INTERNATIONAL JOURNAL OF ENVIRONMENTAL SCIENCES Volume 1, No 4, 2010

Research article ISSN 0976 – 4402

Geomorphic Controls of Arsenic in Ground Water in Purbasthali I & II Blocks of Burdwan District, West Bengal, India

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ABSTRACT

Arsenic values in groundwater above the maximum permissible limit of 0.05 mg/l (Indian standards) have been reported from Bhagirathi-Hooghly flood plain region of West Bengal. The present study area Purbasthali I and II blocks in Burdwan district, West Bengal, evolved due to the flood plain forming processes. Many flood plain features are mapped using satellite image. Close links with the geomorphic features and arsenic pollution in the tube wells are observed here. It has been studied that the higher amount (>0.50mg) of arsenic content tube wells are located around the major flood plain features. It is concluded that the processes of sedimentation is mainly responsible for arsenic deposition in the aquifers. People living along the major flood plain features must be provided alternative safe drinking water.

Keywords: Ground Water, Arsenic, Peoples' sufferings, Geomorphic Features, Correlation.

1. Introduction

The population of the India has already crossed the 1 billion mark and is expected to reach 1.64 billion by the year 2050. Towns and villages are expanding and all requiring and demanding drinking water for sustenance of life. Water is often associated with various issues like lack of adequate water or poor water quality. The present study is concerned with the arsenic related problems in the lower Gangetic region of West Bengal. But Arsenic is very much common occurrence in various parts of the world e.g. Argentina, Australia, Bangladesh, Canada, Chile, China, Finland, Hungary, Japan, Mexico, Southern Thailand, Taiwan, United Kingdom, USA, Vietnam and India (for details, Bhattacharya *et. al.*1997, Bhattacharya *et. al.* 2001, Naidu 2000).

The presence of Arsenic (As) in groundwater is responsible for a major health concern in West Bengal. The occurrence of arsenic rich ground water in the Bengal Deltaic Region (BDR) was first discovered in West Bengal in 1978 (ACIC, 2000). There are some potential human health risks related to livestock and fresh water fisheries as these can be exposed to arsenic via drinking-water, pond water, and feeds. Thousands of people have already shown the symptoms of arsenic poisoning and several millions are at risk of arsenic contamination from drinking tube-well water. The sudden increase in arsenic related diseases has panicked the local people. The Inorganic arsenic, (As III) accumulates in skin, hair, nail, tongue, stomach wall, mouth, bone, and eye lenses. Common visible symptoms are skin disorders such as hyper-pigmentation or hyperkeratosis, and ultimately cancer.

Arsenic is distributed in nature as compounds of iron, copper, lead, silver and gold or as a sulphide mineral. Arsenic can enter the environment either through natural or anthropogenic

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activities. The bio-geochemical cycling of arsenic occurs through natural water with bedrocks, sediments and soils together with the local environment. The weathering of different geologic formations such as volcanic rocks, as well as mining waste consequently results in elevated levels of arsenic in surface and ground water, where it can be transported as suspended particles (Bhattacharya *et. al*. 2001). Arsenic based compounds have been used in pesticides, herbicides, insecticides and fungicides. Mining and related activities are other main sources of arsenic in the ground and surface water (Bhattacharya *et. al*. 2001).

The present study area is the western part of the Bhagirathi-Jalangi confluence. It is a monotonous alluvial plain with relief in the range of 8–11 m. A.S.L. Various levees, active / abandoned channels, cut-off meander loops, ox-bow lakes, back swamps and inter-levee depressions / flood basins –mostly aggraded – are common. The active channels are Banka, Faria, Brahmani, Khari, Gurjani etc. traversing the Purbastali Block from west to east and meet the Bhagirathi River in the east. The general slope is from north to south and southeast. The present landscape evolved from the shifting of channels, which align primarily north to south, with convexity towards the east.

The present study area is characterized by shallow aquifers. It has been established that arsenic comes to this flood plain region as a natural contaminant. The element is deposited together with the sediments, becoming fixed in the mineral constituents of the aquifer (Sengupta *et. al*., 2004; Oremland and Stolz, 2005). It can, therefore, be presumed that arsenic distribution in the aquifer sediments is a product of the same process that created the fluvial landscape. The present work attempts to establish relation between the geomorphic features those are created by fluvial process and the pattern of arsenic distributions in groundwater.

2. Distribution of Geomorphic Features in Purbasthali Block I & II

The river flood plain is a strip of relative smooth land bordering a stream and overflowing at times of high water. Major features of river flood plains of large rivers like Ganges, Bramhaputra, Godavari, Mississippi or the Mekong, majority of these features are distinctively displayed in what might be called the classic model. Major flood plain features were identified using the topographical sheets, surveyed in 1974. The map has further been updated using the satellite imagery of IRS_1C_LISS_III, 2000 (Fig 1). Visual image classification of the image is done. The major flood plain features that are found within the study region are discussed below.

2.1 The River Channel

The river Bhaghirathi formed the north and north-eastern border of the block. The river is flowing from its eastern part in the north to south direction. There are some other rivers which are flowing from eastern part to meet the Bhaghirathi. Other the active channels are Banka, Faria, Brahmani, Khari, Gurjani etc.

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Almost all the rivers of the region are sinuous to meandering. The sinuosity index ranges from 1.30 to 1.95 (Table: 1). All of the rivers are perennial and navigable through out the year.

Table 1: Channel Pattern of Major Rivers of Purbasthali

Name of the Rivers flowing through the Blocks	Total Length (km)	Sinuosity Index (Leopold, et. al. 1957)	Category
Bhagirathi-Hoogly	70.62	1.95	Meandering
Banka	13.18	1.41	Sinuous
Brahmani	11.62	1.30	Sinuous
Khari	35.38	1.46	Sinuous

Source: Author's Calculation

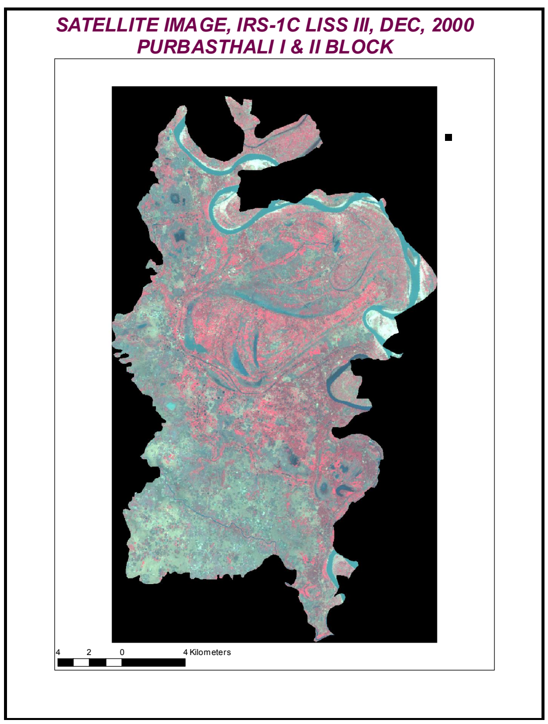

Figure 1: Satellite Image

2.2 Ox-bow Lakes, Meander Scrolls, Sloughs, Back Swamps

The ox-bow lake, meander scrolls and sloughs represent the cut-off portion of meanders, depressions and rises on the convex sides are meander scrolls and areas of dead water formed both in meander-scroll depressions are identified as geomorphic features or surface water bodies. From the 1974's topographical sheet and by updating the map using 2000's satellite imagery (IRS-1C), many more ox-bow lakes, sloughs, marshy lands, bills, ponds or tanks are identified and mapped (Figure 2). Out of 190 villages of the entire Blocks, only 32 villages

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i.e. about 17 % of its total villages have no such important standing water as lakes or ponds. But 20 of them are having perennial rivers. River Bhagirathi-Hoogly is one of them. In our previous section, we have discussed that the river are meandering or sinuous. So, the rivers travel at lest 1.5 times than the air distance of the village. Only 12 villages, i.e. about 6 percent of the total villages do not have significantly large water bodies. Among these 12 villages, some of them are uninhabited village and less than 4 per cent of the total population are living there. More than 29 villages have >10 per cent of their total area under surface water bodies. They are about 15 per cent of the total villages of the Blocks. These villages contain about 17 per cent of total population of the Blocks. All most all the water bodies are permanent and have water through out the year. Many of the ponds are even connected by some narrow links with the main rivers. The distribution of surface water bodies have been quantified. The whole region has been divided into one sq. km. grids and counted the number of surface water bodies within each sq. km. Isolines of 5, 10 and 15 has been drawn and a frequency map of surface water bodies has been drawn (Figure 3, Table: 2).

Table 2: Isoline Zones of Frequency of Surface Water Bodies per Sq. Km.

Isoline Zones of Surface Water Body	Area Covered (Hec.)	% of Area
0 – 5	25370.10	73.47
5 – 10	8103.20	23.47
10 – 15	775.90	2.25
> 15	280.80	0.81

Source: Author's Calculation

The isoline zone of 0 – 5 numbers of ponds / sq. km, cover 73 % area of the Blocks. It is distributed through out the block. Isoline zones of 10 and above are concentrated in the west-central part and it is running through the central part of the Blocks. In the south-western part of the Blocks another zone is there where many ponds are concentrated. This region is covering about 30 per cent area of the Blocks. People do use the water of the ponds mainly for bathing, washing and irrigation too. Some of the water bodies are used for rotting the jute also.

3. Arsenic Distribution in Purbasthali Block I & II

3.1 Spatial Distribution

For the arsenic distribution in the Purbasthali Block of Burdwan district of West Bengal, 40 villages were taken as sample. Average arsenic content in the shallow tube wells of each of the villages have been collected from the State Water Investigation Directorate, Burdwan. From the Fig: 2 we can see that the study villages are located in almost every corner of the Block. The frequency distribution and number of tube wells are presented in Table: 3, Fig: 4 & 5. The WHO specified level of arsenic safe drinking water is below 0.01mg/l. If we consider the international level, the whole sample villages have more arsenic content than the specified level in the domestic tube wells.

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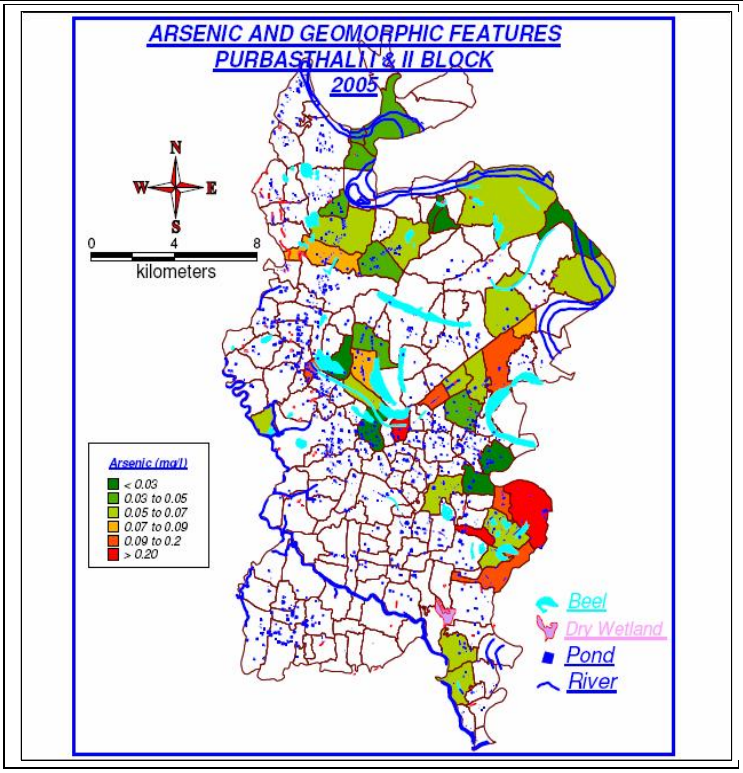

Figure 2: Distribution of Geomorphic Features and Arsenic

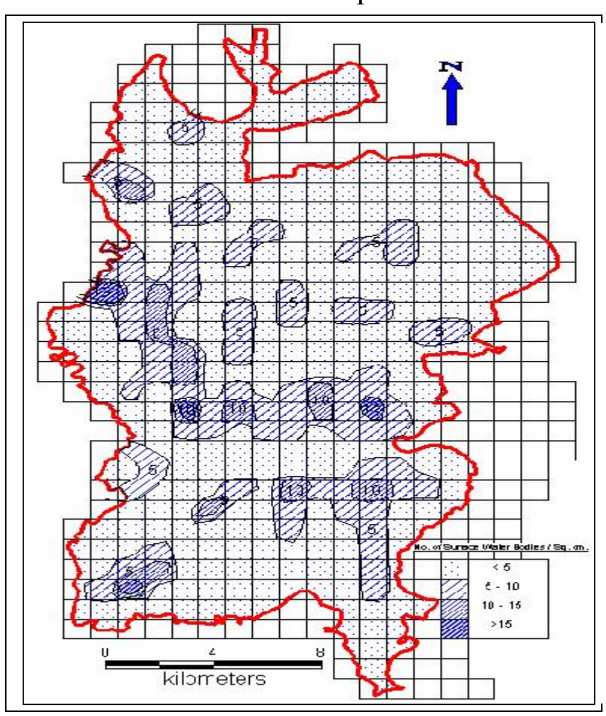

Figure 3: Frequency Distribution of Surface Water Bodies in Purbasthali

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Table 3: Frequency Distribution of Arsenic Contaminated Villages of Different Depths (m) at Purbasthali

Average Depth (m) of Tube Wells	Average Arsenic Content (mg/l)	Frequency of Villages	% of Tube wells
10 – 20	0.09	9	22.50
20 – 30	0.04	8	20.00
30 – 40	0.06	7	17.50
40 – 50	0.03	6	15.00
50 – 70	0.12	6	15.00
70 – 110	0.08	4	10.00

Source: SWID, Burdwan and Author's Calculation

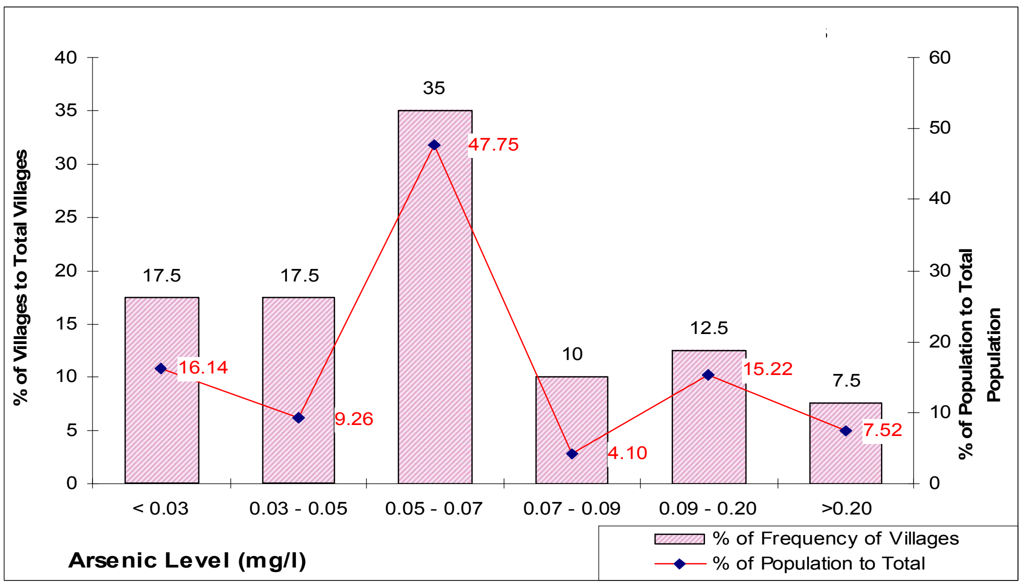

Figure 4: Arsenic Contaminated Villages

The Indian cut-off level of arsenic content in the drinking water is 0.05 mg/l. Out of 40 villages, 26 villages i.e. 70 per cent of the total villages have more than Indian standard of arsenic tolerance limit. Eight of the sampled villages, i.e. 20 per cent of the study villages have arsenic above 0.09 mg/l and one of the villages (J.L. No. 98) has arsenic as high as 0.30 mg/l. Name of the village is Mandra. It is located in almost centre of the Purbasthali block. It has been learnt during the field visit, that the village is the worst sufferers from the arsenicosis. The villagers were the first to report the problems of arsenic contamination.

There are 7 villages i.e. 17.50 per cent of the study villages, where we find the arsenic content is less than 0.03 mg/l. 14 villages of the study area i.e. 35 per cent villages are having average arsenic content ranging from 0.05 to 0.07 mg/l.

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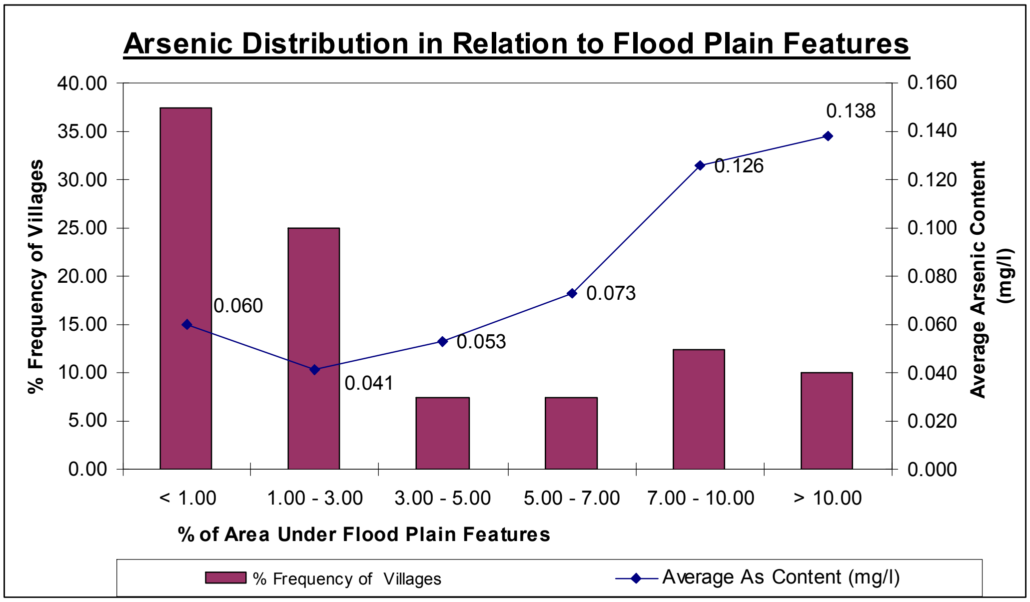

Figure 5: Arsenic Contaminated Villages in Relation to Geomorphic Features

3.2 Vertical Distribution

The depth of the tube wells vary from 10 meter to 110 meter (Table: 4 and Fig: 6). It is surprising to observe that arsenic is available, well above the danger level, in every range of depths. The shallow tube wells of the study villages ranges from 10 – 20 meters and the average arsenic content at this depth is 0.09 mg/l. 22.50 per cent tube wells of the study area belongs to this category. Initially, when the average depth of the tube wells increased from 20 meters to 30 meters, suddenly the average arsenic content decreased from 0.09 mg/l to 0.04mg/l, which was in safe limit as per Indian standard. Further depth of 40 – 50 meter the average arsenic content decreased to 0.03mg/l.

So, planners were of the belief, if the depth of tube wells can be increased, then international standard of drinking water may be available. But unfortunately, after that with increasing depth of tube wells, we observed that the average arsenic content increased to 0.12 mg/l to 0.08mg/l at 110 meter depth of tube wells. Few numbers of tube wells i.e. only 15 per cent, are falling in this category. But the numbers of deep tube wells are growing fast in the belief that it will reduce arsenic contamination, but in reality the data do not support it. So, we can say that tube well of any depth contains arsenic at the much higher level than the safe level.

4. Association between Arsenic Distribution and Geomorphic Features

In the West Bengal part of the Bengal Delta, the Holocene sequence is classified into the Older Alluvium Plain (OAP), overlain by the Young Delta Plain (YDP). Both are incised by the present channel and delta plain of the Bhagirathi River (Acharyya *et al.* 2000). The present landscape evolved from the shifting of channels, which align primarily north to south, with convexity towards the east. Fluvial depositional processes produced different landforms, which has already been discussed.

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Table 4: Frequency Distribution of Arsenic Contaminated Villages of Different Depths (m) at Purbasthali

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40 – 50	0.03	6	15.00
50 – 70	0.12	6	15.00
70 – 110	0.08	4	10.00

Source: SWID, Burdwan and Author's Calculation

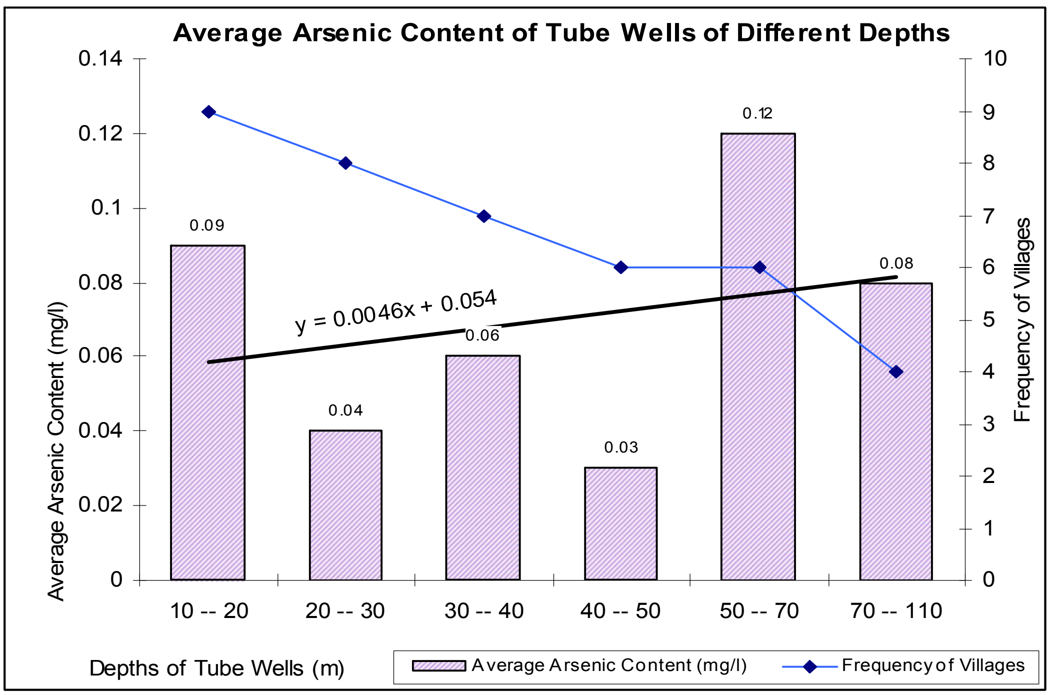

Figure 6: Arsenic in Different Depths

The present study area is characterized by shallow aquifers. The shallow aquifers are mostly unconfined or semi-confined, and are recharged from the top as well as flushed horizontally. It has been established that arsenic comes to this delta as a natural contaminant carried in with sediments by the Himalayan Rivers. The element is deposited together with the sediments, becoming fixed in the mineral constituents of the aquifer (Sengupta *et al.* 2004). It can, therefore, be presumed that arsenic distribution in the aquifer sediments is a product of the same process that created the fluvial landscape. The present work attempts to establish connections between the geomorphic (flood plain) features those are created by fluvial process and the pattern of arsenic distribution in shallow groundwater.

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The figure 2 shows the distribution of the flood plain features in the Purbasthali block. There are numerous small ponds or tanks, distributed through out the Blocks. The patterns of distribution and the field visits, clearly indicate that most of the tanks / ponds are geomorphic in origin. For the present discussion, those features have also been taken into consideration. The figure 2 & 5 clearly shows that the flood plain features and the surveyed villages have very close association. From the map it can be interpreted that in all the arsenic contaminated villages some flood plain features are present.

The table 5 shows the percentage distribution of the area coverage by the flood plain features to the total area of the villages and also the average arsenic content (mg/l) in the shallow tube wells. It has been observed that 15 villages or 37.50 per cent of the sampled villages have less than one percent flood plain features to their total area. Average arsenic content in the shallow ground water of those villages is 0.06mg/l.

Table 5: Area under Surface Water Bodies

% of Flood Plain Features To Total Area	Frequency of Villages	% Frequency of Villages	Average As Content (mg/l)
< 1.00	15	37.50	0.060
1.00 - 3.00	10	25.00	0.041
3.00 - 5.00	3	07.50	0.053
5.00 - 7.00	3	07.50	0.073
7.00 - 10.00	5	12.50	0.126
> 10.00	4	10.00	0.138

Source: Author's Calculation

The second category of the flood plain distribution is 1.00 to 3.00 per cent area coverage by the food plain features to the total area of the villages. There are 10 villages, i.e. 25.00 per cent of the total surveyed villages are falling in this category. The average arsenic content of the villages is 0.041 mg/l. It is less than the Indian standard of arsenic tolerance but much higher than the WHO (0.01 mg/l) standard. From the table 5 and the fig 5, it is clearly visible that with the increasing flood plain / geomorphic features' coverage, the arsenic content in the shallow water is increasing. The villages having flood plain features' coverage 7.00 to 10.00 per cent to their total geographical area have average arsenic content as high as 0.126 mg/l. The villages where the flood plain features' coverage is > 10.00 per cent to their total area have average arsenic content 0.133 mg/l. Further we have done some statistical test for the relationship between the average arsenic content of the villages and their average flood plain features. The correlation coefficient (r) test (Fig: 7) between these two variable is +0.918. The value signifies that there is very strong positive relationship between the presence of flood plain features and availability of arsenic content of the tube wells of any depth.

$$r = \frac{\sum xy - (\sum x \sum y)/n}{\sqrt{\sum x^2 - (\sum x)^2/n}\ \sqrt{\sum y^2 - (\sum y)^2/n}}$$

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r= +0.918
$t = r\sqrt{(n-2)/1-r^2}$
t= 4.22

The r value is being tested using 't' test. It is significant at 99% confidence limit or 1% level of significance.

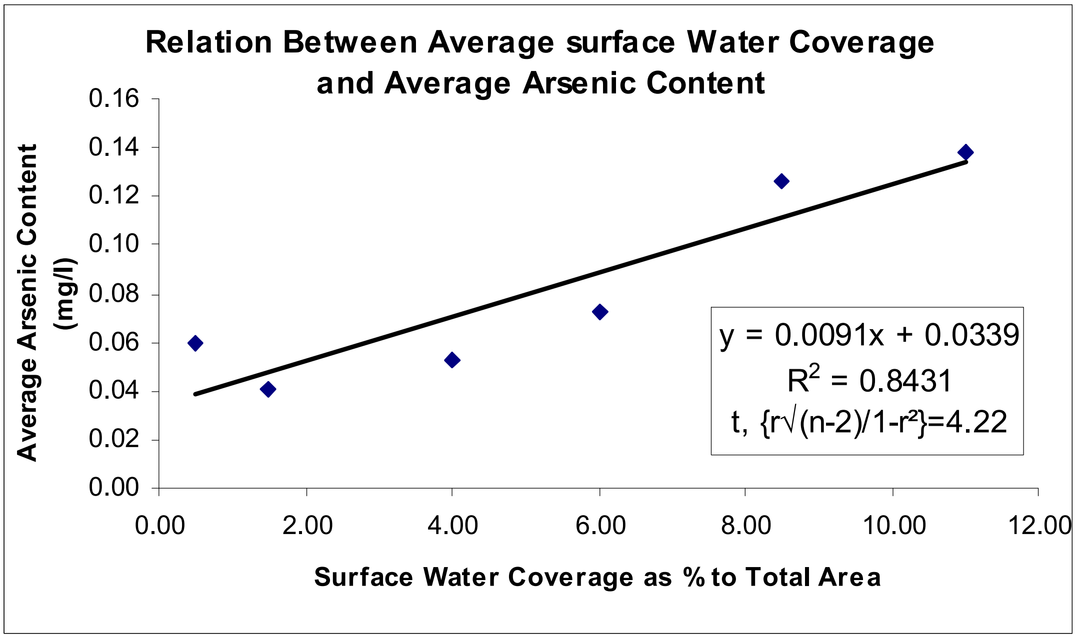

Figure 7: Arsenic in Different Depths

From the above discussion it can be concluded that the arsenic content in the ground water has very much close relationship with the flood plain / geomorphic features.

5. Conclusion

The present study looked at the nature and extent of the arsenic pollution in Purbastali I and II block of Burdwan district of West Bengal and tried to study the relationship with the flood plain or geomorphic features with the arsenic contamination. In the Purbastali I and II block arsenic contamination in groundwater is being determined by the flood plain or geomorphic features. Arsenic content in the aquifers show relationship with the flood plain / geomorphic features. Thus, it can be concluded that prevalent geomorphic processes resulting the origin of the different geomorphic features of deposition leaving arsenic in the aquifers. The tube wells in the aquifers of the active geomorphic units have the arsenic contamination.

Some villages of the present study shows arsenic contamination where less area were under flood plain or geomorphic features. Detail investigation is needed for the factor(s) of causing arsenic in those villages.

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In general we can conclude the present study that the flood plain / geomorphic features have very much control in the arsenic contamination. The planners should take the flood plain or geomorphic features into consideration for the setting up shallow tube-wells in those regions where active geomorphic aggradations are going on. The people, who are living in those active areas, should be careful about using shallow tube well water for drinking and other uses. Immediate action should be taken for providing arsenic free drinking water.

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