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Impact of Brick Industries on Geo-Environment Alongside the Bhagirathi-Hugli River, West Bengal, India using Statistical Techniques and RS and GIS Applications

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Abstract: ***Brick industry assigns a vital role in the commercial and economic activities along sides of the river Bhagirathi-Hugli in this study area. These activities affect on geo - environment of these areas. For this, the study was analysed the present scenario and impact of brick industries on geo-environment along the Bhagirathi-Hugli River between Nadia and Purba Bardhaman districts, West Bengal, India. The statistical techniques, sinuosity index, water quality index, Remote Sensing and Geographical Information System applications were discussed. Most of the brickfields within the study area were established in recent times over the year 2000. Different statistical techniques are used to check the soil fertility of agricultural land around the brickfields within the study area. The study appeared the standard of the soil is failing close to brickfield from far due to activities of brick making. At the right side of the riverbank, brickfields were highly concentrated (70) than the left side (31) but the erosion at the right side (14.17 km²) of the river was lower than the left side (22.45 km²). It is critically noticed during the fieldwork that various human activities related to brickfields lead to severe effects on the river channel morphology and create different geo-environmental problems. Water quality was a significant difference between the close and far distance of brick kilns in the river water. Brickfield workers suffered from various health problems. The activities of this industry are also harmful to the effects on the environment and the river. For inaction of contamination, the brickfield proprietors must comply with the principles and guidelines set up by the administration right now.***

Keywords: Brickfield, Deterioration of land, Riverbank erosion, Loss of soil fertility, Sinuosity Index, Water quality index

1. Introduction

Brick is a pricy building material. Indian brick industry is the second biggest brick manufacturer in the world after China [1]. Brick industry is conventionally a bungalow industry which produces bricks for neighbourhood consumption [2]. It is a vital economic activity that has been concentrated [3] along the perimeters of the river Bhagirathi-Hugli of the study area. This region is an alluvial formation of the streams having a place with the Ganga-Hugli river system [4]. In recent times, it has been found that most of the brick industries tend to be located beside the river bank due to a constant supply of raw materials of brick, like mud, sand and water. Yet it establishes the significant part of the economic activities, it has some harmful consequences for the waterway and its tributaries. Soil cutting from the river bank and lifting of sand from the river bed by brickfields leads to severe effects [5-7] on river channel morphology [8, 9]. These illegal practices occur bank erosion that leads to loss of property and life. It also multiplies silt charge [10] and consequently, the river becomes shallow and deteriorates rapidly [11] due to the emission of pollutants from the brick kilns as well as the leaving of garbage alongside the river [12].

Three rivers of moribund deltaic Bengal mainlyBhagirathi, Mathabhanga, and Jalangi got here to be known as Nadia Rivers [13-15]. The Bhagirathi-Hugli River is taken into consideration because of the lifeline [12] of Nadia and Purba Bardhaman districts as well as West Bengal. This river is one of the primary distributaries of the Ganga River. After originating from the Ganga River near Mithipur in Murshidabad, it's far flowing through the districts of Murshidabad, Nadia, Purba Barddhaman, Hugli, Howrah, Medinipur and lastly falls into the Bay of Bengal. The Bhagirathi is commonly known as Hugli from the confluence of the river Jalangi at Swarupganj in Nabadwip towards downstream.

The brick industry has been highly concentrated on the sides of the river Bhagirathi-Hugli of the study area. Most of the brickfield has been developed over the year 2000 in the agricultural land of the riversides. It is a significant economic activity that is one of the principal operators of topsoil loss and environmental degradation. These activities are decimating enormous areas of agricultural land every year. It has some evil effects on the geo - environment. Indiscriminate cutting of topsoil from the fertile agricultural land, river banks and lifting of sand from the river bed by brickfields lead to a severe impact on geo-environmental such as loss of soil fertility, riverbank erosion, changes in the river channel, degradation of water quality, deterioration of land and the adverse effects on the health of the brick-field workers. An attempt has been made to study (i) the present scenario and growth of brick industries and (ii) to assess the impact of brick industries on geo-environment alongside the Bhagirathi-Hugli River between Nadia and Purba Bardhaman districts.

2. Materials and Methods

2.1 Study Area Description

The selected course of the Bhagirathi-Hugli River is forming the district boundary between Nadia and Purba Bardhaman Districts. This particular watershed area is located in the

heart of the Bengal Delta [16]. The latitudinal and longitudinal extension of the study area lies between 23°12'08.20" N to 23°46'11.88" N and 88°05'05.44" E to 88°29'43.50" E. Its area is 955.45 Sq. Km. (Figure 1). The average annual rainfall is 1455 mm with maximum concentration in June-July. The rainfall is not uniform throughout the districts, the northern and the southern parts receiving more rain than the central part. The average maximum temperature is 36ºC and the average minimum temperature is 8ºC [17]. This river bifurcates the study area into two halves where the Nadia district is located on the eastern bank and the Purba Bardhaman district is on the western bank of the river. The Bhagirathi is commonly known as Hugli from the confluence of the river Jalangi towards downstream. Within the study area, the Bhagirathi-Hugli River is having a length of about 122.4 km.

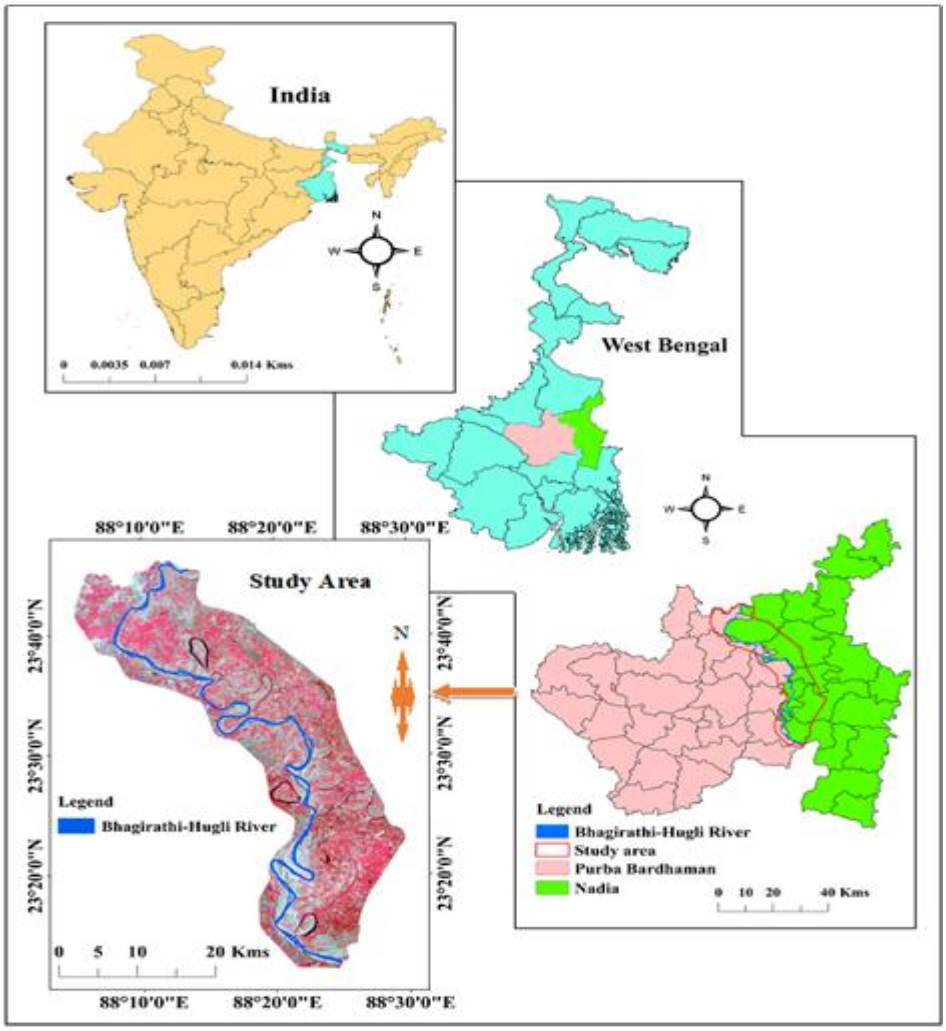

Figure 1: Location map of the study area

2.2 Study Area Extraction

To accumulate materials for the study an intensive survey has been carried out from December 2016 to January 2019. Details information of brickfields, morphological and hydrological regimes of the river Bhagirathi-Hugli are collected in the study area. 1972/1973 Survey of India topographic maps of 1:50000 scale and Google maps are also used to delineate the study area boundary. All of these have been done by using suitable RS and GIS software environment.

2.3 Location of the Brickfields

There are 101 brickfields within the study area along the Bhagirathi-Hugli River banks (Figure 7). Among such 101 Brickfields, only 70 brickfields are located along the right side and 31 brickfields are located along the left side of the river. Out of 101 brickfields, 58 brickfields are located in the Purba Bardhaman and 43 brickfields are located in the Nadia district along the river in the study area.

From the study, it is found that 98 brickfields are located within 1.5 km from both sides of the river bank among which 69 brickfields are found within 0.5 km, 18 brickfields are found within 0.5 to 1 km and 11 brickfields are found within 1to 1.5 km. Only 3 brickfields are located far from the riverbanks. It is shown that most of the brickfields of the study area are concentrated within 1 km from both sides of the riverbank due to a constant supply of alluvium.

2.4 Materials

Materials for the present study, which an intensive survey has been carried out during the period December 2016 to January 2019 to get the detail information of brickfields,

morphological and hydrological regimes of the river Bhagirathi-Hugli in the study area. Topographical maps (1972-1973) of the 1:50000 scale have been collected from the Survey of India (SOI). Satellite images (1989, 2001, 2011 and 2017), SRTM DEM (2000) and ASTER DEM (2011) have been downloaded from the USGS Erath Explorer website (Table 1).

Table 1: Data used for the study and analysis

Reference system (Path and Row)	Satellite/ Sensor	Date of Image	Spatial Resolution/ Scale	Map No./No. of Band Used
	SOI Topographical Map	1972-73	1:50000	79A/1, 79A/2,79A/6, 79A/7,79A/8, 79B/5
WRS_138 & 44	Landsat_5/TM	01.04.1989	30 m	1, 2, 3, 4
WRS_138 & 44	Landsat_7/ETM+	26.04.2001	30 m	1, 2, 3, 5
WRS_138 & 44	Landsat_5/TM	11.04.2010	30 m	1, 2, 3, 5
WRS_138 & 44	Landsat_8/OLI_TIRS	14.04.2017	30 m	2, 3, 4, 5

Spatial Data Source: *USGS & SOI*

2.5 Methodology

SOI topographical maps (1972-1973) of the 1:50000 scale and Google maps are also used for the study area boundary map. The location of the brickfields has initially identified from the Google image and after then verified with the help of GPS during the field survey. The methods that were used for this study is a case study and in-depth interview method that has been generated on 101 brickfields situated along the river course within the study area. Satellite images and DEM at different times have been used for hydro-morphometric analysis by using suitable RS and GIS software.

To check the soil fertility of agricultural land around the brickfields within the study area of the Bhagirathi-Hugli river basin, 18 samples have been collected from 6 brickfields of distance 100, 400 and 800 meters respectively of depth 0-25 cm. It has been carried out by determining the chemical properties such as N, P, and K of soil. After collection the soil samples, these are transported to a laboratory for preparation and analysis. Twenty four farmers who were presented in the agricultural field during soil sample collection are interviewed about cutting topsoil by the brick owner and soil fertility. Different statistical methods such as minimum, maximum, mean, standard deviation (S.D.) and coefficient of variation (C.V.) are calculated in determining the centrality of soil sample data. The higher value of standard deviation indicates that the data points are spread out over a wider range of value and lower value of standard deviation implies similar sample contents [18]. The coefficient of variation (C.V.) is a normalized measure of the amount of dispersion around the mean [19]. The higher C.V. indicates a greater level of dispersion around the mean. It is generally expressed as a percentage. Without units, it consents for comparison between allocations of values whose scales of measurement are not comparable. The low coefficient of variation stands for a more precise estimate.

To determine the area of erosion and deposition, two riverbank lines are prepared for the years 1972/73 and 2017. The length of arcs of each the left and right banks for all the above years is calculated using GIS software. Digitizing, extracting, mapping and analysing the whole features in this study, suitable GIS software tools are used. Extensive field surveys and toposheet are used to identify the location of riverbank erosion and migration.

Sinuosity Index has been defined by Leopold and Wolman [20] as follows-

$$SI = Lc / Lv \quad \text{(I)}$$

Where Lc= Channel thalweg length, Lv= Valley length. According to them, channels are defined as straight when the sinuosity index (SI) is less than 1.05, sinuous when it is between 1.05 and 1.5, and meandering when the sinuosity index (SI) is more than 1.5.

Water samples from twenty-five different points have been collected from December 2018 and January 2019 to check the quality variation of the river water. Temperature, pH, Conductivity, Total Dissolved Solids (TDS), Oxidation Reduction Potential (ORP) and Salt have been real time tested during the sample collection by the Aquasol Digital Water-Proof Hand-Held Tester and Dissolve Oxygen (DO) has been tested by the Digital Meter of Lutron DO-5510. Out of 25 water samples, 11 samples have been collected from adjacent and near brickfield (NB) and 14 samples have been collected far distance from brickfield (FB) sites. WQI is a very useful and important method for the assessment and management of water quality. The water quality index has been computed by using the weighted arithmetic index method as defined by Bhutiani et al. [21]; Cude [22]; Brown et al. [23]; Boah et al. [24]. WQI by weighted arithmetic index method has made by Brown et al. [25] using the following formula:

$$WQI = \sum q_n w_n / \sum w_n \quad \text{(II)}$$

Where, n = Number of water quality parameters, qn = Quality rating of nth water quality parameter, wn= Unit weight of nth water quality parameter. The standards for the drinking water recommended by Indian Standards [26], Environmental Protection Agency [27], World Health Organization [28], and Suslow [29] are considered for the calculation of quality rating (qn) and unit weights (wn). Based on WQI [25] table 2 shows a classification of water quality.

Table 2: Classification of water quality supported weighted arithmetic WQI methodology

Water quality index (WQI)	Status of water
0-25	Excellent
26-50	Good
51-75	Poor
76-100	Very Poor
Above 100	Unsuitable for drinking

To measure health impacts on brickfield workers, the head of the workers from 101 brick kilns has been interviewed about different kinds of health issues during the brickfield survey. Another Geo-environment related impact was critically observed during field studies. Field related different data has been analysed through statistical tools and techniques and represented by suitable diagrams by using Microsoft office software and suitable RS and GIS software.

3. Result

3.1 Present scenario and growth of brick industries within the study area

3.1.1 Temporal growth of the brick industry

In the study area, Radha Brickfield was first established at Ramchandrapur, Nabadwip block of Nadia district in 1950 on the right side of river Bhagirathi-Hugli. Recently, six brickfields, namely BKM brickfield at Dadupur of Nakashipara block in Nadia district on the left side of the river, BNG brickfield at Behara, SBF at Char Bishnupur, GBF, Rahat and Sima Brickfields at Patuli of Purbasthali-II block in Purba Bardhaman was developed in 2016 on the right side of the river within the study area. Before 2000 (1950-1999), there have been only 23 brickfields among the study area on the riversides, 78 brickfields are developed between 2000 and 2016 (Figure 2). It is found that most of the brickfields are increased to fast after 2000 because of the availability of raw materials, the minimum rate of land beside the river and high demand and market of bricks in surroundings in the study area.

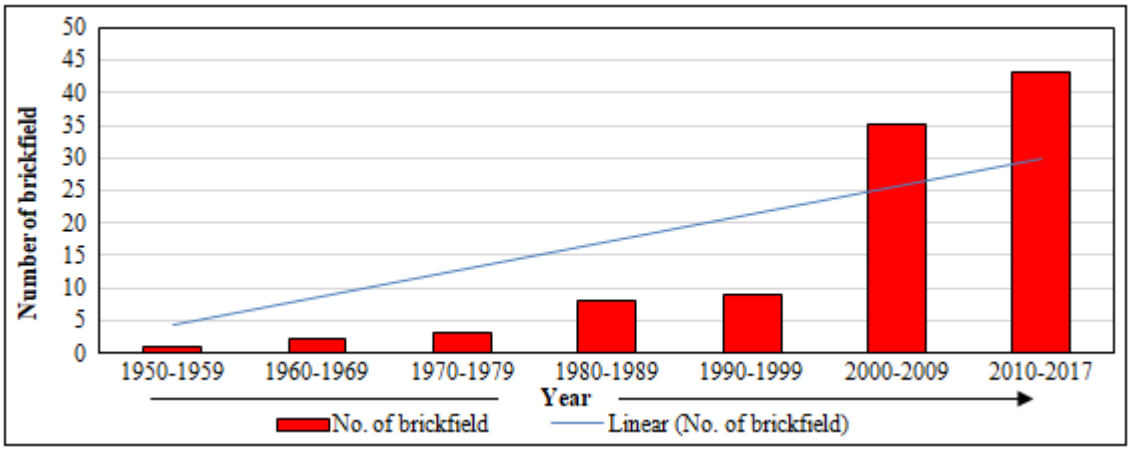

Figure 2: Temporal growth of brickfield on the Bhagirathi-Hugli River banks within the study area (1950-2017) [Data source: Field Survey (December 2016- April 2017)]

3.1.2 Area of brickfields

The area of brickfields among the study area on the riverbanks of Bhagirathi-Hugli varies from 0.015 to 0.115 km² within the study area along the river Bhagirathi-Hugli. The area of brickfields in the study area is divided into three categories. Most of the brickfields (83 out of 101 Brickfields) are considered as the smallest industry as they have small areas ranges between 0.015 and 0.048 km² within their territory. Seventeen brickfields are considered as the medium industry as their land area ranges between 0.049 and 0.082 km². There is only one brickfield, specifically PHBF at Hanspukur in Kalna-II block of Purba Bardhaman having an area of 0.115 km² and is considered as a large industry in this study area (Figure 3-a).

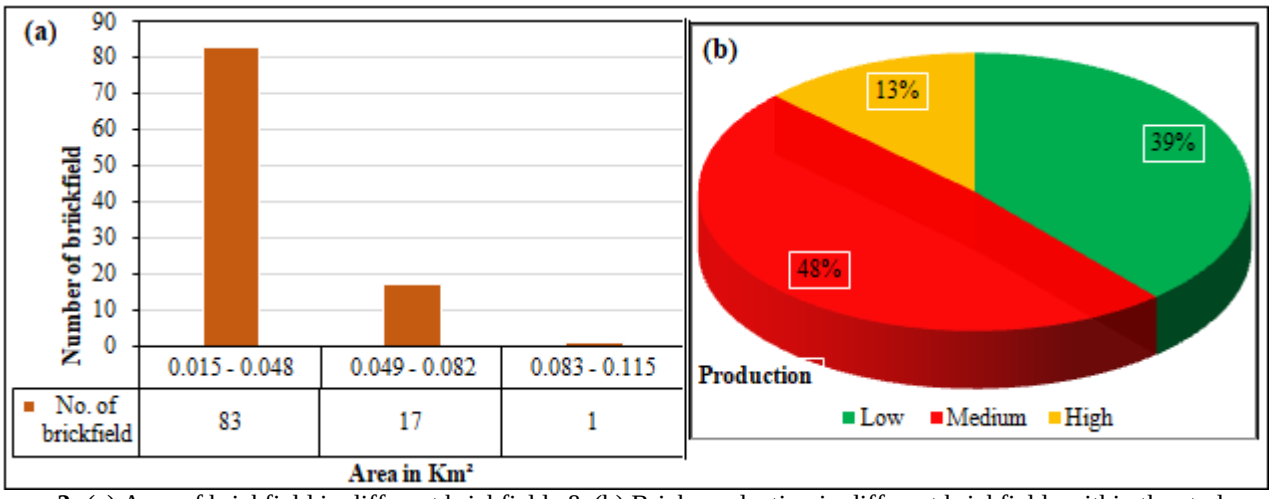

Figure 3: (a) Area of brickfield in different brickfields & (b) Brick production in different brickfields within the study area (Computed by author). [Data source: Field Survey (December 2016-April 2017)].

3.1.3 Brick production

Production of brick is varied from different years because of local atmospherical and weather conditions. Bricks that are to be made only seasonal at the time of the last week of November to April/May within the year. Based on the amount of production, most of the brickfields among the study area are considered as a medium scale industry. The mean production of those brickfields is 38.05 lakhs bricks per season as well as year. In the year 2017, only one brickfield (Ma Porama Brickfield) has recorded the lowest production (about 15 lakhs) whereas three brickfields (United, SOM and SONA Brickfields) have recorded the highest production of about 72 lakhs/year. Thirty-nine brick kilns that produced between 15 to 30 lakhs bricks, forty-nine brick kilns that produced between 31 to 50 lakhs bricks whereas only thirteen brickfields that produced between 51 to 72 lakhs bricks in every year (Figure 3-b).

3.1.4 Raw materials

Soil, sand, mud, and coal are very important raw materials for brick making processes. About 944632.30 m³ mud per brick production season in a year is used for making bricks by 101 brickfields of the study area. Average about 9352.80 m³ mud that is used by these brickfields. There is the highest volume of mud, 17698.03 m³ mud is utilized by three brickfields (United, SOM, SONA) and the lowest volume of mud, 3687.09 m³ mud is employed by only one brickfield namely Ma Porama brickfield (Figure 4).

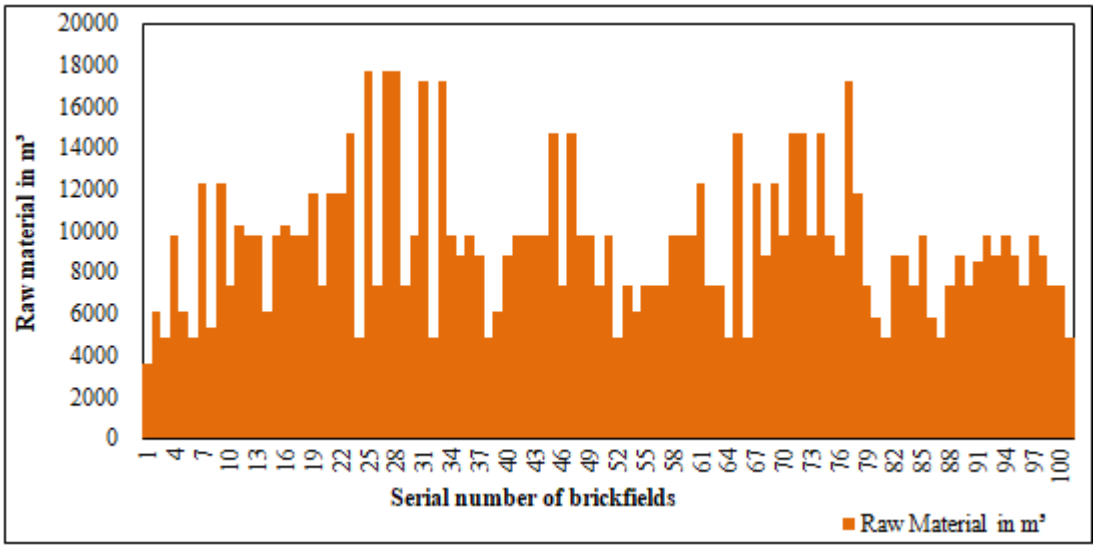

Figure 4: Raw materials used by brickfields. [Data source: Field Survey (December 2016- April 2017)]

Owners of all brickfield among the study area collect mud from lowland of the riverbank, sand from the river bed and bank, topsoil from agricultural land beside the river Bhagirathi-Hugli (Figure 1-a) for brick productions. They are using coal as a fuel for burning bricks that are imported from the Jharia coal belt in Jharkhand and Durgapur-Raniganj coal belt in West Bengal. Consequently, the assorted impacts of the brick industry's effects on geo-environment on the Bhagirathi-Hugli river banks.

3.2 Impact of brick industries on geo-environment along the Bhagirathi-Hugli River banks

3.2.1 Loss of soil fertility of agricultural land

About 944632.30 m³ mud per brick production season in a year is used for making bricks by 101 brickfields of the study area. For these vast amounts of mud, they cut the soils from agricultural fields and river banks. Within the study area, soils of agricultural field and the riverbank are fertile alluviums that are used for brick production. Within the study area, it is found that the excavation depth is generally kept around 0.5 to 2.5 metres (Figure 5-a). Most of these brickfield owners who take lease the agricultural lands from the landowners for cutting soils, remove the top layers of soils 0.5 to 2.5 meters and after the lease period, they shift to another agricultural land. Topsoil that holds most of the organic matter and nutrients like N, P, K and S which are therefore essential for agriculture.

The results of soil quality parameters such as total nitrogen (N), phosphorus (P), and potassium (K) is given in table 3. This table comprises the minimum, maximum, mean, standard deviation and coefficient of variation of each chemical parameter of different distances from brickfields. From the table, it is found that the standard deviation of N, P, and K are relatively high. It has been also observed that the S.D. of N, P, and K of 800 m distance are very higher than 100 m and 400 m from the brick kilns. So the soil samples have a lot of variability regarding N, P, and K. Careful analyses are done on the subsequent parameters. In this study, for comparing the nature of soil quality parameters among the distances from the brick kilns coefficient of variation has been analysed. The lower value of the C.V. is more consistent than the higher value. The above study appears that the standard of the soil is failing close to brickfield from far due to activities of brick making.

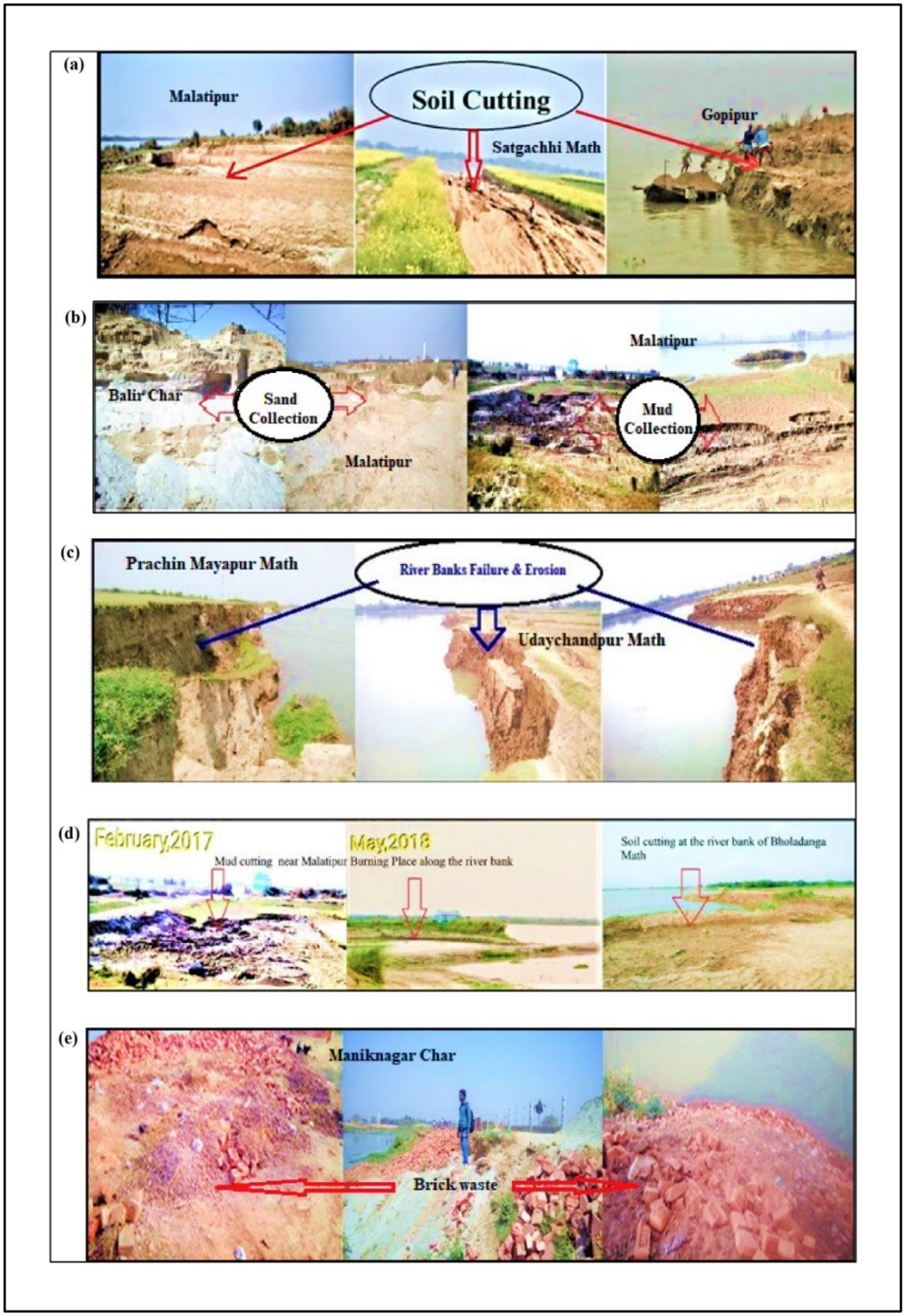

Figure 5: Field photographs showing the: (a) Soil collection, (b) Sand & mud collection, (c) Riverbank failure & erosion, (d) Changes of river banks, and (e) Dumping brick waste along the river banks

Table 3: Result of the soil quality parameters of various distances from the brickfields

Parameter	Distance (m)	Min.	Max.	Mean	S.D	C.V (%)
Total N (Kg/ha)	100	388.70	513.91	433.04	46.40	10.71
	400	404.35	519.13	459.13	41.58	9.06
	800	404.35	675.65	513.04	96.06	18.72
P (Kg/ha)	100	42.33	56.27	45.19	5.49	12.15
	400	45.28	58.10	48.75	4.86	9.97
	800	48.28	69.91	61.96	9.31	15.02
K (Kg/ha)	100	207.20	329.50	295.63	45.43	15.37
	400	327.90	378.90	353.93	18.30	5.17
	800	335.80	459.60	388.15	46.06	11.87

3.2.2 Riverbank erosion

For making bricks, a huge amount of sands, silts and mud are needed as raw materials that are collected from the river banks and bed by brickfield owners. In the study area, these are collected from different locations of the Bhagirathi-Hugli river banks and bed (Figure 5-b). At the time of field surveys, it was found that the sands and silts are collected greedy and unscientifically from the river banks of Bhagirathi near Udaichandrapur ghat of Nakashipara block in Nadia District and the river bed at Nabadwip Bridge of Nabadwip block in Nadia district. It was also found that soil is collected from the riverbank near Gopipur, Satgachi,

Bholadanga math within the study area. It accelerates different types of hydro-geomorphological changes within the river system. It was also found that continuous cutting of the banks on the riversides destroy vegetation on the land that enhances riverbank erosion and shifting of the river (Figure 5-c). It is also noticed that erosion from the banks of the meandering river causes a local influx of sediment to the stream channel [30, 31] and deposits on the river bed that reduced the capacity of water consumption in the river valley [32].

From the study, erosion has been measured to reach-wise areal change due to erosional activities from 1972/73 to 2017. Figure 6 shows the comparison between erosional area and brick kilns alongside the river. At the right side of the riverbank, brickfields are highly concentrated (70) than the left side (31) but the erosion at the right side (14.17 km²) of the river is lower than the left side (22.45 km²) because the soil, sand and mud are primarily collected from the opposite (where the brick kilns are concentred) riverbank.

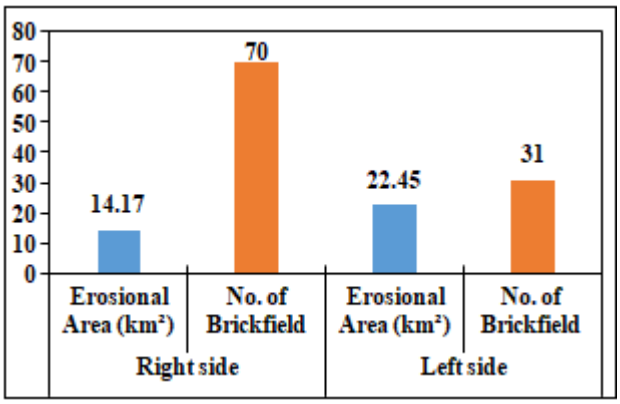

Figure 6: Bank erosion and no.of brickfield alongside the Bhagirathi-Hugli River

3.2.3 Changes of the river channel

Soil cutting from the river banks is a tyrannical problem related to brickfields. It was also noticed that most of the brickfields make on the high banks of the river and brickfield owners excavation (at Mathurapur, Santipur) by cutting soils or mud along the river banks to trap the silt during the floods. Consequently, these holes are increased by the tremendous current on concave river banks due to gradual migrating of the river and soil cutting also enhances of meandering of the river channel [33] (Figure 5-d).

To study temporal changes of the Bhagirathi-Hugli river course, five maps of the year (1972-73, 1989, 2001, 2010 and 2017) have been superimposed (Figure 7). From the superimposed map, it is found that there is no general trend of changes in river course as a whole.

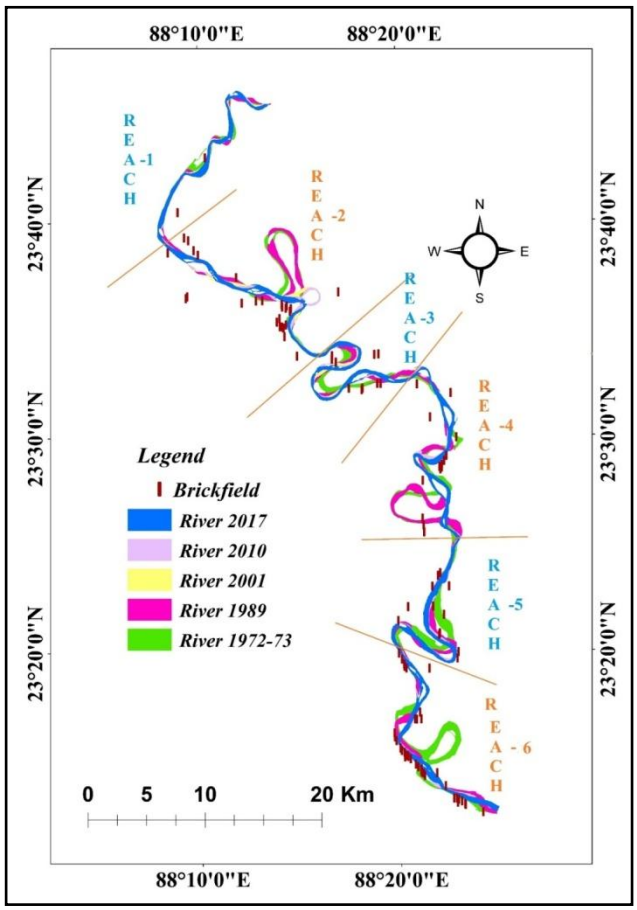

Figure 7: Temporal changes of the river course of the Bhagirathi-Hugli & location of brickfields

Channel pattern is habitually related to alluvial channels. Alluvial channel developed in the space where sedimentation rate is extremely high over removal force of sediments. Most of the cases at the mature and old stages of erosion, channels are alluvial. Lower reaches of Ganga plain are alluvial and these are also characterised by sinuous to meandering and braided channel patterns [34-35]. The sinuosity index of selected Bhagirathi-Hugli river (Ghasuriadanga to Medgachhi) vary from 1.11 to 1.01 in the year from 1972/73 to 2017 (Figure 8-a). It indicates that the channel Bhagirathi-Hugli from Ghasuriadanga to Medgachhi is gradually transformed from a sinuous to the straight pattern. From this study, it is said that the channel length is shortened because of a cut-off meander bend from 1972/73 to 2017.

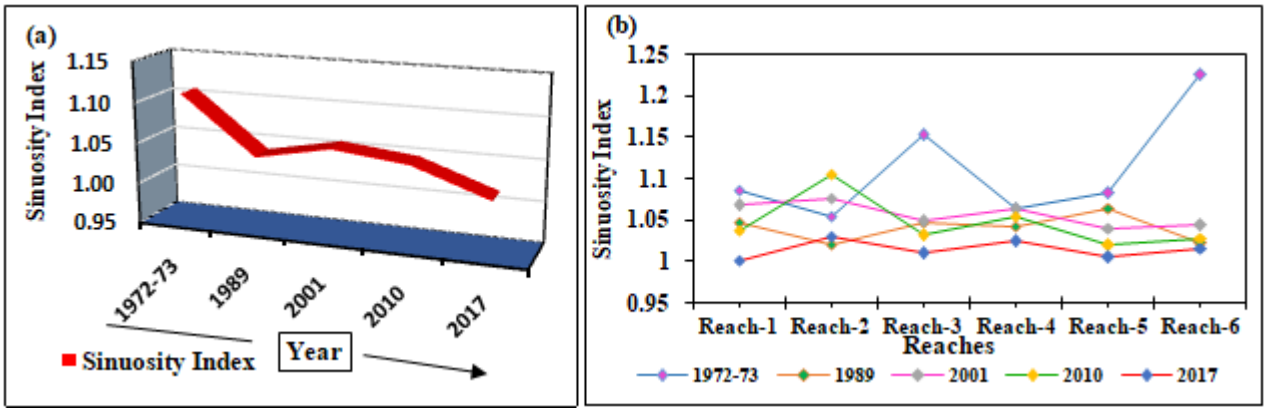

Figure 8: (a). Variation of the sinuosity index from 1972/73 to 2017, (b). Reach-wise variation of sinuosity index from 1972/73-73 to 2017. After Leopold and Wolman [20]

Figure 8-b shows the reach wise variation of sinuosity index of different years from 1972/73 to 2017. In reach-1 sinuosity index varies from 1.09 to 1.00 between Ghasuriadanga to Ballabhpara from 1972/73 to 2017, the river moves sinuously in straight due to channel widening and an incision. In reach-2, 3, 4, 5, and 6 sinuosity index varies from 1.06 to 1.03, 1.15 to 1.01, 1.06 to 1.03, 1.08 to 1.01 and 1.23 to 1.02 from 1972/73 to 2017 those indicate the channel transforms sinuous to a straight pattern. It is also observed that reach-6 of 1972/73, the river is approximately braided because of channel widening and aggregations mid-channel bar formation.

3.2.4 Degradation of water quality

Brick industries have a significant impact on the water quality of the river. There's a higher concentration of brickfields at Hanspukur of Kalna-II block, Nibhuji to Krishnadebpur of Kalna-I block, Behara, Gazipur, Char Bishnupur of Purbasthali-II block right bank of the river Bhagirathi-Hugli (Figure 9) and most of them dump their waste material on the river bank that could be is a higher risk of pollution of the river water than different stretches. Different parameters of water quality measurement quietly change to numerous sample collection points is given below in table 4.

Table 4: Physiochemical parameter of water quality from different sites of the Bhagirathi-Hugli River

Sites	Sample points	Location	Temperature (°C)	pH	Conductivity (µS)	TDS (ppm)	ORP (mV)	DO (mg/l)	Salt (ppm)
Distant from brickfield	FB-1	Majher Char	18.6	6.12	403	265	3	2.4	201
	FB-2	Rudrapara Ferry Ghat	22.5	6.58	422	277	-25	5.1	210
	FB-3	Sankarpur Ghat	19.6	6.57	409	270	-27	5.7	205
	FB-4	Karkaria Ghat	19.7	6.74	414	272	-36	5.7	206
	FB-5	Tamaghata	20	6.67	412	271	-32	5.6	206
	FB-6	Dafarpota	22.6	5.48	477	312	39.5	5.4	236
	FB-7	Danpaler Ghat	19.8	6.52	411	269	-27.9	5.7	204
	FB-8	Patuli	21	5.73	434	286	23	4.2	216
	FB-9	Char Bishnupur	22.5	5.58	440	289	32	3.5	219
	FB-10	Matiary Ghat	21.5	5.68	430	283	27	1.8	215
	FB-11	Sankhai Ghat	21.5	5.64	452	298	29	3.8	226
	FB-12	Duttabati Ghat	22.3	5.7	438	289	25.3	3.6	219
	FB-13	Kalyanpur Ghat	21.5	5.7	428	283	25	3.7	214
	FB-14	Natun Gram	22.5	5.53	470	310	35	4.4	235
Near & adjacent brickfield	NB-1	Hanspukur	19.7	6.43	387	256	-18.8	4.7	194
	NB-2	Nibhuji	19.4	6.57	390	257	-26	2.4	195
	NB-3	Parameshwar Ghat	19.8	6.62	410	270	-32.5	2.5	205
	NB-4	Piarinagar	19.5	6.42	402	266	-18.2	2.3	202
	NB-5	Kalinagar Ghat	19.2	6.58	401	264	-23.5	2.6	200
	NB-6	Malatipur	19.6	6.29	413	272	-9.9	4.6	206
	NB-7	Satkule	18.9	6.74	430	283	-35.5	2.5	215
	NB-8	Near Sona BF	23	6.58	412	271	-26	1.5	205
	NB-9	Forestdanga	20	6.92	415	273	-46.5	4.2	207
	NB-10	Bahera Burning Ghat	22.7	5.45	442	292	40	2.6	222
	NB-11	Kalikapur	21	5.41	498	262	43	2.7	199

From this study, WQI of the samples close to and adjacent brickfield ranges 46.18 to 78.23 and far distance from brickfield ranges from 33.36 to 61.46 (Table 5). Maximum WQI is found in NB- 8 near Sona brickfield and minimum is found on FB- 6 in distant from brickfield. The average WQI near and adjacent brickfield and far distance from brickfield are 64.27 and 49.75. It indicates that the water close to and adjacent brickfield is poor quality and far from brickfield is good quality.

3.2.5 Deterioration of land

Now-a-day, the brick-making industry is increasing greatly in developing countries for urbanization and industrialisation. Most of the brickfields are developed on

fertile agricultural land [36] and river banks for the supply of raw materials. Brickfield owners cut the soils from fertile agricultural land on the river banks, mud from river banks within the study area. Except these, ashes of coal, waste of bricks is dumping unscientifically beside the brick kiln on the agricultural land and the river bank (Figure 5-e). Consequently, it happens the extensive soil erosion, bank failure and land degradation [37] that is environmentally unsustainable.

3.2.6 The setback of the health of the brickfield workers

Brick industries have important hostile impacts on the health of the brickfield workers. Different kinds of health issues are found among the brick workers within the study area. From the field survey, it has been found that the majority of the labours (About 78.07%) suffer from eye irritation problems, 74.37% from skin disease, 64.72% from body pain and about 60.13% from headache. Except these, about 35.40% of workers suffer from fever, 31.71% from cough & cold, and only 23.46% from dehydration because of pollution (Figure 10).

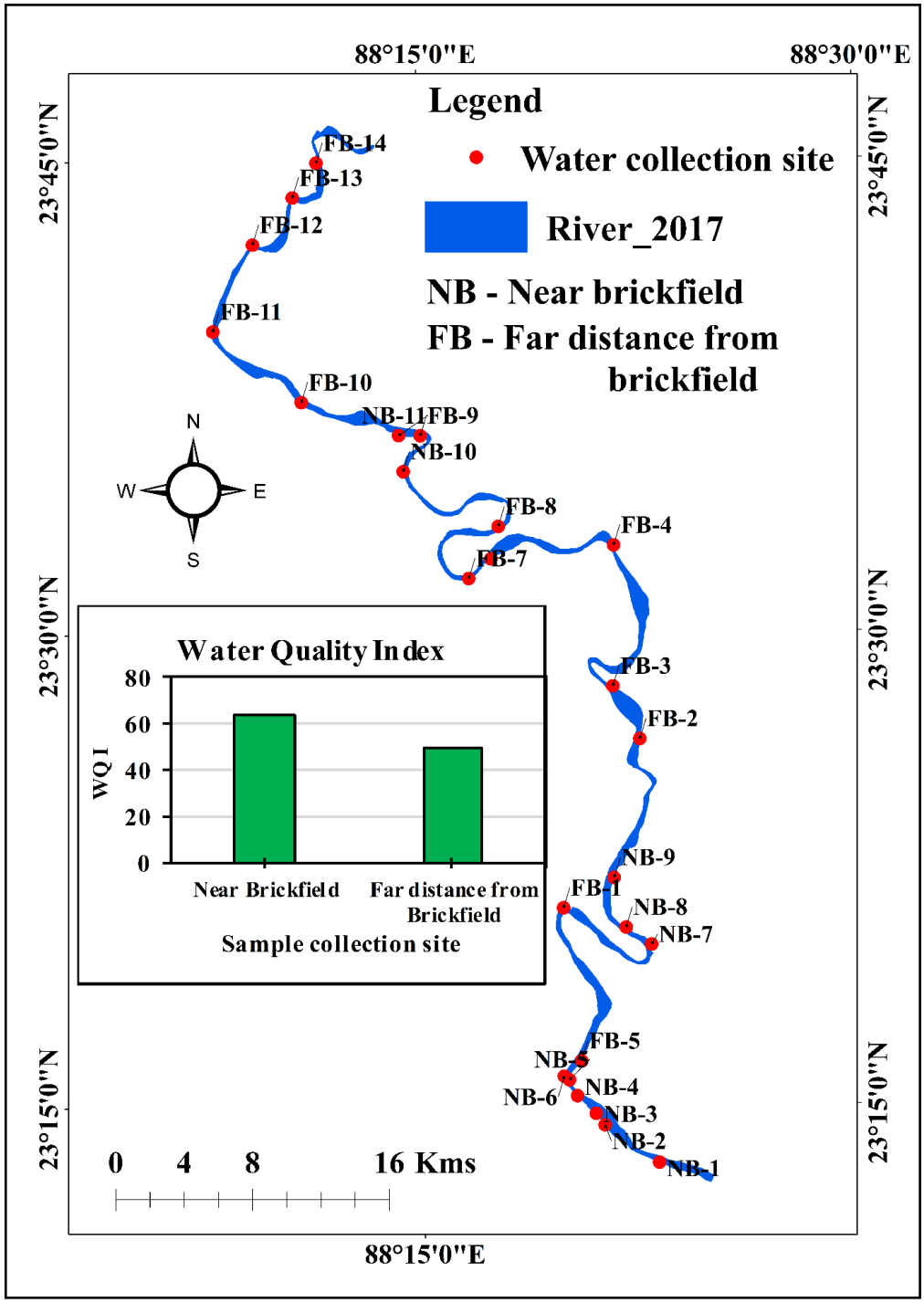

Figure 9: Location of sampling sites with WQI on the river Bhagirathi-Hugli.

Table 5: Water quality index of the Bhagirathi-Hugli River

Sample site	Sample Id	Location		WQI	Sample site	Sample Id	Location		WQI
		Latitude	Longitude				Latitude	Longitude	
Distant from brickfield	FB-1	23°21'15.37"N	88°19'50.33"E	61.46	Near & adjacent brickfield	NB-1	23°13‘9.61“N	88°23‘3.11“E	55.42
	FB-2	23°26‘36.01“N	88°22‘30.67“E	57.84		NB-2	23°14'21.65"N	88°21'11.80"E	71.22
	FB-3	23°28'16.65"N	88°21'36.06"E	52.89		NB-3	23°14'43.60"N	88°20'53.88"E	72.06
	FB-4	23°32'44.79"N	88°21'40.42"E	56.57		NB-4	23°15'17.62"N	88°20'15.76"E	68.76
	FB-5	23°32‘31.42“N	88°20‘22.51“E	55.77		NB-5	23°15'47.90"N	88°19'59.45"E	70.31
	FB-6	23°32‘20.49“N	88°17‘27.07“E	33.36		NB-6	23°15‘54.85“N	88°19‘48.71“E	53.19
	FB-7	23°32‘20.49“N	88°17‘27.07“E	51.92		NB-7	23°20‘4.85“N	88°22‘51.07“E	74.38
	FB-8	23°33‘21.92“N	88°17‘42.70“E	44.37		NB-8	23°20'37.53"N	88°21'58.89"E	78.23
	FB-9	23°36‘15.6“N	88°15‘3.36“E	45.83		NB-9	23°22‘12.14“N	88°21‘35.06“E	68.96
	FB-10	23°37‘20.63“N	88°10‘58.62“E	57.01		NB-10	23°35‘7.62“N	88°14‘27.70“E	48.27
	FB-11	23°39‘36.41“N	88°7‘57.13“E	45.09		NB-11	23°36'16.40"N	88°14'18.98"E	46.18
	FB-12	23°42‘21.21“N	88°9‘20.37“E	47.71					
	FB-13	23°43‘50.26“N	88°10‘43.42“E	46.72					
	FB-14	23°44‘56.04“N	88°11‘33.07“E	39.97					

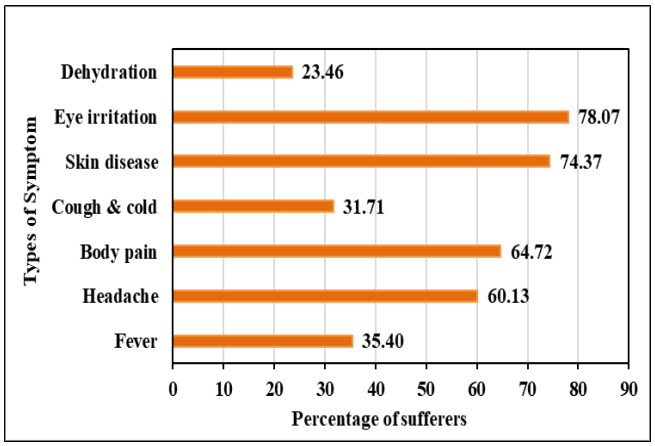

Figure 10: Indication among the brickfield workers [Data source: Field Survey (December 2016- April 2017)]

4. Discussion

From the above study, it is found that most of the brickfields along the Bhagirathi-Hugli River within the study area are increasing too fast after 2000. It is also noticed that most of the brick industries tend to be located beside the river bank due to a constant supply of raw materials of brick, like mud, sand, and water. Most of the brickfields among the study area are considered as a medium scale industry based on production. They are using coal as a fuel for burning bricks that are imported from the different coal belt in Jharkhand and West Bengal. Various activities of brick kilns effects on geo-environment on the Bhagirathi-Hugli river banks.

The study of soil sample reveals that the standard of the soil is deteriorating close to brickfield from far distances because of indiscriminate activities of brick kiln industry. The average value of N, P and K are increased from the brick kilns to far distances of agricultural land that indicate the quality of soil is increased with increasing distances from the brickfields. Loss of ¾th of soil fertility through brick production has indicated from different regions in Bangladesh, wherever constant strategies for topsoil extraction for brick production are used [38, 39]. The quality of soil in terms of heavy metal content and nutrient content was directly proportional to the distance from the kiln; that is, the quality of soil increased with increasing distance [40, 41].

Continuous cutting soil, sand and mud from river banks and bed are enhancing the bank erosion and channel shifting. The Sinuosity index indicates that the Bhagirathi-Hugli River channel from Ghasuriadanga to Medgachhi is progressively transformed from a sinuous to a straight pattern. From this study, it is said that the channel length is shortened because of a cut-off meander bend from 1972/73 to 2017.

Analysis of water quality indicates that the water close to and adjacent brickfield is poor quality and far from brick industries is good quality. Because most of the brick kilns dump their waste materials on the river bank that could be is a higher risk of pollution of the river water than different stretches. Agricultural land is becoming deteriorating due to unscientifically dump the ashes of coal, waste of bricks beside the brick kiln on the agricultural land and the river banks [36]. Polluted substances of brick industries and poor quality house have occurred different types of health effects on brickfield workers [2]. The discoveries of this investigation show that the brick manufacturing and its related exercises to have debased the land and whenever left unchecked will effectively affect the encompassing environment.

5. Conclusion

With the high demand for infrastructure development, the brick-making industry is hasty increasing along the Bhagirathi-Hugli River between Nadia and Purba Bardhaman Districts within the study area. In the overall study, it is critically observed that the indiscriminate and unscientific manufacturing leads to different geo-environmental problems such as loss of soil fertility, riverbank erosion, river course changes, land degradation, water pollution, and health hazard of the workers in the present study. It is also noticed that erosion from the banks of the meandering river causes a local influx of sediment to the stream channel and deposits on the river bed that reduced the capacity of water consumption in the river valley. From the overall analysis, it can be summarized that the livelihood of a lot of people extremely depends on this brick industry. The social and economic life of brickfield workers is very intensive for their living. For collecting soil indiscriminately from agricultural land it is losing fertility of agricultural land. Continuous cutting of the banks on the

riversides destroys vegetation on the land that enhances riverbank erosion, bank failure and shifting of the river. Ashes of coal and waste of bricks are dumping unscientifically near the brickfield on the agricultural land and beside the river bank which is occurring at higher risk of pollution of the river water than other stretches and land degradation. Those polluted substances can cause both short term and long term effects on the health of brickfield workers as well as the local people in the surrounding area. Pollutants emitted from the brick kilns makes a high danger of digestive diseases to the human who is utilizing the water for drinking reason. This is particularly tricky for needy persons, due to fact the contaminants can get appended to the suspended solids. It helps to purify water with chlorine because the particles go about as protections for the pollutant organisms. If the owners of brickfields use modern technology rather than the traditional method of brick making the pollution level may be decreased. It will be the proper determinatives for sustainable development. For inaction of contamination, the brickfield proprietors must comply with the principles and guidelines set up by the administration right now. To protect the environment in this area, the proposals are given as per the following:

1) There is a requirement for support of multi-disciplinary ecological management and improved consciousness of the extent of the impacts of brick making.
2) There is a requirement for government and non-governmental associations to connect as individual associations and all in all to address this movement before there is irreversible harm to the land.

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7. Declaration of interests

The author declares that he has no known competing for financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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