ASSESSMENT OF DRINKING WATER, SANITATION AND HYGIENE STATUS IN SOUTH TWENTY FOUR PARGANAS, WEST BENGAL

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

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BY

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CERTIFICATE

This is to certify that the thesis entitled **"Assessment of Drinking Water, Sanitation and Hygiene Status in South Twenty-four Parganas, West Bengal"** submitted by Mr. Chandan Roy for the award of Doctor of Philosophy in the Department of Geography and Resource Management of the Mizoram university under my supervision.

He has fulfilled all the rules and regulations specified of the university to complete the study. Furthermore, the current thesis is presented in partial fulfilment of the requirements of the Degree of Doctor of Philosophy. The thesis neither submitted as a whole nor any part to any other university for any research degree. I also certify that the thesis depicts objectives of the study and independent work of the scholar.

Dated: (**Prof. Vishwambhar Prasad Sati**)

Place: Aizawl Supervisor

DECLARATION

MIZORAM UNIVERSITY

FEBRUARY, 2025

I **CHANDAN ROY**, hereby declare that the subject matter of this thesis is the record of work done by me, that the contents of this thesis did not form basis of the award of any previous degree to me or to do the best of my knowledge to anybody else, and that the thesis has not been submitted by me for any research degree in any other University/ Institute.

This is being submitted to the Mizoram University for the degree of Doctor of Philosophy in Geography and Resource Management.

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Abbreviation

WHO	:	World Health Organization
IWA	:	International Water Association
ADB	:	Asian Development Bank
GPS	:	Global Positioning System (GPS)
APHA	:	American Public Health Association
PDS	:	Public Distribution System
ATM	:	Automated Teller Machine
ASHA	:	Accredited Social Health Activist
WAWQI	:	Weighted Arithmetic Water Quality Index
PHED	:	Public Health Engineering Department
MSL	:	Mean Sea Level
KMC	:	Kolkata Municipality Area
SEZ	:	Special Economic Zone
ICDS	:	Integrated Child Development Services
SDG	:	Sustainable Development Goal
BIS	:	Bureau of Indian Standards
TDS	:	Total Dissolved Solids
SBM	:	Swachha Bharat Mission
E. coli	:	Escherichia coli
SSA	:	Sub-Saharan Africa

Glossary

Brackish water: A type of water that is more saline than freshwater, but less saline than actual marine water.

Khal: A canal is a waterway used for human purposes such as the abstraction of fresh water or the irrigation of crops, or as a storage area or a conveyance route for water.

Bil or Beel: A beel is a wetland that resembles a lake, unlike rivers and canals, which have static water. It is usually called khāls in the Indian states of West Bengal and Assam.

IT-Khola: The place where bricks are made.

Jhumur: It is a traditional folklore – song and dance, which originated in the western districts of West Bengal. The Jhumur is also performed in Assam, Bihar, Chhattisgarh, Jharkhand, and Odisha.

Bonbibir Pala: This is a dramatic performance tradition associated with worshipping the cult goddess Banbibi. In the Sundarbans, Maa Banbibi's Pala is one of the traditional yatras and palagans. However, due to reduced incomes, many people are forced to migrate, which has led to a decline in skilled artists.

Gajan: The song or festival of Lord Shiva falls during the last week of Chaitra in the Bengali calendar. It is a Hindu religious festival that is mostly celebrated in West Bengal. It is commonly referred to as Charak Puja in Bengali.

Makar Sankranti: The festival celebrates the harvest with songs, dances, prayers, and traditional sweets. The Bengali term for this holiday is Poush Sankranti.

Chapter 1

Introduction

1. Introduction

Access to safe drinking water, sanitation, and hygiene (WASH) is crucial to maintain sound health and well-being (Darvesh et al., 2017). However, consuming contaminated drinking water and unhygienic sanitation practices may lead to an increase in the prevalence of different types of illness (Hall et al., 2020; Roy et al., 2023). Globally, around 2 billion people are consuming water from contaminated sources. A study found that several regions of the world will face a water shortage by 2025. Furthermore, in the least developed countries (LDCs), about 22% of healthcare facilities do not have access to water, while around 21% do not have sanitation facilities, and almost 22% do not have any waste management system (World Health Organization, 2019). On the other hand, Landrigan et al. (2020) unveiled that waterborne diseases are triggered by pathogenic microorganisms like viruses, bacteria, and protozoa transmissible through water. These pathogens may have harmful impacts on human health (Janik et al., 2020). Karande et al. (2021) stated that hygiene is a more important component of waterborne disease than the quality of water, which people in rural areas frequently neglect. However, Ferreira et al. (2021) unveiled that extensive coverage of water and sanitation services (WSS) can prevent the spread of waterborne diseases and their harmful effects.

According to the study conducted by Alagidede & Alagidede (2016) in six Western African countries found that significant advancement has been made regarding access to improved drinking water. Despite this, sanitation progress has lagged behind the target of Millennium Development Goal (MDG) 7c. Armah et al. (2018) revealed that wealth status and urbanicity (rural-urban environment) are the two most important factors affecting access to improved water and sanitation facilities in Sub-Saharan Africa (SSA). Further, a study conducted in Guinea-Bissau (West Africa) found that about 79% of the wells in the region are moderately to heavily contaminated with faces, which can cause various waterborne diseases. In addition, all samples are found to be acidic, and about 11.5% of the population experienced diarrhoea in the region (Bordalo & Savva-Bordalo, 2007). A study carried out by Boschi-Pinto et al. (2008), showed that about 78% of all diarrhoeal deaths in the WHO

African and Southeast Asian Regions occur among under-five children in developing countries. As a result, we may assume that diarrhoea is a common occurrence in drinking water that has been connected to drinking water and sanitation services (WSS) (Merid et al., 2023).

According to Hartman et al. (2023), diarrhoea is the second most common reason of mortality among under-five children in low and middle-income countries (LMICs). Edokpayi et al. (2018) reported that consuming contaminated drinking water in low-resource areas of Limpopo province may cause diarrheal illness and enteropathy in children under-five. There is a large difference in access to WASH services between rural and urban health facilities in SSA. In both public and rural facilities, access to WASH services is consistently low (Kanyangarara et al., 2021). Moreover, according to Momberg et al. (2021), environmental conditions may contribute to poor child health and malnutrition, which are associated with chronic illnesses. Approximately 311 million people are living in SSA without access to safe drinking water. In addition, around 70% of the SSA population lacked access to adequate sanitation facilities. While in LMICs, inadequate access to WASH services remains one of the main causes of the global disease burden among children (Prüss-Ustün et al., 2019).

Islam et al. (2021) conducted a study in Bangladesh *and* stated that the gender, occupation, and level of education status of the participants are closely influenced by the WASH and waste disposal practices. Also, a study in Pakistan demonstrated that stunting is associated with contaminated hand pumps and tank water (Batool et al., 2023). Additionally, Daud et al. (2017) reported that almost 20% of the population in Pakistan has access to safe drinking water, while 80% of the population has compulsory to use unsafe water due to scarcity of water and safe drinking water sources. Moreover, Sharma et al. (2021) unveiled that climate change has an impact on drinking water and adaptation in Nepal.

Besides Kanungo et al. (2021) found that improving human health is fundamentally dependent upon access to WASH services. Kumar et al. (2022) revealed that waterborne diseases among the elderly (aged 60 years and above) are more prevalent in central Indian states like Chhattisgarh and Madhya Pradesh. The study also reported that sex, employment status, educational status, Body Mass Index (BMI), place of residence, type of toilet facility, and water sources are crucial determinants of waterborne disease. While India's most of the population is still primarily dependent on groundwater for drinking purposes, sometimes groundwater is contaminated by various substances like arsenic, fluoride, nitrate, salinity, etc. In addition, high-level exposure to arsenic-contaminated groundwater may lead to various diseases like keratosis, melanosis, and cancer, while high fluoride exposure results in dental and skeletal fluoridise (Asian Development Bank, 2020). Biswas et al. (2022) reported that nearly 95.5% of families in India had access to improved drinking water. Nevertheless, there is a regional variability in India. However, M.R (2021) unveiled that around 54% of families in rural India did not have access to safe drinking water. Although Roy (2023) showed that there are a few central and western Indian states where drinking water and sanitation are limited. Additionally, the study found that education, place of residence, and wealth index are associated with limited access to drinking water and sanitation facilities. According to Patel et al. (2020), about 95% of urban Indian households have access to improved drinking water, while 77% have access to water sources within their premises, and nearly 90% have access to improved sanitation facilities. In addition, the study also revealed that access to improved WASH services is essential to maintain good health and well-being. Moreover, Jeyakumar et al. (2021) reported that in Maharashtra, around 75% of mothers wash their hands before eating and about 35% of mothers wash their hands after defecation. It is also important to note that around 99% of participants have a drainage facility and nearly 50% of households practice open defecation. Moreover, Biswas et al. (2022) carried out a study in 2018 that revealed that access to safe drinking water and sanitation facilities is crucial to preventing acute illness and mortality. Thus, this study suggests that access to WASH services is essential for maintaining a healthy life.

In West Bengal, about 74.35% of families have access to improved drinking water, and 14.60% of households practice open defecation (Roy et al., 2023). Chatterjee et al. (2023) unveiled that prevalence of diarrhoea is linked to house types and water sanitation conditions. Additionally, it has been reported that the prevalence of diarrhoea is lower in pucca, households with access to clean water and hygiene, and children who have received ion fortification.

In South Twenty-four Parganas, most of the districts are still facing severe problems of contaminated groundwater and inadequate sanitation facilities. Furthermore, high concentrations of iron, arsenic, fluoride, pH, TDS, chloride, and other substances in drinking water lead to enhanced prevalence of different diseases. A study found that water quality during the post-monsoon season is alarming in the blocks like Baruipur, Bhangar-II, Bhangar-I, Canning-I, canning-II, Sonarpur, Mograhat-I, and Mograhat-II (Bandyopadhyay & Basu, 2017). According to Singh et al. (2014), arsenic was mainly associated with silt clay and sand layers in the region. Additionally, the study reported that excessive withdrawal of water for domestic and irrigation purposes is a major factor contributing to the fluctuation of the water table. Furthermore, a study conducted in the Sonarpur block revealed that groundwater of the Sonarpur block contaminated with arsenic (As) bearing materials such as opaque materials, limonite, and marcasite (De et al., 2022; Singh et al., 2014). Ray et al. (2020) reported that depending on the pollutants present in the water, constant exposure to contaminated water may cause diarrhoea, skin irritations, and respiratory diseases.

This study demonstrated the present status of WASH services in the region, comprehensively. Furthermore, the study shows how a lack of WASH services is linked to waterborne illness. Therefore, a multilevel planning process aims to manage water resources, manage waste, promote improved sanitation facilities, and maintain basic hygiene in rural areas. The present study has been chosen to formulate spatially-optimized targeted policies and enhance the quality of life of the people in the region.

1.1 Statement of the Problem

The present study investigated the status of WASH in the South Twenty-four Parganas district of West Bengal. The area is located in the southern part of the Gangetic delta, which is rich in surface and groundwater resources. Despite this, the region has some significant problems, including typical hydrology, seawater intrusion, soil salinity, and a high percentage of clay in the soil. In addition, illegal mining activities, reduced groundwater recharge potential, and increased wastewater discharges are contributing to the deterioration of water quality in the region. Because of climate change and sea levels rise, resulting in gradual increases in soil and water salinity. This results in the water of the region being unusable for the people who live there. A study conducted by Bandyopadhyay & Basu (2017) revealed that the region has various problems such as poverty, loss of agriculture lands, large-scale industry, and morbidity of various waterborne diseases directly affecting human health. Moreover, there are lack of literature on the present status of water, sanitation, and hygiene in the region. Therefore, the present study attempted to fill the gaps in the existing literature and open a new avenue for further studies.

1.2 Scope of the Study

Rural residents in South Twenty-four Parganas lack adequate access to safe and affordable drinking water. In the present study, ten villages were selected from ten different development blocks located in different parts of the district. According to Boschi-Pinto et al. (2008), about five lakh children under the age of five die as a result of diarrhoea in India. In addition, Roy et al. (2023) found that only 33.69% of households in West Bengal had access to safe drinking water within their premises, while 14.60% still practice open defecation. Consequently, the present study assessed the status of WASH services in the study villages. The lack of access to WASH services is also a major health concern in the region. In this regard, the present study formulates appropriate policies for improving access and coverage of WASH services in the region.

1.3 Research Questions

The following questions were raised during the study:

1. What is the status of drinking water quality in the study villages?
2. What is the status of sanitation, and waste management in the study area?
3. How waterborne diseases and hygiene behaviours are linked to human health?
4. What are the policy implications for improved WASH services?

1.4 Hypothesis

The hypothesis of the study were:

1. Water quality is contaminated with a several contaminants.
2. Socio-economic factors are determining the WASH services.
3. Lack of access to WASH services is linked to waterborne diseases.

   The hypothesis was checked and found valid.

1.5 Objectives

1. To analyse the water quality of different water sources in the study villages.

2. To examine the utilization patterns of sanitation facilities and community waste management systems.

3. To study the impact of water-borne diseases and hygiene on human health.

4. To suggest policy measures for a better quality of water, sanitation, and hygiene.

1.6 Study Area

The study area is located in the South Twenty-four Parganas district, West Bengal (Figure 1.1). It is the largest district in West Bengal in terms of area and second-largest in terms of population, and it is located on the outskirts of Kolkata. It is the home to the world's largest mangrove forest and riverine Island, both of which serve as carbon sinks. The study area's latitudinal and longitudinal extension is 22° 12' 13" N to 22° 46' 56" N and 87°58' 45" E to 88° 22' 10" E, covering approximately 9960 sq. km. The study's geographical location is to other districts such as Kolkata, Haora, and North Twenty-four Parganas in the North, Paschim Medinipur in the West, and Bangladesh in the East. The Sonarpur is the largest municipality out of seven municipalities in the district. The district of South 24 Parganas is divided into five sub-divisions: Alipore Sadar, Baruipur, Diamond Harbour, Canning, and Kakdwip. In this study, we selected 10 villages from 10 development blocks to examine a spatial comparison of the WASH services. This means one village is selected from one development block. According to the Directorate of Census Operations, West Bengal (2014), the district has 2042 villages distributed across 29 development blocks, of which 1996 are inhabited villages. The district has a total population of 8.16 million people living in the 29 development blocks in West Bengal's southern district.

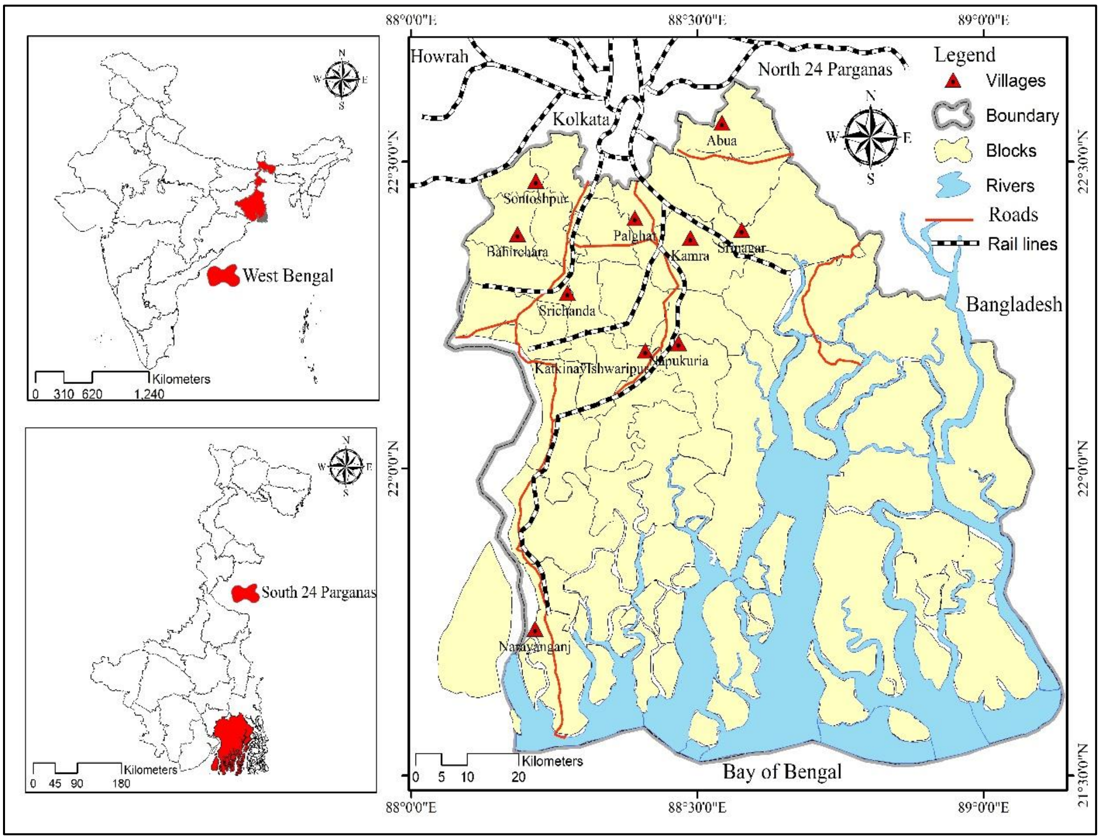

Figure 1.1: Map showing location of the study villages

1.7 Materials and Methods

1.7.1 Data Sources

Both quantitative and qualitative data were collected to conduct the present study. The study was primarily based on the collection of data from both primary and secondary sources. Furthermore, the Census Statistical Handbooks, the Public Health and Engineering Department (PHED), and the state’s report on water quality, sanitation, and hygiene status were the main sources of secondary data. For primary-level data, a cross-sectional study was conducted using a structured questionnaire to examine various socio-economic factors. There is a total of 29 development blocks in the district, out of which, only 10 development blocks were selected. Additionally, a total of 10 villages were selected, which means one village from each development block for water quality analysis and household level survey. For the households’ level survey, a total of 15% of the households were surveyed (Table 1.1). A purposive sampling method was applied to conduct the household-level survey to gather information on socio-economic status, prevalence of waterborne diseases, and WASH services in the region (Figure 1.2).

The water samples were collected from different sampling sites using a random sampling technique. To collect, preserve, and analyze the water samples, the American Public Health Association (APHA) standards were followed (Figure 1.3). Additionally, water samples were collected from various improved water sources from July to September 2022 (Monsoon) and October to January 2023 (Post-Monsoon). Moreover, the Global Positioning System (GPS) was used for geospatial data such as latitude, longitude, and altitude. The detailed methodology of water sample collection is available in Chapter 4.

Table 1.1: Salient features of the study villages

Block Name	Village Name	Total Geographical Area (in Hectares)	Total Population of Village	Total HHs	Number of HHs surveyed	% of surveyed HHs
Baruipur	Kamra	64.75	1352	324	49	15
Sonarpur	Palghat	103.03	2360	520	78	15
Bhangar-II	Abua	61.52	1766	334	50	15
Magarhat-I	Srichanda	107.65	1773	416	62	15
Magrahat-II	Katkina Ishwaripur	230.64	1505	345	52	15
Jaynagar-II	Napukuria	123	1799	399	60	15
Canning-II	Srinagar	342.93	3420	664	100	15
Budge Budge-I	Sontoshpur	146.5	2808	710	107	15
Budge Budge-II	Bahirchara	71.58	723	173	26	15
Namkhana	Narayanganj	157.05	1352	338	51	15
Total		**1408.65**	**18858**	**4223**	**635**	**15**

Source: Primary Survey

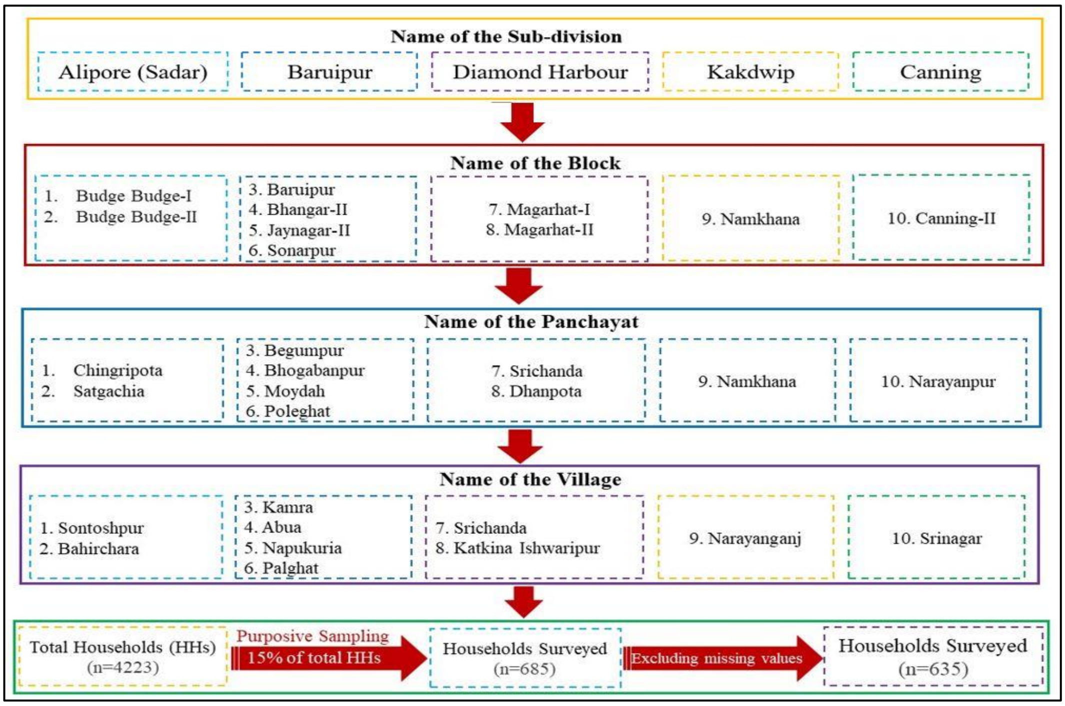

Figure 1.2: Sampling framework of the study

Figure 1.3: Primary survey (a) researcher is collecting household-level data, (b) the researcher is collecting samples of drinking water for testing (c) the researcher is testing water samples, and (d) the results of the water samples test; Source: By author

1.7.2 Data Analysis

Water samples were analyzed using a field testing kit (FTK). To determine the quality of water in study villages, the weighted arithmetic water quality index (WAWQI) was applied. In addition, univariate statistics, descriptive statistics, and logistic regression were used to analyze the data. The data was represented graphically using MS-Excel and Datawrapper data visualization tools. Besides, Stata and Arc Map 10.5 software were used for statistical analysis and geospatial mapping, respectively. The formula of the weighted arithmetic water quality index (WQI) is in the following form:

$$WQI_A = \sum_{i=1}^{n} wiqi \;/\; \sum_{i=1}^{n} wi$$

Apart from these, the attack rate of various waterborne diseases was performed to check the prevalence of diseases. The mathematical expression of the attack rate is given below:

$$\text{Attack Rate} = \frac{The\ total\ number\ of\ cases\ of\ a\ disease}{Total\ population\ at\ risk} * 100$$

1.8 Organization of the Chapters

The Thesis is arranged in the following eight chapters:

Chapter I: Introduction

This chapter explains the concept of WASH services and how WASH services are linked to human health and well-being. In addition, it discusses the literature at international, national, state, and local levels (i.e., village level) to provide a foundation of knowledge of the research. Thereafter, the chapter describes the statement of the problem, the scope of the study, research questions, hypothesis, objectives, study area, materials and methods, and organization of the chapters.

Chapter II: Review of Literature

In this chapter, the literature review is carried out at four levels: international, national, state, and local to provide background of the research. The research analyzes how WASH services are crucial for good health and well-being.

Chapter III: Geographic Background and Socio-Economic Profile

chapter describes the geographical background and socio-economic profile of the region. Furthermore, the physiography, geographical features, major landforms, drainage system, climatic condition, demographic features, culture, and economy of the region are also described in the chapter. Apart from that the chapter also describes a detailed case study of each study village. It also gives an extensive idea about the working population, land use and land cover patterns, educational infrastructure, healthcare facilities, and availability of basic services and amenities.

Chapter IV: Analysis of Drinking Water Quality

The status of drinking water quality of various study villages is discussed in this chapter. In addition, physicochemical parameters and principal component analysis of water samples have been carried out to draw data-driven decisions. Lastly, it also describes the linkage between drinking water quality and human health.

Chapter V: Utilization Patterns of Sanitation Facilities

The chapter discusses household access to sanitation facilities and waste management systems in the region. It also describes how shared sanitation facilities and various explanatory variables are affecting limited access to sanitation facilities.

Chapter VI: Status of Community Waste Management Systems

In Chapter VI, several aspects of community waste management systems are presented, including the environmental and health impacts of improper waste disposal, the role of education in waste management, and factors influencing household perceptions of waste management.

Chapter VII: Impact of Waterborne Disease on Human Health

This chapter discusses the current status of waterborne diseases in the region. Furthermore, it discusses the effects of waterborne diseases and inadequate hygiene practices on human health. Additionally, the chapter presents a schematic framework for the transmission and prevention of waterborne diseases.

Chapter VIII: Policy Measures

The chapter outlines various policy measures to improve the good health and well-being of the region. In addition, it also depicts suggestive policy measures to improve access to WASH services in the region.

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Chapter-2

Review of Literature

2.1 WASH Background

Access to safe drinking Water is a basic right of every citizen in a country. Furthermore, it improves physical health, protects the environment, improves educational outcomes, saves time, and ensures that men and women are treated equally (Hutton & Chase, 2017). According to Biswas et al. (2022), access to WASH services comes under Sustainable Development Goal 6 (SDG 6: ensure access to water and sanitation for all).

Czerniewska et al. (2019) reported that the advancement of low-cost technologies can help to reduce elevated rates of mortality and morbidity in low-income countries. They also revealed that affordable technologies can help to improve access to WASH services. Because WASH services are key indicators for preventing diarrheal diseases, the lack of WASH services kills more than one million people yearly. The study highlighted that individual behavior is an important indicator of maintaining good health and hygiene (Ginja et al., 2021). However, Wasonga et al. (2016) revealed that lack of access to WASH services is linked to diarrhoeal deaths in rural areas of Kenya.

2.2 International Literature

A study conducted by Livingstone & McPherson (1993) found that human resources development (HRD) is a critical component of a program on sustainability in the rural water and sanitation sector.

Bordalo & Savva-Bordalo (2007), found that about 79% of the wells had moderate to heavy fecal contamination and chemical contamination was less prevalent in the region. As a result, the authors propose low-cost measures to reduce fecal contamination and control pH to improve the quality of life.

According to Singh & Aenab (2010), they found that the water quality in the periphery of Bagdad City is more unsatisfactory than in the core area. They highlighted that the absence of wastewater treatment plants made conditions worse in the region. Nevertheless, the authors suggest that upgrading the water plants, raising awareness about drinking water quality, and creating awareness are effective ways to improve quality of life.

Khan et al. (2013) conducted a study that showed that agrochemicals are one of the responsible factors for water pollution. Furthermore, improvement of water knowledge through training and awareness and proper education in rural areas helps to sustainable management of water resources.

A study in Nigeria suggests that people should be made aware of the sources of contaminated water and wells to minimize the health impact. The study also revealed that the prevalence of waterborne diseases was noticed in the study area and many water samples were contaminated with coliform bacteria, physicochemical factors, and heavy metals (Dahunsi et al., 2014).

A study conducted by Ochuko et al. (2014) found that variations in physicochemical and biological parameters. According to the study, there is a higher concentration of pH in urban communities than in rural communities. The author of this study suggests that routine monitoring of human health activities and testing of river water can help protect human health.

Adams et al. (2016) revealed that access to potable water and sanitation is critically low in SSA. The authors found that socio-economic factors like education, income, household size, and region were significantly linked with access to improved water and sanitation services in Ghana.

According to a West African study, little progress has been made to improve access to sanitary facilities and water. A study has found a lag between the MDG 7c goal and the actual progress made towards reaching it. In light of this, the study emphasizes the importance of poverty alleviation, as well as the risk of neglected tropical diseases emerging in the region (Alagidede & Alagidede, 2016).

In a study by Graham et al. (2016), it was found that adult females were the primary water collectors for households in SSA. As mentioned in the study, two-thirds of people leave their homes to collect water, which puts them at risk for a variety of health complications.

Braimah et al. (2016) in their study describes community involvement in rural water and sanitation programmes is important for cost-effective management. The study also discussed that scheduled meetings with local managers enhance water supply.

Yuan et al. (2016) revealed that shallow water sources were more polluted than the deep water sources in Mali. The authors describe that water pollution in the region outcome of the disposal of wastewater and discharge of domestic wastewater.

According to Freeman et al. (2017) revealed that improved sanitation facilities can be protective against active trachoma, diarrhoea, STH infections, stunting, and schistosomiasis.

A study conducted by Foggitt et al. (2019) in Ghana, showed that shared sanitation services are linked with poor management and exclusion. There are nearly a third of the population excluded from sanitation facilities.

A study conducted in Chile found that the lack of infrastructure and technical capacity in rural communities leads to problems with the implementation of water services (Nelson-Nuñez et al., 2019)**.**

A study by Castelli et al. (2020) revealed that a community-based management strategy for water and sanitation will help to mitigate water-related hazards. In addition, the study stated that enhancing water safety plans, wastewater treatment, and monitoring of water resources in rural areas of Myanmar would enhance water and sanitation programs.

Cassivi et al. (2020) revealed that household socio-economic factors strongly influence water and sanitation coverage in Malawi. Therefore, the study suggests targeted interventions to improve access and coverage of WASH services.

A study conducted by Andualem et al. (2021) in Ethiopia revealed that rich women-headed households had better access to improved sources of drinking water. The study also found that households with a higher education background have better access to improved sanitation facilities. The authors reported that rural households have less access to improved sanitation facilities.

According to Ghosh et al. (2021), the prevalence of diarrhoea among under-five children is associated with household socioeconomic factors. It was found that the prevalence of diarrhoea is higher in rural areas where children do not live in pucca households, do not have improved sanitation facilities, and are members of underprivileged communities.

A study conducted by Adil et al. (2021) in the Punjab province of Pakistan, revealed that household media exposure, household education level, household wealth status, social norms, ethnicity, and place of residence were crucial factors for household access to safe drinking water.

Shaji et al. (2021) revealed that elevated levels of arsenic heavy metal can cause potential health risks. Southeast Asia's most affected countries are Bangladesh, India, Pakistan, Nepal, China, Myanmar, Vietnam, Cambodia, and Thailand. The presence of arsenic (As) heavy metal and unconsolidated sedimentary aquifers shows a positive correlation, which is situated within the juvenile orogenic belts of the world. Additionally, nearly 90% of arsenic contamination is induced by geogenic sources. Moreover, prolonged exposure to arsenic-contaminated subsurface water can cause serious health complications like kidney, skin lesions, lung, and bladder cancer.

A study in Ethiopia stated that limited access to drinking water services is linked to educational attainment, place of residence, and household head. Besides the study also revealed that spatial inequalities exist in unimproved drinking water and sanitation facilities in the region (Belay & Andualem, 2022).

According to Tumwebaze et al., (2023), effective policies are necessary to increase the availability, reliability, and proximity of piped water in the households of Uganda.

The WASH services in Southern Punjab, Pakistan were found to be associated with stunting among children. Furthermore, contamination of hand pumps and tank water can be a major cause of stunting in the region (Batool et al., 2023).

According to Khan & Sheikh (2023), household expenditure on safe drinking water is significantly related to family size, household income, and access to television facilities. As a result, the government must place a high priority on the high-high clustered districts by focusing on the key determinants of expenditures on safe drinking water.

According to Hajdu et al. (2024), the quality of the household strongly impacts the health of newborns. The study indicated that 20 to 25% of children reside in households of extremely poor-quality.

2.3 National Literature

A study performed by Kumar & Vollmer (2013) found that access to improved sanitation facilities significantly reduced the risk of diarrhoeal morbidity.

In a study conducted in rural north India, it was found that more than 40% of households with latrines had at least one member who defecated in the open. Consequently, the author suggests establishing a large-scale campaign to promote the use of latrines (Coffey et al., 2014).

The management of water and contentious monitoring of human activities will help to minimize the pollution of the groundwater in the study area (Sowrabha & Narayana, 2014).

The study conducted by Heijnen et al. (2015) found that a higher prevalence of shared sanitation facilities is found in less educated, poorer households in India. Furthermore, the study revealed that persons living in shared households were more likely to practice open defecation.

According to Chaudhuri & Roy (2017), rural-urban inequality in WASH facilities is most pronounced in the central Indian states of Bihar, Madhya Pradesh, Chhattisgarh, Jharkhand, Rajasthan, and Odisha. Furthermore, the authors stated that rural-urban heterogeneity posed a challenge to spatially-optimized policy reforms.

Chaudhuri et al. (2018) found that several social reforms in Punjab and Haryana contributed to the improved WASH profile of these states. The study also revealed that there is an intense spatial inequality in the rural WASH sector in India, which calls for spatially optimized interventions.

Mallick et al. (2020) found that improved sanitation facilities reduce the prevalence of diarrhoea among under five-year-olds in India. Furthermore, the study indicated that various socio-economic factors (SEFs) such as the child's age, gender, birth order, caste, religion, wealth index, the mother's age, and residence have an inherent influence on diarrhea prevalence.

A study conducted by Maramraj et al. (2020) revealed that acute diarrhoeal deaths (ADD) were connected to drinking water from shallow bore wells from open defecation areas in a remote tribal village.

According to a study conducted by Sarkar & Bharat (2021), a lack of communication between local bodies and various departments accounts for the ineffective implementation of programmes and policies in India. Thus, the study indicates that community participation and integration between local bodies and communities are important factors in improving policies and programs.

A study conducted by Ghosh et al. (2021) revealed that the prevalence of diarrhoea among under-five children is highest in unprivileged rural areas, non-Pucca houses, and households living with unimproved sanitation practices.

According to Biswas et al. (2022)**,** about 88.7% of households in India had access to adequate drinking water, while the study also reported that around 79.8% of households had access to sanitation facilities in 2018. In addition, the findings of the study revealed that Himachal Pradesh, Andaman and Nicobar Islands, and Sikkim had accomplished the Sustainable Development Goal (SDG 6).

Nearly 50% of households have access to safe sanitation facilities, followed by basic sanitation facilities, limited sanitation facilities, and open defecation in India. The study found that a strong economic status of households contributes significantly to the decline in the use of unimproved sanitation facilities (Prakash et al., 2022).

It has been found in a study conducted in India that districts located in the central and eastern states of Bihar, West Bengal, Jharkhand, Odisha, Uttar Pradesh, Chhattisgarh, and Madhya Pradesh experienced higher levels of WASH poverty. The capital Delhi and states close to it were found to have relatively lower levels of WASH poverty (Ghosh et al., 2022).

A study conducted by Roy (2023) revealed that the spatial distribution of limited access to drinking water and sanitation facilities was spatially clustered among a few central and western Indian states. Furthermore, the study revealed that limited access to drinking water and sanitation facilities was associated with educational status, wealth index, and location of residence.

Sharma et al. (2023) revealed that typhoid, acute diarrheal disease, cholera, shigellosis, and hepatitis are common waterborne diseases in India. Lack of improved sanitation, poor hygiene, and insufficient waste disposal facilities are contributing factors to the outbreaks of these diseases.

In India, waterborne diseases and food outbreaks have been neglected for a long time, which is a public health concern. The study found that drinking public drinking water is closely associated with acute diarrheal disease. Furthermore, speedy identification of the pathogens and their patterns could help to protect against the harmful impact (Majumdar et al., 2024).

2.4 West Bengal

Chakraborti et al. (2009) concluded that water management is the major issue in the arsenic-affected flood plain of the Ganga River, and the surface geology determines the variation of water quality across regions.

According to Mazumder et al. (2010) found that arsenic contamination in the groundwater is one of the major challenges in the region. The study also revealed that most people in the region are affected by arsenicosis due to lack of poverty, lack of awareness, and in adequate healthcare support.

The prevalence of cholera is related to the washing of kitchen utensils in ponds, bathing, exposure to pond water, exposure to drinking water, mouthwashing, and cooking. However, the study revealed that defecation and washing soiled clothes are the primary causes of cholera's initial outbreak (Mukherjee et al., 2011).

Gupta et al. (2015) found the prevalence of diarrhoea is about 22.36% in the slums area of Bankura. Additionally, the study found that the prevalence of diarrhoea among under-five children decreases with increasing age.

According to Bhar et al. (2017), access to improved drinking water, piped water supply, and sanitation services is significantly associated with diarrhoea prevalence among children.

Anthropogenic activities contribute to the contamination of groundwater. Therefore, the study suggests that maintaining tube wells and following proper sanitation practices will improve the quality of water in the region. In addition, it is recommended that effective management and campaigns against open defecation be implemented to prevent it (Lahiri et al., 2017).

Bhattacharyya et al. (2021) have demonstrated that cooking with safe water can reduce the prevalence of chronic diseases. Therefore, the study suggests the use of arsenic-free water to reduce arsenic load in the food chain in South 24 Parganas, Nadia, North 24 Parganas, Maldah, and Murshidabad.

According to Das et al. (2021), groundwater concentrations of two essential micronutrients (selenium and zinc) are low in the region, contributing to the poor health of the local population. Due to contaminated drinking water, the authors expect that the population will suffer from carcinogenic and non-carcinogenic diseases. The authors reported that male faces a higher risk of cancer than females.

De et al. (2022) reported that heavy metals are more likely to be concentrated at various depths. There is a strong correlation between water and urine.

Jaydhar et al. (2022) found that due to the presence of alkaline organisms in groundwater, it is unfit for drinking and agriculture. Therefore, the study suggests that the use of deep learning as well as several management strategies would help to predict groundwater resources.

A study by Chatterjee et al. (2023) demonstrated that the prevalence of diarrhoea is higher among children under the age of five. Additionally, the study found that diarrhoea prevalence was lower in pucca households and households with a higher score for safe water and hygiene. Moreover, the prevalence of diarrhoea is lower in children who were receiving iron fortification.

A study conducted by Roy et al. (2023), it was determined that approximately 33.69% of households in West Bengal have access to safe drinking water on their premises. Nearly 74.35% of households report having access to hygienic sanitation facilities within their homes. Moreover, about 14.60% of households continue to practice open defecation in the region. Furthermore, the authors found that urban, Pucca, and non-nuclear households have better access to WASH services. However, improved drainage facilities are lacking in the region.

It was found that 58.8% of households found WASH practices satisfactory. The study also revealed that inadequate ventilation in the house and overcrowding are key factors for unsatisfactory practices (Ray et al., 2024).

2.5 North South Twenty-Four Parganas

According to Rahman et al. (2003), report that nearly 6.89% of people suffer from arsenical skin lesions. Furthermore, arsenic-contaminated groundwater is being used in agricultural fields and people are using contaminated water in their agricultural fields, which poses a serious health risk to people.

According to Mondal et al. (2021), the groundwater in the district is contaminated with several heavy metals. Furthermore, the results showed that villagers are more likely to contract gangrene and black-foot diseases than their urban counterparts. Thus, the study indicates that it is not safe to consume drinking water directly.

A study performed by Paul & Das (2021) found that within the past few decades, there has been a remarkable improvement in access to water, sanitation, and hygiene in the region. The study also revealed that government commitments and increased investment will help to get access to improved water, sanitation, and hygiene in the region.

The study found that there is a wide disparity in socio-economic development in the district. Furthermore, the study demonstrates that Habra-I, Rajarhat, and Higalganj are the most developed blocks, whereas Minakhan and Haora are the least developed blocks (Sarkar & Chakraborty, 2021).

Biswas et al. (2022) revealed that the incidence of health hazards is associated with socioeconomic factors. The study suggests an awareness programme for unimproved drinking water.

2.6 South Twenty-Four Parganas

Mukherjee et al. (2005) showed that groundwater is contaminated with fluoride, nitrate, and chloride due to the extensive discharge of municipality wastewater and the widespread use of fertilizers. According to the study, most of the groundwater samples fall into the 'safe' to 'tolerable' category and 22% of water samples are examined in the 'health hazard' category.

The South Bengal Delta's low-land, organic-rich sediments contain high levels of arsenic (As). A study conducted in the Bengal Basin concluded that arsenic pollution in the basin is geogenic and originates primarily from the Himalayas. However, Pleistocene sediments topped by an oxidized impervious layer are free of the issue of arsenic contamination. Arsenic in groundwater is mainly released via the reductive dissolution of hydrated ferric oxide, followed by its oxidation by organic matter. Moreover, arsenic remains confined to alluvium soil, and cannot be released into subsurface water (Acharyya & Shah, 2010).

Bhunia & Ghosh (2011) found that stored drinking water and piped water specimens are susceptible to contamination. Furthermore, contaminated drinking water is a major cause of outbreaks of cholera.

Sehgal et al. (2014) found that 67% of households in the district have access to improved sources of drinking water, and 50% of households have sanitation facilities without flashbacks. It has been reported that water quality plays an important role in determining the prevalence of waterborne diseases in the region.

Singh et al. (2015) found that the chemistry of groundwater in this region is controlled by silicate weathering and ion exchange. It was also discovered that groundwater in the region contains excessive amounts of iron-containing materials, such as Fe (OH) 3, goethite, and hematite while being unsaturated in gypsum and anhydrite.

Bandyopadhyay & Basu (2017) revealed that the cost of fresh water for drinking and irrigation purposes is costly in the region. Therefore, the authors suggest the installation of hand pumps or tube wells in the region to provide access to safe drinking water in the district.

A study performed by Chaudhuri et al. (2019) revealed that the Bengal Delta Plain (BDP) is the most contaminated with arsenic (As) in the world, where thousands of populations consume contaminated drinking water. In addition, children who consume arsenic-contaminated water from an early age are more susceptible to developing skin lesions. Moreover, arsenic has multidimensional effects on society.

The study conducted by Khatun & Ghosh (2019**)** revealed that the region faces challenges such as a lack of primary health centers, inadequate connectivity, and accessibility, which are limiting factors for providing quality healthcare.

Chakraborty et al. (2023) showed that the district has a high prevalence of electrical conductivity (EC) in the freshwater aquifer, which indicates that the region is extremely affected by seawater intrusion. Therefore, rainwater harvesting systems could be adapted for safe drinking water.

2.7 Block Level

A study conducted by Kanti Majumdar (2017) found that the prevalence of diarrhoea in the region is 45.68% among under-five children. Major causes of morbidity among children include the absence of sanitation facilities, personal hygiene, vaccination awareness, and poor nutritional status.

Roy et al. (2023) conducted a study in the Sonarpur development block and found that the bore wells are contaminated with arsenic and iron substances. It is also noted that the water quality in the villages is unfit for consumption. Furthermore, around 82.1% of households regularly consume contaminated drinking water without purification, which could lead to the prevalence of chronic diseases.

A study conducted by Das et al. (2024) revealed that the suitability of groundwater for drinking, agriculture, and domestic purposes varies from acceptable limits. The study indicates that groundwater extraction from deeper aquifers for various purposes is a major cause of arsenic contamination.

Although lots of studies conducted on the WASH services worldwide and in India, however, in the present study area, a few studies were carried out. It is therefore, this present study will fill up the gaps and will present a comprensive litturature to the WASH related study.

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Chapter-3

Geographic Background and Socio-Economic Profile

3.1 Geographical Background

South Twenty-four Parganas is the largest district in terms of land and population in West Bengal. It stretches between 22^o 12' 13" N - 22^o 46' 56" N and 87^o 58' 45" E - 88^o 22' 10" E, covering nearly 9,960 sq. km (Figure 3.1) (Dutta, 2019; Bagchi, 2017). The South Twenty-four Parganas is the largest district in West Bengal in terms of area and the second-largest in population. It is the home of the world's largest mangrove forest and riverine Islands. According to Chowdhury et al. 2008 and Samanta et al. 2021, the region is characterized as a long coastal region, therefore, it holds the largest mangrove forest and riverine islands. Therefore, the region acts as a carbon sink zone. It shares a border with North Twenty-four Parganas in the northeast, Kolkata in the North, Howrah, and Purba Medinipur in the west, and Bangladesh in the east. There are large stretches of border with Bangladesh in the Eastern part, while the Bay of Bengal lies in the Southern part of the district (Dr & Khan, 2012). The Sonarpur is the district's largest municipality out of seven municipalities. The district of South Twenty-four Parganas is divided into five sub-divisions: Alipore Sadar, Baruipur, Diamond Harbour, Canning, and Kakdwip. According to the Directorate of Census Operations, West Bengal (2014), the district has 2042 villages distributed across 29 development blocks, of which 1996 are inhabited villages. The population density of the district is 819 people per sq. km. The decadal growth rate of the population is 18.2 percent. Furthermore, there are a total of 956 females for every 1000 males, and the literacy rate is 77.51 percent. The district is segregated into three board groups: (1) The Marshy Riverine Land of Sundarban (2) The Non-Sundarban Rural Areas (3) The urban and semi-urban areas. The groundwater contains traces of heavy metals, which make it unfit for human consumption (Jaydhar et al., 2022). Besides, the district has been proposed to separate from Sundarbans in the future.

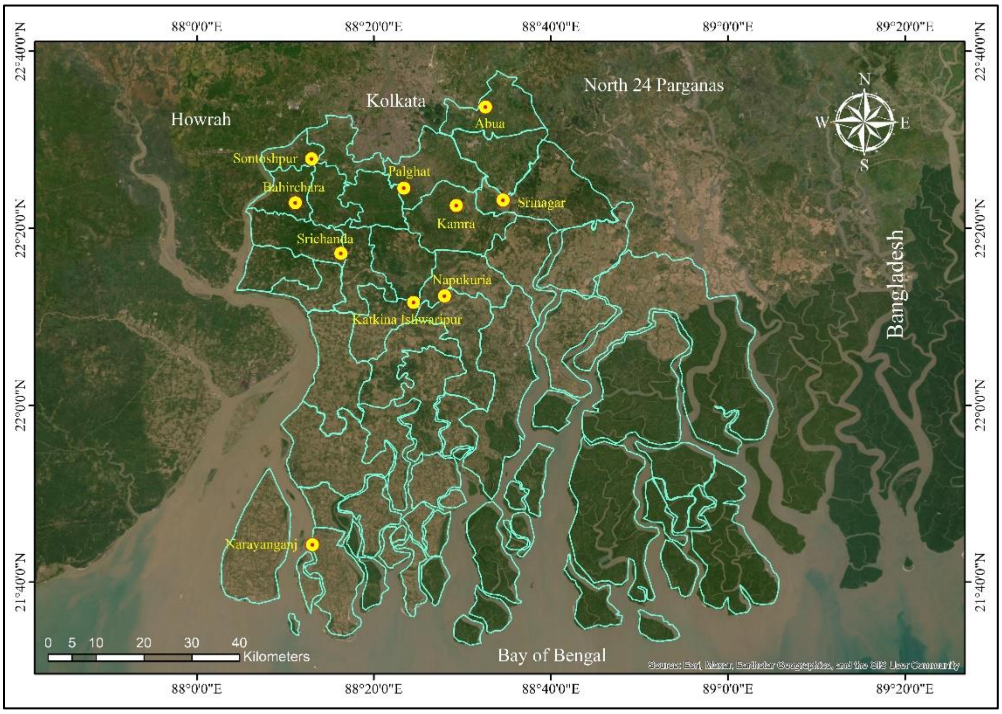

Figure 3.1: Location map of the study villages

Administratively, the district consists of 5 subdivisions, 29 blocks, 33 police stations, 7 municipalities, and 312 gram Panchayats (Table 3.1). Alipore is the administrative headquarters of the district.

Table 3.1: District profile of South Twenty-four Parganas

Sl. No.	Name of the Sub-division	Blocks under Sub-division	Name of the surveyed villages
1	Alipore (Sadar)	**Budge Budge- I, Budge Budge-II**, Bishnupur-I, Bishnupur-II, & Thakurpukur Maheshtala	Sontoshpur, and Bahirchara
2	Baruipur	**Baruipur**, Bhangar-I, **Bhangar-II**, Jaynagar-I, **Jaynagar-II**, Kultali, & **Sonarpur**	Kamra, Abua, Napukuria, and Palghat
3	Diamond Harbour	**Mogarhat-I, Mogarhat-II**, Mathurapur-I, Mathurapur-II,	Srichanda, and Katkina Ishwaripur

		Diamond Harbour-I, Diamond Harbour-II, Falta, Kulpi, & Mandirbazar	
4	Kakdwip	**Namkhana**, Kakdwip, Patharpratima & Sagar	Narayanganj
5	Canning	Basanti, Canning-I, **Canning-II** & Gosaba	Srinagar

Source: District Survey Report, 2018

3.1.1 Physiography

The district is situated in the Gangetic delta, which is comprised of several rivers and tributaries. In addition, the district's topography is generally plain, although some parts are gently sloping, and the altitude ranges from -1 meter to 20 meters above mean sea level (MSL). Physiographically, the district can be divided into three major areas: (1) older floodplains, (2) natural levees, and (3) swamps (Office of the District Magistrate & Collector, 2023). Due to sedimentation, these rivers and tributaries are continually creating islands. Some islands are still submerged under water. A Southern part of the district is covered with mangrove forest, due to the number of rivers and its tributaries creating a fragile ecosystem. Furthermore, in the northern part of the district, Baruipur-Jaynagar Plain and Kulpi-Diamond Harbour Plain lie approximately 5-6 meters above sea level (Figure 3.2). There are four sub-micro regions within the district viz. (a) South Hugli Flats (b) South Bidyadhari Plain (c) Hooghly Delta, and (d) Sundarbans.

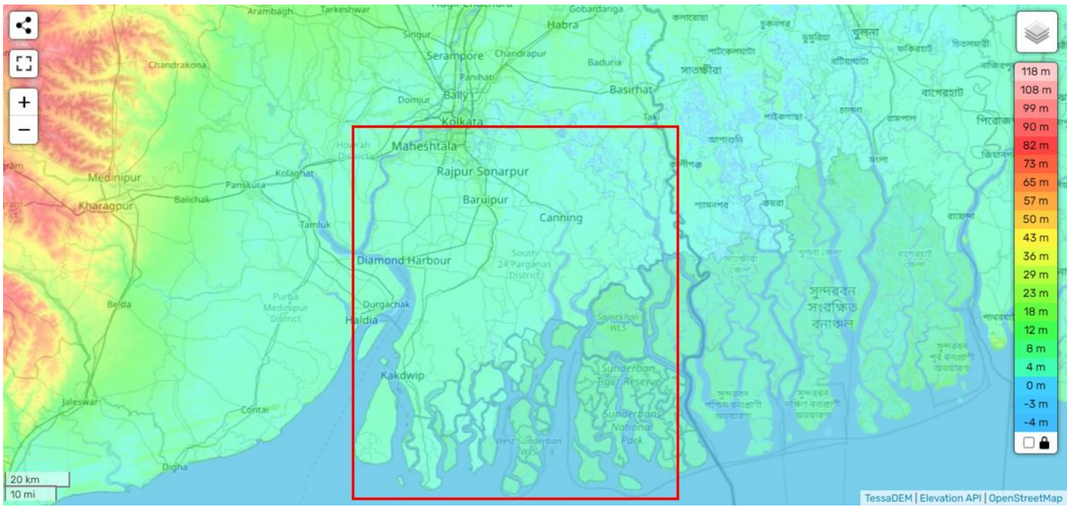

Figure 3.2: The topographic, relief, and elevation map of the district; Notes: Minimum elevation: -1 m; Maximum elevation: 20 m; Average elevation:3 m

3.1.2 Geological Features

This district is situated in the lower Gangetic delta, which is covered by Quaternary sediment deposited by the Ganga and its tributaries. There are a total of six layers in the region including topsoil, saline water, clay layer, brackish water, clay layer, and fresh-water bearing zone (Majumdar et al., 2014). The surface soil in the eastern and central parts is predominantly clayey loam with some peaty patches in the marshy areas. Furthermore, the surface soil of the Sundarban area is heavy clay impregnated with salt. Within Quaternary and Tertiary sediments, ground water-bearing aquifers can be found in the depth ranges from 75m to 360m with numerous layers of clay and sand of differing thicknesses (Figure 3.3). Moreover, a group of aquifers that occur between 160 to 360 meters in depth.

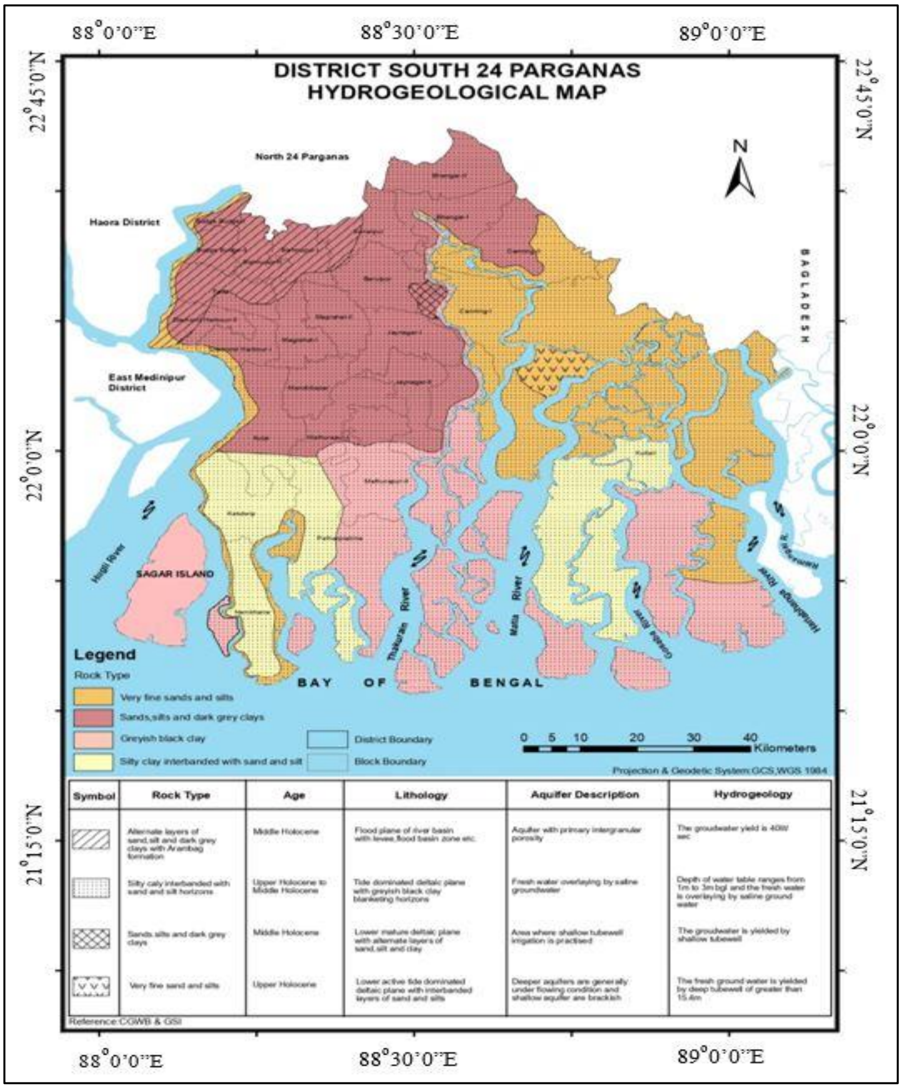

Figure 3.3: Hydrogeological map of the district; Source: Central Ground Water Board and Geological Survey of India

3.1.3 Drainage Patterns

This district is located on the lower bank of the Gangetic delta. The entire drainage pattern of the district is heavily dependent upon the tidal forces of the Bay of Bengal. There are numerous mudflats, coastal wetlands, lagoons, creeks, and estuaries of large rivers. Besides, important rivers are Hooghly, Matla, Piyali, Bidyadhari, Thakuran, Raidighu, Bidya, Saptamukhi, and Hataniya-Doaniya, etc. Several streams and rivulets in the district are known as Khal, and swampy wetlands and forested swamps are known as Bil or Beel. Due to tidal activity, most of the rivers change their paths and form small water bodies throughout the district. In addition, seawater can enter up to 100 km from coastal areas through these small channels.

3.1.4 Climatic Conditions

The climate of the region is humid and tropical with a well-distributed rainfall during the monsoon. However, the coastal parts of the region are moist and sub-humid agroecological sub-region. The annual average temperature in the district ranges from 13.6°C during the winter to 36.3°C during the summer. However, annual average rainfall ranges between 1750 mm to 1770 mm. Besides, the relative annual humidity of the area is 71% to 85%. The skies are moderately clouded in May, heavily clouded during the monsoon season, and clear or lightly clouded during the rest of the year. Moreover, winds are generally stronger in Sundarban and its surrounding area.

3.1.5 Minerals and Mining

There is evidence of oil, natural gas, and groundwater deposits based on different research. In addition, limestone lies in an extra depth that has not yet been explored. Besides, the district has no major mining activities except minor silt Brick Earth mining. During the English era, silt brick earth manufacturing is introduced in the region 200 years ago. Since then, most silt collection ponds have been recorded as "IT-KHOLA" on the Right of Record (ROR) of the Government of West Bengal. Currently, there are more than 300 brick manufacturing units, and around 83 units have been authorized by the Land and Land Reform Department of the Government of West Bengal.

3.1.6 Soil and Cropping Patterns

There are two major types of soil in the region: (1) Gangetic alluvium and (2) Saline soil (Alam & Banerjee, 2022). Due to the excessive presence of sodium chloride in this region, the soil is saline. This factor causes the soil to be more fertile and scanty. Furthermore, the soil structure varies from stiff clay to clay loam. Matla, Herobhang, Bidhadhari, Thaneram, Saptamukhi, and Mridhangabhang are the six major rivers of the district. This fertile soil provides a strong foundation for agriculture and horticulture. This region has a Floriculture and Horticulture base with calcium and magnesium nutrient-rich soils, which are formed by the direct deposit of the Ganga

River. The major staple crops of the region are (1) rice (2) oilseeds (sunflower, safflower, mustard, and linseed), and (3) cucurbits (Bagchi, 2017).

3.1.7 Flora and Fauna

There are two agro-ecological zones in the district. It has 4,220 sq. km of forest cover (Protected: 42 km^2; Reserved: 4,177 km^2; Unclassified: 1 km^2). There are mostly mangrove scrubs, salt water mixed forests, littoral forests, brackish water mixed forests, wet forests, and wet alluvial grasslands in the region. In addition, the region has a vast eco-region along its coastline, which encompasses the largest mangrove ecosystem in the world, covering an area of 20,400 km^2. The region is known as Sundarbans due to the dominant mangrove species Heritiera fomes, locally called Sundari and sundri (Figure 3.4). There are 50 broad types of mangroves in the world, 26 of which are found in the Sundarbans region, including Ceriops decandra, Avicennia spp., Xylocarpus Granatum, Bruguiera gymnorrhiza, and Rhizophora mucronata. In 1984, the World Wildlife Fund sponsored Project Tiger, which resulted in the creation of the Sundarbans National Park, and later promoted into a World Heritage Site by UNESCO in 1989.

Figure 3.4: Mangrove forests of the Sundarbans; Source: By author

On the other hand, Sundarbans mangrove forest is the region's biggest attraction and it has a rich fauna diversity. Various species of local and other migratory birds are Seagull, Tern, Kingfisher, Heron, Egret, Whimprel, Golden Plover, Ospery, and Shaheen Falcon. Besides, Saltwater Crocodile, Chinese Pangolin, Wild Boar, Spotted and Axis Deer, Leopard Cat, Fishing Cat, Olive Ridley Turtles, Monkey, Royal Bengal Tiger, and Gangetic Dolphin are major animals in the region. Moreover, Figure 3.5 shows the Royal Bengal Tiger moving in an ecologically fragile mangrove forest, a wild boar traveling towards its ecological niche, a saltwater crocodile receiving sunshine to maintain their body temperature, and a heron bird standing motionless in swamp land.

Figure 3.5: Rich fauna diversity of Sundarbans (a) Royal Bengal Tiger, (b) Wild Boar, (d) Salt Water Crocodile, and (d) Heron Bird, Source: By author

3.1.8 Land Use Patterns

The district is in the proper delta of the lower Ganga plain. There are a few meters above flood level, and its physical characteristics are like deltaic land in India. In the northern part of the inland tract, there is a very well-raised delta while in the southern part, there is a low-lying Sundarbans. There are several river creeks, tidal channels, and islands in the Sundarbans. In addition, some swampy marshes are covered with low forest and scrub. Besides, 15.11% of land in the region is used for non-agricultural purposes, 37.78% for under cultivation, and 44.94% for forest (Figure 3.6). According to Alam & Banerjee (2022), from 1991 to 2021, the built-up area (BUA) increased by 716.63%, resulting in a considerable loss of agricultural and natural ecosystems. In South 24 Parganas, significant urban growth has been observed along the east bank of the Hooghly River near the Kolkata Municipal Corporation (KMC).

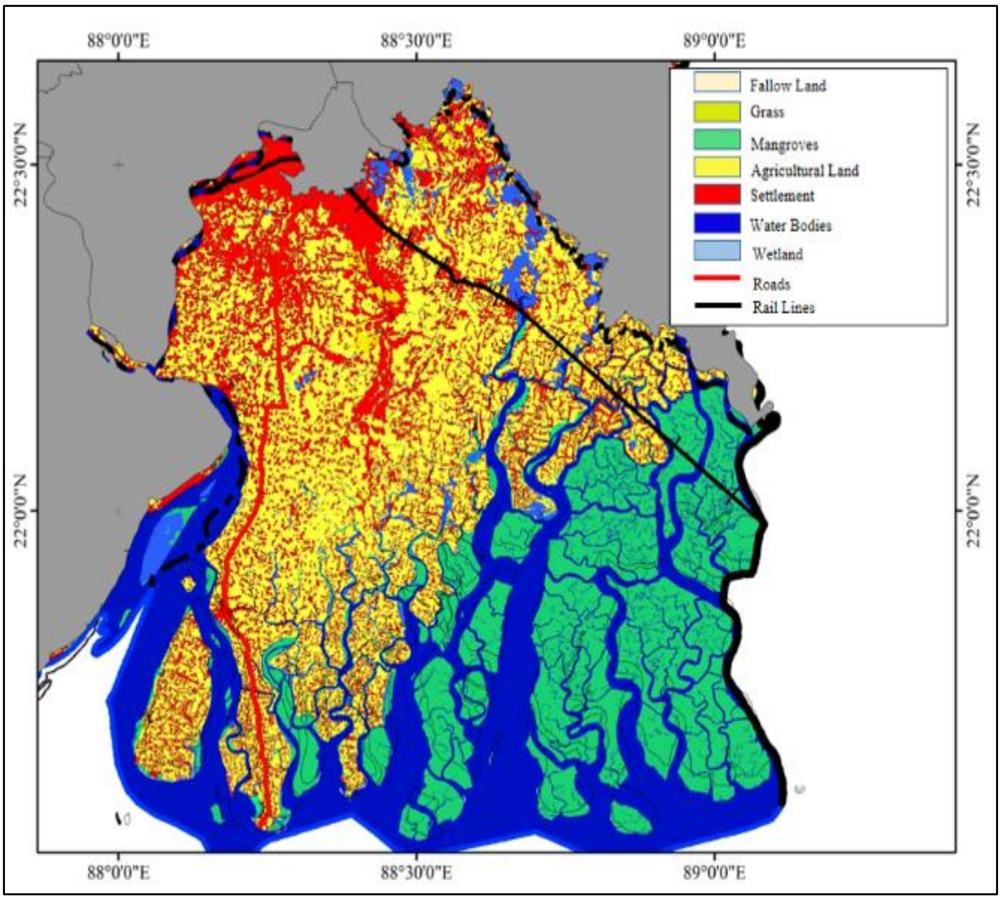

Figure 3.6: Land use and land cover map of the district

3.1.9 Agriculture

There are two types of soils present in the district viz. coastal soil and non-saline soil. Due to the abundance of water in non-salty soils, these soils are fertile (Table 3.2). Rice is one of the most important food crops in the district. However, the soils are extensively cultivated for potato, pulse, gram, and chili. However, Jute is an important cash crop (Goswami et al., 2014). In addition to these, the saline soil of the district is unfit for cultivation.

Table 3.2: Land use and land cover areas of the district

Sl. No.	Area	Hectare	%
1	Cultivate Area	4,06,215	23.63
2	Area under Forest	1,70,580	9.92
3	Area under Barren and uncultivable land	845	0.05
4	Area under permanent pastures	5,445	0.32
5	Area under Culturable Waste land	2,924	0.17
6	Area under Misc. Tree Crops & Groves	8,427	0.49
7	Fallow land other than current fallow	87	0.01
8	Area under current fallow	13,299	0.77
9	Net Cropped Area	3,93,465	22.89
10	Area under more than one Crop	1,60,217	9.32
11	Area under more than Double Crop	1,890	0.11
12	Gross Cropped Area	5,55,572	32.32
13	Cropping Intensity	141.20%	

Source: District Environment Plan, 2023

3.1.10 Water Quality

Access to safe, affordable, and adequate drinking water is essential to maintain good health and well-being. However, contaminated drinking water can lead to a variety of waterborne illnesses. Factors such as mining activities, land use and land cover changes, wastewater discharge, and rapid urbanization can cause pollution of drinking water. On the other hand, arsenic, fluoride, iron, and salinity are some of the chemicals that are present in the region (Figure 3.7). The diarrhoea is the dominant waterborne disease in the district. Furthermore, the district has India Mark II hand pumps with galvanized iron components that are prone to corrosion. As a result of corrosion activities, the water quality of India Mark II hand pumps is adversely affecting human health. According to Roy et al. (2023), 94.99% of households in the district had access to safe drinking water, while 6.46% of households had access to safe drinking water within their premises. Moreover, to ensure access to safe drinking water, the Government of West Bengal has run the 'Jal Jeevan Mission' or 'Har Ghar Jal Yojana'. Besides, rivers and canals are major sources of irrigation in the region.

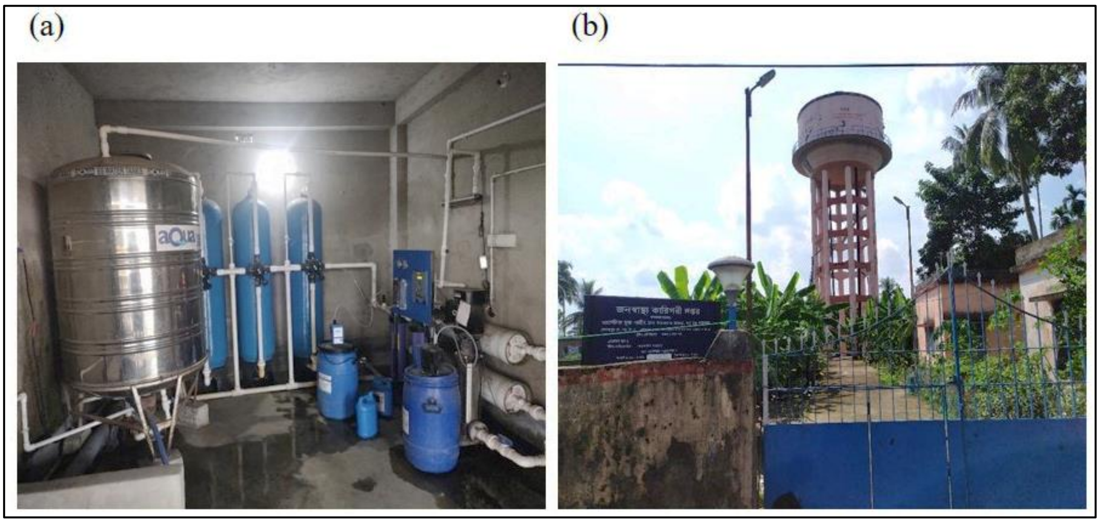

Figure 3.7: Drinking water purification infrastructures (a) arsenic removal plant in Srinagar village and (b) arsenic-free drinking water supply scheme in Palghat village by the Public Health and Engineering Department; Source: By author

3.2 Socio-economic Profile

3.2.1 Demography

The region has a population of 81.62 lakhs, of which 41.74 lakhs are males and 39.88 lakhs are females (Goswami et al., 2014). The sex ratio of the district is 956 females out of 1000 males. However, the child sex ratio of the region is 963 females out of 1000 males. Moreover, the average literacy rate in the region is 77.51%, whereas male literacy is 83.35% and female literacy is 71.4%. Furthermore, the region has three major religions: Hinduism (63.17%), Muslim (35.57%), Christianity (0.81%), and other or not stated (0.45%). On the other hand, the demographic profile of the study villages is shown in Table 3.3. In the region, there are heterogeneous socio-demographic factors that impacting the quality of life of residents. The above table shows that the lowest literacy rate is reported in Srinagar village, whereas the highest is reported in Bahirchara village. Moreover, the highest sex ratio is found in Srichanda village, and the lowest is found in Bahirchara village.

Table 3.3: Demographic profile of the study villages

Block Name	Village Name	Total Geographical Area (in Hectares)	Total Population of Village	Total HHs	Literacy (%)	Sex Ratio
Baruipur	Kamra	64.75	1352	324	73.45	991
Sonarpur	Palghat	103.03	2360	520	78.26	902
Bhangar II	Abua	61.52	1766	334	65.57	922
Magarhat-I	Srichanda	107.65	1773	416	77.89	997
Magrahat-II	Katkina Ishwaripur	230.64	1505	345	70.63	900
Jaynagar-II	Napukuria	123	1799	399	77.53	986
Canning-II	Srinagar	342.93	3420	664	56.67	973
Budge Budge-I	Sontoshpur	146.5	2808	710	74.64	943
Budge Budge-II	Bahirchara	71.58	723	173	79.94	893
Namkhana	Narayanganj	157.05	1352	338	78.55	954

Source: Primary Census Abstract

3.2.2 Culture

This district is known for its traditional Jhumur music and folk drama from Bonbibir Pala. It is the home of 220 Jhumur, 167 Shola, and 252 Bonbibir Pala artists. Traditionally, Indian culture and art have been characterized by rich folk cultures and traditional heritages. Some districts in West Bengal are renowned for their traditional Gajan (traditional songs) and folk culture. Every year, the Gajan festival is celebrated during the Charak festival, which celebrates Shiva's worship. It is particularly observed in the Kulpi block, that Gajan songs express social, religious, political, and social stratification, exploitation of marginal classes by the upper classes, and the history of class struggle in the area. Gajan songs fall into two categories: (1) those composed by Namsudras (untouchables) and (2) those composed by groups of women.

The district is renowned for the Kapil Muni Ashram, one of the important pilgrimages of India, located in Gangasagar (Figure 3.8). In the Indian religious wishdom, it is said about the Gangasagar that “Saare Tirth Baar Baar, Gangasagar Ek Baar”, which shows its divinity. The Gangasagar Mela, which takes place annually on the occasion of Makar Sankranti (winter solstice), is an important festival for the Hindus (Hajra et al., 2012). The confluence of the Ganga and the Bay of Bengal attracts millions of Hindu pilgrims on the auspicious day. The Gangasagar is a continental shelf, located at the mouth of the sacred river Ganga, in the Bay of Bengal.

Figure 3.8: Pilgrimage of the district (a) a monk in Gangasagar fair, and (b) Kapil Muni Ashram in Gangasagar; Source: Wikipedia

3.2.3 Settlement Types

There are three main settlement patterns found in the region: (1) nucleated, (2) dispersed and (3) linear. In addition, the region is dominated by (1) Kutcha (2) Semi-pucca (3) Pucca households (Figure 3.9). Brick, cement, tally, mud, and tally are commonly used raw materials in regions to construct houses.

(a) (b)

Figure 3.9: Types of households (a) semi-pucca household in Narayanganj village and (b) pucca household in Napukuria village; Source: By author

3.2.4 Economy

The economic activities of the economically backward people in the region are shown in Figures 3.10 and 3.11. According to Bagchi (2017), it is one of the backward district in West Bengal and considered the most backward region in India.

The primary economic activities of the region are agriculture, livestock farming, nursery cultivation, household, and surgical tool industries, which are major earning sources for these unprivileged people. Apart from that the region has one special economic zone (Falta SEZ), which is located on the western side of the district. This SEZ acts as a hub for all major economic activities, which generate jobs for unemployed youth.

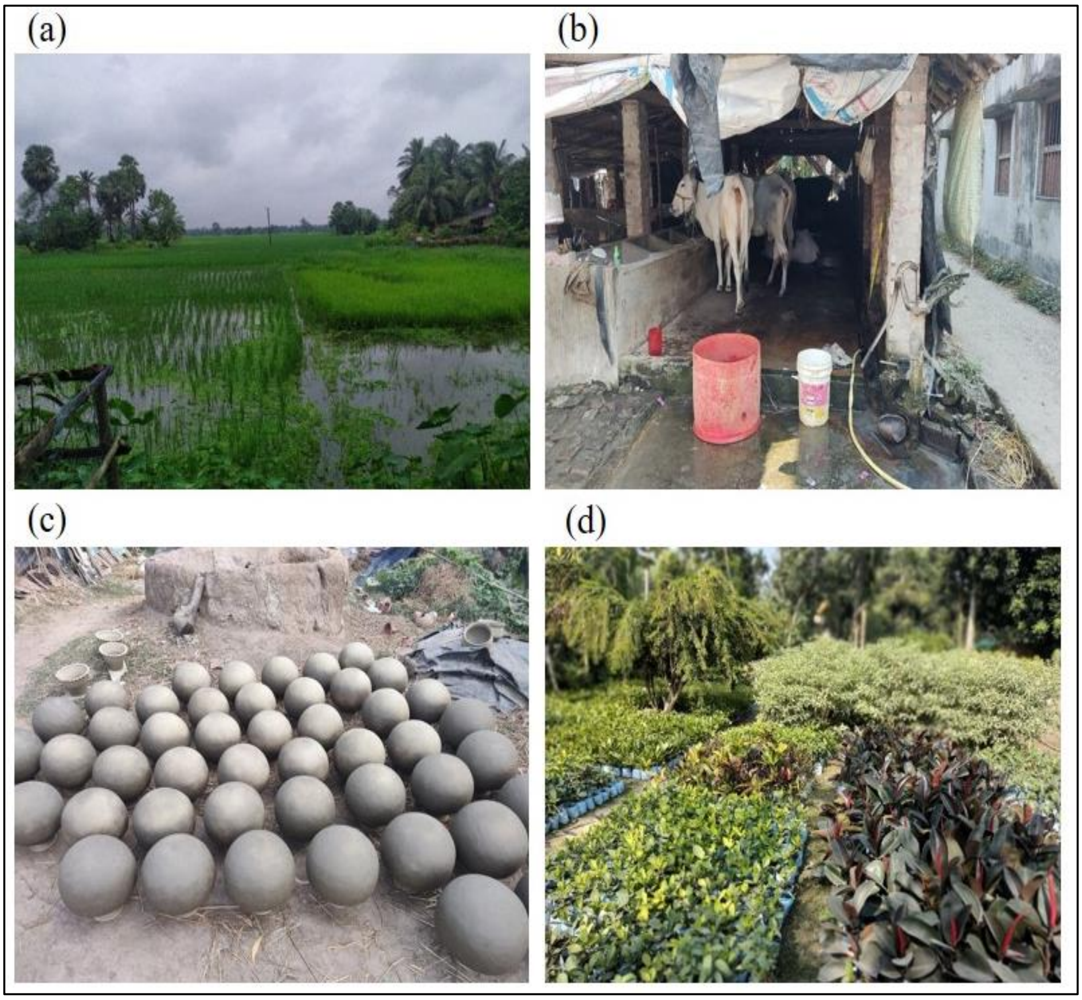

Figure 3.10: Economic activities (a) paddy field, (b) livestock farming in Abua village, (c) a household making clay water pot in Narayanganj village, and (d) nursery practices in Bahirchara village; Source: By author

Figure 3.11: Earning sources for the villagers (a) tailoring business in Sontoshpur village and (b) villagers engaged in a hand gloves occupation; Source: By author

3.3 Case Study

There are a total of 10 villages were selected to conduct a detailed case study across the district. These villages are Kamra, Palghat, Abua, Srichanda, Katkina Ishwaripur, Napukuria, Srinagar, Sontoshpur, Bahirchara, and Narayanganj. Furthermore, several variables related to socio-economic development, population profile, and physicochemical parameters of water are selected to understand water and the health quality of people.

Figures 3.12, 3.13, and 3.14 provide an overview of the land use and land cover, educational infrastructure, and healthcare services of the study villages. Furthermore, Tables 3.4 describe the working-age population of the study villages. The regional heterogeneity of land use and land cover changes are present in the region. Apart from that, the study revealed disparities in education infrastructure and healthcare facilities in the district. Therefore, the socioeconomic indicators of each village were analyzed in detail in this section.

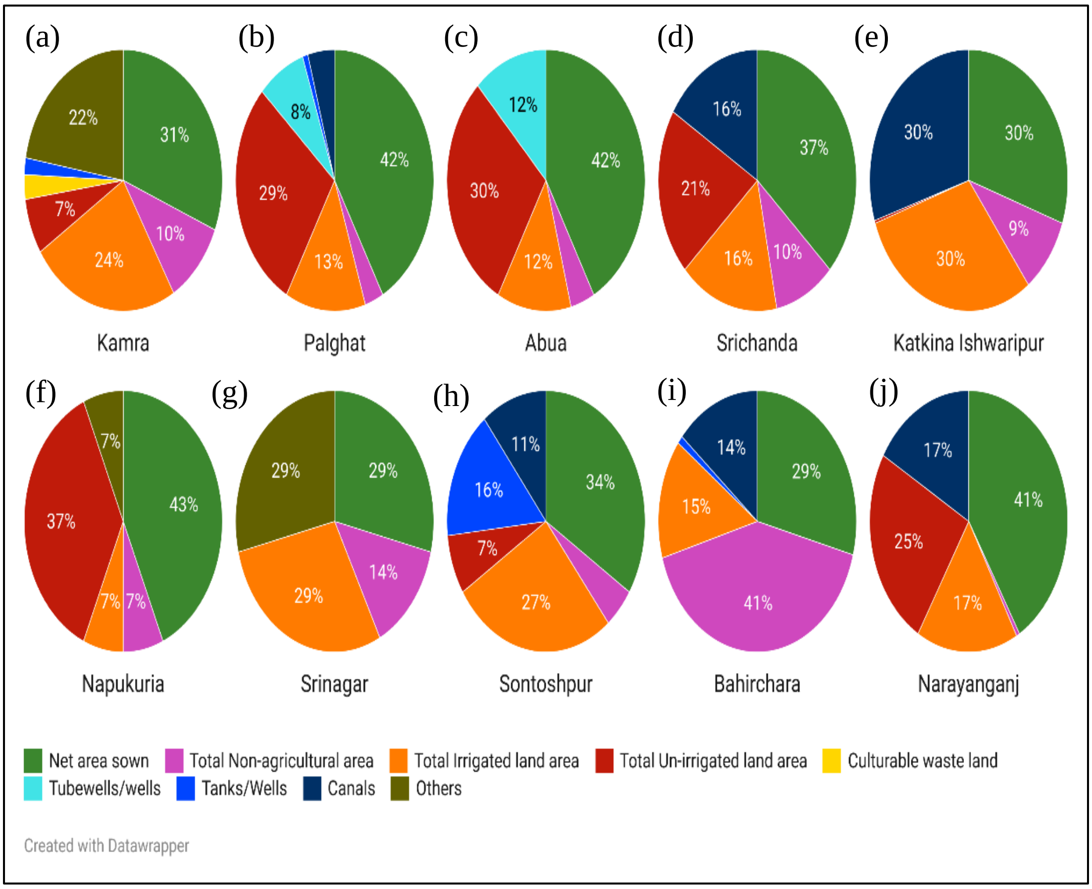

Figure 3.12: Land use and land cover of the each study villages

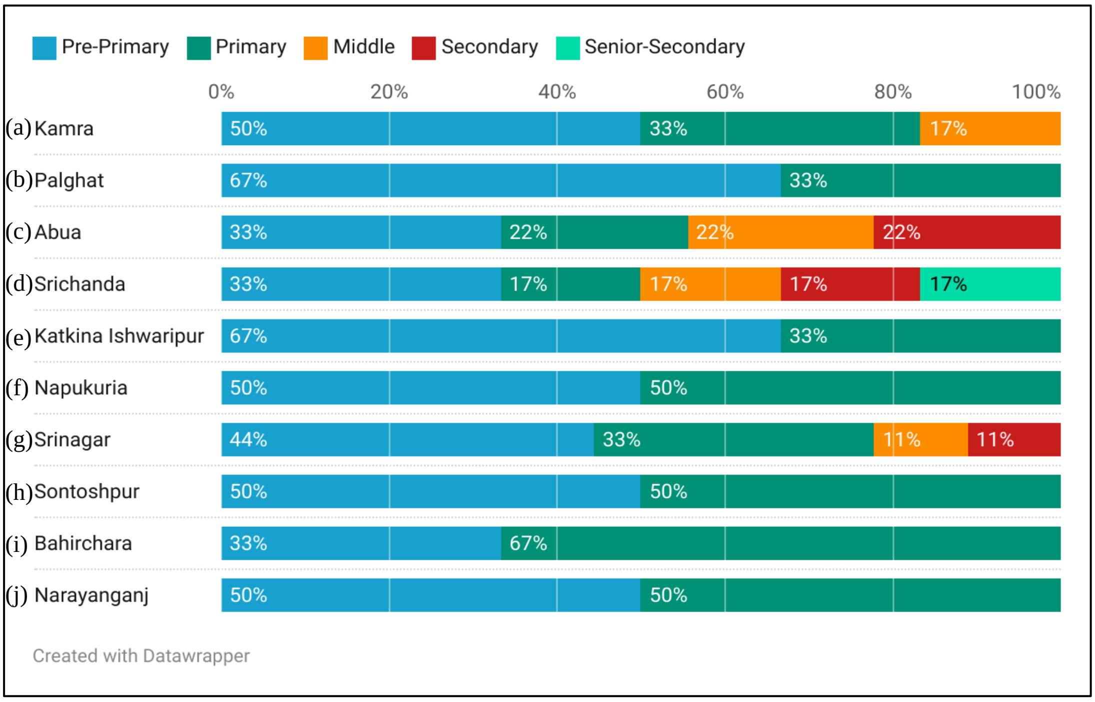

Figure 3.13: Educational infrastructure of the study village

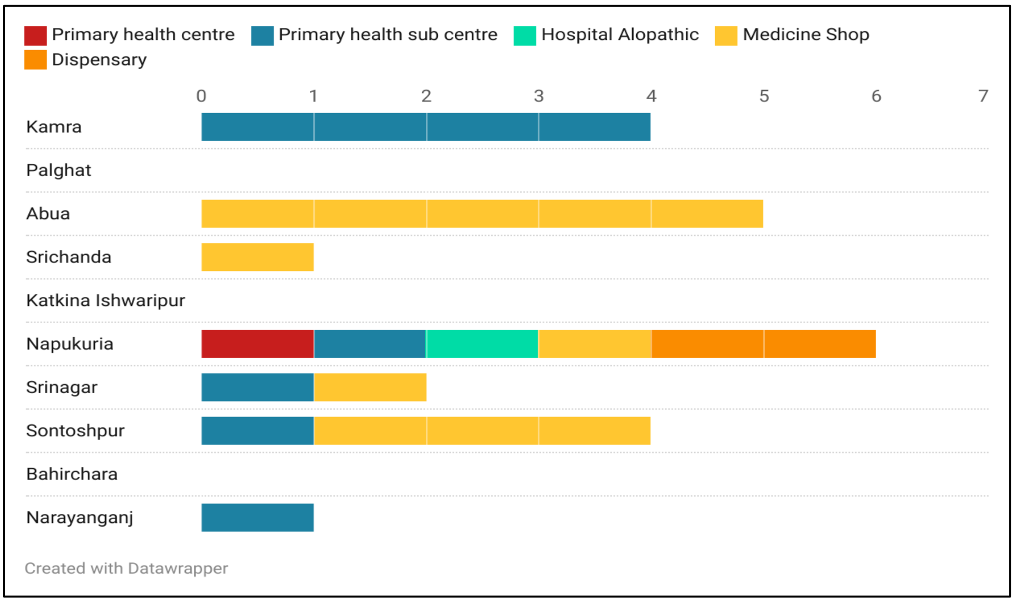

Figure 3.14: Healthcare services in the study villages

3.3.1 Kamra Village

Kamra village is located in the Baruipur subdivision of the South Twenty-four Parganas district of West Bengal. The village is 8.4 km away from the sub-district headquarters (Tehsildar Office) of Piyali, and 29.1 km away from the district headquarters of Alipore. It comes under Begumpur gram panchayet. Furthermore, Baruipur is the nearest town to the village, which is located around 14 km from the village, considered a hub of major economic activities (Table 3.4).

Table 3.4: Working population of the study villages

Block Name	**Village Name**	**Total Population of Village**	**Total working Population (%)**	**Nearest Town (in km)**
Baruipur	Kamra	1352	33.65	Baruipur (14 km)
Sonarpur	Palghat	2360	38.56	Rajpur (3 km)
Bhangar II	Abua	1766	34.52	Dum Dum (21 km)
Magarhat-I	Srichanda	1773	47.11	Diamond Harbour (20 km)
Magrahat-II	Katkina Ishwaripur	1505	36.80	Jaynagar (5 km)
Jaynagar-II	Napukuria	1799	30.44	Jaynagar (8 km)
Canning-II	Srinagar	3420	40.39	Baruipur (30 km)
Budge Budge-I	Sontoshpur	2808	39.00	Mahestala (10 km)
Budge Budge-II	Bahirchara	723	33.28	Dakshin Raipur (4 km)
Namkhana	Narayanganj	1352	36.39	Kakdwip (17 km)

Source: Primary survey

In this village, a potable water factory is located, which fulfills the demand for safe water in the study village and adjacent areas (Figure 3.15).

Figure 3.15: Potable water factory in Kamra village; Source: By Author

The overall geographical area of the village is 64.75 hectares. The land use pattern comprises net sown area (31%), un-irrigated area (7%), Tanks (4.53%), and cultivable wasteland (1.43%) (Figure 3.12a) . The village has a total of 324 households, with a total population of 1,352 people, of which 679 are males and 673 are females (Directorate of Census Operations, West Bengal, 2014). The majority of the population is Hindu. Almost 33.65% of the population engage in economic activities. The literacy rate is 73.45%, with 81.59% of males and 65.23% of females. There are a total of 6 schools, out of which 50% are pre-primary schools, 33% are primary schools, and 17% are middle schools, demonstrating that the village has a basic education infrastructure (Figure 3.13a). Besides, the village has 4 primary health sub-centers, however, these centers are not well-equipped with cutting-edge equipment. Therefore, the rural poor people suffer from several health complexities. In the meantime, the village has a variety of amenities and services like pucca roads, telephone coverage, a post office, a sports field, assembly polling station, power supply, and newspaper supply.

3.3.2 Palghat Village

Palghat village is located in the Sonarpur subdivision of South Twenty-four Parganas district in West Bengal. It is located about 3 km from the sub-district headquarters Rajpur and 30.4 km away from the district headquarters Alipore. It comes under the Poleghat panchayet of the Sonarpur development block. The village has a total land area of 103.03 hectares. The land use pattern contains net sown area (42%), irrigated area (13%), unirrigated area (29%), and tube wells or wells (8%) (Figure 3.12b). There are a total of 520 households, with a total population of 2,360 people, of which 1,241 are males and 1,119 are females. The overall literacy rate is 78.26%, with 82.59% male literacy and 73.46% female literacy (Directorate of Census Operations, West Bengal, 2014). In the village, there are three major religious groups: Muslims, Christians, and Hindus. Besides, there are a total of 4 schools, out of which 67% of pre-primary schools and 33% of primary schools (Figure 3.13b), demonstrating that the village has a basic education infrastructure. However, the village lacks basic healthcare services, which poses a problem for the lower socio-economic classes. In the meantime, the village has a variety of amenities and services like pucca roads, sports field, cinema hall or video hall, public library, a public reading room, and newspaper supply.

3.3.3 Abua Village

Abua village is situated in the Bhangar II subdivision of the district in West Bengal. The village is located around 9.5 km away from the Bhangar II subdivision and about 58.3 km from the district headquarters Alipore. It comes under the Bhogabanpur panchayet. Furthermore, the village has the nearest town of Dum Dum, which is located nearly 21 km away from the village. It is considered a hub of all major economic activities. The total geographical area of the village is 61.52 hectares, which is distributed into different parts, including net sown area (42%), irrigated area (12%), unirrigated area (30%), and wells or tubewells (12%) (Figure 3.12c).

The village has a population of 1,766 people, of which 919 are males and 847 are females. A total of 65.57% of the village's population is literate, including 61.51% of females and 69.31% of males. Furthermore, there are a total of 9 schools, of which

34% are pre-primary schools, 22% are primary schools, 22% are middle schools, and 22% are secondary schools (Figure 3.13c) (Directorate of Census Operations, West Bengal, 2014). Besides, it has a total of 4 medicine shops, which somehow manage to fulfill the basic medical requirements of the people. However, it does not have any primary health sub-center, which could cause a concern. Besides, the village has a variety of facilities like pucca roads, banks, post office, common service center, public reading room, newspaper supply, assembly polling station, and power supply.

3.3.4 Srichanda Village

Srichanda village is located in the Magarhat I subdivision of the southern district of West Bengal. The village is located 2.9 km away from the sub-district headquarters in Usthi and 29.6 from the district headquarters in Alipore. In addition, Diamond Harbour is considered a hub of major economic activities, which is located 20 km away from the village. It comes under the Srichanda panchayet of the Magarhat I development block. It has a total of 416 households (Directorate of Census Operations, West Bengal, 2014). The total area of the village is 107.65 hectares, which are divided into various parts like net sown area (37%), non-agricultural area (10%), irrigated area (16%), unirrigated area (21%), and canals (16%) (Figure 3.12d). Furthermore, the total population of the village is 1,773 people, of which 888 are males and 885 are females. In addition, the overall literacy rate of the village is 77.89%, with 84.46% being males and 71.30% being females. Additionally, there are a total of 6 schools in the village, of which 33% are pre-primary schools, 17% are primary schools, 17% are middle schools, 17% are secondary schools, and 17% are senior-secondary schools (Figure 3.13d). The village has a medicine shop, which serves the people's basic medical needs. However, there are no other healthcare facilities in the village. Moreover, it has various services like bus services, pucca roads, power supply, and newspaper supply.

3.3.5 Katkina Ishwaripur Village

The village is situated in the Magarhat II subdivision of the southern district of West Bengal. It is located 8 km from the sub-district headquarters in Magarhat and

50.3km away from the district headquarters in Alipore. Furthermore, Jaynagar is considered a hub of major economic activities, which is located about 5 km away from the village. There are around 345 households in the village. The village comes under Dhanpota gram Panchayat. The total geographical area of the village is 230.64 hectares. The geographical area of the village is divided into several parts net sown area (30%), non-agricultural area (9%), irrigated area (30%), and canals (30%) (Figure 3.12e).

The village has a total population of 1,505 people, of which 792 are males and 713 are females. The overall literacy rate of the village is 70.63%, with 79.42% male literacy and 60.87% female literacy (Directorate of Census Operations, West Bengal, 2014). The village is home to two major religious groups, Hindus and Christians. In the village, there are a total of 3 schools, of which 67% are pre-primary schools and 33% are primary schools (Figure 3.13e). However, there are no healthcare facilities in the village, which could cause serious concern for the villagers. Besides, it has various kinds of services like self-help groups, a community health center with TV, sports field, newspaper supply, an assembly polling station, and power supply.

3.3.6 Napukuria Village

The village is located in the Jaynagar II subdivision of the ecologically fragile district of West Bengal. It is located 0.5 km from the sub-district headquarters Jaynagar and 36.3 km away from the district headquarters Alipore. Furthermore, Jaynagar is the nearest town to the village (8km away), which is considered a hub of all major economic activities. There are a total of 399 households in the village. The village comes under Maida Panchayat. The total geographical area of the district is 123 hectares, which are divided into various parts like net sown area (43%), non-agricultural area (7%), irrigated land area (7%), unirrigated land area (37%), and others (7%) (Figure 3.12f). The total population of the village is 1,799 people, of which 906 are males and 893 are females. The literacy rate of the village is 69.43%, with 76.38% male literacy and 62.37% female literacy (Directorate of Census Operations, West Bengal, 2014). There are a total of 4 schools, out of which the village consists of 50% of pre-primary schools and 50% of primary schools (Figure 3.13f). Additionally, it has a primary health center, a primary health sub-center, an allopathic hospital, a medicine shop (Sonar Bangla Pharmacy), and a dispensary. Overall, the village has properly structured healthcare facilities, which could able to serve the villagers. Moreover, various kinds of facilities like public libraries, public reading rooms, newspaper supply, and assembly polling stations are available in the village.

3.3.7 Srinagar Village

The village is situated in the Canning II subdivision of the southern district of West Bengal. It is located 18.2 km from the sub-district headquarters Canning and 66.1 km from the district headquarters Alipore. It comes under Narayanpur gram panchayet. Baruipur is the nearest town to the village (30 km away), which is considered a hub of all major economic activities. It has about 664 households, which are located throughout the village. The village has a total area of 342.93 hectares, and land use patterns of the village comprise net sown area (29%), non-agricultural area (14%), irrigated land area (29%), and others (29%) (Figure 3.12g). The total population of the village is 3,420 people, out of which 1,733 are males and 1,687 are females. It has an overall literacy rate of 56.67%, with 59.90% male literacy and 53.35% female literacy (Directorate of Census Operations, West Bengal, 2014). There are a total of 10 schools in the village, of which 44% are pre-primary schools, 33% are primary schools, 11% are middle schools, and 11% are secondary schools (Figure 3.13g). In the village, one primary health sub-center and one medicine shop are present. Additionally, various facilities like pucca roads, ICDS centers, Anganwadis centers, cinema halls, assembly power supplies, newspaper supplies, and power supplies are available in the village.

3.3.8 Sontoshpur Village

Sontoshpur village is situated in Budge Budge I subdivision of South Twenty-four Parganas district in West Bengal. The village is located 11.2 km from the sub-district headquarters Bara Nischintapur and 15.9 km away from the district headquarters Alipore. The nearest town to the village is Mahestola (10 km away), which is considered a hub of all major economic activities. There are around 710 households, and the village comes under Chingripota gram Panchayat of Budge Budge

I development block. The village has a total geographical area of 146.5 ha, which is distributed into several parts like net sown area (34%), irrigated area (27%), unirrigated area (7%), tanks (16%), and canals (11%) (Figure 3.12h).

The total population of the village is 2,808 people, of which 1,445 are males and 1,363 are females. The overall literacy rate of the village is 74.64%, with 77.58% male literacy and 71.53% female literacy (Directorate of Census Operations, West Bengal, 2014). In the village, there are a total of two schools, of which 50% are pre-primary schools and 50% are primary schools (Figure 3.13h). Besides, it has one primary health sub-center and three medicine shops, which somehow manage to fulfill the basic needs of poor villagers. Moreover, the village has various kinds of facilities like pucca roads, an agricultural marketing society, Anganwadis center, sports field, reading room, newspaper supply, an assembly polling station, and a power supply.

3.3.9 Bahirchara Village

The village is located in the Budge Budge II subdivision of the southern district of West Bengal. It is located around 6.3 km from the sub-district headquarters in Dongaria and 25.8 km away from the district headquarters in Alipore. Dakshin Raipur is the nearest town to the village (4 km away), which is considered a hub of all major economic activities. The village comes under Satgachhia gram Panchayat, which comprises 174 households. The total geographical area of the village is 71.58 ha, which is distributed into several parts like net sown area (29%), total non-agricultural area (41%), total irrigated land area (15%), and canals (14%) (Figure 3.12i).

The total population of the village is 723 people, of which 382 are males and 341 are females. Furthermore, the literacy rate of the village is 79.94%, with 84.03% male literacy and 75.37% female literacy (Directorate of Census Operations, West Bengal, 2014). There are a total of three schools, of which 33% are pre-primary schools and 67% are primary schools (Figure 3.13i). These educational infrastructure fulfil the basic need of the education in the village (3.16). Besides, the village has no healthcare facilities, which could cause serious problems for villagers to fulfill their basic healthcare services. However, it has various kinds of services like pucca roads, ICDS centers, newspaper supplies, assembly polling stations, and power supplies.

Figure 3.16: Schools in the study villages (a) primary school in Bahirchara village, (b) primary school in Palghat village, (c) Tentulia Buniyadi School in Kamra village and (d) primary school in Santoshpur village; Source: By author

3.3.10 Narayanganj Village

The village is located in the Namkhana subdivision of the district in West Bengal. It is situated nearly 3.3 kilometers from the sub-district headquarters in Namkhana and 95.8 kilometers from the district headquarters in Alipore. The nearest town to the village is Kakdwip (17 km away), which is considered a hub of all major economic activities. The gram Panchayat of Narayanganj village is Narayanpur, which comprises a total of 338 households. The total geographic area of the village is 157.05 ha, which is distributed into several parts including net sown area (41%), irrigated area (17%), unirrigated area (25%), and canals (17%) (Figure 3.12j).

The village has a total population of 1,352 people, of which 692 are males, and 692 are females. The general literacy rate of the village is 78.55%, of which 84.10% are male literacy and 72.73% are female literacy (Directorate of Census Operations, West Bengal, 2014). In the village, there are a total of four schools, of which 50% are pre-primary schools and 50% are primary schools (Figure 3.13j). Moreover, an artificial dam is present along the village to obstruct saline water intrusion in agricultural fields, which helps prevent losses of major staple crops (Figure 3.17).

Figure 3.17: Basic infrastructure and healthcare facilities (a) efforts to manage of saline water intrusion in Narayanganj village, and (b) primary health sub-center in Narayanganj village; Source: By author

Besides, there is one public health sub-center in the village, which fulfills the healthcare demand of the people. Apart from that it has various services like Kutcha roads, Anganwadi centers, newspaper supply, assembly polling station, and power supply (Table 3.5). These services and amenities fulfill the basic needs of the people. However, the village is located in a remote area of Namkhana block, which faces frequent natural calamities. It impacts the livelihood of economically backward people of the village. Therefore, various schemes are urgently needed to raise their living standards.

Table 3.5: Availability of amenities and services in the study villages

Availability of amenities and services	Name of the study villages									
	Kamra	Palghat	Abua	Srichanda	Katkina Ishwaripur	Napukuria	Srinagar	Sontoshpur	Bahirchara	Narayanganj
Drinking Water	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Availability of Sanitary Mart	X	X	X	✓	X	X	X	X	X	X
Anganwadis Centre	X	X	✓	✓	✓	✓	✓	✓	✓	✓
Self-Help Groups	X	X	✓	✓	✓	✓	✓	X	✓	✓
ICDS	X	X	✓	X	✓	✓	✓	X	✓	X
ASHA	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Kutcha Roads	✓	X	✓	X	✓	✓	✓	✓	✓	✓
Pucca Roads	✓	✓	✓	✓	X	X	X	✓	✓	X
Bus (Public and Private)	X	X	✓	✓	X	X	X	X	X	X
Auto/ Modified Toto	X	✓	✓	✓	✓	✓	✓	✓	✓	✓
Taxi and Vans	X	✓	✓	✓	X	X	✓	✓	X	X
Post office	✓	X	✓	✓	X	X	X	X	X	X
Bank	X	X	✓	✓	X	X	✓	X	X	X
ATM	X	X	✓	X	X	X	X	X	X	X
Newspaper Supply	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Continue…

Availability of amenities and services	Name of the study villages									
	Kamra	Palghat	Abua	Srichanda	Katkina Ishwaripur	Napukuria	Srinagar	Sontoshpur	Bahirchara	Narayanganj
Power Supply	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Common Service Centre (CSC)	X	X	✓	✓	X	X	X	X	X	X
Aadhar Seva Kendra	X	X	✓	X	X	X	X	X	X	X
Telephone Coverage	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Assembly Polling Station	✓	✓	✓	✓	✓	✓	X	✓	✓	✓
Public Library	X	✓	X	X	X	✓	X	✓	X	X
Cinema Hall/ Video Hall	X	X	✓	X	X	X	✓	X	X	X
Public Reading Room	X	✓	✓	X	X	✓	X	✓	X	X
Community Centre With TV / Without TV	X	✓	X	X	✓	✓	✓	X	✓	X
PDS System	X	X	✓	✓	X	✓	X	✓	X	X
Agricultural Credit Societies	X	X	✓	X	X	X	X	X	X	X
Mandi/Regular Market	X	X	✓	X	X	✓	✓	X	X	X
Sport Field	✓	X	X	✓	X	X	✓	X	X	X

3.4 Conclusion

The region is in the ecological fragile ecosystems of the lower Gangetic Delta, which includes several rivers and tributaries. The lower Gangetic plain is covered with quaternary sediment. The region is located between -1 m and 20 m above MSL. The tropical and humid climate of the region and enough rainfall are received during the monsoon season. Besides, the major mineral resources in the region are natural gas, limestone, oil, and abundant groundwater resources. There are two types of soil in the region, which include (1) Gangetic alluvium soil and (2) Saline soil. Agro-ecologically, the region is highly diverse, with a wide variety of species. This region is home to the world's largest biosphere reserve. Major staple crops are Rice, Wheat, and Oil seeds, while an important cash crop is Jute. The district is ecologically fragile and economically backward. The livelihood of the people is primarily dependent on subsistence agriculture and fishing. The water quality is not satisfactory and contaminated with various physicochemical substances, which could lead to health hazards.

There is a regional heterogeneity of education and healthcare infrastructure availability in the study villages. People in the study villages of Palghat, Katkina Ishwaripur, and Bahirchara have no basic healthcare facilities, which could cause problems for them to fulfil basic healthcare needs. Besides, there is a regional heterogeneity of lack of education and other essential services. Therefore, it is essential to provide basic healthcare infrastructure and essential services for better health and well-being of the people.

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Chapter 4

Analysis of Drinking Water Quality

4.1 Introduction

Many natural and anthropogenic factors contribute to water quality deterioration, including leaching from soil, runoff due to hydrological factors, biological processes, illegal sewage discharge, industrial discharge, unprotected river sites, and inadequate sanitation (Shah & Joshi, 2017). Furthermore, the physicochemical parameters of water have become a serious concern due to various man-made causes. However, access to safe drinking water is essential for maintaining good health and wellbeing. It is important to note that around 2 billion people drink contaminated water globally, posing a significant threat to their health (Shehu & Nazim, 2022).

A study conducted by Jung et al. (2023) reported that climate change is closely associated with waterborne diseases (WBDs), which adversely impact environmental quality and human health, especially in developing countries. The primary source of waterborne disease is contaminated water containing coliform bacteria and pollutants (Khan et al., 2013). According to Ashraf & Yunus (1997) revealed that various waterborne diseases such as typhoid, diarrhoea, and bacillary dysentery have a bacterial origin, which causes serious health problems in developing countries.

Access to safe and quality drinking water is essential for achieving Sustainable Development Goal 6.1 (SDG 6.1-universal and equitable access to safe and affordable drinking water for all) by 2030. However, achieving SDG 6 by 2030 will present a significant challenge (Ho et al., 2020; Roy et al., 2023).

Generally, a water quality index (WQI) is used for measuring drinking and irrigation water quality. The WQI was first proposed by Horton in 1965, later improved by Deiniger and Landwehr in 1971, and after that by Brown et al. in 1972 (Soren et al., 2023). The index merged all physicochemical parameters in a single value to measure the quality of water. The WQI is calculated in three steps: (1) selection of physicochemical parameters, (2) determination of the quality function of each physicochemical parameter, and (3) Aggregation through mathematical formulas

(Akter et al., 2016; Atta et al., 2022; Roy et al., 2023; Soren et al., 2023; Tyagi et al., 2013).

The quality of drinking water has declined in Asia as a result of rapid urbanization, industrialization, overpopulation, and the use of agrochemicals in agricultural fields (Parvin et al., 2022; Roy et al., 2023). In addition, a study concluded that anthropogenic activities are responsible for 80% of all waterborne diseases and 33% of all deaths in Pakistan. It is also stated in the article that typhoid, giardiasis, dysentery, and cryptosporidiosis are the major causes of death in the region (Khan et al., 2013). Noor et al. (2023) revealed that drinking water quality in Pakistan is contaminated with microbial and toxic metals, posing serious health risks. A study in China found that the primary health risk in the longevity area water environment is the non-carcinogenic (HQ_{CA}) caused by chlorine, while the carcinogenic ($Risk_{CA}$) is caused by arsenic (Yu et al., 2019).

The water quality of adjacent villages of the river Ganga in the Bhojpur district of Bihar is contaminated with arsenic (As) due to geogenic factors. It also found that water is polluted with other heavy metals like iron, zinc, and manganese (Maity et al., 2020). In Uttar Pradesh, Singh & Hussian (2016) found that industrial and construction activities are associated with very poor quality of water.

Arsenic (As) contamination in groundwater was first detected in 1982, and it was brought to public attention during the International Conference on Arsenic in 1995, held in Kolkata (Rahman et al., 2015). In West Bengal, there are a total of 3417 villages in 107 blocks in the nine districts that are contaminated with high concentrations of arsenic (As), which exceed the standards recommended by the World Health Organization (WHO). These districts are Malda, Nadia, Murshidabad, Bardhaman, North Twenty-four Parganas, South Twenty-four Parganas, Hugli, Howrah, and Kolkata (Chakraborti et al., 2009). A study by Mazumder et al. (2010) found that nearly 0.14 million people suffer from arsenicosis, while the study assumes that 0.84 million people are suspected to be exposed to arsenic. In the above study, drinking water has been detected at the highest level of 1362 mg/L and in some cases, over 100 mg/L. Arsenic traces in water can cause lung disease, cancer, and peripheral neuropathy (Chakraborti et al., 2018).

In the South Twenty-four Parganas, arsenic is mostly located in sandy layers and silty clay of the soil. Excessive withdrawal of water may cause water table fluctuation. Due to water table fluctuations, carbonic acid forms in void parts of the ground, resulting in ion exchange and silicate materials (Singh et al., 2014). According to Ray et al. (2020), regular exposure to contaminated water is linked to diseases such as diarrhea, respiratory infections, and skin irritations. A study conducted by Mukherjee et al. (2005) indicates that excessive use of fertilizers and large-scale discharge of municipal waste are major causes of groundwater contamination with nitrate, fluoride, and chloride. Furthermore, the authors also stated that most groundwater samples fall in the “tolerable” to “safe” category.

Only a few studies have been conducted to examine the quality of drinking water in the district. As these studies are old and outdated, they are no longer relevant to the present context. Consequently, the present study analyses the quality of drinking water in various study villages to formulate spatially optimized targeted policy measures. Numerous studies have shown that contamination of drinking water is associated with chronic diseases and may even lead to death from cancer (Figure 4.1) (Farzan et al., 2013; Xue et al., 2020; Yuan et al., 2016). Besides, this study would help various stakeholders to formulate effective policies in the region.

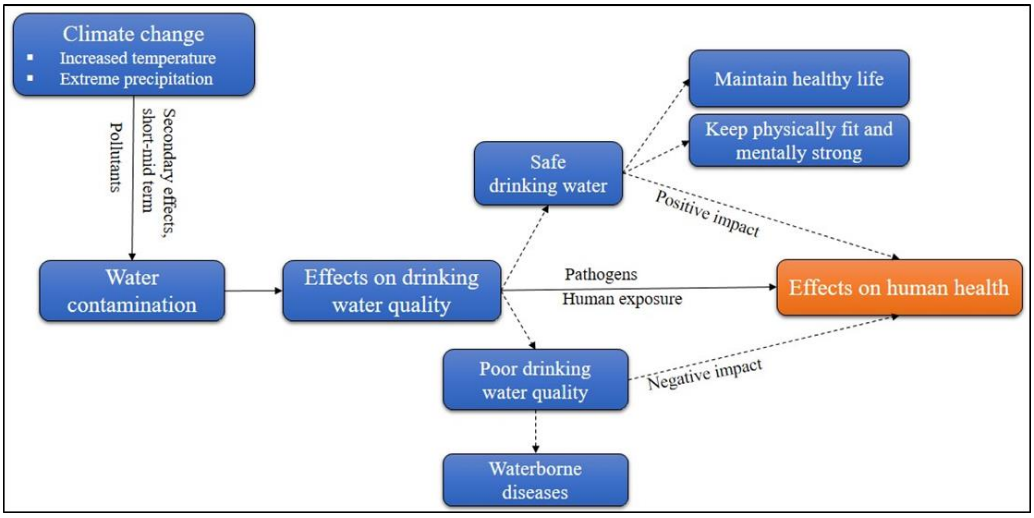

Figure 4.1: Schematic framework of drinking water quality linkages with human health

4.2 Materials and Methods

4.2.1 Data Sources

Water samples were collected from a variety of sampling sites using random sampling techniques in polyethylene bottles (Figure 4.2). For sample collection, preservation, and analysis, the American Public Health Association (APHA) standard procedures were followed. To remove dirt, turbidity, and slime from bore wells or tube wells, samples were collected after pumping water for three to five minutes. The water samples for metallic elements (e.g., arsenic and iron) were filtered and preserved with 5% HNO3 (nitric acid) to prevent soluble salts from converting into insoluble salts (Dahunsi et al., 2014; Parks et al., 2004). This procedure was followed to ensure the accuracy and reliability of the test results to facilitate comparisons with other studies. For the fecal coliform bacteria test, samples were collected from all sources in an H2S glass bottle to avoid contamination. Additionally, water samples were collected from various improved water sources between July and September 2022 (monsoon) and October to January 2023 (post-monsoon) (Table 4.1). A Global Positioning System (GPS) device was used to measure the latitude and longitude of the sampling sites.

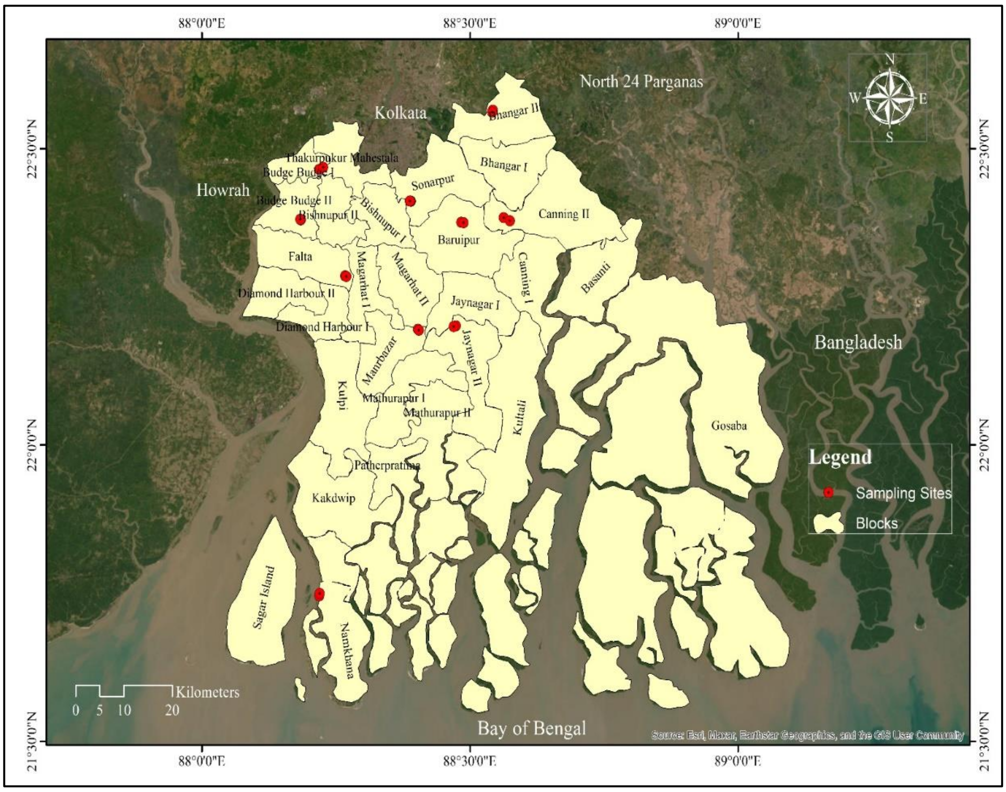

Figure 4.2: Location of the water sampling sites

Table 4.1: Location of the drinking water sources

Block	Panchayat	Village	Habitation	Drinking Water Sources
Bhangar-II	Bhogabanpur	Abua	Shilkata Para	Tube well ordinary
Bhangar-II	Bhogabanpur	Abua	Uttar Madhya Para	Household Submersible
Budge Budge-II	Satgachia	Bahirchara	Bera Para	Tube well mark II
Budge Budge-II	Satgachia	Bahirchara	Samanta Para	Household Tap Water
Baruipur	Begumpur	Kamra	Kamra	Tube well mark II
Baruipur	Begumpur	Kamra	Kamra Kalitala	Tube well ordinary
Magarhat-II	Dhanpota	Katkina Iswaripur	Kaji Para	Tube well mark II
Magarhat-II	Dhanpota	Katkina Iswaripur	Bagh Para (Near Sani Mandir)	Tube well ordinary
Jaynagar-II	Moydah	Napukuria	Banstola	Tube well ordinary
Jaynagar-II	Moydah	Napukuria	Naskar Para	Tube well mark II
Namkhana	Namkhana	Narayanganj	Izer Khand	Tube well ordinary
Namkhana	Namkhana	Narayanganj	Dakshin Para	Tube well mark II
Sonarpur	Poleghat	Palghat	Naskar Para	Tube well mark II
Sonarpur	Poleghat	Palghat	Gazi Para	Public tap water
Sonarpur	Poleghat	Palghat	Gazi Para	Tube well ordinary
Budge Budge-I	Chingripota	Sontoshpur	Rajarampur Uttar Para	Public tap water
Budge Budge-I	Chingripota	Sontoshpur	Ghosh Para	Tube well mark II
Magarhat-I	Srichanda	Srichanda	Halder Para	Tube well mark II
Magarhat-I	Srichanda	Srichanda	Koyal Para	Tube well ordinary
Canning-II	Narayanpur	Srinagar	Molla Para	Tube well ordinary
Canning-II	Narayanpur	Srinagar	Mitali Bazar	Household Tap Water

Source: Primary Survey

4.2.2 Data Analysis

Physicochemical parameters of improved water sources were evaluated using the field using a field testing kit (FTK). A multi-parameter water testing kit, the ‘HiMedia WT023’ was used to analyze various physicochemical parameters of water samples. In addition, the 'HiMedia WT025' test kit was used to analyze arsenic traces in drinking water. With the help of the 'HiMedia K055' test kit, fecal coliform bacteria in drinking water were also analyzed. The 'HiMedia K055' test kit is designed to detect Salmonella, Citrobacter, and Escherichia coli (E.coli) species in water based on the production of H_2S in a glass bottle.

Moreover, various physicochemical and bacterial parameters like Temperature, pH, TDS, Conductivity, Turbidity, Total Hardness (CaCO3), Arsenic (As), Nitrate (NO3), Residual Free Chlorine (Cl2), Iron (Fe), and Fecal Coliform were also examined. Temperature, pH, TDS, and EC were evaluated using a digital meter, while the rest of the physicochemical parameters were examined through a field testing kit (FTK). Besides, a colorimetric test was performed to determine the concentration of Iron (Fe), Arsenic (As), and Nitrate (NO3) in drinking water with the help of a colour chart. The turbidity was measured using a visual comparison method in the field. In addition, CaCO3, Cl-, and Cl2 were measured by the titration method, and the presence of fecal coliform bacteria in drinking water was assessed using the H_2S method in a glass bottle. All fecal coliform bacteria testing samples were kept in a closed room at around 30^{o}C and incubated for 24 hours to 48 hours (Islam et al., 2017). The water source was considered unfit for drinking if its colour turned black during the test. A detailed procedure for analysing the physicochemical properties including fecal coliform bacteria test in drinking water, is presented in Table 4.2.

Table 4.2: Physicochemical analysis of water quality parameters

Parameter	**Unit**	**Range**	**Method**	**BIS Standards[a]**
Temperature	°C	0-98.89	Electrode	-
pH	NA	0.00-14.00	Electrode	8.5
TDS	ppm	0 - 9999	Electrode	500
Conductivity (EC)	µS/cm	0-9999	Electrode	300
Total Hardness ($CaCO_3$)	mg/L	25-600	Titration	200
Arsenic (As)	mg/L	0.05-3.0	Colorimetric	0.01
Nitrate (NO3-)	mg/L	0-100	Colorimetric	45
Fluoride (F^-)	mg/L	0-2.5	Colorimetric	1

Chloride (Cl^-)	mg/L	10-200 & 50-1000	Titration	250
Residual Free Chlorine (Cl_2)	mg/L	0-3.0	Titration	0.2
Turbidity	NTU	0-25	Visual Comparison	1
Iron (Fe)	mg/L	0-2.0	Colorimetric	0.3
Coliform Bacteria[b]	NA	NA	(H_2S Method)	0

[a]BIS: Bureau of Indian Standards (IS 10500, 2012)
[b]Primary detection of Citrobacter, E.coli, and Salmonella based on H_2S production glass bottle. Escherichia coli (E. coli) are the most common type of fecal coliform.

4.2.3 Operational Definitions of Improved Drinking Water Sources

India Mark II hand Pump

This is a robust hand pump typically used in Rural Water Supply Networks (RWSN). The system is designed according to Indian standards (IS 9301). It has a maximum operational range of 45 meters (147 feet). Further, it was designed to serve 300 people.

Public tap or standpipe

The public tap or fountain serves as a water source for the community. Concrete, brickwork, or masonry are used for the base of public taps and fountains.

Tube well or borehole

This deep hole is driven, bored, or drilled to reach groundwater. Electric, diesel, solar, or human-powered pumps deliver water from a tube well or borehole.

Potable water or Bottled water

The water is conserved in a container and sold to households in a bottle.

4.2.4 Physicochemical Parameters of Drinking Water

Temperature

For measuring the kinetic energy of water, temperature is a significant parameter that holds great importance. It is denoted in Celsius (°C) and Fahrenheit (°F) units. Fluctuations in water depth, seasonal variations, and time of day can affect the physicochemical characteristics of water. The freezing and boiling points of pure water are 32°F (0°C) and 212°F (100°C), respectively (Ma et al. 2020). In the present study, the temperature was ranging from 22.5°C to 33.3°C, with a mean value of 28.55°C.

pH of water

The acidity or alkalinity of water is determined by pH, which is a significant parameter in water. The pH ranges from 0 to 14, with 7 being normal, below 7 being acidic, and above 7 being alkaline. A pH level lower than 7 indicates the presence of acidic substances in the water, while a pH level higher than 7 indicates the presence of alkaline substances in the water (Ma et al. 2020; Rahmanian et al. 2015). In this study, pH ranges from 7.1 to 8.08 in the drinking water, with a mean value of 7.54 which indicates that the water is slightly alkaline.

Total dissolved solids (TDS)

The measurement of Total Dissolved Solids (TDS) is based on the quantity of inorganic and organic materials or salts present in water, such as sodium, potassium, calcium, bicarbonates, chlorides, magnesium, and sulphates. The range of TDS in the study area is ranging between 159 to 445 ppm, with a mean of 312.33 ppm. Besides, TDS contains essential minerals such as Calcium (Ca2+), Magnesium (Mg2+), and Potassium (K+), which provide various health benefits to humans. For instance, Ca2+ helps in bone development, Potassium K+ supports a robust nervous system, and Mg2+ can help protect against cardiovascular disease (Islam et al., 2016). Furthermore, TDS levels in groundwater are not hazardous to human health. Nevertheless, excessive TDS levels in drinking water can have negative health effects on kidney and heart conditions. A high TDS level is indicative of water that is rich in minerals (Ma et al. 2020; Rahmanian et al. 2015).

$TDS\ (mg/L) = k_e \times EC\ (\mu S/cm)$ where k_e is a constant of proportionality (Taylor et al. 2018).

Electrical conductivity (EC)

Pure water is not a suitable conductor of electric current but it is a reliable insulator. The EC is related to water temperature and TDS presence in the water (Ma et al. 2020; Rahmanian et al. 2015). In the study area, the EC ranges from 290 µs/cm to 897 µs/cm with a mean value of 617 µs/cm. It is noted that the concentration of ions in water increases its electrical conductivity. In general, the amount of dissolved solids in water determines its electrical conductivity (Meride & Ayenew 2016). Many factors that can affect mineral content in drinking water as well as soil include agricultural activities, industrial activities, and land use. Additionally, the excessive EC in soil may lead to the extinction of food plants and habitat-farming plants (Rahmanian et al. 2015).

Total Hardness ($CaCO_3$)

Total hardness ($CaCO_3$) in drinking water is a crucial chemical parameter in drinking water. In the study area, $CaCO_3$ ranges from 75 *mg/L* to 400 *mg/L*, and a mean of 250 mg/L, which is 50 mg/L greater than the BIS standard. A study conducted in the Netherlands revealed that there is no association between calcium, magnesium, and total hardness with heart disease or mortality in the general population (Leurs et al. 2010). Therefore, the total hardness has fewer health impacts compared to other chemical parameters.

Arsenic (As)

Arsenic in drinking water has detrimental effects on human health. In the study area, arsenic value ranges from 0 mg/L to 0.05 mg/L, with a mean value of 0.02 mg/L. Besides, various human activities, including industrial wastewater dumping and the use of pesticides or herbicides on agricultural land, increase the likelihood of groundwater contamination with arsenic. Moreover, a study conducted by Chowdhury (2010) stated that the concentration of arsenic depends on the depth of the tube wells as it gradually increases about 39.4 m from the surface, after which it declines. Chronic exposure to arsenic is linked to the development of cancerous and skin diseases (Rahmanian et al. 2015).

Nitrate (NO3-)

Nitrate is one of the most critical parameters of drinking water. The presence of nitrate in drinking water is responsible for blue baby syndrome in Infants (Table 5.7) (Johnson 2019; Yan et al. 2016). The sources of Nitrate in drinking water are the nitrogen cycle, industrial waste, nitrogenous fertilizer, etc. The nitrate value ranges from 0 mg/L to 10 mg/L, and a mean value of 3.33 mg/L, which is under permissible limits of BIS.

Fluoride (F^-)

The fluoride in drinking water is one of the crucial parameters to determine water quality in a place. In the region, fluoride value ranges from 0.2 *mg/L* to 0.5 *mg/L*, and a mean value of 0.35 *mg/L*, which is under the permissible limit of the BIS standard. Past studies revealed that excessive fluoride in drinking water is responsible for skeletal fluorosis (Srivastava & Flora 2020), and it adversely impacts human health and well-being (Chen et al. 2017; Zhang et al. 2017).

Chloride (Cl^-)

The principal origin of chloride in water is from salts of hydrochloric acid, which can be found in table salt (NaCl), seawater, sewage, industrial waste, and other sources (Meride & Ayenew 2016). Groundwater is more heavily contaminated with chlorides than surface water (Samadder et al. 2017). Additionally, excessive chloride levels in drinking water can cause harm to metallic pipes, structures, and the growth of plants (Meride & Ayenew 2016). The chloride in the study area ranges from 20 mg/L to 120 mg/L, with a mean value of 46.67 mg/L.

Turbidity

Turbidity indicates the amount of total dissolved solids present in drinking water (Ma et al. 2020; Rahmanian et al. 2015). The turbidity value in the study area ranges from 0 NTU to 10.1 NTU, with a mean value of 5.05 NTU. Furthermore, the high level of turbidity in drinking water can cause pathogens-related diseases, as shown in many past studies conducted across the world (Meride & Ayenew 2016; Stevenson & Bravo 2019).

Iron (Fe)

A significant amount of iron in drinking water causes skin diseases. An excess amount of iron in drinking water causes brown or yellow stains (Rahmanian et al. 2015). The iron ranges from 0.3 mg/L to 1 mg/L, and a mean of 0.48 mg/L, which is slightly higher than the Bureau of Indian Standards (BIS: 0.3 Mg/L).

Bacterial contamination

The fecal coliform bacteria examination is a vital parameter in determining the quality of water. It determines a specific set of coliform bacteria, including E.coli, Citrobacter, and Salmonella (Figure 4.3), among others, that indicates whether the water is safe for human consumption or not. The most prevalent bacterium found in drinking water is Escherichia coli (E.coli). Moreover, the presence of coliform bacteria in household drinking water is closely linked with the risk of diarrhea (Gruber et al. 2014).

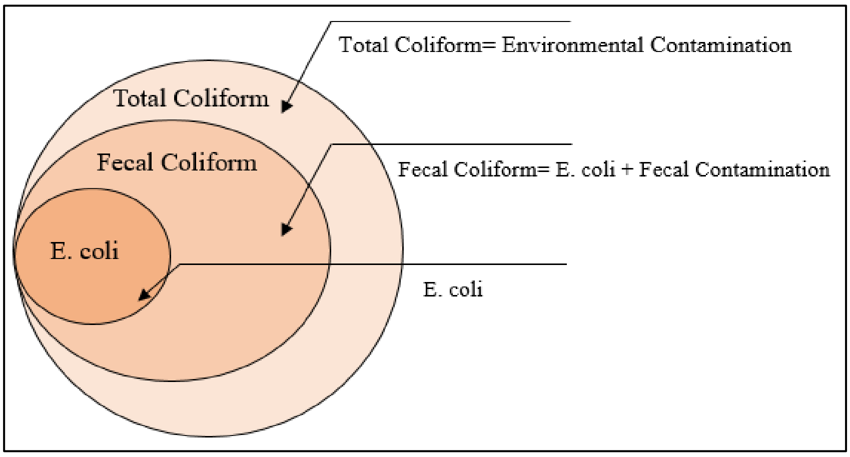

Figure 4.3: Different groups of coliform bacteria

4.2.5Weighted Arithmetic Water Quality Index (WAWQI)

To analyze water quality, the weighted arithmetic water quality index (WAWQI) was applied. The WQI summarizes several physiochemical parameters into a single value that shows the quality of water. Its value ranges from 0 to >100, where 0 indicates ‘Excellent’ and >100 indicates ‘unfit for consumption. The grading of WQI was proposed as ‘Excellent’ (0-25); ‘Good’ (26-50); ‘Poor’ (51-75); ‘Very poor’ (76-100); and ‘unfit for consumption (>100) (Addisie 2022; Osta et al. 2022; Uddin et al. 2022). The unit weight (Wn) factors for each parameter were calculated, using the formula:

$$Wn = \frac{K}{Sn} \qquad \textbf{(1)}$$

$$K = \frac{1}{\frac{1}{S1} + \frac{1}{S2} + \frac{1}{S3} + \cdots + \frac{1}{Sn}} = \frac{1}{\sum 1/Sn}$$

Where,

In this case, "Sn" refers to the standard value that is considered desirable for the nth parameter. The sum of all the physicochemical parameters is used to determine a unit weight factor, which is denoted by "Wn=1".

Calculation of sub-index (Qn) value using the formula.

$$Qn = \frac{[(Vn-Vo)]}{[(Sn-Vo)]} * 100 \qquad \textbf{(2)}$$

In this context, "Vn" represents the value of the nth parameter being analyzed, while "Sn" represents the standard value of the same parameter. The WQI uses the BIS standard to determine Sn. For most water parameters, “V0” is typically equal to zero in pure water, except for pH, which is equal to 7.

Weighted Arithmetic Water Quality Index.

To calculate the weighted arithmetic water quality index (WAWQI), steps 1 and 2 must be combined. The mathematical representation of WAWQI is provided below.

$$WQI = \frac{\sum WnQn}{\sum Wn} \qquad \textbf{(3)}$$

Figure 4.4: Drinking water collection and quality in the study villages (a) women are walking long distances to collect drinking water in Namkhana village, (b) woman collecting drinking water from India Mark II hand pump in Katkina Iswaripur village, (c) Abandoned public tap water in Kamra village, and (d) Fecal coliform bacteria test of drinking water samples; Source: By author

4.3 Results

4.3.1 Descriptive Statistics of Physicochemical Parameters

The descriptive statistics of the physicochemical parameters of water samples are presented in Table 4.3. Temperature ranged between 19.20^{o}C to 35.40^{o}C in the study villages, with a mean value of 27.76^{o}C (σ: ± 4.30). The 'pH' values of various drinking water sources ranged from 7.05 to 8.21, with a mean of 7.70 (σ: ± 0.31), pointing that the water is slightly alkaline. While 'TDS' varied between 159.00 ppm to 1121.00 ppm, with a mean value of 508.86 ppm (σ: ± 226.10), whereas 'EC' varied between 290.00 µS/cm to 2265.00 µS/cm, with a mean value of 1017.21 µS/cm (σ: ± 459.75); which is exceeding the permissible limit of BIS standards. 'As' in the drinking water is ranged between 0.00 mg/L to 0.05 mg/L, with a mean value of 0.02 mg/L (σ: ± 0.02); which is slightly higher than the BIS standards. Moreover, 'Turbidity' in the drinking water ranges between 0.00 NTU to 25.00 NTU, with a mean value of 6.67 NTU (σ: ± 5.37); which is 5.57 NTU greater than the BIS standards. The parameters like $CaCO_3$, NO_3^-, F^-, Cl^-, and Fe are within the permissible limit of the BIS standards.

Table 4.3: Descriptive statistics of physicochemical parameters of water samples

Parameters	Min	Max	Mean	Std. Dev.	[95% CI]
Temp	19.20	35.40	27.76	4.30	26.42 - 29.09
pH	7.05	8.21	7.70	0.31	7.60 - 7.79
TDS	159.00	1121.00	508.86	226.10	438.40 - 579.31
EC	290.00	2265.00	1017.21	459.75	873.95 - 1160.48
CaCO3	75.00	975.00	305.95	179.41	250.04 - 361.86
As	0.00	0.05	0.02	0.02	0.01 - 0.03
NO3	0.00	10.00	1.55	3.58	0.43 - 2.66
F	0.00	0.50	0.24	0.13	0.20 - 0.28
Cl	0.00	300.00	81.07	67.42	60.06 - 102.08
Turbidity	0.00	25.00	6.67	5.37	4.99 -8.34
Fe	0.00	1.00	0.43	0.15	0.38 - 0.47

Notes: CI; Confidence Interval

4.3.2 Water Quality of the Study Villages

The water quality during the monsoon and post-monsoon seasons is shown in Table 4.4. The ranges of water quality are presented in Table 4.5. In the study villages, the water quality ranged between 3.10 and 466.97 during the monsoon season, whereas the water quality ranged between 5.57 and 462.55 after the monsoon season. The overall water quality of the study villages ranged between 95.54 and 459.8. Among all the study villages, Kamra village had the ‘excellent quality of water’ (WQI: 9.54); whereas Bahirchara village had the poorest water quality (WQI: 459.80) (Table 5.5). EC, CaCO3, As, and Turbidity are key indicators of water quality. There is a strong correlation between the quality of drinking water in the region and the level of 'As' in the water. Further, traces of fecal coliform bacteria (i.e., E.coli, salmonella, and Citrobacter) were detected in Katkina Iswaripur, Napukuria, and Srinagar villages. It is also possible that these bacteria contaminated the drinking water somehow.

Table 4.4: Water quality index of different water sampling sites

Villages	Samples No.	Season	Lat	Long	WQI	Overall WQI
Abua	1	M	22° 33' 53"	88° 32' 34"	3.14	120.28
		PM			457.90	
	2	M	22° 33' 40"	88° 32' 30"	7.68	
		PM			12.41	
Bahirchara	1	M	22° 22' 47"	88° 11' 3"	464.84	459.80
		PM			460.53	
	2	M	22° 22' 51"	88° 11' 01"	457.82	
		PM			456.01	
Kamra	1	M	22° 22' 32"	88° 29' 1"	9.88	9.54
		PM			9.62	
	2	M	22° 22' 31"	88° 29' 17"	8.77	
		PM			9.90	
Katkina Iswaripur	1	M	22° 11' 43"	88° 24' 10"	460.44	234
		PM			9.82	
	2	M	22° 11' 38"	88° 24' 17"	9.72	
		PM			456.01	
Napukuria	1	M	22° 12' 4"	88° 28' 26"	466.72	238.18
		PM			9.64	
	2	M	22° 12' 35"	88° 27' 49"	462.20	
		PM			14.17	
Narayanganj	1	M	21° 44' 41"	88° 12' 59"	466.88	373.59
		PM			462.55	
	2	M	21° 44' 55"	88° 13' 2"	102.75	
		PM			462.19	
Palghat	1	M	22° 24' 41"	88° 23' 23"	19.60	190.87
		PM			14.59	
	2	M	22° 24' 42"	88° 24' 59"	8.06	
		PM			5.57	
	3	M	22° 24' 42"	88° 23' 17"	456.40	
		PM			460.59	
Santoshpur	1	M	22° 27' 54"	88° 13' 7"	7.78	18.92
		PM			14.41	
	2	M	22° 28' 7"	88° 13' 34"	27.69	
		PM			25.79	
Srichanda	1	M	22° 17' 7"	88° 16' 2"	466.77	351.00
		PM			462.45	
	2	M	22° 17' 4"	88° 16' 10"	466.97	
		PM			7.81	
Srinagar	1	M	22° 23' 1"	88° 33' 46"	9.80	10.92
		PM			9.90	
	2	M	22° 22' 41"	88° 34' 28"	14.54	
		PM			9.43	

Notes: M: Monsoon; PM: Post Monsoon

Table 4.5: Range of water quality index

Water Quality Index	Water Quality Status
0-25	Excellent quality of water
26-50	Good quality of water
51-75	Poor quality of water
76-100	Very poor quality of water
>100	Unfit for consumption

A comparison of the water quality of study villages can be found in Figure 4.5. In the South Twenty-Four district, there are seven villages with poor water quality, which is ‘unfit for consumption’. In addition, Bahirchara village had the poorest water quality, whereas Kamra village had ‘excellent quality of water’.

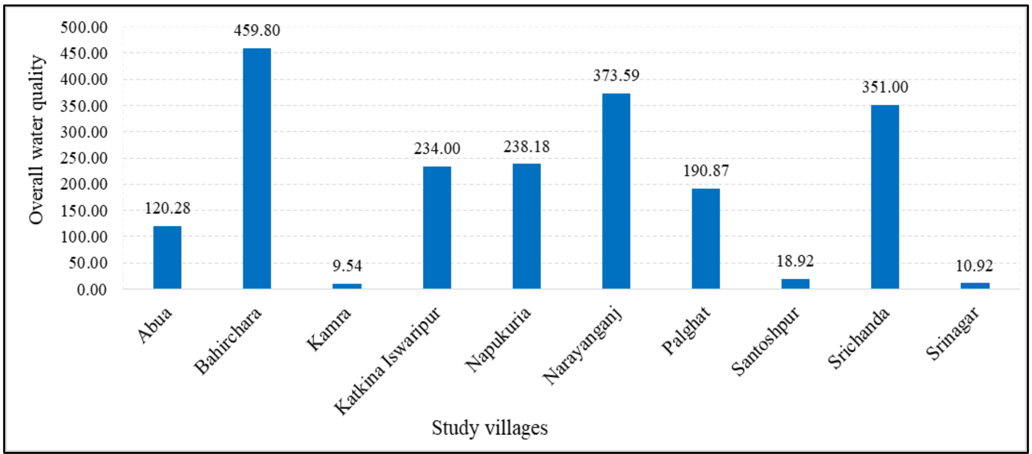

Figure 4.5: Water quality of the study villages

4.3.3 Pearson Correlation of Physicochemical Parameters

The Pearson correlation of various physicochemical parameters is shown in Table 4.6. The physicochemical parameters like pH, TDS, EC, CaCO3, As, and Cl- had significant relations. The study revealed that TDS and EC showed a significant strong positive correlation ($r=0.988$; $p< 0.05$); whereas TDS had a negative correlation with As, NO3, F, and Fe. It is important to note that TDS and EC also have a strong positive correlation with CaCO3 ($r=0.697$, $p<0.05$; $r=0.674$, $p<0.05$). On the other hand, CaCO3 was a moderate positive correlation with Cl ($r= 0.475$; $p<0.05$); whereas a negative correlation with As, NO3, F, and Fe.

Table 4.6: Pearson correlation of physicochemical parameters of drinking water

Parameters	Temp	pH	TDS	EC	CaCO3	As	NO3	F	Cl-	Turbidity	Fe
Temp	1										
pH	-0.3752*	1.00									
TDS	0.0042	-0.13	1.00								
EC	0.0011	-0.12	0.9878*	1.00							
CaCO3	-0.0436	-0.6071*	0.6965*	0.6741*	1.00						
As	-0.0401	0.2897	-0.2394	-0.1887	-0.3200*	1.00					
NO3	-0.0931	0.0119	-0.1932	-0.1897	-0.1287	-0.0914	1.00				
F	-0.1679	0.2117	-0.0785	-0.0304	-0.1134	0.3034	0.1282	1.00			
Cl	-0.0941	-0.4047*	0.209	0.2151	0.4753*	-0.1029	0.2104	-0.4276*	1.00		
Turbidity	0.1686	-0.2762	0.259	0.289	0.2109	-0.2544	0.2433	-0.3607*	0.5875*	1.00	
Fe	0.1388	-0.0139	-0.2434	-0.2577	-0.2356	-0.0574	-0.0559	-0.0767	-0.1238	0.0671	1.00

Note: * significance at $p<0.05$

4.4 Discussion

The study aimed to assess the quality of drinking water from various drinking water sources in the region. Furthermore, the present study found that TDS, EC, iron and As exceed the BIS standards, which can induce several waterborne diseases (Li & Wu, 2019). During moderate to heavy storm surges, the region has high values of electrical conductivity (EC) due to saline seawater intrusion into groundwater (Chakraborty et al., 2023). Besides, overexploitation of groundwater and the fall of the piezometric level of groundwater can be probable reasons behind the high EC in the region (Sarkar et al., 2021). However, the EC has minimal direct human health impact. A past study performed by Fish & Geddes (2009), reported that high EC in drinking water can lead to medical and surgical problems. According to Mazumder et al. (2010), revealed that excessive levels of arsenic (As) in drinking water can cause chronic lung diseases and arsenic skin lesions (4.7). Therefore, it is crucial to provide safe and affordable drinking water in the region to maintain the health and well-being of people.

Table 4.7: Effects of water quality parameters on human health

Parameters	Probable Health Effects
pH	An indication of acidic or alkaline water which affects taste, corrosion, and water supply systems.
TDS	A decrease in palatability may result in gastrointestinal irritation.
Turbidity	The presence of high turbidity indicates contamination or pollution.
Hardness	It is associated with scaling of the water supply system, excessive soap consumption, and calcification of the arteries. It may lead to urinary concretions, diseases of the kidney or bladder, and digestive disorders.
Iron	This substance has a bittersweet taste that is astringent and causes stains on laundry and porcelain. In trace, it is essential for nutrition.
Chloride	It affects the taste, indigestion, corrosion, and palatability of foods.
Fluoride	Ensure dental carries are reduced, as high levels of fluorosis can have devastating effects on the skeletal system.
Nitrate	A high concentration of this substance can lead to infant methemoglobinemia (blue babies), gastric cancer, and adverse effects on the central nervous system and cardiovascular systems.
Arsenic	A variety of skin diseases, including cancer

The findings of the present study revealed that only a few villages' quality of water is ranked as 'excellent' for consumption. It means that the water quality of the remaining villages are not fit for consumption. The primary reason behind that excessive levels of arsenic (As) in drinking water lead to deteriorating water quality in the region (Omwene et al., 2019). Therefore, it can be assumed that elevated levels of arsenic presence in drinking water can cause liver, kidney, and lung-related diseases (Basu et al., 2014; Saha et al., 1999). According to Islam & Mostafa (2021), stated that irresponsible use of chemical fertilizers and pesticides in agricultural fields is the source of arsenic presence in groundwater. Overall lithological conditions are the primary reason behind heavy arsenic load in the region.

Additionally, the study found that three villages have traces of fecal coliform bacteria in drinking water samples. These villages are Katkina Iswaripur, Napukuria, and Srinagar. According to Martin et al. (1982), pH in drinking water affects the survival of coliform bacteria, which means high pH is negatively associated with bacterial growth in drinking water. In this study, the mean pH value is nearly normal, which means favorable conditions for bacterial growth. The findings of the present study align with the past research (Pearson et al., 1987). Additionally, fecal coliforms in drinking water are harmful to humans through waterborne and foodborne outbreaks (Abhirosh et al., 2011; Gruber et al., 2014; Xu et al., 2022). In light of the findings of this study, the author recommends targeted policy interventions to reduce health complications.

The study findings cannot be generalized due to small sample sizes. However, the present study uncover the quality of drinking water at the micro-level in the region, which would help various stakeholders for targeted public health interventions. Besides, the study suggests that future studies should be focused on the water quality of shallow tube wells. Moreover, deep tube wells, water quality awareness, and cutting-edge technologies can help to minimize health risks.

4.5 Conclusion

Drinking water plays a significant role in maintaining human health and well-being. It is essential to a better quality of life. We must ensure that everyone has access to safe and affordable drinking water by 2030 to achieve Sustainable Development Goal 6.1 (SDG 6.1). Therefore, the quality of the drinking water in this region has been examined.

The findings of the study revealed that the water quality of most study villages are not fit for consumption. Furthermore, the presence of arsenic traces in drinking water can impact human health in the region. A variety of micro-level measures must be implemented to ensure safe access to drinking water. It is also possible to use the arsenic removal filter for the purification of safe water. Additionally, minimal pesticide and fertilizer usage can reduce arsenic contamination in agricultural fields. These measures would improve the quality of drinking water in the region. In light of these factors, this study provides meaningful insights into micro-level planning in the region.

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Chapter 5

Utilization Patterns of Sanitation Facilities

5.1 Introduction

Globally, around 4.2 billion people lack access to hygienic sanitation facilities. In addition, nearly 673 million people regularly practice open defecation. Thus, lack of access to adequate sanitation facilities is associated with several diseases, which can trigger deaths and morbidity. These diseases are diarrhoea, schistosomiasis, intestinal worm infections, and trachoma (Andrés et al., 2021). According to Freeman et al. (2017), access to adequate sanitation facilities plays an vital role in protecting against various kinds of diseases. However, inadequate, unhygienic, and unsafe sanitation results in multiple health, social, and economic impacts that disproportionately impact girls and women living in urban areas. In Africa, there are 88% of health facilities have access to improved water sources, 94% of households have access to improved sanitation facilities, 74% of households have soap and running water or alcohol-based hand rub, and 17% of households have followed infection prevention precautions (Kanyangarara et al., 2021). Moreover, Ezeh et al. (2014) reported that access to unimproved water and sanitation leads to rise mortality among children.

In Southeast Asian countries, the situation of sanitation facilities is inadequate due to poor design, performance, and maintenance of on-site sanitation systems. Furthermore, Chakravarty et al. (2017) revealed that access to sufficient WASH services is crucial for good health and well-being. The study also stated that in the region coverage of drinking water increases, while sanitation coverage remains low, and people still practice open defecation. Additionally, lack of access to WASH services can cause iron deficiency anemia, diarrhoea, long-term under nutrition, impaired cognitive development, and reduced growth. Besides, a study conducted by Wang et al. (2019) in Nepal revealed that households located in mountain regions have less access to improved drinking water and sanitation facilities. Apanga et al. (2020) showed that wealthy households have better access to improved sanitation facilities.

Furthermore, according to Baker et al. (2016) showed that the frequent practice of open defecation can increase the risk of moderate-to-severe diarrhoea (MSD) among children under five years in Kenya. The study also found that households with access to handwashing facilities, soap, or ash are more likely to be protected from MSDs. Moreover, a study carried out in Asia showed that household-level interventions marginally reduced the risk of cholera and other fecal-transmitted diseases. The study also stated that the development of water and sanitation infrastructure provides various advantages, including the reduction of cholera (Luby et al., 2020).

A study conducted in poverty pockets of eastern India revealed that unimproved sanitation facilities and non-use of soap after open defecation are significantly associated with malnutrition among adolescent girls. Access to WASH services is influenced by household socio-economic factors. They found that wealthy households have better access to improved sanitation facilities, drainage systems, and handwashing facilities. In addition, higher education increases access to improved toilets, drainage facilities, and handwashing facilities (Mondal, 2022). Ghosh et al. (2022) reported that WASH poverty is prevalent in West Bengal, Bihar, Chhattisgarh, Uttar Pradesh, Madhya Pradesh, and Odisha. Additionally, Delhi and its adjacent states have been found to have lower levels of WASH poverty. Roy (2023) showed that the prevalence of limited access to drinking water and sanitation facilities is spatially clustered among some central and western Indian states. The study also stated that wealth index, education, and place of residence are significantly associated with limited access to drinking water and sanitation services.

The study conducted by Trivedy & Khatun (2024) revealed that Kolkata ranked first, whereas Purulia ranked last in terms of WASH conditions. Chatterjee et al. (2023) observed that the prevalence of diarrhoea is lower in pucca households, which have adequate sources of water, and hygiene, and follow safe disposal of children’s stool. Furthermore, a study performed in West Bengal reported that only 33.69% of households have access to improved sources of drinking water within their premises. Apart from this about 74.35% of households have access to sanitation facilities within their premises. While 14.60% are still practicing open defecation (Roy et al., 2023). According to Biswas et al. (2014), the use of pond water for cooking fermented rice and for washing kitchen utensils is linked to the outbreak of cholera in Purba Medinipur district in West Bengal.

According to Trivedy & Khatun (2024), nearly 99.99% of households in South Twenty-four Parganas have access to improved drinking water, while 96.4% of households have access to sanitation facilities. However, 70.1% of households have access to improved sanitation facilities. Additionally, only 42.97 percent of households practice handwashing, and 80.3% maintain menstrual hygiene.

The prevalence of shared sanitation facilities has been studied very rarely. Furthermore, the past studies are outdated and unable to reflect the current situation of sanitation facilities (Figure 5.1). Therefore, the present study has been performed to explore utilization patterns of sanitation facilities. Since the study was conducted at a micro level, it would fill the gap in the existing literature. Hence, this comprehensive study could be used for targeted policies.

Figure 5.1: Types of sanitation facilities (a) Improved sanitation facilities in Palghat village, and (b) Unimproved sanitation facilities in Napukuria village; Source: By author

5.2 Materials and Methods

Data for this study was collected from the primary sample survey. The study surveyed 15% of the total households from each study village. Furthermore, a purposive sampling method was applied to conduct the present study. The codes of the study variables are given in Table 5.1. Aside from that, the operational definition of the each dummy variables are given in Table 5.2. Moreover, the detailed methodology of the household survey has been reported in Chapter 1.

Table 5.1: Codes of the study variables

Variables	**Codes of the study variables**
Dependent Variables	
Household shared sanitation facility	Coded as 1 = Yes, 0 = No
Socio-economic characteristics	
Age	Coded as 1 = 0-30; 2= 31-60; 3= >60
Sex	Coded as 1 = Female; 2= Male
Marital Status	Coded as 1 = Married; 2 = Unmarried
Education	Coded as 1 = Illiterate; 2 = Primary, 3 = Secondary, 4 = Higher Secondary
Religion	Coded as 1 = Hindu, 2 = Muslim, 3 = Christan
Income	Coded as 1 = <10000, 2 = 10000-20000, 3 = >20000
Family Members	Coded as 1 = 1-4, 2 = 5-8, 3 = >8
Types of house	Coded as 1 = Kutcha, 2 = Semi-Pucca, 3 = Pucca
Structure of house	Coded as 1 = Nuclear, 2 = Non-Nuclear

Table 5.2: Operational definition of the study variables

Study variables	Definition
Age	Current age of the household head
Sex	Sex of the household head
Marital Status	Current marital status of the household head
Married	A person having husband or wife
Unmarried	An individual has not yet married
Education	Education received by the person
Illiterate (No Education)	A person having no formal education
Primary	A person having formal education up to class VIII
Secondary	A person having formal education up to class XII
Higher	A person having tertiary level education
Religion	The belief in the worship of a supernatural being, particularly one associated with God or gods
Hindu	An individual who believes in Hinduism
Muslim	A person who believes in Islam and follows its rules
Christan	An individual who believes in the principle of Jesus Christ
Income	Combined gross monthly income earned by all family members
Family Member	The total number of family members in a household
Types of house	Different types of house
Kutcha	A house made of naturally available materials like mud and straw
Semi-Pucca	A house roof or wall made of materials other than materials used in a pucca
Pucca	A house permanently made with solid materials like cement and brick
Structure of households	Type of family structure
Nuclear	Two parents and their children living together in a household
Non-nuclear (Joint Family)	A multi-generational family having two or more married children

5.3 Results

5.3.1 Access to sanitation facilities

The status of sanitation facilities in the district is shown in Table 5.3. About 96.54% of households had access to sanitation facilities, of which around 95.12% of households had sanitation facilities within their premises. Furthermore, only 17.01% of households had sanitation facilities within their dwelling. Apart from that, about 4.88% of households were still practicing open defecation. Moreover, only 18.51% of households reported that they had received government assistance for sanitation facilities.

Table 5.3: Status of sanitation facilities in the district

Do you have a sanitation facility?		**Do you share your sanitation facilities?**	
Yes	96.54%	Yes (Limited)	7.44%
No	3.46%	No	92.56%
What are the types of sanitation facilities?		**Where is the location of sanitation facilities?**	
Within Premises	*95.12%*	*Open defecation (Elsewhere)*	*4.88%*
Septic Tank	89.45%	In own dwelling	17.01%
Flash or Pour Flash Toilet	6.61%	In own yard/plot	78.11%
No Facility/Bush/Field	3.31%	Elsewhere	4.88%
Others	0.63%		
How do you clean sanitation facilities?		**Do you receive financial assistant for sanitation facilities?**	
Harpic or Finale	92.91%	Yes	18.51%
Acid	2.68%	No	81.49%
Others	2.36%		

5.3.2 Impact of Socio-economic Factors on Shared Sanitation Facilities

The socio-economic characteristics of households in the district are shown in Table 5.4. Additionally, the results of the logistic regression are shown in Table 5.5. The study was estimated that Muslims were 1.68 times more likely to use shared sanitation facilities than Hindus. While illiterate households were 1.23 times more likely to use shared sanitation facilities compared to higher-educated households. In comparison with poor households, wealthy households were 0.74 times less likely to access shared sanitation facilities. Besides, the study found that households with more than 8 family members were 5.30 times more likely to use shared sanitation facilities. Moreover, non-nuclear households were 0.94 times less likely to practice shared sanitation facilities than nuclear households.

Table 5.4: Socio-economic characteristics of households (n=635)

Variables	Categories	Sample Size	%
Access to drinking water in own dwelling or plot	Yes	152	23.94
	No	483	76.06
Prevalence of shared sanitation facilities	Yes	45	7.09
	No	590	92.91
Age of the household head	0-30	29	4.57
	31-60	464	73.07
	>60	142	22.36
Sex of the household head	Male	578	91.02
	Female	57	8.98
Marital Status of the household head	Married	615	96.85
	Unmarried	20	3.15
Religion of the household	Hindu	340	53.54
	Muslim	269	42.36
	Christan	26	4.09
Current educational status of the household head	Illiterate	166	26.14
	Primary	368	57.95
	Secondary	82	12.91
	Higher	19	2.99
Income of a household in a month	<10000	286	45.04
	10000-20000	296	46.61
	>20000	53	8.35
No. of family members in a household	1-4	286	45.04
	5-8	316	49.76
	>8	33	5.2
Household types	Kachha	93	14.65
	Semi-Pucca	206	32.44
	Pucca	336	52.91
Household structure	Nuclear	314	49.45
	Non-nuclear	321	50.55

Table 5.5: Logistic regression of shared sanitation facilities (n= 635)

Variables	Model I OR (95% CI)	Model II OR (95% CI)
Age		
0-30®	1	1
31-60	0.83 (0.18-3.81)	0.73 (0.16-3.42)
>60	1.66 (0.33-8.19)	1.25 (0.24-6.40)
Sex		
Male	0.50 (0.18-1.40)	0.57 (0.19-1.66)
Female®	1	1
Marital Status		
Married®	1	1
Unmarried	0.35 (0.04-3.22)	0.35 (0.04-3.40)
Religion		
Hindu®	1	1
Muslim	1.91 (0.98-3.75)**	1.68 (0.83-3.40)*
Christan	0.69 (0.09-5.50)	0.72 (0.09-5.76)
Education Level		
Illiterate	1.76 (0.19-15.81)*	1.23 (0.13-11.31)**
Primary	1.75 (0.21-14.91)*	1.28 (0.14-11.13)
Secondary	1.26 (1.23-12.62)	1.11 (0.10-11.25)
Higher®	1	1
Income		
<10000®	1	1
10000-20000	0.87 (0.44-1.72)	0.73 (0.33-1.60)*
>20000	1.83 (0.66-5.02)	0.74 (0.20-2.74)
Household Members		
1-4®		1
05-8		1.34 (0.60-3.02)
>8		5.30 (1.40-20.14)**
House Types		
Kachha®		1
Semi-Pucca		0.86 (0.32-2.34)*
Pucca		1.08 (0.39-2.98)
House Structure		
Nuclear®		1
Non-Nuclear		0.94 (0.41-2.11)
_cons	0.11 (0.02-0.76)**	0.11 (0.01-0.80)*
Model fit statistics		
Log-likelihood	-155.84	-152.22
Deviance	311.68	304.44
Goodness of fit test	Pearson Chi2 (74)= 63.46*	Pearson Chi2 (252)= 284.46*
Likelihood ratio test		LR chi2 (5)= 7.23*

Note: *p, 0.10; **p, 0.05; *** p, 0.01; OR, odds ratio; CI, confidence interval; ® represent reference category; Model I: six explanatory variables; Model II: nine explanatory variables.

5.4 Discussion

The study results showed that around 7.44% of households had practiced shared sanitation facilities. Furthermore, the study revealed that education, household members, and house types are closely associated with shared sanitation facilities (Mondal, 2022). Additionally, the study found that only 18.51% of households received financial assistance for the construction of sanitation facilities.

Two studies performed by Mondal (2022) and Demsash et al. (2023) revealed that factors like education, economic status, family members, and house types are closely associated with shared sanitation facilities. In the present study, households with no education or illiterate are more likely to practice shared sanitation facilities than higher-educated households. It means that educated households are aware of the health consequences of limited access to sanitation facilities. Additionally, a study by Heijnen et al. (2014) stated that illiterate households aere more frequently used shared sanitation facilities are linked with poorer and low educational status. It means the findings of the present study align with the past studies. Besides, according to Colombo et al. (2023), diarrheal infections are more likely to occur when sanitation facilities are insecurely accessible. It is also found in the study that shared sanitation facilities is linked to the prevalence of diarrhoea. Further, containment of human faeces in sanitation facilities used by more than one household can lead to various health outcomes like diarrhoea, enteric fevers, trachoma, and fecal-oral diseases (Heijnen, Cumming, et al., 2014). Therefore, the present study suggests that there is a need for safe, appropriate, and individual household latrines to maintain good health and well-being. Apart from that economic status of the households is aligned with access to sanitation facilities. The present study showed that financially backward households are more likely to access shared sanitation facilities, which means private sanitation facilities are out of reach (Demsash et al., 2023). The findings of the present study align with the past studies.

Despite the study being limited to 10 villages in development blocks of the district. The present study is complete to show the overall sanitation facilities situation (Figure 5.2). Due to these limitations, the authors have attempted to minimize them through their keen observations, adequate sample size, and in-depth interviews. It is recommended, however, that future studies should take place on a large scale, in which all development blocks of the district would be included in the study.

Figure 5.2: Sanitation facilities, wastewater drainage facilities, and type of household in the district (a) Sanitation and wastewater facilities in the district (a) community sanitation facility at Palghat village, (b) sanitation facilities in Abua village, (c) wastewater drainage facility in Abua village, and (d) a semi-structure household in Narayanganj village; Source: By author

5.5 Conclusion

The present study explores the utilization patterns of sanitation facilities in the region. To achieve the SDG 6, access to safe and hygienic sanitation facilities is crucial in the district. However, the findings of the study revealed that 7.44% of households used shared sanitation facilities. Additionally, the study found that education, economic status, house types, and family members of a household are closely associated with limited access to sanitation facilities. Despite all of these, the present study is unable to provide the rural-urban dichotomy of limited sanitation services. However, it opens a new avenue for future studies with larger sample sizes. Moreover, the study suggests promoting awareness of shared sanitation services among vulnerable groups would help to minimize health risks from several chronic diseases.

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Chapter 6

Status of Community Waste Management Systems

6.1 Introduction

The disposal of waste is an economic and environmental concern for developing countries. Furthermore, waste disposal practices and the restriction of open waste disposal reduce the risk of diseases spreading (Bhunia et al., 2022). In LMICs, waste-borne and water-borne hazards are associated with communities, watersheds, and environment. Additionally, the study revealed that household waste is linked to toxic or hazardous waste pickers, municipal or private waste collectors, and small waste traders if not collected or inadequately managed (Gutberlet & Uddin, 2017). A study performed by Vinti & Vaccari (2022) and Moharana (2012) found that adequate solid waste management safeguards public health and environmental risks. Moreover, waste management practices are improper due to a lack of awareness.

The study conducted by Debrah et al. (2021) revealed that solid waste management is a complex issue that includes socioeconomic, political, institutional, and environmental factors. And lack of environmental knowledge and awareness among the people in developing countries contributes to ecological issues or waste management problems. Besides, the disposal of waste is an economic and environmental concern for developing countries. Apart from that waste disposal practices and the restriction of open waste disposal reduce the risk of diseases spreading (Bhunia et al., 2022). A study in Malaysia found that diseases like malaria and diarrhoea are associated with improper waste management. In addition, waste management practices are closely linked with various factors such as age, marital status, locality, and house type (Fadhullah et al., 2022). In Ethiopia, attitudes, knowledge, and behaviours improve solid waste management (Adefris et al., 2023). The majority of households agree that there is a potential risk associated with improper solid waste disposal. In the study, improper waste management is linked to knowledge of the 3Rs, inadequate landfills, removal methods, and household waste collection services (Eshete et al., 2023). According to Omang et al. (2021) revealed that diseases like diarrhoea, cholera, malaria, and fever are closely associated with improper solid waste management in Nigeria. A study carried out by Hettiaratchi et al. (2010) found that environmental control plays a big role in eliminating surface water contamination and harmful land gas emissions.

A study found that poor waste disposal practices hinder integrated solid waste management in households. The study also stated that knowledge of present practices and perceptions of solid waste management is required for a sustainable strategy (Fadhullah et al., 2022). A study conducted in Nepal revealed that gender and source segregation are statistically significant, but that there is no relationship between waste management and educational attainment (Khanal et al., 2023). It has been found that minority status, gender, and the sanitary condition of household canvases have the greatest influence on satisfaction. Besides, Ethnic minorities, male respondents, non-farming residents, and respondents with more sanitary household toilets are more satisfied (Zhou et al., 2022).

In south India, about 77% of the generated waste is used for various purposes like animal fodder, domestic fuel, and organic fertilizer for crop production. The remaining 23% of waste is left out in open fields for natural decomposition (Gowda et al., 1995). Gupta et al. (2023), economic, technical, legislative, and operational constraints adversely affect solid waste management. Furthermore, improper waste management harms ecosystems, human health, economic development, and destroys the environment. In India, urban waste generation is higher than rural waste generation, and income is closely related to waste generation (Chaudhary et al., 2021). A study performed by Devi et al. (2019) revealed that regular training on biomedical waste management and infrastructural development can help to improve biomedical waste management.

Several problems plague the study area, such as uncontrolled solid waste disposal, inadequate waste collection infrastructure, air pollution, and soil pollution (Figure 6.1). Additionally, the region has a wide range of waste-borne and water-borne diseases. Furthermore, in the region, sustainable waste management practices (Figure 6.2) are not widely known. Economic poverty, primary education, and a fragile riverine environment are the primary reasons for unawareness of waste management (Figure 6.3). Therefore, the present study aims to investigate the status of waste management and household perceptions of waste management in the region. The author is confident that the findings of the study opens a new avenue for further research.

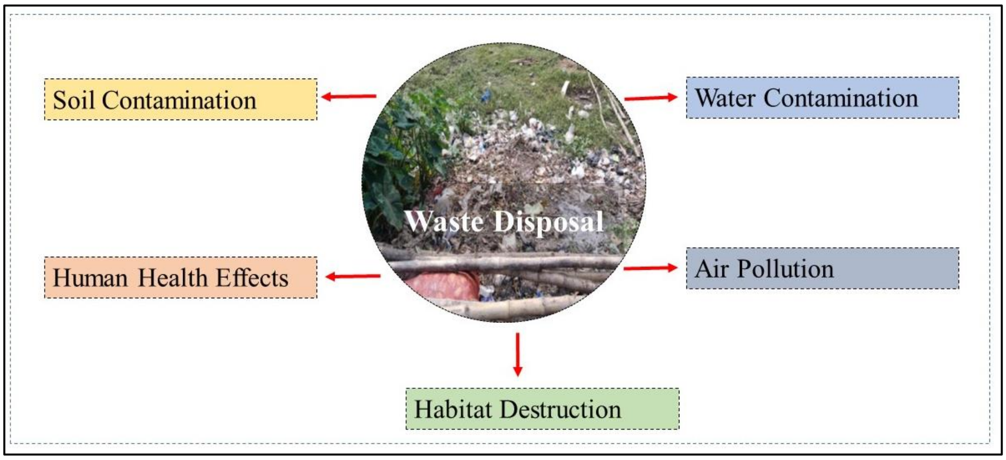

Figure 6.1: Environmental and health impact of waste disposal

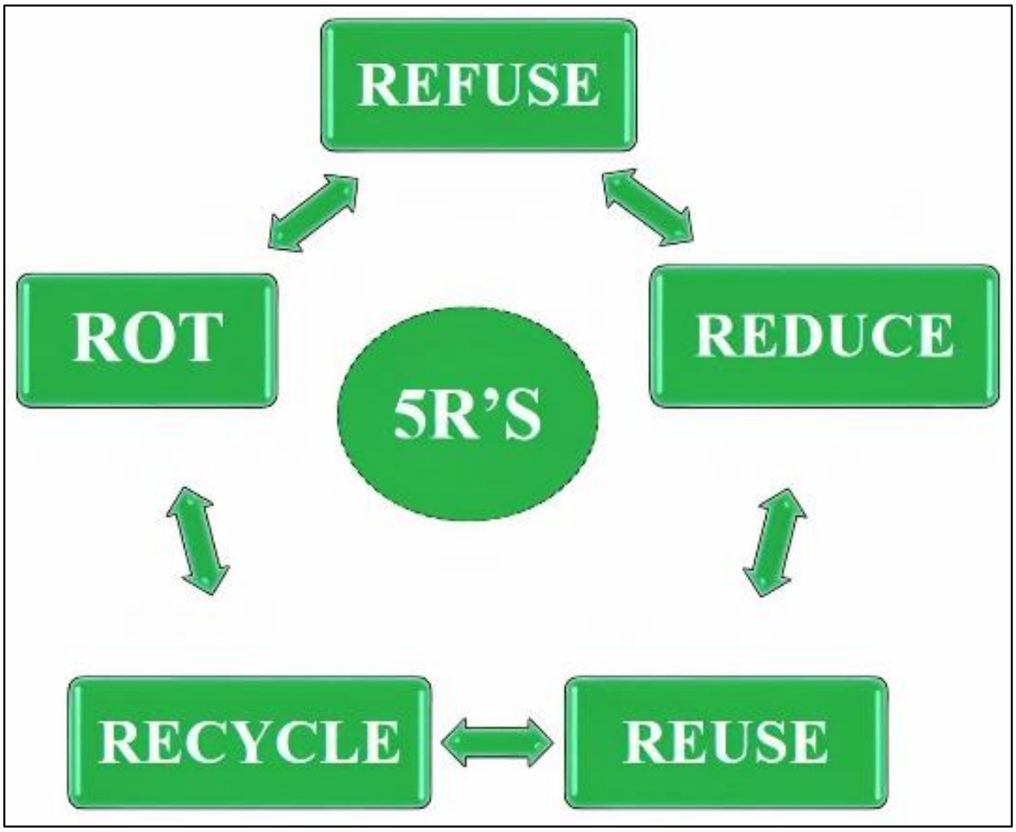

Figure 6.2: The 5 R's Principles of Solid Waste Management

Figure 6.3: Solid waste management in the rural areas (a) a household separates solid waste for livestock animals, (b) villagers dump garbage in an open space, (c) household digs hole for solid waste management inside its premises, and (d) villagers dump waste in an open space; Source: By author

6.2 Results

6.2.1 Status of Waste Management Systems

The status of waste management is presented in Table 6.1. The study found that only 9.16% of households were aware of waste management. In addition, about 25.67% of households usually separate their waste. Around 95.75% of households dispose of waste in an open space, while only 1.89% of households reported the practice of burning trash (plastic and paper).

Table 6.1: Status of waste management in the district

Are you aware of waste management?	9.16%	**Do you separate waste materials?**	25.67%
How do you manage waste?			
Open Spaces	95.75%	**Where is the location of drainage facilities?**	
Poly Bags or Cardboard Box	2.36%	Within Premises	11.03%
Burned (Plastic and Paper)	1.89%	Away from Premises	88.97%
What are the types of drainage facilities?			
Open	62.52%		
No Drainage	32.28%		
Closed	5.20%		

Types of drainage facilities in the study villages are shown in Figure 6.4. The study found that there were nearly 62.52% of households in the region had open drainage facilities, 32.28% had no drainage facilities, and only 5.20% had closed drainage facilities. Additionally, only 11.03% of households reported that they had drainage facilities within their premises, while about 88.97% reported that they had wastewater drainage facilities away from their homes.

Figure 6.4: Drainage infrastructure in the study villages (a) open drainage facilities in Abua village, (b) closed drainage facilities in Sontoshpur village, (c) a household has no drainage facilities in Kamra village, and (d) no drainage facilities in Narayanganj village; Source: By author

6.2.2 Role of Education in Waste Management

Table 6.2 shows the relationship between waste management and education level. According to the study, nearly 36.69% of primary educated households were aware about waste management. However, the study found that only 15.52% of illiterate households were aware of waste management. Apart from that, around 35.07% of primary-educated households report that they separate their waste. Furthermore, there were 44.28% of households primary educated households informed that they disposed of their waste in an open area. Besides, nearly 5.92% of higher-educated households dispose of their waste in an open space. Moreover, there were 44.67% of primary educated households informed that they burned plastic and paper waste.

Table 6.2: Role of Education in Waste Management

Variables	**Level of Education (%)**			
	illiterate	Primary	Secondary	Higher
Are you aware of waste management?	15.52	36.69	29.14	18.65
Do you separate waste materials?	24.54	35.07	24.46	15.93
Where is the location of disposed waste?				
Open Space	26.64	44.28	19.52	9.56
Poly Bags or Cardboard	13.33	37.78	38.31	10.58
Burned (plastic and paper)	24.33	44.67	21.67	9.33

Source: Primary Survey

6.2.3 Logistic Regression of Waste Management and Socio-economic Factors

The socioeconomic characteristics of households are shown in Table 6.3. According to this study, 9.29% of households had a perception of waste management. Furthermore, a binary logistic regression was applied to check the association between various dependent and independent variables in Table 6.4. The study revealed that secondary educated households were 2.14 times more likely to have a perception of waste management than illiterate households. Apart from that those households earning >20000 were 5.57 times more likely to be aware of waste management than less-income households. Besides, pucca households were 1.53 times more likely to be aware of waste management. Moreover, non-nuclear households were 0.55 times less likely to be aware of waste management.

Table 6.3: socio-economic characteristics of households (n=635)

Variables	Categories	Sample Size	%
Sex of the household head	Male	578	91.02
	Female	57	8.98
Educational Status	Illiterate	166	26.14
	Primary	368	57.95
	Secondary	82	12.91
	Higher	19	2.99
Income of a household in a month	<10000	286	45.04
	10000-20000	296	46.61
	>20000	53	8.35
No. of family members in a household	1-4	286	45.04
	5-8	316	49.76
	>8	33	5.2
Household types	Kachha	93	14.65
	Semi-Pucca	206	32.44
	Pucca	336	52.91
Household structure	Nuclear	314	49.45
	Non-nuclear	321	50.55

Table 6.4: A logistic regression model of perception of waste management

Variables	Model I	Model II
	OR (95% CI)	OR (95% CI)
Sex		
Male	1.48 (0.43-5.05)	1.54 (0.44-5.42)
Female®	1	1
Education Level		
Illiterate ®	1	1
Primary	1.38 (0.65-2.91)	1.38 (0.64-2.97)
Secondary	2.34 (0.96-5.70)**	2.14 (0.85-5.38)*
Higher	2.15 (0.57-8.11)	1.71 (0.44-6.74)
Income		
<10000®	1	1
10000-20000	3.73 (1.81-7.69)***	3.20 (1.42-7.21)***
>20000	6.03 (2.32-15.67)***	5.57 (1.78-17.41)***
Household Members		
1-4®		1
05-8		0.70 (0.34-1.43)
>8		1.29 (0.35-4.82)

House Types		
Kachha®		1
Semi-Pucca		0.91 (0.27-3.11)
Pucca		1.53 (0.48-4.89)*
House Structure		
Nuclear®		1
Non-Nuclear		0.55 (0.27-1.14)*
_cons	**0.02 (0.01-0.08)*** **	**0.02 (0.01-0.13)*** **
Model fit statistics		
Log-likelihood	181.36***	176.46***
Deviance	362.72	352.92
Likelihood ratio test		LR chi2 (5)= 9.80*

Note: *p, 0.10; **p, 0.05; *** p, 0.01; OR, odds ratio; CI, confidence interval; ®represent: reference category; Model I: six explanatory variable; Model II: nine explanatory variables

6.3 Discussion

The study showed that the perception of waste management among households were influenced by various factors like education, income, house types, and house structure. The odds of perception of waste management are significantly higher among secondary-educated households. According to Adzawla et al. (2019), education plays an important role in solid waste management. Furthermore, higher-educated households are actively involved in waste collection instead of open dumping or burning (Noufal et al., 2020). Furthermore, households with higher educational status are aware of the negative impact of improper waste disposal. A study by Eshete et al. (2023) showed that a lack of knowledge of solid waste management is identified as a crucial factor for improper solid waste management practices. Therefore, the study suggests that active waste management reduces the prevalence of waste-borne diseases and contamination of the environment. Besides, household income also plays a significant role in determining a household's perception of waste management. It can assume that higher-income households are more likely to be aware of the health and environmental consequences of improper waste disposal. A study by Omotayo et al. (2020) reported that educational attainment and income of households are driving factors affecting households’ recycling behaviour of waste. It means higher-income households are more likely to have better access to waste management services, and they are also more likely to be concerned about quality of life. In addition, access to a wide range of media landscapes in the household allows them to become aware of the environmental consequences of improper waste disposal (Alhassan et al., 2020).

Similarly, pucca households are 1.53 times probably more aware of waste management than kutcha households. A study carried out by Fadhullah et al. (2022) showed that house type was associated with waste segregation practices. It means pucca households are more aware of the harmful impacts of improper waste disposal. Therefore, they practice waste management to minimize the negative effects of uncontrol waste disposal. According to Gupta et al. (2023), Kutcha households are primarily responsible for the disposal of waste. The findings of the past study are aligned with the present study. Moreover, a study found that Pucca households are less likely to be exposed to Malaria than Kutcha households due to uncontrol waste disposal (Yadav et al., 2014). It is hypothesized that families residing in Pucca households are more aware of environmental sustainability, and health consequences of uncontrolled solid waste disposal.

Moreover, the empirical study does not demonstrate the dichotomy between the rural and urban management of waste in the region. In addition, this study does not focus on the various types of waste and how it impacts human health. This study provides an empirical assessment of the current state of waste management practices in the study villages. Therefore, the study is helpful for policymakers to plan targeted policies in the region for the betterment of people.

6.4 Conclusion

The management of waste is one of the major environmental problems in most developing countries. The present study found that the educational attainment of household head, income, house types, and house structure are driving factors for awareness about waste management. Only 9.16% of households in the region are aware of waste management practices and about 25.67% of households are separating their waste. Besides, the present study provides a glimpse that improper waste disposal leads to waste-borne diseases, which can be harmful to human health. As a result, the study emphasizes the importance of sustainable waste management to minimize the environmental and health impacts of improper waste disposal. Additionally, the Swachha Bharat Mission (SBM-Gramin) should be given special attention to proper waste management in rural areas.

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Chapter 7

Impact of Waterborne Disease and Hygiene on Human Health

7.1 Introduction

Water quality issues are a critical challenge for mankind in the twenty first[t] century. Several substances like chemical micropollutants, hazardous metals, metalloids, and synthetic organic compounds have a huge potential to negatively impact the quality of drinking water (Singh et al., 2024; Zhang et al., 2023). Furthermore, waterborne diseases and mortality have an effect in developed and developing countries (Cissé, 2019). These diseases are more prevalent in developing countries than in developed countries (Shayo et al., 2023). A study performed by Prüss-Ustün et al. (2019) revealed that around 0.83 million WASH-attributable fatalities occurred in developing countries due to diarrhoeal diseases in 2016, which equal to 60% of all diarrhoeal fatalities. Additionally, the study also found that nearly 0.30 million WASH-attributable fatalities occurred among under-five children, representing 5.3% of all deaths in this age-group.

A study performed by Aboah & Miyittah (2022) found that men have better access to safe water than women. On the other hand, women have better access to hygiene practices than men. Furthermore, epidemics spread more rapidly in urban environments,which affects public health, economy, and shortens life expectancy. The traces of viral, bacterial, and protozoa pathogens in drinking water pose health risks to humans (Ashbolt, 2015). Besides, Ferreira et al. (2021) conducted a study in Brazil showed that investment in drinking water infrastructure and sanitation are essential for access to water and sanitation services in developing countries. Apart from this, a study reported that use of isopropanol-based hand sanitizer provides better planetary health than water and soap. However, the study revealed that no method of hand hygiene is sound (Duane et al., 2022). Moreover, a study in Kenya found that there is a significant association between Escherichia coli (E. coli) and water sources. This study also stated that storage of drinking water in a large plastic container has a higher presence of total coliform (TC) and E. coli. In addition, they reported that typhoid is the most prevalent waterborne disease in the dry season, followed by diarrhoea in the wet season (Osiemo et al., 2019).

A study conducted by Sharma et al. (2023) reported that typhoid, acute diarrheal disease (ADD), cholera, shigellosis, and hepatitis are common water-induced diseases in India. Furthermore, Kumar et al. (2022) revealed that due to the use of unimproved water sources, rural areas have a higher prevalence of waterborne diseases among the elderly than in urban areas. The study revealed that several diseases may spread due to inadequate sanitation, hygiene, and lack of proper waste disposal systems. According to Goyanka (2021), the prevalence of WASH-associated diseases in India is 5.7% for all outpatient visits and 6.9% for all hospital admissions. Conversely, the mean out-of-pocket expenditure across all WASH-related diseases is ₹703 per outpatient visit and ₹9656 per hospital admission.

In West Bengal, the attack rate of cholera is highest among under-five children. Furthermore, the study found that drinking water contaminated by municipality waste water is associated with illness (Bhunia et al., 2009). Besides, Batabyal et al. (2013) found that the diarrheogenic strain of E. coli exhibits toxicity, and resistant to several kinds of drugs like tetracycline, kanamycin, furazolidone, amoxicillin, ampicillin, norfloxacin, and ciprofloxacin. Therefore, the presence of E.coli strain in drinking water can lead to an impact on human health.

A study by Majumdar et al. (2017) revealed that the absence of toilets, improper hand-washing behaviour with soap after defecation, lack of vaccination against measles, and malnutrition status in households are the primary reasons for morbidity among children in the district. Apart from this, Panda et al. (2016) found that four out of five villages in the district have acute and chronic nutritional deprivation. They also revealed that around 41% of women use mud/ash, water, and soap-free products to wash their hands after defecation. This indicates that women in the region practice poor hygiene practices. In addition, all villages have a high prevalence of anaemia (>40%) among women, which indicates a serious public health concern.

Based on previous studies, the present study concludes that the region is not well developed and that the majority of people have only a basic level of education. Additionally, the region has a high prevalence of waterborne diseases due to contaminated drinking water. Excessive use of Pesticides in agricultural fields, uncontrolled groundwater extraction, and improper disposal can adversely affect human health. Therefore, the present study aims to assess the impact of water-borne diseases on human health (Figure 7.1) and hygiene (Figure 7.2). Thus, the present study will open avenue for future studies. The findings of this study will be helpful for multiple stakeholders.

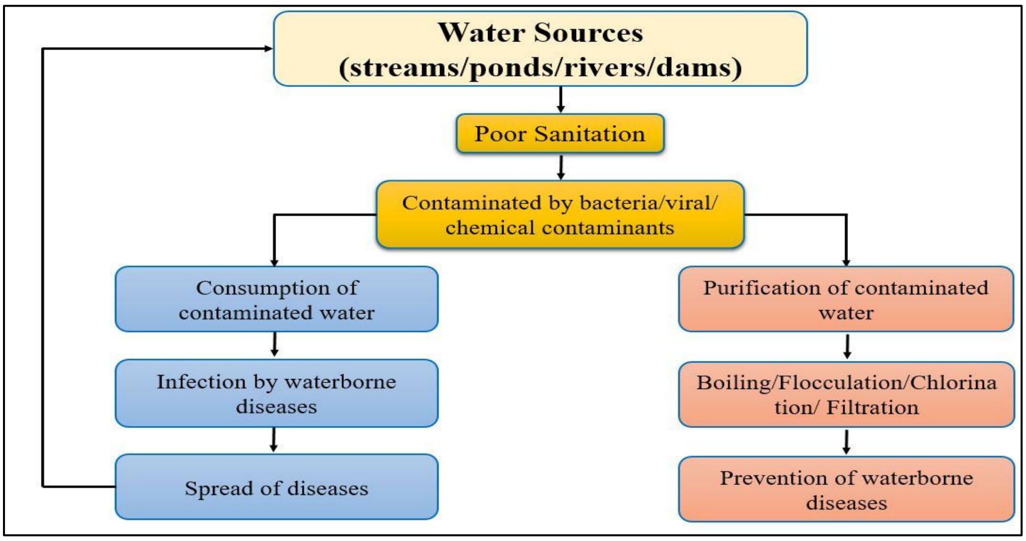

Figure 7.1: Schematic framework of waterborne diseases transmission in human being

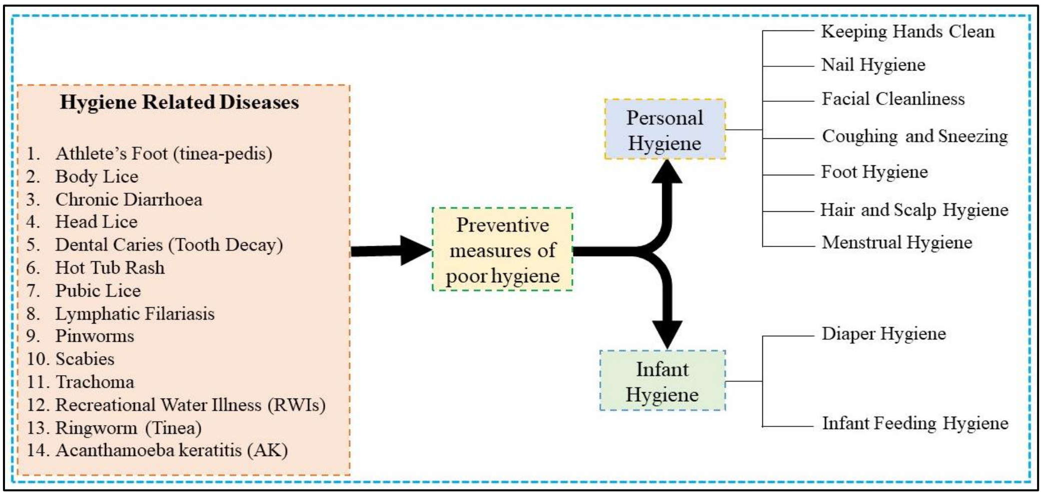

Figure 7.2: Hygiene related diseases and preventive measures for poor hygiene

7.2 Results

7.2.1 Present Situation of Drinking Water and Hygiene

The status of drinking water and hygiene are shown in Table 7.1. The study revealed that 58.43% of households relied on tube wells, 23.15% of households relied on potable water, and 17.32% of households relied on public tap water. Around 81.42% of households used soap or detergent to wash their hands. Additionally, 78.90% of households reported that they had handwashing facilities in their yards or plots. Besides, around 19.53% of households had access to handwashing facilities in their dwelling. Nevertheless, only 1.57% of households reported that their handwashing facilities were located outside of their premises. The study revealed that 69.26% of households followed hand hygiene with soap and water. Further analysis revealed that 90.55% of households directly consume water, 7.24% of households boil drinking water for their children, and only 1.42% of households use purified drinking water.

Table 7.1: Status of drinking water and hygiene

What are the sources of drinking water?		**Where is the location of drinking water sources?**	
Tube well/Borehole	58.43%	In own Dwelling	4.72%
Potable water	23.15%	In own yard/plot	19.37%
Public tap/standpipe	17.32%	Elsewhere	75.91%
Submersible	0.63%		
Purifier	0.47%		
Do you use soap or detergent to wash your hands?		**Do you wash your hands after defecation?**	
Yes	81.42%	Yes	98.10%
No	18.58%	No	1.90%
Where is the location of the hand washing facility?		**Do you use any essential items to maintain basic hygiene?**	
In own Dwelling	19.53%	Only Water	30.74%
In own yard/Plot	78.90%	Water and Soap	69.26%
Elsewhere	1.57%		

What are the methods to purify water?	
Directly	90.55%
Boil for child	7.24%
Purifier	1.42%
Don't know	0.79%

Source: Primary Survey

7.2.2 Prevalence of Waterborne Diseases

The prevalence of waterborne diseases are shown in Table 7.2. There was a wide variation in the prevalence of waterborne diseases in the region. The study found that prevalence of diarrhoea was higher in Katkina Ishwaripur village (7.69%), followed by Srinagar (3%), and Palghat (2.56%). Furthermore, the prevalence of Typhoid was higher in Katkina Ishwaripur (5.77%), followed by Srinagar (2%), and Palghat (1.28%). Besides, the prevalence of Cholera was only found in Srinagar village.

Table 7.2: Attack rate of various waterborne diseases

Village	Diarrhoea	Typhoid	Cholera
Abua (n=50)	2.00%	Nil	Nil
Bahirchara (n=26)	Nil	Nil	Nil
Kamra (n=49)	4.08%	Nil	Nil
Katkina Ishwaripur (n=52)	7.69%	5.77%	Nil
Napukuria (n=60)	Nil	Nil	Nil
Narayanganj (n=51)	5.88%	Nil	Nil
Palghat (n=78)	2.56%	1.28%	Nil
Sontoshpur (n=107)	1.87%	Nil	Nil
Srichanda (n=62)	1.61%	Nil	Nil
Srinagar (n=100)	3.00%	2.00%	2.00%
Total (n=635)	**2.84%**	**0.95%**	**0.32%**

The prevalence of water-induced diseases is presented in Figure 7.3. The findings of the study revealed that the most prevalent waterborne diseases were diarrhoea (2.83%), followed by Typhoid (0.9%), and Cholera (0.31%).

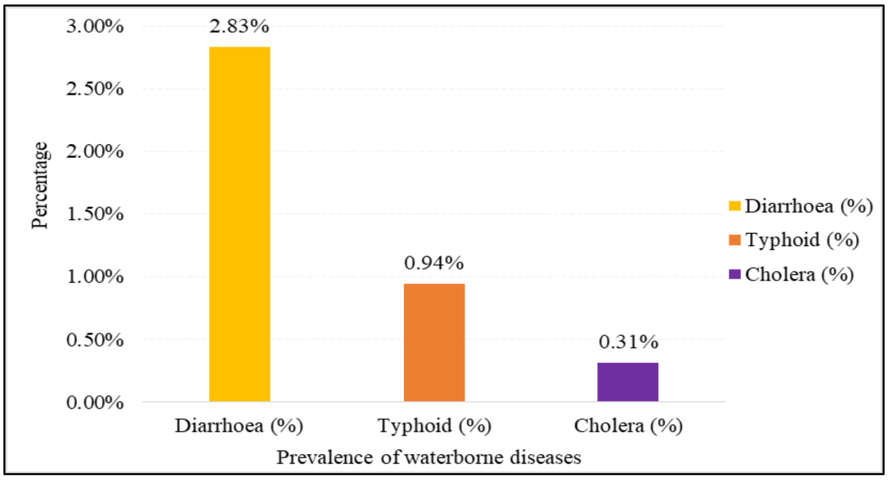

Figure 7.3: Prevalence of waterborne diseases

7.3 Discussion

This study examines the impact of waterborne diseases and hygiene on human health (Figure 7.4). It has been found that nearly 31.74% of households wash their hands only with water. Furthermore, around 78.90% of households reported that their handwashing facilities were located outside their homes. On the other hand, Katkina Ishwaripur has the highest attack rate of diarrhoea (7.69%), followed by Narayanganj (5.88%), and Kamra (4.08%). Aside from that, the study revealed that Srinagar village has a high prevalence of cholera (2.00%).

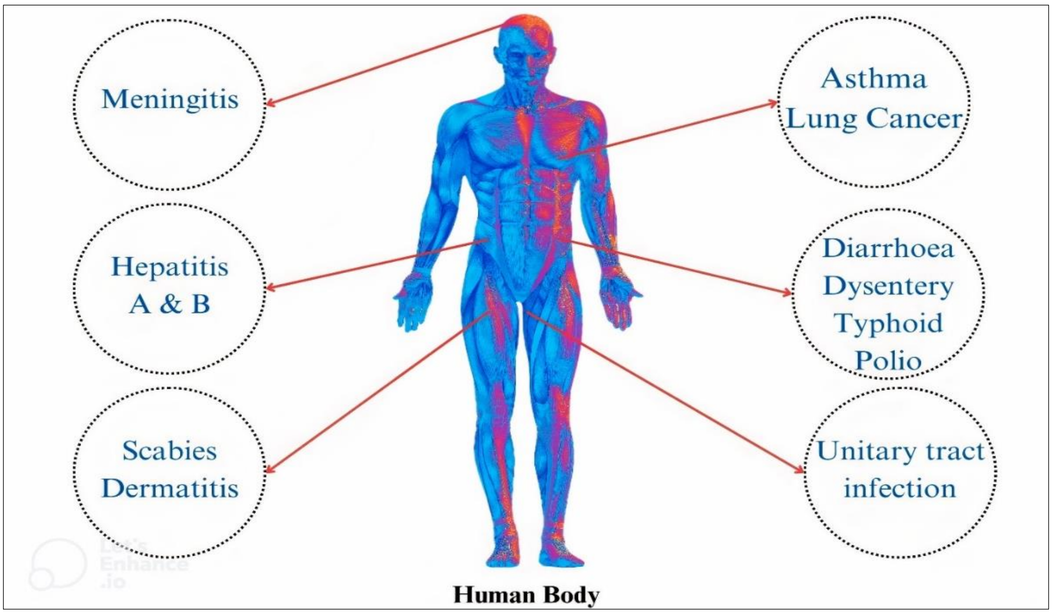

Figure 7.4: Potential health impact of waterborne diseases on human health

A study carried out by Burton et al. (2011) revealed that handwashing with water can reduce the presence of bacteria by 23%. Further, Karande et al. (2021) concluded that personal hygiene in rural India is one of the most crucial factors influencing the transmission of waterborne diseases than the quality of water. In this study, the author found that about 31.74% of households wash their hands with water. It means that waterborne diseases are more likely to spread among households who wash their hands with water. However, the handwashing practices of households are not associated with diarrhoea (Wolf et al., 2023).

In this study, diarrhoea (2.84%) was found to be the most prevalent waterborne disease, followed by typhoid (0.94%) and cholera (0.31%). Majumdar et al. (2017) finds that factors such as the absence of toilets in households, the non-use of soap for hand washing after defecation, and the low nutritional status of children play an vital role in diarrhoea among under-five children. The findings of past studies have shown that these factors can cause waterborne diseases. Besides, 90.55% of households reported that they directly consume drinking water without any purification. In addition, traces of E. coli, salmonella, and Citrobacter are found in Katkina Ishwaripur, Srinagar, and Napukuria. According to Gomes et al. (2016) and Levy (2015), E.coli contamination in drinking water is associated with diarrhoea. This may be a possible reason for the higher prevalence of waterborne diseases in the region.

Figure 7.5: Drinking water and sanitation practices (a) elderly person putting potable water in a plastic dispenser, (b) household purchasing potable drinking water due to contamination in Narayanganj village, (c) community sanitation facilities in Palghat village, and (d) woman cooking food on a chula for her household in Srinagar village; Source: By author

Many scholars have not yet extensively examined waterborne diseases, hygiene, and human health (Figure 7.5). Thus, the present study aims to bridge gaps between existing and present research. However, the study has some limitations, hence its findings should be interpreted cautiously. Furthermore, the study relies on cross-sectional data, so the findings of the study may change over time. To determine the health status of the region, the author suggests that future research should be conducted on a large scale with a large sample sizes.

7.4 Conclusion

This study demonstrates a direct link between personal hygiene and waterborne diseases. This study found that almost one-third of households wash their hands with water. Furthermore, traces of fecal coliform bacteria are found in three villages in the region, where the prevalence of diarrhoea is detected. Infrastructure development will have a limited impact on disease control. However, improvement of personal hygiene can play a significant role in reducing the number of water-borne diseases. It is therefore recommended that India run extensive campaigns such as Nirmal Bharat Abhiyan, Swachh Bharat Abhiyan (Clean India Mission), Central Rural Sanitation Programme, and Total Sanitation Campaign to prevent water-borne and waste-borne diseases.

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Chapter-8

Conclusions

8.1 Programmes and Policies for Improved WASH Services

The region faces environmental vulnerability due to natural calamities like cyclones, floods, and soil erosion. Furthermore, socio-economic challenges such as poverty, unemployment, and inadequate infrastructure are major factors in a fragile environment. The region faces various past cyclones like Aila, Fani, Bulbul, and Amphan, which is one of the major causes of fragile ecosystems. In West Bengal, about 12% of water sources are contaminated by various chemical substances like arsenic, fluoride, iron, and salinity (Dave & Sundarraj, n.d.). Additionally, Biswas et al. (2023) reported that around 55% of the region is contaminated with arsenic and fluoride, which may pose health risks to children. According to Singh et al. (2014), excessive groundwater withdrawal for drinking and irrigation purposes have resulted in fluctuations in the water table. In addition, water table fluctuations may result in the formation of carbonic acid, which is responsible for the weathering of silicate minerals. These hydrogeological processes may be responsible for the formation of arsenic (As). It is important to note that Baruipur is the most affected block in the district (Chaudhuri et al., 2020). Additionally, a significant challenge in the region is salinity due to its close proximity to the Bay of Bengal. Therefore, one of the biggest challenges communities face is access to safe drinking water in their households. While, Kanti Majumdar (2017) showed that the absence of sanitation in households, improper hand-washing practices, and low nutritional status among children are controlling factors for diarrhoea. On the other hand, nearly 93.86% of households have access to improved sanitation facilities. Nevertheless, only 8.01% of households reported that they shared their toilet facilities, whereas around 1.53% defecated in the open. Moreover, a study found that 76.48% of households have handwashing facilities, and 52.20% stated that they have soap (Roy et al., 2023).

In this study, arsenic, iron, TDS, and EC levels in improved drinking water sources exceeded BIS standards. Furthermore, the study also revealed that very few water samples contain traces of coliform bacteria. Besides, the findings of the study found that education, family members, and house types are closely associated with shared sanitation facilities. Apart from that the results of the study revealed that perception of waste management is related to factors like education, income, house types, and house structure. Moreover, Katkina Ishwaripur has reported a higher prevalence of diarrhoea, followed by Narayanganj, and Kamra.

This study examined WASH services in the district from a cross-sectional perspective. The study is conducted in ten villages spread across the region. In addition, very few previous studies have been performed on WASH services in the fragile region. Despite this, these studies are outdated and cannot provide an accurate picture of the present condition of WASH services. Therefore, a comprehensive study is necessary to assess the current state of WASH services. Furthermore, the study suggests future studies should focus on the spatial distribution of water quality and health complications caused by improper WASH services. As a result, this comprehensive study is needed as a foundation for future research and opens avenue for further study.

8.2 Major Challenges

8.2.1 Data Limitation

It's a cross-sectional study, which especially focuses on WASH services in the fragile region of West Bengal. The limited water samples and the short time frame are primary constraints that could impact the generalizability of the findings. Furthermore, the present study is unable to provide a comprehensive information regarding the health infrastructure due to the lack of data. Nevertheless, the results of the study are not affected by these limitations.

8.2.2 Methodological Problem

This study is unable to perform Kriging interpolation using ArcMap software due to the limited number of drinking water samples. The primary reason of this methodological constraint is limited drinking water sample sizes of known points. Thus, it could influence targeted policy interventions by stakeholders.

8.2.3 Theoretical Challenges

There are few studies that have been conducted related to WASH services in the study area. Furthermore, these studies are outdated and do not provide any methodological framework for future research. Therefore, the present study aims to provide an overview of WASH services and the study fills the gaps in the existing literature.

8.2.4 Implementation of Policy Recommendations

The availability of WASH services is a key indicator of good health and well-being. However, water samples of the region are contaminated with various substances like arsenic, iron, and fluoride, which could lead to adverse effects on human health. Additionally, there is a lack of access to improved sanitation facilities and hygiene in the region. Despite these prominent problems, various stakeholders are not implementing targeted regional policies.

8.2.5 Economic and Social Variability

The region is facing several economic and social variability in development, which directly impacts the quality of life. Economic factors like income, employment rates, economic resources, and access to resources affect an economic disparity in the district. The study revealed that the above region is an economically backward region with a low employment rate. Additionally, the region is mainly dependent on agriculture. Aside from this, education, health infrastructure, living standards, social cohesion, and cultural practices influence quality of life.

8.2.6 Public Transport

Due to coastal erosion and cyclones throughout the year, the region is geographically fragile. Additionally, there are several islands in the region, which developed dependence on boats and ferries. There are geographical barriers that restrict the construction of bridges and the availability of public transportation.

8.3 Major Opportunities

8.3.1 Improved Public Health

This study will contribute to the reduction of poverty, the improvement of access to clean water, and the development of the economy through the development of targeted policy interventions. Furthermore, it would decrease healthcare costs and improve quality of life. Moreover, this comprehensive micro-level study would be useful for minimizing health complications for residents with targeted WASH policies.

8.3.2 Sustainable Water Management

A primary concern of the study area is access and coverage of improved drinking water. The present study would serve as a bridge between previous research, and provide long-term solutions for sustainable water resource management. Moreover, the study would identify potential sources of pollution and suggest sustainable measures to reduce water pollution. Lastly, it would also provide insights into the effectiveness of existing policies and strategies.

8.3.3 Enhanced Sanitation Facilities

The availability of improved sanitation facilities is an important indicator of sound health and well-being. Additionally, the study would provide an overview of the development and upgrading of infrastructure. Further, it contributes to community engagement, the implementation of sustainable sanitation solutions, monitoring and evaluation, and the development of targeted policies.

8.3.4 Community Empowerment

The purpose of this study is to provide information regarding access to WASH services, which will assist in promoting community participation. It is possible to use the findings of the study to make better decisions.

8.3.5 Economic Benefits

Lack of access to WASH services negatively impacts human health. Hence, this extensive study examines the present situation of WASH services in the region. It will help to reduce healthcare expenditures, enhance economic opportunity, and support sustainable development through minimizing disease outbreaks. Last but not least, the study will also provide suggestions for policymakers and stakeholders to ensure equitable access to WASH services.

8.3.6 Educational Improvements

This study will help to promote awareness about unimproved WASH services, which would help local administration. Additionally, it would enhance WASH infrastructure in schools, which is essential to maintain sound health among children.

8.3.7 Policy and Advocacy

It would help to influence policy decisions and engagement of various stakeholders to develop effective WASH policies for the betterment of the resident. These steps would help to enhance investment, public awareness, behavior change, increase funding, and resource mobilization in WASH infrastructure and services. Moreover, it will improve the quality of life in the region.

8.3.8 Innovation and Technology

This study will foster innovation and promote sustainable water resource management through economically viable solutions. Furthermore, the author anticipates that this study will assist in the development of several cutting-edge technologies like the Internet of Things (IoT), water purification industries, and digital platforms. These innovative technologies will help various agencies to implement targeted policies in the region.

8.4 Policy Measures

8.4.1 Improve Water Supply Infrastructure

Lack of access to WASH services could be harmful to human health. A study performed by Kanti Majumdar (2017) revealed that the absence of sanitation facilities and deficiency of soap at handwashing facilities are primary contributing factors to diarrhoea among under-five children. Furthermore, Roy et al. (2023) found that only 6.46% of households have access to water in their own dwelling and nearly 52.20% of households have availability of soap. There are several natural constraints that also exist throughout the region, including seawater intrusion, toxic substances, and soil salinity (Bandyopadhyay & Basu, 2017; Roy et al., 2023). These factors play a vital role in determining the quality of water. Moreover, persistent leaks in water pipes (Figure 8.1) and inoperative tube wells (Figure 8.2) impact both the quality and quantity of drinking water, respectively. To ensure safe drinking water in every household in the district, this study suggests focusing on sustainable water safety planning, improving water distribution systems, and water treatment. These policy measures will ensure improved and consistent water supplies for the people by upgrading and expanding the water supply networks (Figure 8.3).

Figure 8.1: Effect of water pipe leaks in Sontoshpur village (a) water pipe leaks impact community access in Sontoshpur village, and (b) deteriorating road ambient due to persistent leaks; Source: By author

Figure 8.2: (a) Abandoned hand pumps in the study villages (a) typical abandoned hand pump in Kamra Tentulia Buniyadi School, and (b) abandoned hand pump in Katkina Iswaripur village; Source: By author

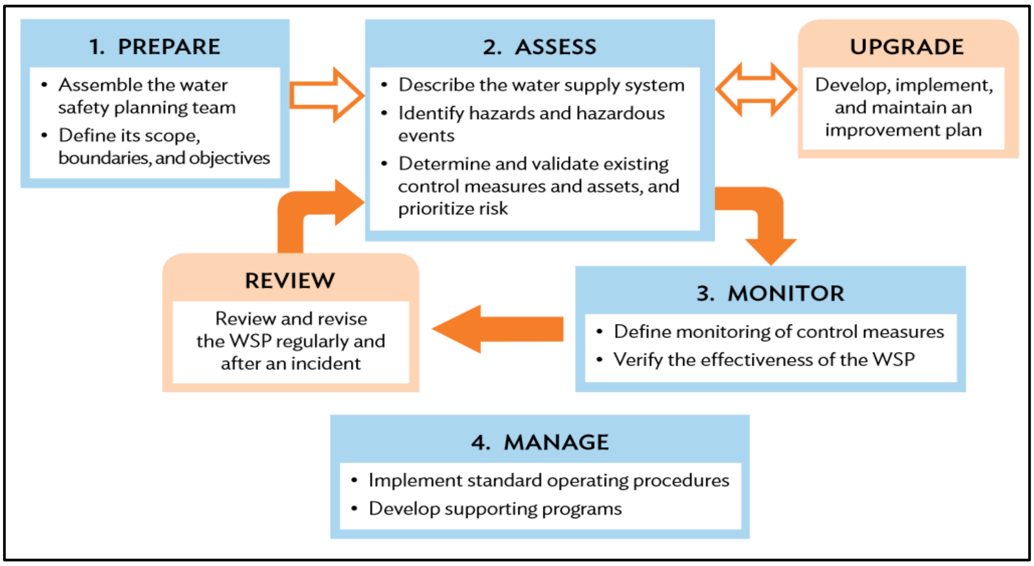

Figure 8.3: A step-by-step approach to water safety planning; Source: adapted from the WHO and the IWA, 2009

8.4.2 Enhance Sanitation Facilities

There are few households are still practicing open defecation, which could lead to adverse health impacts (Figure 8.4). It may be assumed that shared sanitation practices correlate with the incidence of diarrhoeal/ soil-transmitted helminth (STH) infections (Ramlal et al., 2019). Hence, there is need for construction of sanitation facilities, enhance access of sanitation in rural areas, sustainable sanitation solutions, and maintenance are required to prevent diarrhoeal and STH infections (Figure 8.5).

Figure 8.5: Sanitation Safety Planning; Source: World Health Organization (WHO)

Figure 8.4: Patterns of sanitation facilities (a) septic tank-based sanitation facilities transforming Sontoshpur village, and (b) Unimproved sanitation facilities in Abua village; Source: By author

8.4.3 Promote Hygiene Education and Practices

Awareness of hygiene plays a vital role in maintaining the good health of the people. However, poor hygiene could have adverse health effects, which include skin irritation, dental complications, the spread of illness, and malnutrition (Azzolino et al., 2019). Therefore, it is imperative to prevent health and hygiene hazards (Figure 8.6). Aside from this, comprehensive hygiene programmes, community awareness campaigns, and school hygiene programs, as well as handwashing practices with soap, are urgently needed to reduce the risks of hygiene-related hazards. These measures can help to minimize the risks of several infectious diseases.

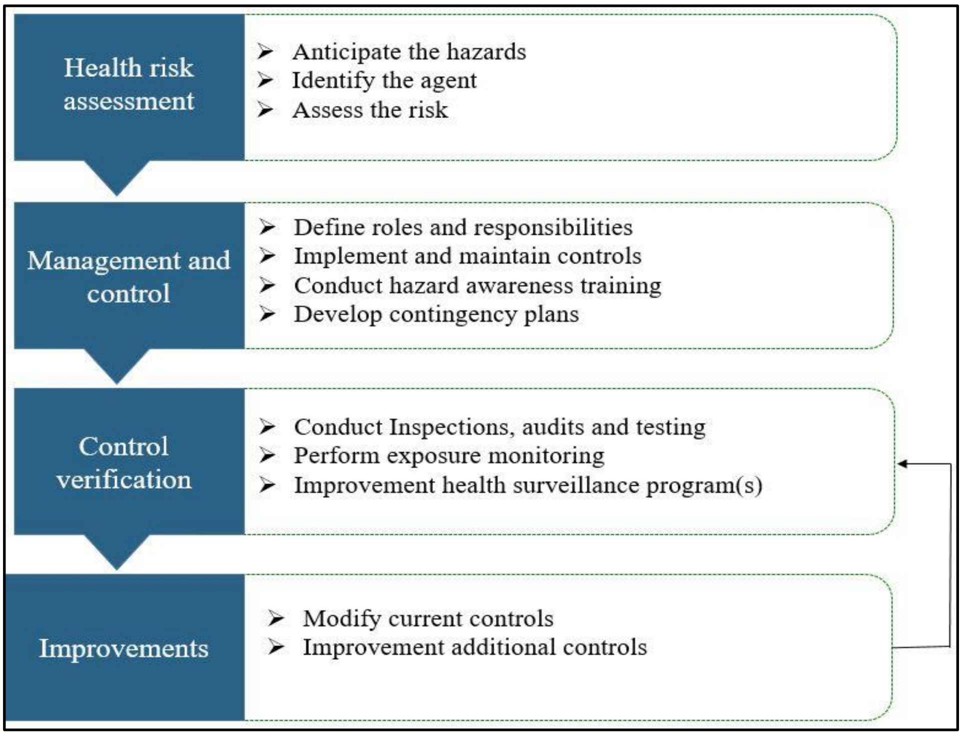

Figure 8.6: Stages in managing health and hygiene hazards; Source: Government of Western Australia and modified by author

8.4.4 Improvement of Waste Management Systems and Drainage Facilities

Factors like uncontrolled waste disposal, landfills, and open-air incineration negatively impact the environment (Figure 8.7). Furthermore, it is associated with significant environmental and public health costs, which may negatively impact marginalized groups of society (Abubakar et al., 2022; Omang et al., 2021; Siddiqua et al., 2022). Besides, Akpor & Muchie (2011) showed that inadequate wastewater treatment could lead to eutrophication in water bodies (Figure 8.8), which produces a favorable environment for waterborne pathogens (Akpor & Muchie, 2011; Wear et al., 2021). Therefore, the study suggests the development of integrated waste management plans, enhancement of waste collection and transportation, and upgrading of waste processing facilities as well as community education on sustainable waste management. For effective drainage facility management, drainage facilities, infrastructure, and drainage systems need to be upgraded.

Figure 8.7: Waste management in action (a) improper disposal of solid waste in Sontoshpur village, and (b) wet waste collection vehicle in Chingripota Gram Panchayat ; Source: By author

Figure 8.8: Difficulties in wastewater drainage facilities (a) nonfunctional wastewater drainage systems in Abua village, and (b) broken wastewater drainage facilities in Srinagar village; Source: By author

8.4.5 Strengthen Institution Capacity and Governance

The lack of access to WASH services has serious consequences for the health and well-being of the population. Due to geographical and socioeconomic factors, the region has limited access to WASH services. Thus, the study recommends mobilizing resources, improving institutions' decision-making, and improving governance to enhance WASH services. These steps would help to enhance the quality of life of economically deprived people.

8.4.6 Increase Funding and Investment

The WASH services are lacking in the region, which is a major concern for vulnerable groups (Cairncross & Valdmanis, 2006; PALO et al., 2021). Thus, the present study suggests private sector engagement and government funding are crucial to addressing the critical challenges and prevent various waterborne diseases.

8.4.7 Implementation of Technological Innovation

This study proposes both traditional and cutting-edge solutions for improving WASH services. These solutions include rooftop rainwater harvesting and desalinization processes to fulfill safe water needs in the region. Apart from these, there is a need for smart water solutions to detect water leakage and ensure efficient water use. Aside from that, the improvement of the WASH sector needs ecological sanitation toilets, biodegradable toilets, and integrated sanitation solutions. For targeted policies, these advanced technological solutions would be useful to government bodies and NGOs.

Conclusion

With the inclusion of these policies, the region would be able to enhance its WASH services, which will reduce the risk of different diseases. According to the study, targeted policy interventions can be implemented with the involvement of multiple stakeholders to improve the quality of life of economically disadvantaged individuals in the region.

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Appendices

Villages	Samples No.	Season	Lat	Long	Temp	pH	TDS	EC	CaCO3	As	NO3	F	Cl-	Cl2	Turbidity	Fe
Kamra	1	M	22° 22' 32"	88° 29' 1"	31.3	7.5	352	705	250	0.00	0	0.3	50	0	5	0.5
		PM			25.6	7.7	338	689	275	0.00	0	0	40	0	5	0.5
	2	M	22° 22' 31"	88° 29' 17"	32.5	7.3	410	785	250	0.00	0	0.2	45	0	5	0.4
		PM			19.2	7.8	425	860	275	0.00	0	0.3	30	0	5	0.5
Abua	1	M	22° 33' 53"	88° 32' 34"	31.5	7.25	399	610	400	0.00	0	0.1	60	0	0	0.3
		PM			22.8	7.6	438	876	425	0.05	0	0.3	50	0	0	0.5
	2	M	22° 33' 40"	88° 32' 30"	31.4	7.1	945	1850	925	0.00	0	0.1	220	0	5	0.3
		PM			23.2	7.3	1000	2000	975	0.00	0	0.3	200	0	10	0.3
Bahirchara	1	M	22° 22' 47"	88° 11' 3"	30.5	7.6	405	818	225	0.05	0	0.2	70	0	10	0.3
		PM			22.2	7.9	429	862	250	0.05	10	0.4	60	0	5	0.3
	2	M	22° 22' 51"	88° 11' 01"	30.4	7.9	165	325	150	0.05	0	0.2	40	0	0	0.5
		PM			22.7	8.2	178	355	175	0.05	0	0.4	30	0	0	0.3
Srichanda	1	M	22° 17' 7"	88° 16' 2"	32.85	7.7	535	1095	200	0.05	0	0.1	90	0	10	0.5
		PM			23.3	7.9	562	1134	225	0.05	0	0.3	80	0	5	0.5
	2	M	22° 17' 4"	88° 16' 10"	32.84	7.9	513	1022	175	0.05	0	0.3	90	0	10	0.5
		PM			23.1	8	532	1064	175	0.00	0	0.2	80	0	5	0.3
Narayanganj	1	M	21° 44' 41"	88° 12' 59"	32.4	7.9	451	895	150	0.05	0	0.2	60	0	10	0.5
		PM			25.1	8.1	481	965	175	0.05	0	0.4	60	0	5	0.5
	2	M	21° 44' 55"	88° 13' 2"	32.1	8	438	891	125	0.01	0	0.1	70	0	10	0.3
		PM			25.4	8.2	456	912	150	0.05	0	0	60	0	5	0.5
Santoshpur	1	M	22° 27' 54"	88° 13' 7"	31.95	7.5	312	655	275	0.00	0	0.2	70	0	5	0.3
		PM			24.1	7.7	341	680	300	0.00	0	0.3	80	0	10	0.5
	2	M	22° 28' 7"	88° 13' 34"	31.9	7.1	548	1110	450	0.00	5	0	270	0	25	0.5
		PM			25.5	7.3	573	1250	475	0.00	10	0.1	300	0	25	0.3
Katkina Ishwaripur	1	M	22° 11' 43"	88° 24' 10"	29.5	7.9	521	1249	200	0.05	0	0.3	90	0	5	0.3
		PM			24.1	7.9	615	1231	250	0.00	0	0.2	130	0	5	0.5
	2	M	22° 11' 38"	88° 24' 17"	27.5	7.7	562	1038	250	0.00	10	0.1	120	0	5	0.5
		PM			24.4	7.9	623	1257	275	0.05	0	0.4	120	0	0	0.3
Napukuria	1	M	22° 12' 4"	88° 28' 26"	27.6	7.8	504	1005	250	0.05	10	0	80	0	10	0.5
		PM			24.4	7.9	538	812	300	0.00	0	0	130	0	5	0.5
	2	M	22° 12' 35"	88° 27' 49"	27.9	7.7	446	1080	275	0.05	0	0	90	0	5	0.5
		PM			24.3	7.9	569	1143	325	0.00	0	0	160	0	10	0.5
Palghat	1	M	22° 24' 41"	88° 23' 23"	33.3	7.3	337	636	250	0.00	0	0.3	30	0	10	1.0
		PM			26.1	7.6	360	731	275	0.00	0	0.2	40	0	10	0.5
	2	M	22° 24' 42"	88° 24' 59"	32.4	7.8	159	290	75	0.00	10	0.4	20	0	5	0.3
		PM			23.4	8.1	166	333	125	0.00	10	0.5	20	0	0	0.5
	3	M	22° 24' 42"	88° 23' 17"	33.1	7.1	407	815	375	0.05	0	0.3	50	0	0	0.3
		PM			24.5	7.4	455	897	400	0.05	0	0.4	120	0	5	0.3
Srinagar	1	M	22° 23' 1"	88° 33' 46"	35.2	7.5	831	1663	400	0.00	0	0.2	0	0	5	0.5
		PM			24.3	7.7	910	1826	450	0.00	0	0.3	0	0	5	0.5
	2	M	22° 22' 41"	88° 34' 28"	35.4	7.9	1022	2044	450	0.00	0	0.4	0	0	10	0.5
		PM			24.5	8	1121	2265	475	0.00	0	0.3	0	0	10	0.0

Questionnaire for Household Survey

Topic: Assessment of Drinking Water, Sanitation, and Hygiene Status in South Twenty-four Parganas, West Bengal

Household ID. | | | | |

Name of Block: ______________________Name of G.P.________________________

Name of Village______________________ Language of Interview: _______________

Date of Interview: ________/________/2022
(Day) (Month)

Start time: _______________ End time: _______________

INTRODUCTION AND CONSENT

Hello, I am Chandan Roy, a research scholar at the Department of Geography and Resource Management. Currently pursuing my Ph.D. at Mizoram University, Aizawl. First, I would like to thank you for your valuable time and cooperation in this survey. I am working on "Assessment of Drinking Water, Sanitation, and Hygiene Status in South Twenty-four Parganas, West Bengal". The information will be confidential and will be used for research purposes only. In this survey, I would like to ask some essential questions related to my research topic. And the survey will take a few minutes. If you need any further clarification about the survey, you can ask any questions at any time during the survey. However, if you don't want to answer any questions let me know, I will skip those questions and go for the next questions. If you agree then only we can conduct this survey.

1. May I begin the interview now? [1] Yes → **SECTION A**; [2] No → **END**
2. Are you a permanent resident of this household? [1] Yes → **SECTION A**; [2] No → **END**

Section A: Personal Information of the Respondent

Questions	Choice Code
A1. Name of Respondent	
A2. Sex of Respondent	[1] Male [2] Female [3] Third gender
A3. Age of Respondent	[1] _____________Years [Numeric]
	[96] Don’t Know
A4. Relationship to the Household Head	[1] Household head [2] Spouse [3] Father or Mother [4] Brother or Mother [5] Child [99] Others Specify_________________[Text]
A5. What is your current marital status?	[1] Married [2] Single [3] Widowed [4] Divorced/ Separated [96] Don’t Know
A6. Current educational status of respondent	[1] No Education (Illiterate) [2] Primary [3] Upper Primary [4] Secondary [5] Higher Secondary [6] Higher [96] Don’t Know
A7. Current employment status of respondent	[1] Yes [2] No [3] Don’t Know

Section B: Household Roster

B.1: Now, I will enumerate your all family members with various socio-demographic factors. You are requested to tell me your household member's details, starting from the head of the household.

Sl. No.	Sex	Age (years)	Marital status	Current Educational Status	Occupations	Currently Employed	Children status (Age under 5)
1.							
2.							
3.							
4.							
5.							
6.							
7.							
8.							
9.							
10.							

Codes:

Sex:
1. Male
2. Female
3. Third gender

Occupations:
1. Unemployed
2. Self-employment
3. Government
4. Private Company
5. Student
6. Seasonal Worker
7. Housewife

99. Others, Specify___________

Marital Status:
1. Married
2. Single
3. Widowed
4. Divorced/ Sepa

96. Don't Know

Currently Employed:
1. Yes
2. No

96. Don't Know

Codes for Qn. B5:
1. Nuclear
2. Non-Nuclear

96. Don't Know

Educational Qualifications:
1. No Education (Illiterate)
2. Primary
3. Upper Primary
4. Secondary
5. Higher Secondary
6. Higher

96. Don't Know

Codes for Qn. B3:
1. Pucca
2. Kutcha
3. Semi-Pucca

99. Other (Specify)

Codes for Qn. B2:
1. <10000
2. 10000-20000
3. 20000-50000
4. 50000-100000
5. >100000

B2. What is the monthly average income of your household?	
B3. What is the type of house (observed by the Interviewer)?	
B4. Household materials (observed by the Interviewer)	
B5. Household Structure	

Section C: Accessibility of Water Resources

Questions	Choice Code	SKIP
C1. What are the main sources of drinking water for your household?		
C2. What are the main sources of water used by your household for other purposes, such as cooking, and hand washing?		
C3. Where is the drinking water source located?		**C3 to C7**
C4. How long it will take to go there, collect water, and come back?		
C5. Who usually goes there to collect water for the household?	SL. No. -	
C6. How many trips did the people make in the last week?	Number of times:	
C7. Why do you prefer main water sources of drinking water?		
C8. What is the main source of washing?		
C 9. What are the main sources of drinking water in monsoon season?		
C10. What are the main sources of drinking water in the dry season?		
C11. What methods are you usually using to make this water safer for drinking?		
C12. How long do you stand in a queue at main drinking water sources?		
C13. What is the quality of household drinking water sources?		
C14. Do you usually have to pay for drinking water?		
C15. If yes, how much you must pay for drinking water?	₹__________	

Codes for Qn. C1, C2, C8, C9 & C10:

1. Piped Water
2. Public tab/ stand pipe
3. Tube well/Borehole
4. Protected Dug Well
5. Unprotected Dug Well
6. Rainwater Collection
7. Bottled Water

Codes for Qn. C3:

1. In own Dwelling
2. In own yard/ Plot
3. Elsewhere

Codes for Qn. C7:

1. Distance
2. Time
3. Water Availability
4. Safe Water
5. Affordability
99. Other (Specify)

Codes for Qn. C9:

1. < 6 hours
2. 6-12 hours
3. 12-18 hours
4. 18-24 hours
96. Don’t Know

Codes for Qn. C11:

1. Boil
2. Add bleach/ chorine
3. Use water filter
4. Let it sand and settle
5. Others (specify)
96. Don’t Know

Codes for Qn. C12:

1. < 30 minutes
2. > 30 minutes
96. Don’t Know

Codes for Qn. C14:

1. Yes
2. No
96. Don’t Know

Section D: Sanitation Facilities

Questions	Choice Code	SKIP
D1. Do you have a toilet facility in your dwelling or household?		**No to E1**
D2. Types of toilet facility (observed by researcher)		
D3. Where is the toilet facility located?		
D4. Do you share this toilet facility with anyone other than your household members?		
D5. Does the sanitation facility overflow or leak waste at any time of year?		
D6. What is your septic tank discharge to?		
D7. How many years ago of your toilet facility built?	(Numeric)	
D8. Do you feel any risks while using this toilet facility?		
D9. Do you clean your toilet facility?		
D10. How many times in a month toilet facility is clean?	(Numeric)	
D11. Is there any separate toilet for women in your household?		
D12. Did you receive any financial assistance for the building of a sanitation facility?		
D13. What type of essentials are you using in the bathroom to maintain hygiene?		**No D1 to SKIP E1**

Codes for Qn. D2:

1. Flash or Pour Flash Toilet
2. Pit Latrine
3. Container based sanitation
4. Hanging toilet/ Hanging latrine
5. No Facility/ Bush/ Filed

96. Don’t Know
99. Other (Specify)

Codes for Qn. D3:

1. In own dwelling
2. In own yard/plot
3. Elsewhere

Codes for Qn. D5:

1. Never
2. Yes, Sometimes
3. Yes, Frequently

96. Don’t Know

Codes for Qn. D6:

1. To a Soak Pit
2. To an Open field
3. To an open drain
4. To open ground or watercourse

96. Don’t Know
99. Other (Specify)

Codes for Qn. D1, D4, D9, D11 & D12:

1. No
2. Yes

96. Don’t Know

Codes for Qn. D13:

1. Not using
2. Toilet Disinfections
3. Acid

96. Don’t Know
99. Other (specify)

Codes for Qn. D8:

1. No risks
2. Yes, risks of health
3. Yes, risks of hygiene

96. Don’t Know
99. Other (Specify)

Section E: Waste Management Systems

Questions	Choice Code	SKIP
E1. Have you heard about solid waste management systems?		
E2. Are you using any type of waste management system?		**No to E11**
E3. If yes, what type of solid waste management system are you currently using?		
E4. Where do you dispose of your solid waste?		
E5. Do you separate different types of solid waste in your household?		
E6. How many times in a week do you clean your household?		
E7. Has anyone in your household been affected by a different disease?		
E8. Do you feel effective waste management reduces health outcomes?		
E9. Where wastewater drainage facility is available?		
E10. Types of drainage facility is available		

Codes for Qn. E1, E2, E5, E7 & E8:
1. No
2. Yes

96. Don't Know

Codes for Qn. E3:
1. Plastic bags
2. Cardboard boxes
3. Rubbish bin / drum
4. No storage- direct disposal to dump

96. Don't Know

Codes for Qn. E4:
1. Nearby container
2. Open spaces

96. Don't Know
99. Other (Specify)

Codes for Qn. E9:
1. Within Premises
2. Away from premises

96. Don't Know

Codes for Qn. E10:
1. None
2. Open
3. Closed

Section F: Health and Hygiene of Household

Questions	**Choice Code**	**SKIP**
F1. Can you show me where members of your household most often wash their hands?		
F2. If hand washing facilities are available in your household, then which types of hand washing facility available in your household? (Multiple Responses)		
F3. Verify the availability of water at the place of hand washing.		
F4. Do you use soap or detergent for washing hands?		
F5. If others, can you show me? (observed by the interviewer)		
F6. Record type of soap available for hand washing. (Multiple Responses)		
F7. What are the major waterborne diseases that have affected your family members or household in the last six months?		**No to F9**
F8. During the past six months, have any members of your household been affected by diarrhea?		**No to F12**
F9. If yes to F9, then who had diarrhoea? (Multiple Responses)		
F10. Are there any under-five children who died due to diarrhoea?		

Questions	Choice Code	SKIP
F11. What type of preventive measures does your household take for waterborne disease?		
F12. Do you know of any disease linked with poor water quality and unhygienic sanitation facilities?		
F13. Are there any organizations that create awareness about waterborne diseases?		
F14. If yes to F14, please specify the name of the organization. (Multiple Response)		

Codes for Qn. F1 & F2:
1. In Dwelling
2. In yard/Plot.
3. Mobile Object reported (bucket/Jug/Kettle)
4. No hand washing facility (Dwelling/Plot/ Yard)

96. Don't Know
99. Other (Specify)

Codes for Qn. F3:
1. Yes
2. No
3. Frequent available of water

96. Don't Know

Codes for Qn. F4, 8, 11, 12 & 13:
1. Yes
2. No

96. Don't Know
99. Other (specify)

Codes for Qn. F9:
1. Yes, <5 years
2. Yes, 5-14 years
3. Yes, > 15 years and above Adult
4. Yes, 15-49 years women

96. Don't Know
99. Other (Specify)

Codes for Qn. F5:
1. Water
2. Ash
3. Soil
4. Sand

96. Don't Know
99. Other traditional materials (Specify)

Codes for Qn. F6:
1. Bar Soap
2. Liquid Soap
3. Powder Detergent

99. Other (Specify)

Codes for Qn. F7:
1. Cholera
2. Typhoid
3. Hepatitis A & E
4. Diarrhoea

99. Other (Specify)

Codes for Qn. F11:
1. Hand Washing with Water
2. Hand Washing with Soap
3. Covering Food
4. Store water safely
5. Boil Water
6. Use soap after latrine

96. Other (specify)

Codes for Qn. F15:
1. Local Govt.
2. ASHA
3. Local Health Centre
4. NGO

99. Others (specify)

Interviewer's Observations

(To be filled after interview)

Comments about interview: ____

Comments on specific questions: ____

************************************** **Thank You** *****************************

BIO-DATA

Personal Details

Name	Chandan Roy
Position	Research Scholar, Department of Geography and Resource Management, Mizoram University, Aizawl-796004
Phone No. (M)	+91 7059458311; 9064650966
Email	chandan96.roy@gmail.com; roymzu@gmail.com
Degree	Doctor of Philosophy
Department	Geography and Resource Management
Title of Thesis	Assessment of Drinking Water, Sanitation and Hygiene Status in South Twenty Four Parganas, West Bengal
Date of Admission	25/08/2021
Ph.D. Reg. No. and Date	**MZU/Ph.D./1791 of 25.08.2021**

ID Available

1. ORCID 0000-0001-6246-4263
2. Researcher ID GLS-2179-2022
3. Scopus Author ID 58089328500

Research Area

Water quality, WASH, Population ageing, Public health, Climate change and Migration in India.

Educational Qualification:

Educational Qualification	Year	University/Board
Ph.D.	-	Mizoram University
Master of Population Studies (MPS)	2021	IIPS, Mumbai
M.Sc. in Geography and EM	2019	Vidyasagar University
B.Sc. in Geography (H)	2017	Calcutta University
High Secondary	2014	W.B.C.H.S.E.
Secondary	2012	W.B.B.S.E.

Other Academic Qualification:

National Level Exam Qualified

1. UGC-NTA National Level Eligibility Test (NET). Certificate No. - JUN19U48942, June 2019.

State Level Exam Qualified

1. West Bengal State Eligibility Test (WBSET). Certificate No. - WBCSC20221193, January 2022.

Publications

1. **Roy, C.** (2023). Spatial distribution and determinants of limited access to drinking water and sanitation services of households in India. Journal of Water, Sanitation and Hygiene for Development, 13(12), 1–16. https://doi.org/10.2166/washdev.2023.181

2. **Roy, C.**, Sati, V. P., Biswas, A., & Kumar, S. (2023). Status of drinking water, sanitation facilities, and hygiene in West Bengal: Evidence from the National Family Health Survey of India (NFHS), 2019–2021. *Journal of Water, Sanitation and Hygiene for Development*, 13(1), 50–62. https://doi.org/10.2166/washdev.2023.228

3. Kumar, S., Sati, V. P., Singh, R., & **Roy, C.** (2023). Patterns and drivers of internal migration: Insights from Jharkhand, India. *GeoJournal*. https://doi.org/10.1007/s10708-023-10895-6

4. **Roy, C.**, Biswas, S., Sati, V. P., Biswas, A., & Kumar, S. (2023). Bio-demographical determinants of diabetes among women in reproductive age group (15–49) in India: Evidence from National Family Health Survey (NFHS) of India, 2019–2021. International Journal of Diabetes in Developing Countries. https://doi.org/10.1007/s13410-023-01237-w

5. **Roy, C.,** Kumar, S., Sati, V. P., & Pal, S. (2023). Investigating the physico-chemical properties of drinking water: A case study of South Twenty-Four Parganas, West Bengal. SN Social Sciences, 3(11), 1–23. https://doi.org/10.1007/s43545-023-00778-5

6. **Roy, C**., Kumar, S. ., Kumar, G. ., Sati, V. P., & Dhar, M. (2024). Population Aging in India: A Regional Comparison and Implications for Older Persons' Welfare and Healthcare Infrastructure. Journal of Population and Social Studies [JPSS], 32, 399–415. Retrieved from https://so03.tcithaijo.org/index.php/jpss/article/view/266894

7. Biswas, A., **Roy, C**., Sati, V. P., & Kumar, S. (2024). The role of Mahatma Gandhi National Rural Employment Guarantee Act on women empowerment in selected districts of West Bengal, India. SN Social Sciences, 4(2), 55. https://doi.org/10.1007/s43545-024-00857-1

8. Sati, V., Banerjee, S., & Roy, C. (2024). Land Use and Land Cover Dynamics and Factors Affecting It in The Central Himalaya. 2, 35–43. https://doi.org/10.26480/magg.02.2024.35.43

Scholarships and Awards

1. ICSSR Doctoral Fellow (December 2022–Present) awarded by the Indian Council of Social Science Research (ICSSR), New Delhi.

2. Government of India (Ministry of Health and Family Welfare) Fellowship awarded for pursuing a Master's Degree in Population Studies from the International Institute for Population Sciences, Mumbai, 2020-2021.

3. Swami Vivekananda Merit-Cum Means Scholarship (SVMCM) for pursuing a Master's degree in Geography and Environmental Management, Govt. West Bengal, 2017-2019.

4. Rank first in the Higher Secondary qualifying examination, and received a cash award of Rs. 5000/- from the B.E. College Model School Alumni Association.

Travel Grants Awarded

International:

1. ‘Travel Grants’ awarded by the ICSSR, New Delhi to participate in the Singapore International Water Week 2024, in Sands Expo and Convention Centre, Singapore – 18-22 June 2024

National:

1. ‘Travel Grants’ awarded by the IIPS, Mumbai, to participate in the XVII IIPS National Seminar 2022-23 on “75 years of India’s Demographic Change: Processes and Consequences” to be held at Institute for Social and Economic Change (ISEC), Bengaluru – 23-24 February 2023.

2. “Travel Grants” awarded by IIPS, Mumbai, to participate in the XVIII National Seminar 2023-24 to be held at Banaras Hindu University (BHU), Uttar Pradesh – 12-13 February 2024.

Professional Membership/Scientific Editor/Expert Member/Peer Reviewer

1. Peer Reviewer at BMJ Open (2023); (ISSN: 2044-6055; IF-3.007)
2. Peer Reviewer at Journal of Primary Prevention (2023); Springer Nature, (ISSN: 0278-095X; IF-1.9)
3. Peer Reviewer at Singapore International Water Week 2024 Water Convention
4. Peer Reviewer at BMC Public Health (2024); Springer Nature), (ISSN: 1471-2458)

Workshops/ Research Methodology Courses/Capacity Development Programme

1. Participated in the Two Days International Workshop on ‘Psychosocial Adaptation, Disaster Mitigation and Preparedness of Climate Change affected Communities’ on 15th to 16th April 2024 organized by the Department of Social Work, Mizoram University

Paper Presentation (Conferences / Seminar)

International:

1. Paper presented on “Status of drinking water, sanitation facilities, and hygiene in West Bengal: Evidence from the National Family Health Survey of India (NFHS), 2019–2021”, in the international conference, held on 29th August to 1st September 2023, at the Imperial College London, London, United Kingdom (***Oral: Online***).

2. Paper presented on “Investigation of Drinking Water Quality in Different Villages of South Twenty Four Parganas District, West Bengal”, in the international conference, held on 29 September 2023, at the University of Zagreb, Zagreb, Croatia (***Oral***).

3. Paper presented on “Analysis of drinking water quality in South Twenty-Four Parganas, West Bengal, in the 4th International Sustainability Conference on HSFEA, held on 30-31 October 2023, at the University of Petroleum and Energy Studies, Uttarakhand, India (***Oral*)**.

4. Paper presented on “Spatial distribution and determinants of limited access to drinking water and sanitation services of households in India”, ‘Singapore International Water Week 2024 (SIWW-2024)’ hosted by the PUB, Singapore’s National Water Agency and the Ministry of Sustainability and the Environment, Sands Expo and Convention Centre, Mariana Bay Sands, Singapore from 18th-22nd June 2024 (***Oral*).**

National:

1. Paper presented on “Assessment of drinking water quality in Palghat village of South Twenty Four Parganas District, West Bengal: a Case Study”, in the national seminar, held on 23-25 February 2023, at the Institute for Social and Economic Change (ISEC), Bengaluru, India (***Oral*)**.

2. Paper presented on “Assessment of drinking water quality in South Twenty Four Parganas, West Bengal”, in the national seminar, held on 25-26 April 2023, Mizoram University, Aizawl, India (***Oral***).

3. Paper presented on “Trend and Pattern of Tourist Arrival in West Bengal and Impact of the Covid-19 Pandemic: A Temporal Analysis”, in the international conference, held on 18-19 May 2023, Mizoram University, Aizawl, India (***Oral***).

Skills

Remote Sensing and GIS, Stata, SPSS, R, and Proficiency in English.

Place: Aizawl   Yours Sincerely,

Dated:

(CHANDAN ROY)

PARTICULARS OF THE CANDIDATE

NAME OF CANDIDATE: CHANDAN ROY

DEGREE: DOCTOR OF PHILOSOPHY

DEPARTMENT: GEOGRAPHY AND RESOURCE MANAGEMENT

TITLE OF THESIS: ASSESSMENT OF DRINKING WATER, SANITATION, AND HYGIENE STATUS IN SOUTH TWENTY FOUR PARGANAS, WEST BENGAL

DATE OF ADMISSION: 25/08/2021

APPROVAL OF RESEARCH PROPOSAL:

1. DRC: 21/03/2022
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ABSTRACT

ASSESSMENT OF DRINKING WATER, SANITATION AND HYGIENE STATUS IN SOUTH TWENTY FOUR PARGANAS, WEST BENGAL

AN ABSTRACT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

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DEPARTMENT OF GEOGRAPHY AND RESOURCE MANAGEMENT

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BY

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ABSTRACT

Introduction

Access and coverage of drinking water, sanitation, and hygiene (WASH) is crucial to retain sound health and well-being. (Darvesh et al., 2017). However, consuming contaminated drinking water and unhygienic sanitation practices may lead to an increase in the prevalence of several types of diseases (Hall et al., 2020; Roy et al., 2023). Globally, around 2 billion people are consuming water from contaminated sources. A study found that several regions of the world will face a water shortage by 2025. Furthermore, in the least developed countries (LDCs), about 22% of healthcare facilities do not have access to water, while around 21% do not have sanitation facilities, and almost 22% do not have any waste management system (World Health Organization, 2019). On the other hand, Landrigan et al. (2020) unveiled that waterborne diseases are triggered by pathogenic microorganisms like viruses, bacteria, and protozoa transmissible through water. These pathogens may have harmful impacts on human health (Janik et al., 2020). Karande et al. (2021) stated that hygiene is a more important component of waterborne disease than the quality of water, which people in rural areas frequently neglect. However, Ferreira et al. (2021) unveiled that extensive coverage of water and sanitation services (WSS) can prevent the spread of waterborne diseases and their harmful effects.

According to Hartman et al. (2023), diarrhoea is the second most common reason for mortality among under-five children in low and middle-income countries (LMICs). Biswas et al. (2022) reported that nearly 95.5% of families in India had access to improved drinking water. Nevertheless, there is a regional variability in India. However, M.R (2021) unveiled that around 54% of families in rural India did not have access to safe drinking water. Although Roy (2023) showed that there are a few central and western Indian states where drinking water and sanitation are limited. Additionally, the study found that education, place of residence, and wealth index are associated with limited access to drinking water and sanitation facilities. Besides, Biswas et al. (2022) carried out a study in 2018 that revealed that access to safe drinking water and sanitation facilities is crucial to preventing acute illness and

mortality. Moreover, Chatterjee et al. (2023) unveiled that prevalence of diarrhoea is linked to house types, water, and sanitation conditions.

In South Twenty-four Parganas, most of the districts are still facing severe problems of contaminated groundwater and inadequate sanitation facilities. Furthermore, high concentrations of iron, arsenic, fluoride, pH, TDS, chloride, and other substances in drinking water lead to the prevalence of different diseases (Bhattacharyya et al., 2021; Kanti Majumdar, 2017).

This study extensively demonstrated the status of WASH services in the region. It also shows how a lack of WASH services is associated with several waterborne illnesses. A limited number of studies have been conducted, which cannot adequately illustrate the status of WASH services in the region. Therefore, the study attempted to assess WASH services in the region, which would be helpful for multiple stakeholders for targeted policies. Moreover, it will fill gaps in the existing literature and establish a foundation for future research.

Statement of the Problem

The present study investigated the status of WASH services in the South Twenty-four Parganas district of West Bengal. The area is in the southern part of the Gangetic delta, which is rich in surface and groundwater resources. Despite this, the region has some significant problems, including typical hydrology, seawater intrusion, soil salinity, and a high percentage of clay in the soil. In addition, illegal mining activities, reduced groundwater recharge potential, and increased wastewater discharges are contributing to the deterioration of water quality in the region. Because of climate change and sea levels rise, resulting in gradual increases in soil and water salinity. This results in the water of the region being unusable for the people who live there. A study conducted by Bandyopadhyay & Basu (2017) revealed that the region has various problems such as poverty, loss of agricultural lands, large-scale industry, and morbidity of various waterborne diseases directly affecting human health and well-being. Moreover, there are lack of literature on the present status of water, sanitation, and hygiene in the region. Therefore, the present study attempted to fill the gaps in the existing literature and open a new avenue for further studies.

Research Questions

The following questions were raised during the study:

1. What is the status of drinking water quality in the study villages?
2. What is the status of sanitation, and waste management in the study area?
3. How waterborne diseases and hygiene behaviours are linked to human health?
4. What are the policy implications for improved WASH services?

Objectives

1. To analyse the water quality of different water sources in the study villages.
2. To examine the utilization patterns of sanitation facilities and community waste management systems.
3. To study the impact of water-borne diseases and hygiene on human health.
4. To suggest policy measures for a better quality of water, sanitation, and hygiene.

Materials and Methods

Study Area

The study area is in the South Twenty-four Parganas district, West Bengal. It is the largest district in West Bengal in terms of area and second-largest in terms of population, and it is located on the outskirts of Kolkata. It is the home to the world's largest mangrove forest and riverine Island, both of which serve as carbon sinks. The study area's latitudinal and longitudinal extension is 22^o 12' 13'' N to 22^o 46' 56'' N and 87^{o}58' 45'' E to 88^o 22' 10'' E, covering approximately 9960 sq. km. The study's geographical location is to other districts such as Kolkata, Haora, and North Twenty-four Parganas in the North, Paschim Medinipur in the West, and Bangladesh in the East. The Sonarpur is the largest municipality out of seven municipalities in the district. The district of South 24 Parganas is divided into five sub-divisions: Alipore Sadar, Baruipur, Diamond Harbour, Canning, and Kakdwip. In this study, we selected 10 villages from 10 development blocks to examine a spatial comparison of the WASH services. This means one village is selected from one development block. According to the Directorate of Census Operations, West Bengal (2014), the district has 2042 villages distributed across 29 development blocks, of which 1996 are inhabited villages. The district has a total population of 8.16 million people living in the 29 development blocks in West Bengal's southern district.

Data Sources

Both quantitative and qualitative data were collected to conduct the present study. The study was primarily based on the collection of data from both primary and secondary sources. Furthermore, the Census Statistical Handbooks, the Public Health and Engineering Department (PHED), and the state’s report on water quality, sanitation, and hygiene status were the main sources of secondary data. For primary-level data, a cross-sectional study was conducted using a structured questionnaire to examine various socio-economic factors. There is a total of 29 development blocks in the district, out of which, only 10 development blocks were selected for this study. Additionally, a total of 10 villages were selected, which means one village from each development block for water quality analysis and household level survey. For the households’ level survey, a total of 15% of the households were surveyed. A purposive sampling method was applied to conduct the household-level survey to gather information on socio-economic status, prevalence of waterborne diseases, and WASH services in the region.

Water samples were collected from a variety of sampling sites using random sampling techniques in polyethylene bottles. To collect, preserve, and analyse the water samples, the American Public Health Association (APHA) standards were followed. To remove dirt, turbidity, and slime from bore wells or tube wells, samples were collected after pumping water for three to five minutes. The water samples for metallic elements (e.g., arsenic and iron) were filtered and preserved with 5% HNO_3 (nitric acid) to prevent soluble salts from converting into insoluble salts (Dahunsi et al., 2014; Parks et al., 2004). For the fecal coliform bacteria test, samples were collected from all sources in a H_2S glass bottle to avoid contamination. Additionally, water samples were collected from various improved water sources from July to September 2022 (Monsoon) and October to January 2023 (Post-Monsoon). Moreover, the Global Positioning System (GPS) was used for geospatial data such as latitude, longitude, and altitude.

Data Analysis

Physicochemical parameters of improved water sources were examined using the field using a field-testing kit (FTK). A multi-parameter water testing kit, the 'HiMedia WT023' was used to analyse various physicochemical parameters of water samples. In addition, the 'HiMedia WT025' test kit was used to analyse arsenic traces in drinking water. With the help of the 'HiMedia K055' test kit, fecal coliform bacteria in drinking water were also analysed. The 'HiMedia K055' test kit is designed to detect Salmonella, Citrobacter, and Escherichia coli (E. coli) species in water based on the production of H_2S in a glass bottle.

Moreover, various physicochemical and bacterial parameters like Temperature, pH, TDS, Conductivity, Turbidity, Total Hardness (CaCO3), Arsenic (As), Nitrate (NO3), Residual Free Chlorine (Cl2), Iron (Fe), and Fecal Coliform were also examined. Temperature, pH, TDS, and EC were evaluated using a digital meter, while the rest of the physicochemical parameters were examined through a field-testing kit (FTK). Besides, a colorimetric test was performed to determine the concentration of Iron (Fe), Arsenic (As), and Nitrate (NO3) in drinking water with the help of a colour chart. The turbidity was measured using a visual comparison method in the field. In addition, CaCO3, Cl-, and Cl2 were measured by the titration method, and the presence of fecal coliform bacteria in drinking water was assessed using the H_2S method in a glass bottle. All fecal coliform bacteria testing samples were kept in a closed room at around 30^{o}C and incubated for 24 hours to 48 hours (Islam et al., 2017). The water source was considered unfit for drinking if its colour turned black during the test.

To determine the quality of water in study villages, the weighted arithmetic water quality index (WAWQI) was applied. In addition, univariate statistics, descriptive statistics, and logistic regression were used to analyse the data. The data was represented graphically using MS-Excel and Datawrapper data visualization tools. Besides, Stata and Arc Map 10.5 software were used for statistical analysis and geospatial mapping, respectively. Apart from these, the attack rate of various waterborne diseases was performed to check the prevalence of waterborne diseases.

Summary of Chapters and Major Findings

This thesis consists of eight chapters. Chapter 1 describes the introduction of the study, the statement of the problem, the scope of the study, research questions, hypotheses, objectives, materials and methods, and the organization of the chapters. Furthermore, the chapter also explains a sampling framework and a comprehensive map of the study area. The study area map shows the location of the villages, major roads, and railway connections. Moreover, in this chapter, salient features of the villages have been stated to provide a broader picture of their geographical area, population, and surveyed household composition.

Chapter 2 describes a comprehensive review of the literature. The chapter covers several topics including the background of WASH services, at the international level, the national level, the state level, the North Twenty-four Parganas, the South Twenty-four Parganas, and block-level literature. Additionally, the chapter discusses the factors affecting WASH services and the quality of drinking water in the region.

Chapter 3 illustrates the geographical background and socio-economic profile of the study area, including a case study of the villages. The geographical background section consists of several subtopics such as physiography, geological features, drainage patterns, climatic conditions, minerals and mining, soils and cropping patterns, flora and fauna, land use patterns, agriculture, and water quality in the study area. Additionally, the socio-economic profile includes four subsections: demography, culture, settlement type, and economy. The study revealed that no healthcare facilities are available in Palghat, Katkina Ishwaripur, and Bahirchara villages. Aside from that there is regional heterogeneity of availability of amenities and services in the region. Moreover, the chapter concludes with a comprehensive outline of several aspects of the study villages.

Chapter 4 investigates the physicochemical parameters of drinking water quality using field testing kits (FTK). Furthermore, the study found that arsenic, iron, TDS, and EC exceeded the Bureau of Indian Standards. Excessive levels of heavy metals in drinking water can cause cancer, liver, kidney, and lung-related diseases.

Additionally, seven villages' water quality was unfit for consumption, which is a major concern for human health. Therefore, this study suggests that the installation of deep tube wells and increasing awareness of water quality can help to reduce health-related complications in the region.

Chapter 5 elucidates the utilization patterns of sanitation facilities using cross-sectional data. This chapter comprises codes of the study variables, operational definitions, status of sanitation facilities, and factors affecting shared sanitation facilities. Additionally, the study revealed that education, income, family size, and religion are closely related to the prevalence of shared sanitation facilities. Hence, the present study suggests that providing improved sanitation facilities to every household helps to reduce the risk of health complexities.

Chapter 6 discusses waste management systems, which primarily focus on the perception of waste management systems in the study villages. In the study, only 9.16% of households were aware of waste management systems, which is alarming for human health. Additionally, the study found that the perception of waste management was associated with several factors, including income, education, house type, and family structure. It was also found that wealthy households with higher education are more aware of the environmental and health consequences of improper waste disposal. Therefore, the present study emphasizes the importance of sustainable waste management to prevent the spread of waste-borne illness.

Chapter 7 delineates the impact of waterborne diseases on human health. The present study found that only 1.57% of households reported having handwashing facilities outside their homes. Furthermore, nearly 69.26% of households followed hand hygiene with soap and water. It is also unveiled that diarrhoea is more prevalent in Katkina Ishwaripur village (7.69%), followed by Srinagar (3%), and Palghat (2.56%). Besides that, Katkina Ishwaripur is a higher prevalence of Typhoid (5.77%), followed by Srinagar (2%), and Palghat (1.28%). Moreover, a few villages are also found to have coliform bacteria, which is linked to numerous waterborne illnesses. Therefore, the present study suggests adaptation of sustainable waste management practices.

Programmes and policies for improving water, sanitation, and hygiene services are described in Chapter 8. This chapter illustrates the major challenges, major opportunities, and policy measures of the study in three sections. The major challenges in the section include a limited number of micro-level data, methodological issues, theoretical issues, implementation of policy recommendations, and economic variability. Furthermore, the section's major opportunities include various subsections such as sustainable water management, enhanced sanitation facilities, community empowerment, economic benefits, and technological advancement. In contrast, the section on policy measures explains how to improve water supply infrastructure, enhance sanitation facilities, promote hygiene and education, and strengthen institutional capacity. Moreover, this chapter provides an extensive overview of opportunities and policies for improving WASH services.

Conclusion

Lack of access to WASH services can negatively impact human health. Furthermore, there are limited studies have been conducted in ecologically fragile and economically backward regions. Consequently, this multidisciplinary study provides a comprehensive assessment of the present status of WASH services, which would be helpful to several stakeholders in developing a targeted policy. Additionally, it will generate micro-level data on water quality, sanitation, and hygiene. These micro-level data will be helpful to government agencies in formulating policies and driving immediate interventions to tackle the critical problems in the region. Moreover, it will open an avenue for future research and fill the gaps in the existing literature.

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