Chapter-1

Introduction

1.1. Introduction:

Water is an integral part of our life. For maintaining good living standards, we need an adequate supply of non-polluted safe water. The accessibility of safe water is also one of the most important determinants of health and socio-economic development. In the present day, water pollution and water scarcity are worldwide threats that affect the world economy, social life, and the subsistence of human beings. Though 71% of our planet is covered with water mass, only about 2.5 % of the planet's water is found as freshwater. Out of that water, 98.8% is located in the ice and groundwater. Less than 0.5% of entire freshwater is found in rivers, lakes, and the atmosphere, and this small proportion of fresh water is available for human use only (Bhat, 2019). But such small quantities of usable water from different freshwater sources become depleted, polluted, and diverted. Therefore, conservation and management of water, both in quantity and quality, are necessary for the general well-being of human beings.

In recent periods, groundwater has played an essential role in supplying safe potable water throughout the World. Due to less contamination and less pollution than surface water, groundwater is extensively used as a principal source of drinking water and mitigates the water demand for different purposes. India has also faced the problem of water scarcity and water pollution. Since groundwater is widely used in this country as a prime source of drinking water (Kumar and Shah, 2004), it also mitigates the rural-urban water demand. Every year India extracts the highest amount of groundwater on the earth's surface. Around 80% of the rural domestic needs and 50% of the urban water needs are fulfilled by groundwater utilization (Aguilar, 2010). According to the Annual Report of 2018-2019, India has extracted 248.69 BCM (Billion cubic meters) of groundwater, 24.87 BCM has been used for domestic purposes, and 221.46 BCM for irrigation purposes. For mitigating such enormous demands, groundwater quantity and quality are now equally diminishing continuously. Moreover, groundwater has become polluted and a threat for humans as it absorbed numerous geogenic and anthropogenic pollutants during some past decades in few parts of India. The most important source of these geogenic contaminants is Fluoride, Iron, Arsenic, etc., which have adverse effects on public health (Chakrabarty et al., 2011).

At present, Indian states have suffered from large-scale groundwater contamination through the amalgamation of Arsenic. These problems have primarily been observed in the Himalayan riverine plains (Chakraborty et al., 2009). But gradually, this problem spreads throughout the different states, i.e., Arunachal Pradesh,

Jharkhand, Manipur, Nagaland, Tripura, Bihar, Uttar Pradesh, Assam, Chhattisgarh, and West Bengal (Pal and David, 2010). In 1983, however, it was discovered that the tube well, which is the primary source of drinking and cooking water in West Bengal, is contaminated by naturally occurring Arsenic (Das, 2013). In this state, more importance has been given to groundwater utilization for acquiring safe water from time immemorial. So, West Bengal has also faced the problem of groundwater arsenic contamination. Since the five districts of West Bengal, i.e., Maldah, Murshidabad, Nadia, North 24-Parganas, and South 24-Parganas, situated at eastern bank of river Bhagirathi is severely affected (Rana, 2013), while the three districts Burdwan, Howrah, and Hooghly of the western bank are comparatively less affected. Some parts of Kolkata metropolitan area are also affected by these problems (Das, 2013; 2015). The harmful effects of groundwater arsenic contamination are not confined to our country. Still, it also influences the different countries of the World like Mexico, Chile, Argentina, Bangladesh, Pakistan, and Myanmar, and it is spread constantly (Sing, 2001). The World Health Organization ranked this calamity as "the largest poisoning of a population in history" (Smith et al., 2000).

Arsenic is a natural semi-metallic chemical having no flavor or odor. Historically Arsenic has been accepted as a poison, and many misnomers are attached to this. The impact of Arsenic on human beings is prolonged but is danger from long-term perspective. The chronic effects can appear from its accumulation in the body at even low intake levels for prolonged periods, and toxicity starts from 2 to 20 years (Rana, 2013). Consumption of arsenic-contaminated water has developed arsenicosis patients, suffering from different diseases like lung cancer, bladder cancer, skin cancer, prostate cancer, kidney cancer, nasal cancer, ischemic heart disease (heart attack), diabetes mellitus, nephritis (chronic inflammation of the kidneys), nephrosis (degenerative kidney diseases), hypertension, bronchitis, chronic airway obstruction, lymphoma (tumors in the lymph), black-foot disease, developmental deficit, etc. (Fazal, 2001; Mazumder, 2010; Chaurasia et al., 2012).

These arsenic-related health hazards are strongly associated with the socio-economic and demographic status of the inhabitants of the affected region (Das, 2013; Mahmood and Halder, 2011). It is not only the cause of sickness and death but also causes to increase the health care cost, poverty, decreases the workability and school enrollment as well as finally collapses the socio-economic condition of the people and hamper the human wellbeing (Ahmed et al., 2011; Haq et al., 2012; Das and Roy, 2013).

Since Arsenic affected inhabitants are usually discarded from their family members and society, they are treated as untouchable and remain ostracized. Sometimes husband has divorced their wife due to arsenicosis issues. The toxic effect of Arsenic, diminishes the patients' physical capability and increases the health expenditure, which ultimately increases the economic burden. Such problems have increased due to the lack of necessary treatment and substitute arsenic-free safe water sources, along with illiteracy and the economically poor condition of the people. It also causes to developed the psychological issues among arsenicosis patients. Consequently, arsenic toxicity breakdowns the social and economic status of the people.

Socio-economic status determines the social and economic position of each family or an individual in relation to the others, based on income level, education level, occupational structure, and other parameters. Socio-economic status is an essential key to developing anybody or any family as such progress has covered a multi-dimensional development. An important dimension of such development includes education, health care services, women's position in society, level of nutrition, degree of economic improvement, access to drinking water and communication, etc. It is also considered a process that develops the quality of human and increases their awareness level in various aspects. Groundwater arsenic contamination is one of the serious environmental problems responsible for going up the problem of arsenicosis ailments. Moreover, socioeconomic status is also liable for developing arsenicosis diseases. On the other hand, such disease can hamper the social stability and economic stability of human beings.

1.2. Statement of the problem:

Groundwater arsenic contamination was detected in 1984, in lower Ganga Plain region of West Bengal (Garai et al., 1984). Maldah district is one of the worst arsenic-affected districts of West Bengal. A study has been carried out through seven Arsenic affected blocks of Maldah district, i.e., Kaliachak-I, Kaliachak-II, Kaliachak-III, Manickchak, English bazar, Ratua-I, and Ratua-II which contained beyond the permissible limit of arsenic concentration in groundwater (0.05 mg/ l, Indian standard). In these contaminated blocks, the maximum concentration level of Arsenic in shallow tube wells varies between 0.072 mg/l to 0.929 mg/l (Source: PHE, Maldah, 2018). Based on the secondary data sources, the Arsenic concentration level is comparatively higher in five blocks; i.e., Kaliachak-I, Kaliachak-II, Kaliachak-III, Manikchak, and English Bazar. Ratua–I and Ratua –II have experienced relatively lower amount of Arsenic. The

rest of the blocks contain an insignificant amount, i.e., the permissible limit of Arsenic. Moreover, a considerable number of tube wells of these blocks are contaminated with Arsenic. Hence, in Maldah district, the extensive groundwater arsenic contamination has become a significant issue of concern, where the water supply is profoundly reliant on groundwater (Madhuvan and Subramanian, 2006) extracted from the shallow aquifers. The fundamental aspect of the present research work is to study the socio-economic status of the arsenicosis affected inhabitants of the Maldah district. These affected inhabitants have suffered from the problem of arsenicosis diseases as they have been forced to use Arsenic contaminated water due to the unavailable supply of arsenic-free water. As a basis for this study, the researcher identified the problem to be fourfold. First, the issue is the going up the problem of arsenicosis diseases as the common trace of Arsenic in drinking water ascertains numerous symptoms as well as considerable health risks. Moreover, public health is severely endangered for its high toxicity and ability to create skin cancer after a long-time ingestion (Panigrahi, 2016). Arsenic pollution has been thought to be a menace for the population of Maldah district, where considerable number of people are still suffering from this problem which is really of crucial concern. The second issue is that several social and economic factors influenced the level of occurrences of arsenicosis disease. The third issue is that the problem of arsenicosis and public health risks have affected the arsenicosis patient's social and economic life. It can collapse the social and economic stability of the patient's life and breakdowns the socio-economic backbone of the society. The fourth issue is the necessity to provide arsenic-free water as there are still many pockets in this district where no arsenic-free safe water source is available while supplying arsenic-free safe water by the Department of Public Health Engineering and the Government of West Bengal. It is essential to improve the devastating situation of the arsenicosis inhabitants. Therefore, it is necessary to determine the causes and consequences of arsenicosis diseases in Maldah district and to study the socio-economic conditions of the people suffering from arsenicosis ailments.

1.3. Location of the study area:

Maldah district has been chosen as a study area located within the latitudes of 24^0 40' N to 25^0 32' N and longitudes of 87^0 45' E to 88^0 28' E, covering an area of 3566.17 sq. Km. Maldah district is surrounded by Jharkhand in the west, Bangladesh in the east, Murshidabad district in the south, and Uttar and Dakshin Dinajpur districts in the north. The district comprises two subdivisions: Maldah Sadar and Chanchal. The Maldah

Sadar subdivision consists of English Bazar and Old Maldah municipality, and this district is divided into15 blocks (District Census Handbook, 2011) (Figure 1.1, 1.2)

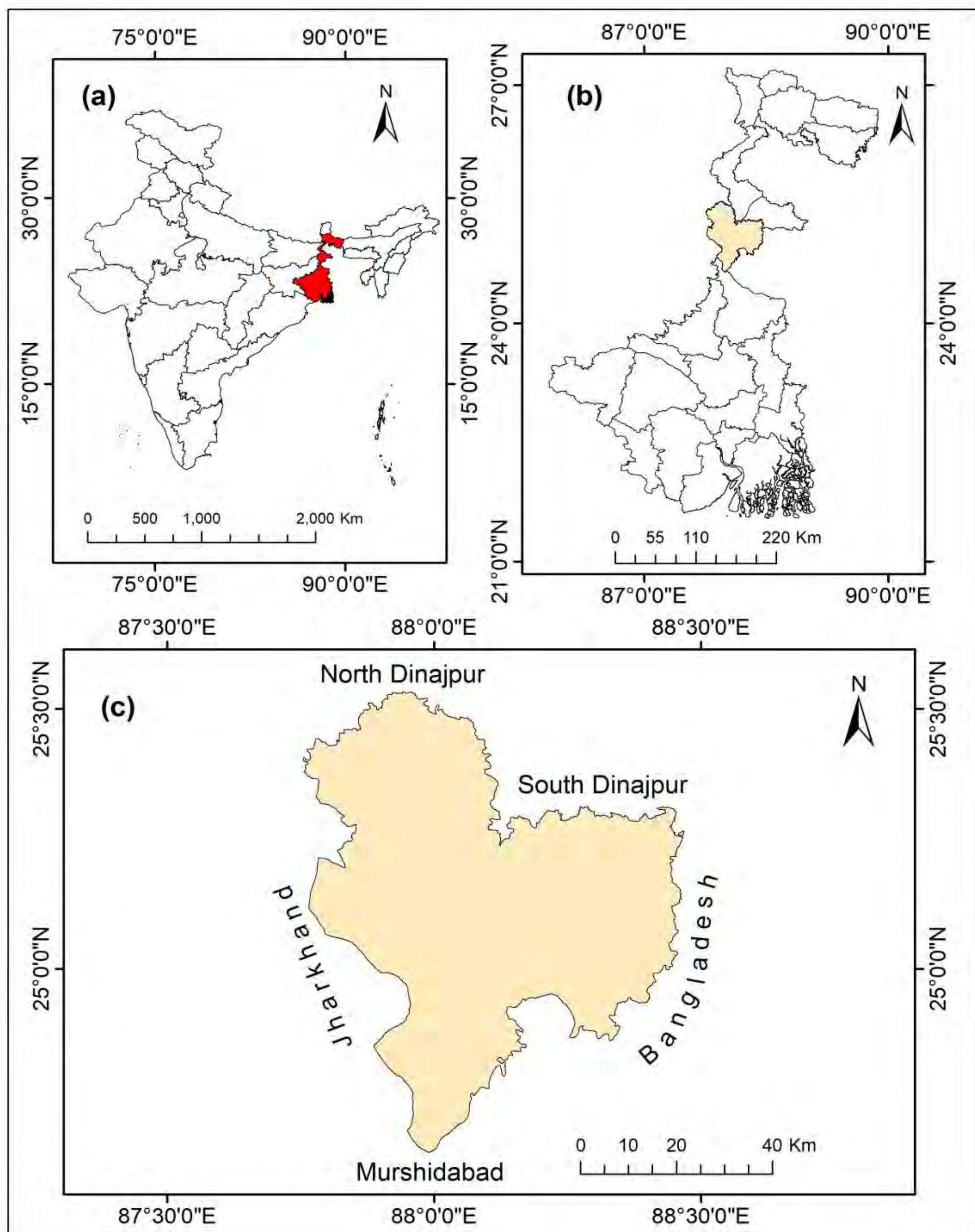

Figure 1.1 Location map of the study area (a) India. (b)West Bengal. (c) Maldah

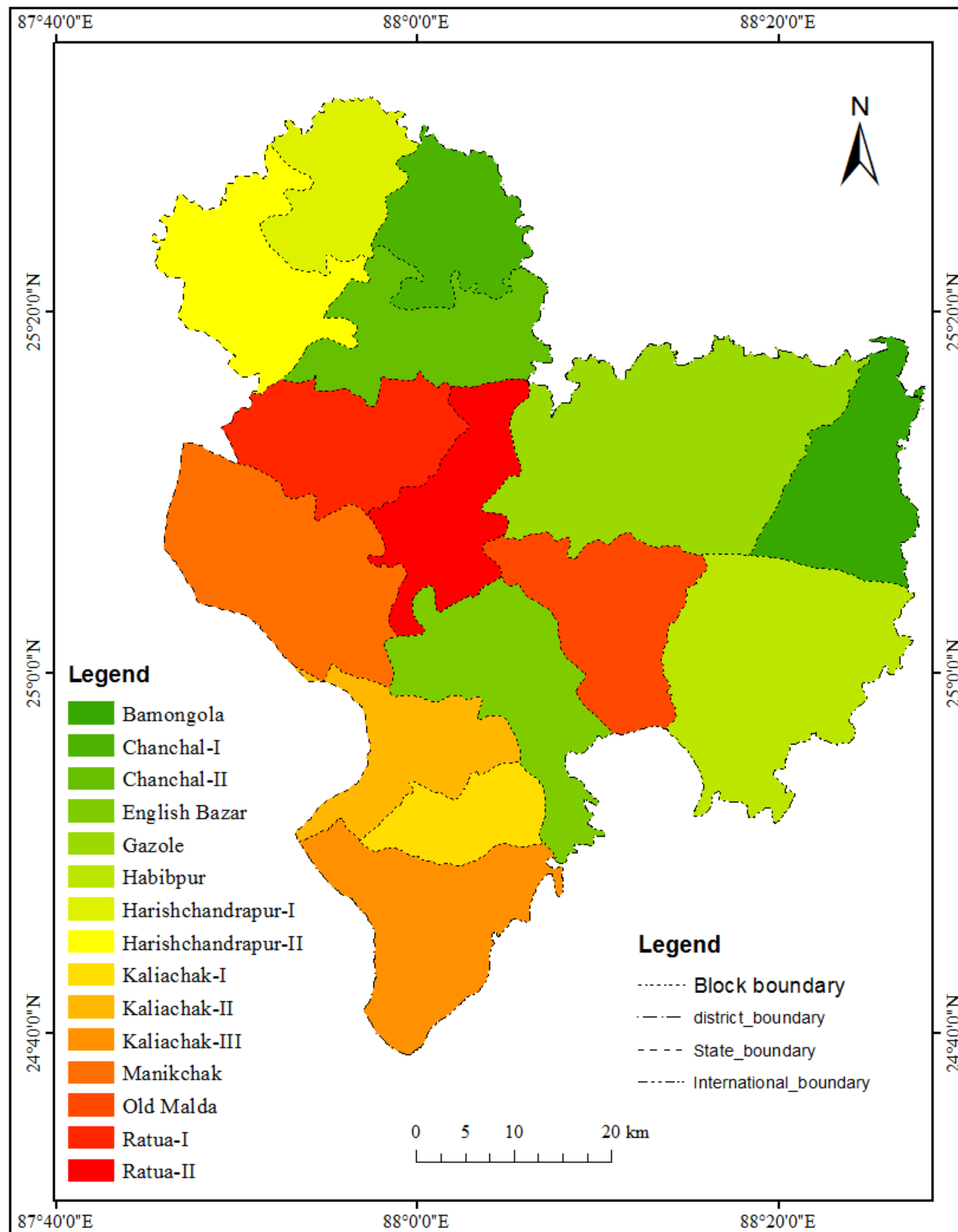

Figure 1.2 Block map of the study area

The characteristic feature of Maldah district is low plain area slanting from northern part to southern part. This area contains alluvial soil creating from different rivers like Ganga, Mahananda, Punarbhaba, Tangon and Kalindi. Physiographically and topographically, the Maldah district can be divided into three broads, 'Ecological Sub Regions,' depending upon the nature of the topography, drainage pattern, and soil. These regions are Barind, Diara, and Tal (Figure 1.3)

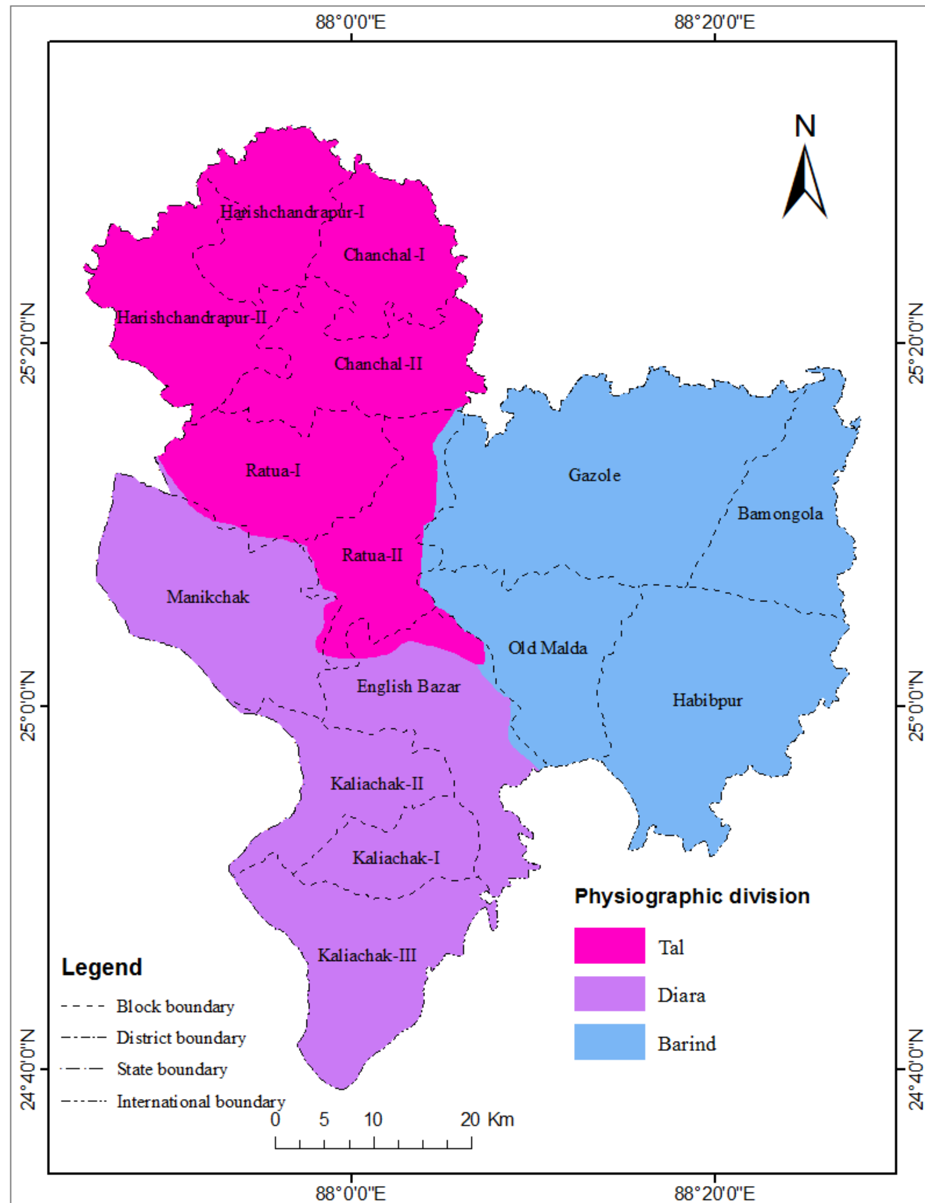

Figure 1.3 Physiographic division of Maldah district

'Barind' plain is characterized by comparatively high lands and the mature alluvium that lies across the eastern boundary of the Mahananda River. Due to high elevation, this area does not contain a considerable proportion of ‘As’ (Arsenic). Some portion of the southwestern part of the ‘Tal’ region has experienced the presence of arsenic in groundwater as significant amount of Arsenic (As) is found in low slope areas. Due to the flat surface, the Diara region has significant arsenic concentration along the downslope area. Furthermore, the economic sources of this study area are mainly depended on different types of rural activities as recorded number of inhabitants have involved in primary sector being the prime source of livelihood.

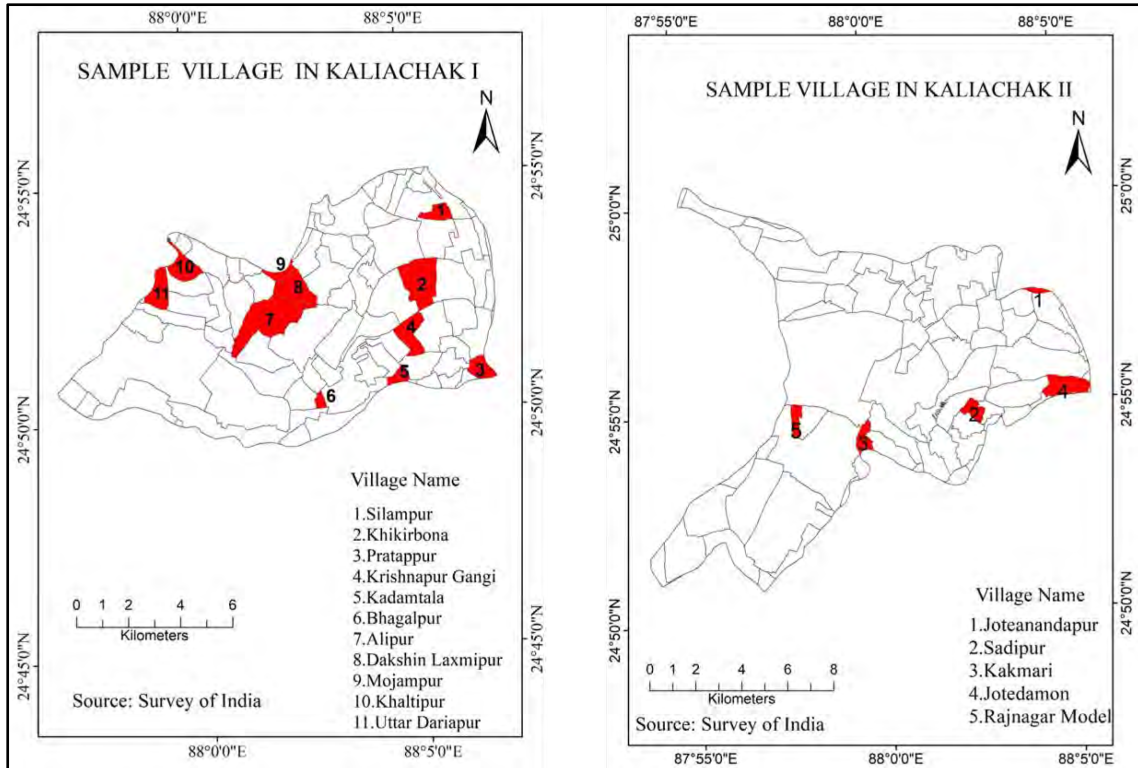

Figure 1.4 Sample villages in Kaliachak-I and Kaliachak-II block

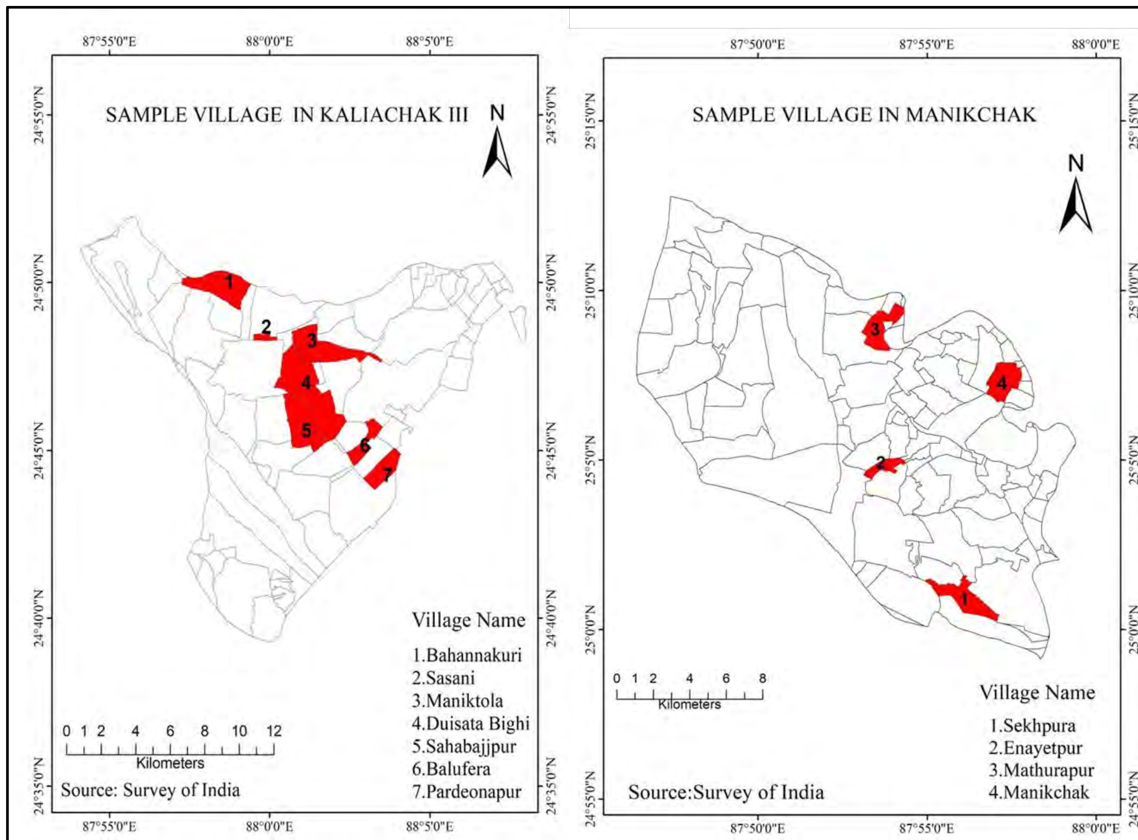

Figure 1.5 Sample villages in Kaliachak-III and Manikchak block

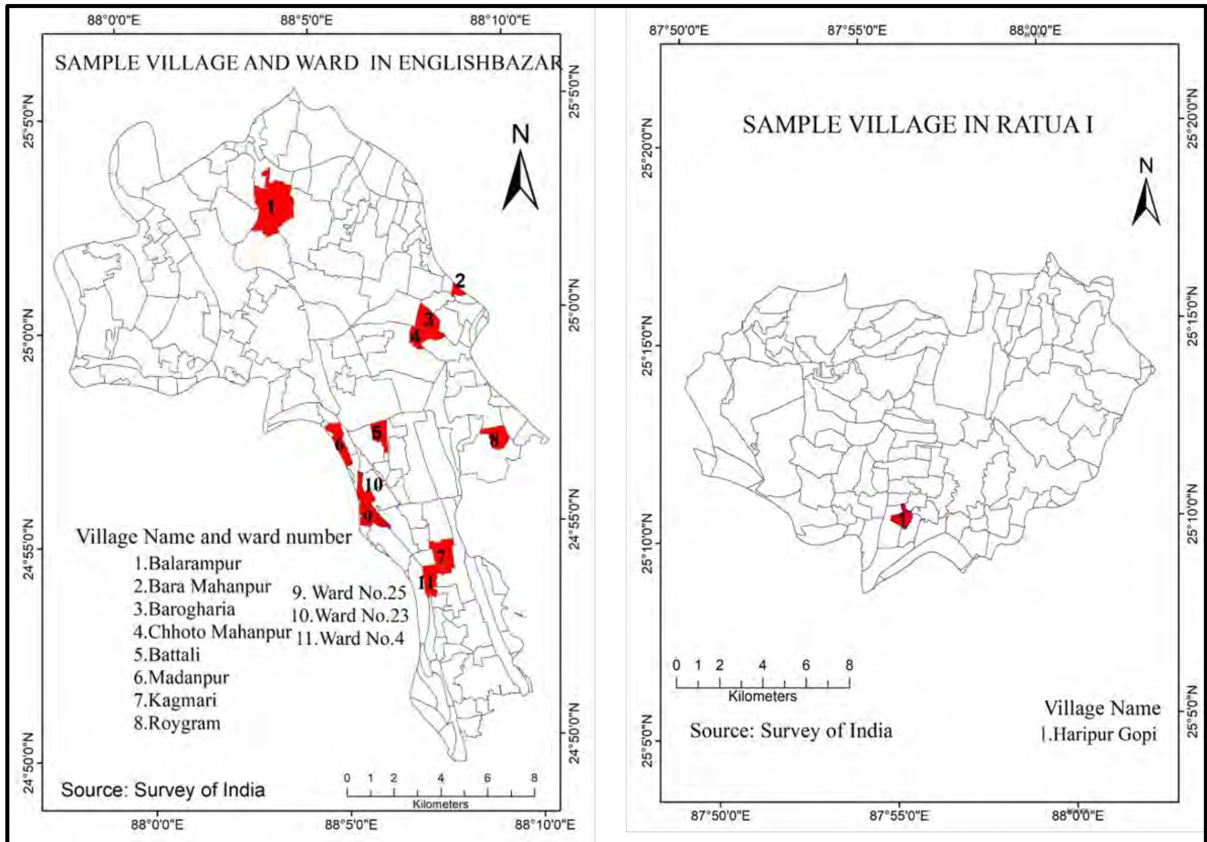

Figure 1.6 Sample villages in English Bazar and Ratua-1 block

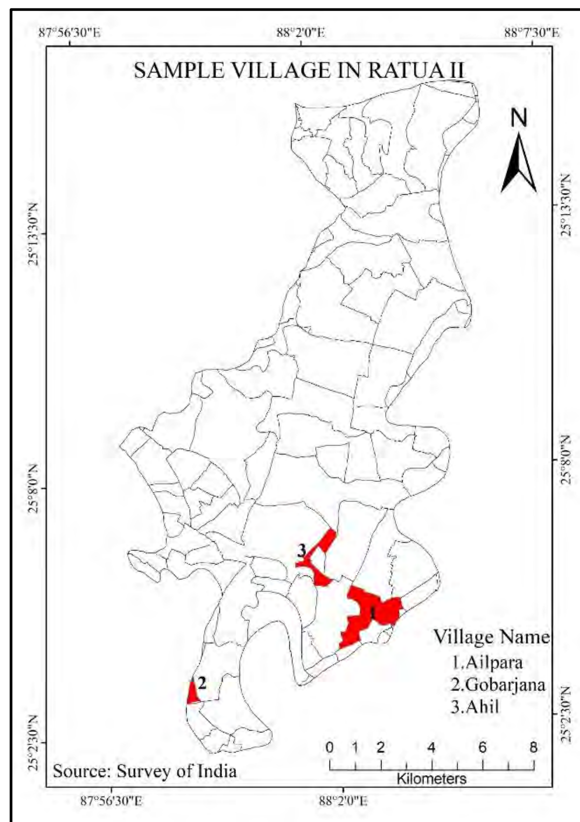

Figure 1.7 Sample villages in Ratua-II block

1.4. Literature Review:

Many articles, seminar papers, research works, books, and various web information have been studied to identify the research gap in this field. In this context, some essential views of renowned researchers have been summarized below.

The National Institute of Hydrology, Patna in 1996-97 prepared a report on Arsenic Pollution in Ground Water in Ganga Plains. They mainly focused on the chemical properties and physical properties of Arsenic. The source of arsenic contamination is an important discussed matters in this report. This report also highlights some processes which control arsenic contamination in groundwater. Occurrences of iron pyrite in groundwater lithology are one of the most important causes of arsenic concentration. This report stated some arsenic determination techniques, i.e., AAS, EM, DC Helium method, DPP HG. It also highlighted the problem of arsenic pollution in Chile, Taiwan, the southeast part of Hungary, Mexico, etc. According to this report, in West Bengal, arsenic pollution occurred due to the geological formation. It has been emphasized that arsenic polluted districts of West Bengal are Maldah, Murshidabad, South & North 24 Parganas, and Nadia. This report also gives some preventive measures for such pollution.

Das et al. (1996), identified the districts of West Bengal under the threat of arsenic pollution and also identified the responsible factors for such pollution. They analysed the efficiency of arsenicosis and mentioned the maximum allowable limit of arsenic in groundwater is 0.05 mg lt-1, as given by WHO. This paper stated that 37 administrative blocks along the river Ganga and adjoining areas are highly exaggerated by arsenic contamination. Groundwater Arsenic contamination has been found in the upper delta plain and is mainly confined in the abandoned meander belts. This paper has also noted that more than 8 00,000 people from 312 villages/ wards are drinking Arsenic contaminated water. Among them, at least 1 75,000 people have suffered from arsenical skin lesions. According to them, in most cases, the source is the geological subsurface bed. They also noticed that various social problems have arisen due to skin diseases caused by the consumption of Arsenic contaminated water among inhabitants of these districts. This paper emphasized, malnutrition, poor socio-economic status, illiteracy, improper food habits, and consumption of arsenic (As) polluted water for several years have increased the problem of arsenic toxicity. They noticed that important sources of

required water for all habitants in all of the concerned districts and massive water-lifting may cause arsenic leaching from the sources.

Fazal (2001), stated the problem of arsenic contamination in groundwater in Bangladesh. He identified two hypotheses: the causes (mobilization) of groundwater arsenic contamination in Bangladesh. One is called "pyrite oxidation," The other is "Oxi-hydroxide reduction." He rejected the pyrite oxidation hypothesis and accepted the oxi-hydroxide reduction hypothesis. He used the validity test, which shows the space-dependent relationship among different hydrogeological parameters for the heterogeneous aquifer system.

Fazal (2001), in his paper titled *"Extent and Severity of Groundwater Arsenic Contamination in Bangladesh,"* attempted to find out the source of Arsenic in groundwater in Bangladesh. He observed the main proportion of the irrigational and drinking water is supplied from underground sources, which are the causes of arsenic contamination in groundwater. He also identified that the source of Arsenic is in the geological deposits. In this paper, he noticed that thousands of people suffer from arsenic diseases ranging from melanosis to skin cancer and gangrene, and many have even died. He has given some suggestions to overcome this problem.

Singh (2001), explained that 20 countries in different parts of the World are suffering from groundwater arsenic contamination. Arsenic concentration is highest in five Asian countries: Bangladesh, India, Mongolia, China, and Taiwan. He identified that massive groundwater lifting had occurred in all of these countries for irrigation purposes. He also discussed about the groundwater arsenic contamination in part(s) of Assam, Arunachal Pradesh, Manipur, Nagaland, and Tripura. He suggested that long-term environmental planning is essential to combat the risk of such pollution.

Madhuvan and Subramanian (2006), focused on the picture of arsenic pollution in Maldah district. They noticed that Holocene sediments being drained by the river Ganga are one of the major sources of Arsenic, which causes groundwater contamination. The main objective of this paper is to provide an assessment of the level of natural Arsenic concentration in stratigraphic profiles of the sediment deposits. The tube wells located between Ganga and Mahananda River in the Maldah district are the main area of arsenic concentration. This paper made some field and laboratory experiments to identify the relationship between arsenic concentration versus pH level of groundwater.

Somaddar and Subba Rao (2007), have given more attention to identifying the level of arsenic concentrations and number of people at risk of death in Murshidabad district. They asserted that six blocks (65%) have less than 0.05 mg l-1 of arsenic in groundwater, 26.12% of the area has experienced more than 0.05 mg l-1 of Arsenic and have reported that about 11,890 people are at death risk due to arsenic threat. Large number of populations have passed away at Domkal and BeldangaI blocks whereas, Bhagabangola block of concerned district has experienced minimum number of death cases.

Purkait and Mukherjee (2008), have emphasized on arsenic pollution in Maldah district. Four blocks, Kaliachak-1, 2, 3, and English Bazar, were critically studied in this paper. They stated that the area exhibits three geomorphological terraces: the present youngest terrace, the older shaugaon surface, and the most aged Baikunthapur surface. They noticed that the arsenic concentrated belt mainly lying within the older terrace and the flood plain which are recently deposited by silvery-white, fine sands, adjacent to the river Ganga, have not contained extensive amounts of Arsenic. But the elevated Arsenic in groundwater was detected in the region away from the margin of the Ganga River characterized with sandy alluvial soils. The oldest terraces further away from the Ganga margin and Barind surface have contained less amount of Arsenic in ground-water. The Barind surface is hard capping with ferruginous sands and lateritic formation. They are chocolate-colored, whereas mottled and purple-brown coloured occur in the northeast of the studied area.

Mahmood and Halder (2011), have found the health effects of arsenic poisoning in Bangladesh and discussed the socio-economic consequences of such poisonous impact along with the prediction of some alternative methods of mitigation as well as a recommendation of several governmental measures to prevent the arsenic poisoning including the surface water treatment, arranged through the various educational programs, also with the special supports of Government and NGOs. Besides this, they have focused on the affected people's socio-economic condition and finally found out that most low-income families have suffered from this problem.

Chaurasia et al. (2012), have evaluated that maximum arsenic concentration above the permissible limit in groundwater is present in the phreatic younger alluvium of Ganga and Ghaghara rivers along the meandering course. The authors have also discussed different diseases caused by highly arsenic contaminated water intake. This paper also

mentioned some diseases like skin cancer, ulcers, pigmentation in the skin, and hardening in the palm. The authors have used different analytical methods that provide detailed information like the quantity of arsenic in water, its impact and the risk factors, and some measures which can prevent such pollution.

Haq et al. (2012), have observed, the southern part of Pakistan is highly affected by groundwater arsenic contamination, severely affected the human life. On the other hand, scarcity of safe drinking water is another existing problem in this part of Pakistan. They conducted a household survey to accumulate the information about some required socio-economic variables to prepare their studies. About 50% of the population have experienced arsenicosis symptoms and have invested their earnings for treatment purposes. They also emphasized on poverty and illiteracy as these are the causes of people's unawareness about the adverse impact of arsenic pollution.

Hoque (2013), have attempted to discuss about arsenic pollution in North 24 Parganas and mentioned the dangerous level of Arsenic in drinking water, its sources, and its impacts on human health and also create some awareness among the rural people about the preventive measures. But he pointed out that taking Arsenic through drinking water or other forms is not always harmful to health to a certain degree. It becomes effective when its intake is over the danger level, and the people's lack of awareness about arsenic pollution and ignorant attitudes are the causes of arsenicosis diseases. He has suggested some initiatives taken by Government, semi-Govt organizations, and other individuals to generate awareness among the general people.

Das (2013), have studied the impacts of social and demographic factors of arsenicosis in the Murshidabad district of West Bengal. The most significant finding of this study is that the most Arsenic affected people are the poor, male, working-class mainly associated with agricultural activities, and the poor people cannot afford medical and health care costs. Gender disparities regarding the medical treatment between male and female patients are crucial issues in this district. The respondents' income, age, gender, and education status play a significant role in augmenting or lowering this risk, which was identified by using the Logistic regression model.

Rana (2013), have identified the extent and causes of high occurrences of Arsenic in groundwater in different districts of West Bengal. In this paper, he highlighted the scenario of arsenic pollution in the Maldah district. He observed the six blocks in the southwestern part along the Ganga River, i.e., KaliachakI, Kaliachak-II, Kaliachak-III,

Manikchak, Englishbazar, Ratua-II, are highly affected. He also mentioned the impact of Arsenic on human beings and the different diseases attached to this. In this paper, some secondary data have been used to depict the arsenic contamination in Maldah district.

Das and Roy (2013), have observed millions of people of West Bengal have faced the problem of arsenic contamination in groundwater and have been affected by several arsenic-related health diseases due to intake of the contaminated drinking water. It hampers the social as well as the general well-being of human life. In this paper, the authors conducted a household survey. They identified that 20 villages of Jalangi blocks and Raninagar II block of Murshidabad district have suffered from this problem. They also observed the significant effects of groundwater Arsenic contamination on social life. Different arsenic-related health diseases have diminished the labor productivity, ability to income-earning process, longevity, etc.

Panigrahi (2016), in his paper titled *"Groundwater Arsenic Contamination: A Study of Maldah District of West Bengal, India,"* elaborates the scenario of arsenic contamination in Maldah district. The severely affected blocks of Maldah district are Kaliachak-I, Kaliachak-II, Kaliachak-III, Manikchak, Englishbazar, and Ratua-II. According to their findings, the maximum value of Arsenic concentration is found in Manikchak and Kaliachak i.e., <0.01 mg/L to .08 mg/L. In his research work, he has explained that mainly two reasons are responsible for the arsenic contamination in groundwater in Maldah District. One is groundwater consumption for drinking purposes and the Boro cultivation, which is dependent mainly on tube well irrigation. The concentration of Holocene sediments mostly contained Arsenic, originating from the Himalayas along the Ganga River. He also noticed that different health diseases have arisen due to the intake of Arsenic contaminated water during an extended period. In this paper, he has used several cartographic techniques.

Santra (2017), has evaluated that 20% population of nine districts in West Bengal are suffering from the problem of arsenic contamination through the consumption of contaminated water and food grains. Consequently, some health and social issues have arisen, but he noticed that most economically poor and illiterate people have suffered from this problem. According to an awareness level of the people through their education, people must mitigate such kind of problem.

Bhardwaj et al. (2019) studied present status of arsenic remediation of India. They estimated that nearly 26 million people in West Bengal are potentially at risk from arsenic contaminated drinking water. On the other hand, Maldah is categorized highly arsenic-affected district in West Bengal (School of Environmental Studies (SOEs), Jadavpur University). They reviewed various arsenic removal techniques and suggested some long-term and short-term arsenic remediation measures. Central and State governments have taken different mitigation plans for providing arsenic free drinking water, but the gap still exists.

Khanam et al. (2021) measured arsenic contamination in soil, irrigation water, and rice plant of five blocks of Maldah district, namely, Manikchak, Kaliachak-I, Kaliachak-II, Kaliachak-III, and Ratua-I. They summarized that maximum concentrations of arsenic in irrigation water and soil are found in the Manikchack block, followed by KaliachakIII, Kaliachak-II, and Kaliacghak-I blocks. They also concluded that in remote areas of the district, people have been consuming arsenic-contaminated drinking water, arsenic tainted rice due to a lack of awareness; as a result, arsenic associated health hazards increased day by day.

Majumder and Bhunia (2022) studied arsenic-contamination in groundwater using the geostatistical approach in the Karimpur block of the Nadia district. They found that shallow groundwater was highly arsenic contaminated. They also concluded that the maximum concentration of arsenic in groundwater is found in pre-monsoon season due to high groundwater withdrawal.

1.5. Research Gap:

A Survey of the relevant literature on the socio-economic study of the inhabitants affected by arsenicosis ailments showed that very few works had been done on this perspective in India. However, some research on this aspect has been done in the neighbouring country of Bangladesh. The School of Environmental Studies group, Jadavpur University (SOES), has also conducted a comprehensive study on arsenic contamination in West Bengal. But no systematic work has been done by any scholar so far on the socioeconomic aspect of arsenicosis inhabitants, hence there is an urgent need for investigation and analysis on this crucial aspect. Certain research gaps have been identified by the present researcher, which are now laid down as follows

a) Most studies have been carried out to determine the status and sources of arsenic toxicity in groundwater.

b) Maximum works have been intended to determine the impact of arsenic contamination on human health only.

c) On the other hand, very limited works have emphasized the socio-economic study of the arsenicosis affected people in West Bengal. Such kind of research work has been confined to the few districts of West Bengal, i.e., Murshidabad, Nadia, and South 24 Parganas.

d) No work has so far been done on these aspects. The socio-economic studies of the arsenicosis affected people in the Maldah district are not studied extensively previously. But it attempts to recognize the socio-economic study as causes of the spread of arsenicosis in the arsenic hit areas of Maldah district because there is a clear link between the socio-economic status and arsenic exposure. The households' socioeconomic condition also deteriorates due to arsenic poisoning. Hence, the present research work will examine the socio-economic status of the people suffering from the arsenicosis diseases in Maldah district.

e) None of the scholars highlighted the respondents' willingness to pay (WTP) to install the arsenic-free water supply sources at community level by applying the Binary Probit Model. Through this research, we shall know the respondents' opinions regarding Arsenic-free safe water and their perception of the public health risk of consuming arsenic-contaminated water. These factors may have a considerable impact on WTP. Hence, such research can help in decision-making strategies concerning the demands of regular and permanent supply of arsenic-free safe water to the population suffering from arsenicosis.

Therefore, it is necessary to take a holistic view of this issue and view it from a policy perspective.

1.6. Aims and Objectives of the study

The present study has the following research objectives –

1. To study the spatial distribution and causes of arsenic concentration in groundwater in Maldah district
2. To study the socio-economic status of the arsenicosis inhabitants in the study area
3. To study the socio-economic determinants of arsenicosis in the study area

4. To assess the impact of arsenicosis on the health and socio-economic condition of the inhabitants in the study area
5. To find out the present status of demand and supply of arsenic-free safe water in Maldah district
6. To suggest some remedial measures to overcome the problems of arsenicosis

1.7. Hypotheses:

The present study tries to prove the following research hypothesis, either true or false:

1. The prevalence of arsenicosis varies with some socio-economic determinants.
2. The impact of arsenicosis is related to some socio-economic variables.
3. Willingness to agree with mitigation strategies depends on the socio-economic condition of the respondents.

1.8. Methodology:

Keeping in mind the objectives mentioned above, the hypotheses and methodology adopted by the present researcher are rationalistic, based on the quantitative method depending on both primary and secondary data.

1.8.1. Primary Data:

Primary data has been collected from the Arsenic affected areas of the study area through a survey using a schedule and questionnaire method.

1.8.1.1. Coverage and design of sample:

Keeping in mind the hypotheses of the study, the multi-stage random stratified sampling design has been adopted. The district consists of three physiographic regions, i.e., Tal, Barind, and Diara, and is divided into 15 administrative blocks. **In the first stage**, physiographic division of 'Diara' and Tal (south western part) have been chosen due to its high arsenic concentration. The district has 1,613 inhabited villages, as per the 2011 census. The number of inhabited villages/wards for the individual physiographic divisions, blocks, and municipalities is shown in Table 1.1

Table 1.1 Number of inhabited Villages

Subdivisi on	C.D.Block	Inhabited villages/wards	Households	Physiographic division
		2011	2011	
Chanchal	Harishchandra pur-I	104	44284	Tal
	Harishchandra pur-II	73	49311	
	Chanchal-I	98	49273	
	Chanchal-II	90	43218	
	Ratua-I	95	56241	Partly Tal and Diara
	Ratua-II	48	43168	
Maldah Sadar	Gazole	286	75068	Barind
	Bamongola	141	32154	
	Habibpur	233	47951	
	Old Malda	112	33629	
	Old Malda(M)	18	16479	
	English Bazar	108	58815	Diara
	English Bazar(M)	25	42867	
	Manikchak	72	59567	
	Kaliachak-I	49	80508	
	Kaliachak-II	40	44913	
	Kaliachak-III	65	69545	

Source: Census of India, 2011

On the other hand, the physical environment such as climate, structure, relief, drainage, and soils are quite homogeneous across the Diara tract while varying amongst the physiographic division (Barind, Taal, Diara) of Maldah district, but these broad parameters are comparatively similar within the physiographic region. But, the socioeconomic parameters of the Arsenic affected villages are varied within the physiographic area. Keeping in mind these variations, sample villages have been identified randomly using the random table in **the second stage** (Table 1.2). The sample size among the seven blocks of Diara physiographic division and south western part of Tal region have been calculated using G*Power 3.1.9.7 software. Using this method, the estimated sample villages are 42. In these Diara and Tal tract, all seven blocks have been covered for sampling. For the purposes, simple random sampling with a non-proportionate technique has been adopted due to variations of arsenicosis patients

among the villages. The whole Maldah district as a study area also calculated N/n ratio in which 'N' is the total number of inhabited villages, while 'n' is the total number of sample villages, i.e., 1657 (including the inhabited municipal area of English Bazar block)/42 = 39.45. Using this relationship, 1 sample village represents every 40 villages of Maldah district.

Table 1.2 List of the sample villages

Block	No. of surveyed villages	Random number	Sample villages
Manikchak	4	53, 17, 3, 1	Mathurapur, Sekhpura, Manikchak, Enayetpur
Kaliachak I	11	2,24,31,42, 13,41,30,5, 29,26,24,	Dakshin Lakhsmipur, Silampur, Krishnapur Gangi, Jalalpur, Mojampur, Khaltipur, Alipur, Bhagalpur, Khikir Bona, Uttar Dariapur, Kadamtala,
Kaliachak II	5	15,23,18,12,7	Jotanandapur, Sadipur, J Kakmari, Jotdomon, Rajnagar Model
KaliachakIII	7	2,27,21, 6,28,58, 39	Bahannakuri, Maniktola, Sasani, Duisata Bighi, Sahabajpur, Deonapur, Balufara,
English Bazar	11	4 No. word, 25 No. word, 23 No. word	Roygram, Bara Mohanpara, Madanpur, Balarampur, Barogharia, Battalli, Chhoto Mohanpara, Kagmari
		65,15,11,64,4, 83,94,57	
Ratua I	1	24	Haripur Gopi
RatuaII	3	31,44,3	Ailpara, Ahil, Goborjana

Source: Calculated by present researcher

Plate1.1 Household survey. Data collected from Health worker and arsenicosis patient

After selecting the sample villages, Arsenic **affected households have been identified in the third stage** of sampling. Then, the desired sample size was calculated by using Cochran's method (Cochran, 1963), as regards the minimum sample size approach adopted wherein among all the observations pertaining to various variables, lowest prevalence was anticipated at 25 percent, required minimum sample size came to be 288 at 95 percent level of confidence. The following formula has been used

$$N = \frac{Z^2PQ}{E^2} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots .1.1$$

N= Sample size

Z= Z value found in the Z table at a given confidence interval

P= Estimated proportion of an attribute that is present in the population

Q = 1-P

E= Desired level of precision

To overcome the unavoidable circumstances, number of non-response rate of about 4 percent of the sample respondent is proposed to cover a sample of 300 instead of 288.

1.8.2. Secondary Source of Data:

The secondary data has been collected from various secondary sources. The Arsenic affected information has been collected from Primary Health Centers; various Block Health Centers of the district; District Hospital, Maldah; District Census Handbook, Maldah of 2011; Public Health Engineering Laboratory; Paschim Banga Vigyan Mancha, Maldah. The information regarding the physical environment, the drainage system has been collected from the satellite imageries.

1.8.3. Method of data analysis

After collecting primary data by supplying a questionnaire to the respondents, the information was coded, edited, tabulated, and presented systematically in tables to enable purposeful analysis and meaningful interpretation.

1.8.3.1. Statistical Tools

The data is analysed, by using the statistical techniques of Arithmetic Mean, Standard Deviations, Paired T-Test, Binary probit model, Likert scale, and other suitable descriptive and inferential statistics. The Statistical Package for the Social Science (SPSS) version 25 and R version 4.0.2 was used to calculate these statistics.

1.8.3.2. Lower bound and upper bound at 95 % interval

The statistical technique, lower bound at 95 % interval and upper bound at 95 % interval, has been used to identify the upper and lower limit of the respondents' perception regarding the socio-economic and health vulnerability of the sample

respondents through the arsenicosis illness. Generally, Lower bound at 95 % interval and the upper bound at 95 % interval measure the expected upper and lower limit of the respective variables from the true mean.

1.8.3.3. TOPSIS method

The study of the prevalence of arsenicosis is important to identify the most significant determinants of arsenicosis issues. The fourth chapter applies the MCDM technique to explore the level of prevalence of arsenicosis of each sample respondents. A few criteria are considered to examine the prevalence of sample respondents' knowledge, attitude, and practices about such problems. Similarly, the respondent's awareness about this problem is also evaluated. The MCDM TOPSIS is applied to rank the different criteria and an equal weight (0.042) has been assigned to each criterion. The MCDM tool called TOPSIS is applied to rank the different criteria weights. TOPSIS method is a problem-solving approach used when exact results are not obtained for any multifaceted and real-world problems.

1.8.3.4. Likert scale

The socio-economic and health impact of arsenicosis is assessed through a scaling technique in chapter four and five. Likert five-point scales are applied to collect the data regarding the level of different (social, economic, health) impacts related to arsenicosis illness and arsenic contamination. The social, economic, and health-related variables are measured on the Likert scale, and scores are assigned for each statement.

1.8.3.5. Socio-Economic-Health Vulnerability Index (S.E.H.V.I)

A self-created S.E.H.V.I (Socio-Economic Health Vulnerability Index) has prepared in chapter five (5) to measure the perception level of the respondents regarding the overall (social, economic, health) impact of arsenicosis. The respondents' perception level about the vulnerability in different domain (social, economic, health) can be assessed through Socio Economic Health Vulnerability Index (SEHVI). Analysis of these different vulnerability (social, economic, health) among arsenicosis patients in Maldah district highlights the socio-economic impact of arsenicosis. For this purpose, individual S.V.I (Social Vulnerability Index), E.V.I (Economic Vulnerability Index), and H.V.I (Health Vulnerability Index) have been prepared. Then social, economic, and health vulnerability scores have also been calculated through the scaling technique and consolidated efficiently through a Socio-Economic Health Vulnerability Index.

Each vulnerability (social, economic, and health) is assessed at five stages. They are 1. Strongly disagree 2. Disagree 3. Neutral 4. Agree and 5. Strongly agree.

1.8.3.6. ANCOVA

ANCOVA is applied in chapter five to test the main and interacted effects of categorical variables on a continuous dependent variable, controlling for the impact of selected other continuous variables, which co-vary with the dependent. Few independent socioeconomic variables are chosen to solve this statistic. These are 1) family size 2) age 3) monthly household income 4) marital status, etc. Different social, economic, and health impacts are considered as dependent variables. A one-factor ANCOVA is an attempt to evaluate the relationship between each of the impact and the variables by measuring the effect of the socio-economic status of the arsenicosis inhabitants.

1.8.3.8. Karl Pearson's technique of product-moment coefficient of correlation and 't-test.'

Karl Pearson's technique of product-moment coefficient of correlation have been estimated in chapter five to examine the relationship between the indices of different vulnerability as Social Vulnerability Index and Economic Vulnerability Index, Social Vulnerability Index and Health Vulnerability Index, Economic Vulnerability Index, and Health Vulnerability Index, and 't-test' technique has been adopted to identify the level of significance of their correlation.

1.8.3.9. Willingness to Pay (WTP)

A Binary Probit Model has been applied in chapter six to study the factors that might have influenced the respondents' willingness to pay for installation of arsenic-free water supply sources at community level. Respondents' WTP is defined in two categories, i.e., zero and one, according to the respondents' responses during the survey. Zero WTP depicts that the respondent is unwilling to pay while one shows that the respondent is willing to pay. The responses, i.e., respondents' WTP was considered as the dependent variable. On the other hand, the factors (socio-economic) that influence people's WTP, i.e., independent variable, consisted of age, sex, marital status, number of years spent in formal education, and households' average monthly income.

A survey has been conducted to gather detailed information about the respondents' perception level regarding arsenic pollution and their preferences and choice of technologies (submersible, deep hand tube well, domestic pipeline) for acquiring

arsenic-free water. Four different levels of charges for each of the mentioned technology were quoted during the interview in each area. The respondents were asked to choose the three options of submersible, deep hand tube well, and domestic pipeline.

1.8.4. Cartographic Techniques

The calculated data are plotted by suitable cartographic methods such as histograms, line graphs, bar graphs, pie charts, etc., through MS Excel and MS office to portray or document the facts.

1.8.5. GIS

Maps were prepared under the GIS platform. Global mapper and Arc GIS 10.3 software were used to create a spatial database.

1.9. Limitation of the study

The present research work has assumed to study the socio-economic status of arsenicosis inhabitants in Maldah district. The researcher has acquired different primary and secondary data from various reliable sources. On the other hand, a household survey was conducted to collect the primary data. Some primary data has also been collected from several government offices like Paschim Banga Bigyan Manch, Maldah, Public Health Engineering Department, the health center of different blocks, etc. The researcher has no control over the nature and quality of primary data as these data have been acquired directly from respondents. Occasionally, the respondents are too unwilling to deliver truthful information due to lack of knowledge, lack of awareness, and some hesitation due to fear and some unexplained reason.

1.10. Conclusion:

In this chapter, the researcher has tried to mention the problem, location of the study area, aims and objective of the study, hypothesis of the study, different data sources, and methodology. Moreover, this chapter also highlights the coverage and sample design adopted for the study. At the same time, some selected literature reviews directly or indirectly related to this study have also been incorporated in this chapter.

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