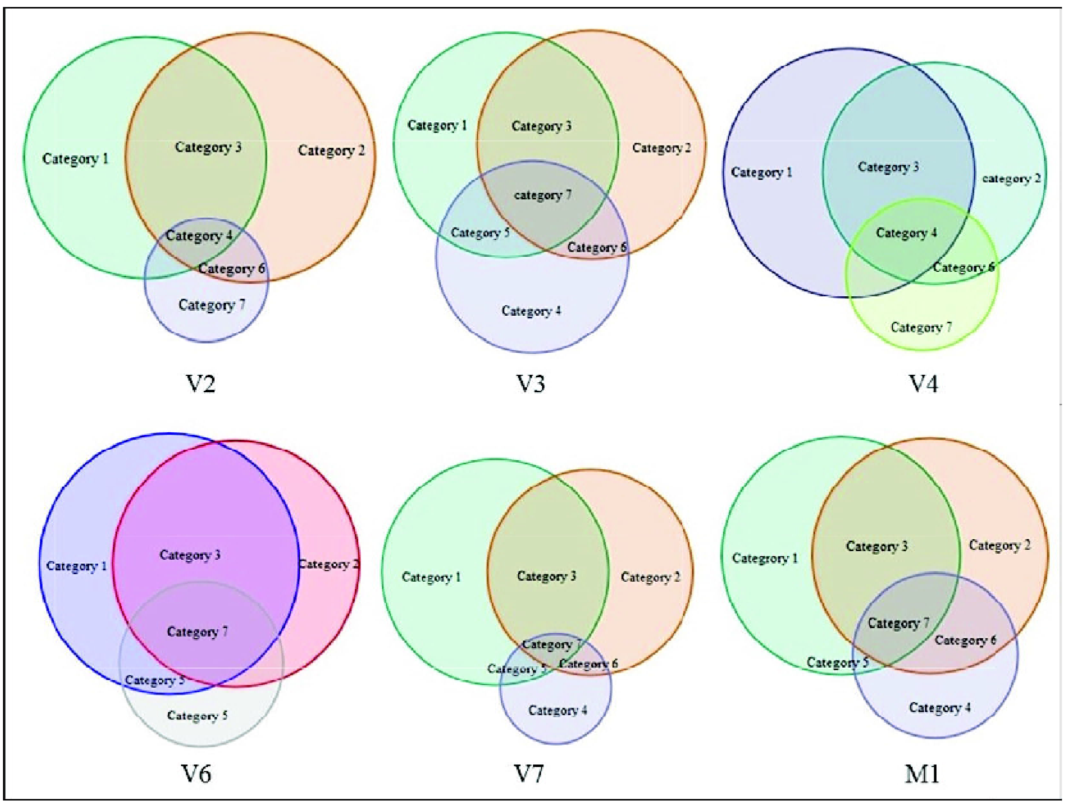

Fig. 6: Distribution of diseases in the study area

As most of the respondents suffer from more than one disease, using the Venn diagram is appropriate to represent the different types of diseases from which respondents suffer. The majority of the respondents suffer from digestive problems, which also include problems such as diarrhea and gallstones. For instance, in village V2, Category 1 overlaps with Category 3 and Category 2, indicating that these diseases are common in this area. Similarly, V3 shows an overlap of Categories 3, 2, and 5, suggesting a more complex disease distribution. Village V4 exhibits a more dispersed pattern, with multiple categories overlapping, particularly around Category 4 and Category 7. In V6, the overlap between Categories 1, 2, and 3 is pronounced, indicating these are prevalent, while V7 and M1 show similar patterns with slight variations in category overlap. Overall, these diagrams provide insight into the co-occurrence of disease categories across the villages, highlighting areas where multiple diseases are prevalent and potentially indicating underlying environmental or social factors contributing to these patterns. This is followed by skin-related diseases, as a large number of respondents suffer from them. Some respondents also suffer from dental and bone-related diseases, though the affected numbers are not as massive as the first two diseases, but it has a considerable size of affected respondents. Other diseases, such as heart and nerve-related diseases, blood-related diseases, high blood pressure and sugar, problems related to the ear and eye, colds and coughs, and the number of affected respondents is lower compared to the first three diseases. Case histories of waterborne diseases in various medical fields have been found worldwide, such as Acute Gastrointestinal illness (AGI) in the United States (Murphy et al., 2016); AGI, typhoid, hepatitis A in Hyderabad, India (Mohanty et al., 2002). Numerous reasons can cause these types of diseases, such as sewage overflows, accumulation of sewage around houses, where utensils are used to be cleaned, distribution of leaked pipelines, some socio-economic factors like education and income are also associated with waterborne diseases. For this particular study area, engagement in activities like agriculture and fishing is also the reason behind the increasing cases of skin-related diseases. Also, those diagnosed as underweight are subjected to waterborne and water-related diseases. Also, previous studies already established that people with poor nutrition are more likely to be affected by any type of disease.

3.6. Correlation analysis

The blue colour of the Pearson correlation coefficient matrix indicates a positive relation and the red colour for negative relation (Fig. 7), while white represents the absence of any relation among the variables. The darker the colour, the stronger the relation is. The result shows that those who are below 20 years old mainly suffer from cold, cough, fever (0.67), and skin diseases and allergies (0.67), indicating a positive relation among them. Nerve and Heart-related issues among them are rare (-0.01), indicating very weak negative relation on the other hand, very few respondents under 20 years are suffering from digestive problems (0.32), indicating weak positive relation among them. But the problem of digestion increases with age. The highest number of respondents who are suffering from digestive problems are found in 50 to 60-year age group

(0.83). Also, heart and nerve-related diseases are more common among the middle-aged and elderly population as the maximum number of the sufferer is from 40 to 70-year age group (0.94, 0.84, and 0.90). The diagram also shows that most of the respondents who are suffering from skin-related diseases are from less than 20 to 40-year age group, as most of them fall under the working-class population. The diagram showed that most farmers and fishermen are suffering from Skin related diseases like itching, rashes, redness (0.81, and 0.83) due to their direct contact with lake water, which shows strong positive relation. The majority of farmers also suffer from digestive problems (0.58). In the case of service, business, housewives and labourers, they are mainly

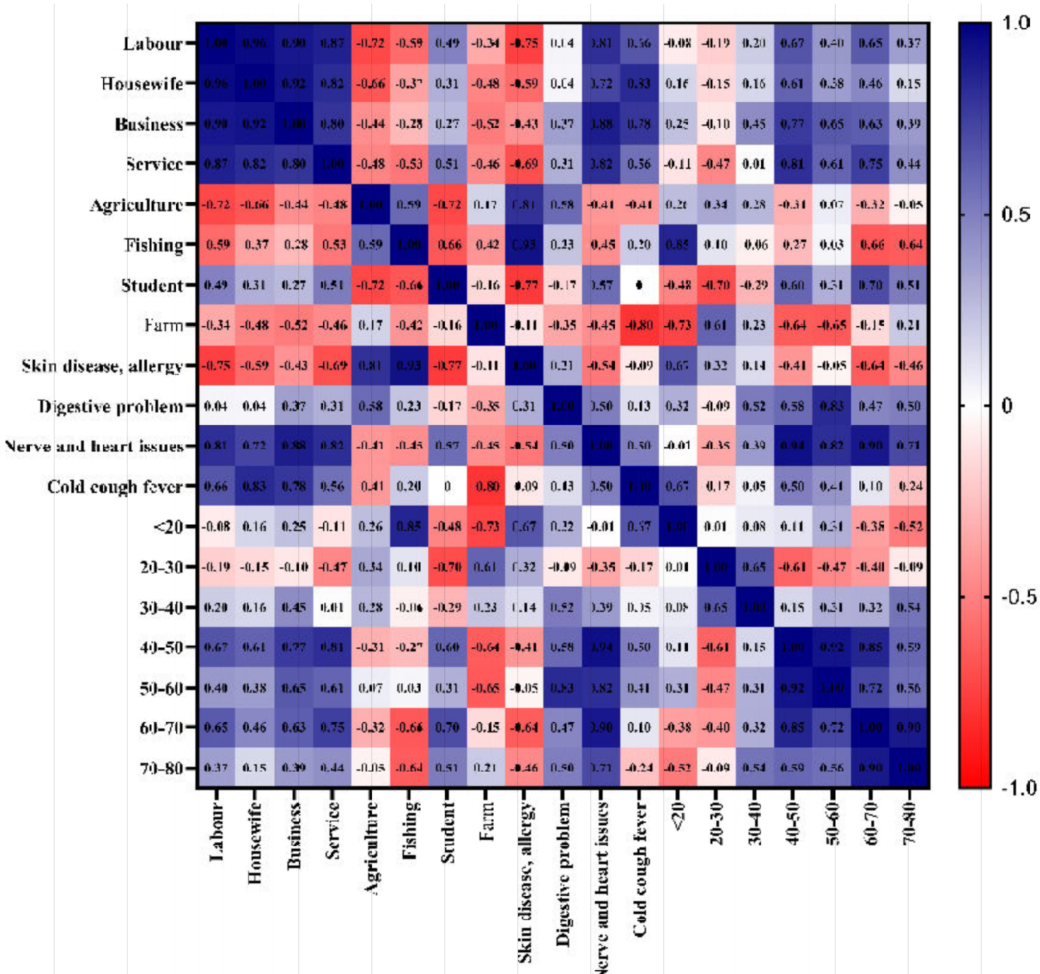

Fig. 7: Pearson Correlation Coefficient among different variables

suffering from nerve heart-related diseases and also with colds and cough. The heatmap provides a visual representation of the linear relationships between different variables in the study area, focusing on various occupations, health conditions, and age groups. Each cell in the matrix corresponds to the correlation coefficient between pairs of variables, where blue shades indicate a positive correlation and red shades signify a negative correlation. For instance, there is a strong positive correlation between labourers and cold/cough/fever (indicated by a deep blue colour), suggesting that individuals in this occupation are more prone to these health issues. Similarly, digestive problems show a strong positive correlation with the age group 60–70, while skin diseases and allergies are notably correlated with housewives and students, as seen by the blue cells in those rows. On the other hand, negative correlations (red shades) can be observed between business-related occupations and health issues like nerve and heart problems, indicating that people in this field may have a lower incidence of these conditions. Additionally, the younger age group (<20 years) shows a negative correlation with digestive problems, suggesting that this issue is less prevalent in younger individuals. Overall, the heatmap highlights significant associations between occupations, health conditions, and age groups, providing insights into the possible influence of work type and age on health outcomes within the community.

3.7 Communities' perception

To show respondent's perception of lake water Hall's satisfaction index is used. After calculating SI and RSI values of different parameters, shown in Table 7, it is clear that most respondents are dissatisfied about the quality of lake water because the SI value of each parameter shows a minus value. The SI values in the present study ranged from the highest -0.057 to the lowest -1, reflecting the perception of the local community as unsatisfactory. The maximum dissatisfaction comes from the lack of drinking water, as they have not been able to use lake water for drinking purposes for at least the last ten years. The relative satisfaction index (RSI) value ranges from 0.54–0.20. A higher value represents a higher degree of satisfaction. Results from the RSI index are the same as SI index. Respondents were mostly dissatisfied with the taste of the water (0.20) because no one actually uses lake water for drinking, followed by odor (0.48) and clarity (0.49). Regarding the colour of the lake water, RSI value is (0.54), which is slightly less compared to other RSI values, though it indicates dissatisfaction of respondents towards the colour of the lake water. The overall results indicate the fact that no respondents are satisfied about the overall quality of lake water.

Table 7 presented the Satisfaction Index (SI) and Relative Satisfaction Index (RSI), providing an assessment of overall satisfaction levels and relative satisfaction comparisons across different variables or categories. This parameter assesses the visual clarity or transparency of the water. A negative SI value (-0.12) suggests that, on average, respondents expressed dissatisfaction with the clarity of the water. However, the positive RSI value (0.49) indicates that, relative to other parameters, clarity was perceived more favourably compared to some other aspects. This parameter evaluates the presence or absence of any odour in the water. Similar to clarity, the negative SI value (-0.13) implies overall dissatisfaction with the odour of the water. The positive RSI value (0.48) indicates that, in relative terms, odour perception was somewhat better compared to other parameters. This parameter refers to the visual appearance or hue of the water. The negative SI value (-0.06) suggests a slight dissatisfaction with the colour of the water. However, the relatively higher positive RSI value (0.54) indicates that colour perception was comparatively more satisfactory relative to other parameters. This parameter evaluates the taste or flavour of the water. The SI value of -1.0 indicates a high level of dissatisfaction with the taste of the water among respondents. The relatively low RSI value (0.20) suggests that taste perception was the least satisfactory.

Table 7: Satisfaction Index (SI) and Relative Satisfaction Index (RSI) from villagers' perception

Parameters	SI	RSI
Clarity	-0.11792	0.485849
Odour	-0.12736	0.478302
Colour	-0.05660	0.536792
Taste	-1.00000	0.200000

Source: Calculated by the authors from the primary data

compared to other parameters. These indices are derived from responses collected during the field survey and provide valuable insights into the perception of Rudrasagar Lake water quality among the surveyed population. Reasons behind their dissatisfaction regarding lake water, due to increasing lake pollution. In the lake water, uncontrolled growth of alien invasive species along with excessive algae was found. Pollutants enter water bodies from fixed point sources such as sewage, domestic effluents discharged by households and municipal authorities, as well as organic, inorganic, and toxic pollutants originating from industrial sources and stormwater run-off. Also, some impurities that enter from nonpoint sources, like nutrients by means of fertilisers, chemicals and other toxic pesticides, mainly coming from agriculture run-off; organic pollution from human sources spreads over the periphery of lakes (Biswas et al., 2024).

4. Conclusion

This study found that the prevalence of agricultural and fishing occupations among respondents significantly increased the rate of exposure to lake water, thereby increasing the risk of waterborne diseases. This risk is further exacerbated by the education gap and lack of awareness about water safety practices, as the use of water filters is very low among uneducated and unaware people. The overlapping of waterborne disease risk and demographic characteristics – age, gender, educational attainment, and occupation – created a complex public health problem.

The alarming rate of underweight BMI category has revealed the ongoing problem of malnutrition among the uninformed population. Although most respondents do not drink lake water directly, the prevalent use of motorised pumping equipment creates an indirect way for lake water pollution. Shallow tube wells in particular increase this risk due to increased hydropower connections to lake waters. In unison, respondents expressed dissatisfaction with the existing lake water conditions. Notably, perceptions of water quality and related health concerns varied systematically according to demographic groups such as age, gender, economic sector, and education level. To effectively address these challenges, a holistic strategy is required. Strategic investments in proper water treatment technologies – such as household drinking water treatment (HDWT) systems and bio-sand filters (BSF) – along with improved sanitation infrastructure and focused public health education programs will significantly reduce the burden of waterborne diseases. These interventions, when specified with consideration of the demographic diversity of the community and carried out with local involvement, create promising pathways for sustainable community health improvement.

5. Limitation

1. This study focused on Rudrasagar Lake, wetland ecosystem and was conducted over a limited time period. Long-term monitoring and comparison with other wetland systems would provide more robust insights into wetland health dynamics.
2. While the study surveyed 212 respondents, a larger sample size would increase the statistical power and generalizability of the findings, particularly for subgroup analyses.
3. The health status assessment relied on self-reported data, which may be subject to recall bias or misreporting. Clinical assessments would provide more accurate health information.
4. While the study identifies correlations between various factors (e.g., occupation and health issues), it cannot establish causal relationships. Longitudinal studies would be needed to determine causality.
5. The study does not include a comparison with communities not dependent upon wetland resources.
6. While occupation was considered, other socio-economic factors (e.g., income levels, education) that might influence health outcomes and perceptions were not extensively explored.
7. The satisfaction indices may be subject to response bias, as respondents might tend to give socially desirable answers. Triangulation with objective measures could strengthen these findings.

Statements and Declaration

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Author contribution

Pradip Debnath: conceptualisation, map preparation, visualisation, and final drafting. Arpita Biswas: data structuring, methodology, statistical analysis, review draft, supervision, and validation. Aritri Ghosh: Conduct field survey, Data curation and writing initial draft. Saptarshi Mitra: review, supervision, and validation.

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Competing interest

The author(s) declared that no potential conflicts with respect to publication and authorships

Ethical approval

The research does not involve human participants, involved animals and did not hamper the environment during the study period.

Data availability

All the primary data were generated in field study and laboratory. The analysed data of this study are included in this published article. The administrative boundary of the study area was collected from https://www.diva-gis.org/datadown and the secondary data was collected from Survey of India.

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