Presence of Arsenic in Groundwater in the 18 District Towns Project

Short Mission Report

Geohydrologist

Period: December 1996

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Glossary

18DTP	18 District Towns Water Supply, Sanitation and Drainage Project
ADP	Annual Development Plan
AT	Advisory Team
BAD	Bi-lateraal Assistent Deskundige (Bilateral Associate Expert)
BOQ	Bill of Quantities
DG	Director General
DGIS	(Netherlands) Directorate General for International Cooperation
DPHE	Department of Public Health Engineering
EE	Executive Engineer
GOB	Government of Bangladesh
GoN	Government of the Netherlands
GT	Group Tap
HE	Hygiene Education
HC	House Connection
HTW	Hand Tubewell
ID	Institutional Development
IRP	Iron Removal Plant
MLGRD&C	Ministry of Local Government, Rural Development and Cooperatives
MOU	Memorandum of Understanding
NGO	Non-Government Organization
OHT	Overhead Tank
O&M	Operation and Maintenance
PCS	Pourashava Conservancy Section
PD	Project Director
PDB	Power Development Board
PHS	Pourashava Health Section
PO	Programme Office
ppm	parts per million
Pourashava	Municipality
PP	Project Proforma
PTW	Production Tubewell
PWSS	Pourashava Water Supply Section
RNE	Royal Netherlands Embassy
SAE	Sub-Divisional Assistant Engineer
SDE	Sub-Divisional Engineer
SH	Street hydrant
TAPP	Technical Assistance Project Proforma
TL	Team Leader
WID	Women-in-Development
WO	Work Order
WSSC	Water Supply and Sanitation Committee
WTP	Water Treatment Plants

1 Introduction

1.1 Background

Since 1994 in Bangladesh awareness has grown about the presence of elevated concentrations of arsenic in groundwater in the area near the West Bengal border. Several towns resorting under the 18-District Town Project (18-DTP) are situated in the zone where elevated arsenic concentrations in ground water may be present.

Chronic intake of high levels of arsenic (As) may have adverse effects on health, such as colouring of the skin (the so-called 'Blackfoot disease'), infection of the eyes or the trachea. The guideline for drinking water as set by the World Health Organization (WHO) has been reduced in 1993 from 50 µg/l to 10 µg/l (Ref. WHO, 1993).

In order to be able to anticipate on this potential threat to public health, in December 1995, the 18-DTP project collected groundwater samples for analyses on arsenic in Meherpur. In nine of the ten groundwater samples the arsenic concentration was above the WHO guideline value of 10 µg/l.

The results in Meherpur prompted the project to extend the investigations to other district towns situated in the zone with a potential hazard of elevated arsenic concentration in groundwater. In August 1996, an inventory of arsenic concentrations in groundwater in 9 other District Towns was carried out. Before the results could be elaborated and reported, the environmentalist who was engaged with this inventory left the project.

In order to finalize these first investigations of arsenic in groundwater in 18-DTP, the team leader invited the project hydrogeologist to come to Bangladesh and assigned him the followings tasks:

- to report and verify the results collected;
- to propose further relevant investigations on the presence of arsenic in groundwater in the frame work of the 18 DTP;
- to check with the Bangladeshi authorities and relevant institutions, what measures at national level are to be expected on short notice to anticipate on the potential threat to public health.

Consequently, the project's hydrogeologist visited the 18-DTP project from 4 to 24 December 1996. During the visit groundwater samples were taken to confirm previous results and to extend the baseline study on arsenic in groundwater to all 18 district towns under the project.

1.2 This report

The aim of this report is to evaluate all available data collected in the framework of the 18-DTP project on the presence of arsenic in groundwater. All samples were analyzed on arsenic by the laboratory of IWACO in Rotterdam, the Netherlands.
Chapter 2 of this report describes briefly the theoretical background of arsenic in groundwater. In chapter 3 the data collected in the framework of the 18-DTP project are presented and evaluated, whereas chapter 4 summarizes the response of the authorities of Bangladesh on the potential health hazard of arsenic in groundwater. Chapter 5 and 6 contain the conclusions and recommendations.

A map showing the location in Bangladesh of all 18 district towns under the 18-DTP project is shown as Figure 1.

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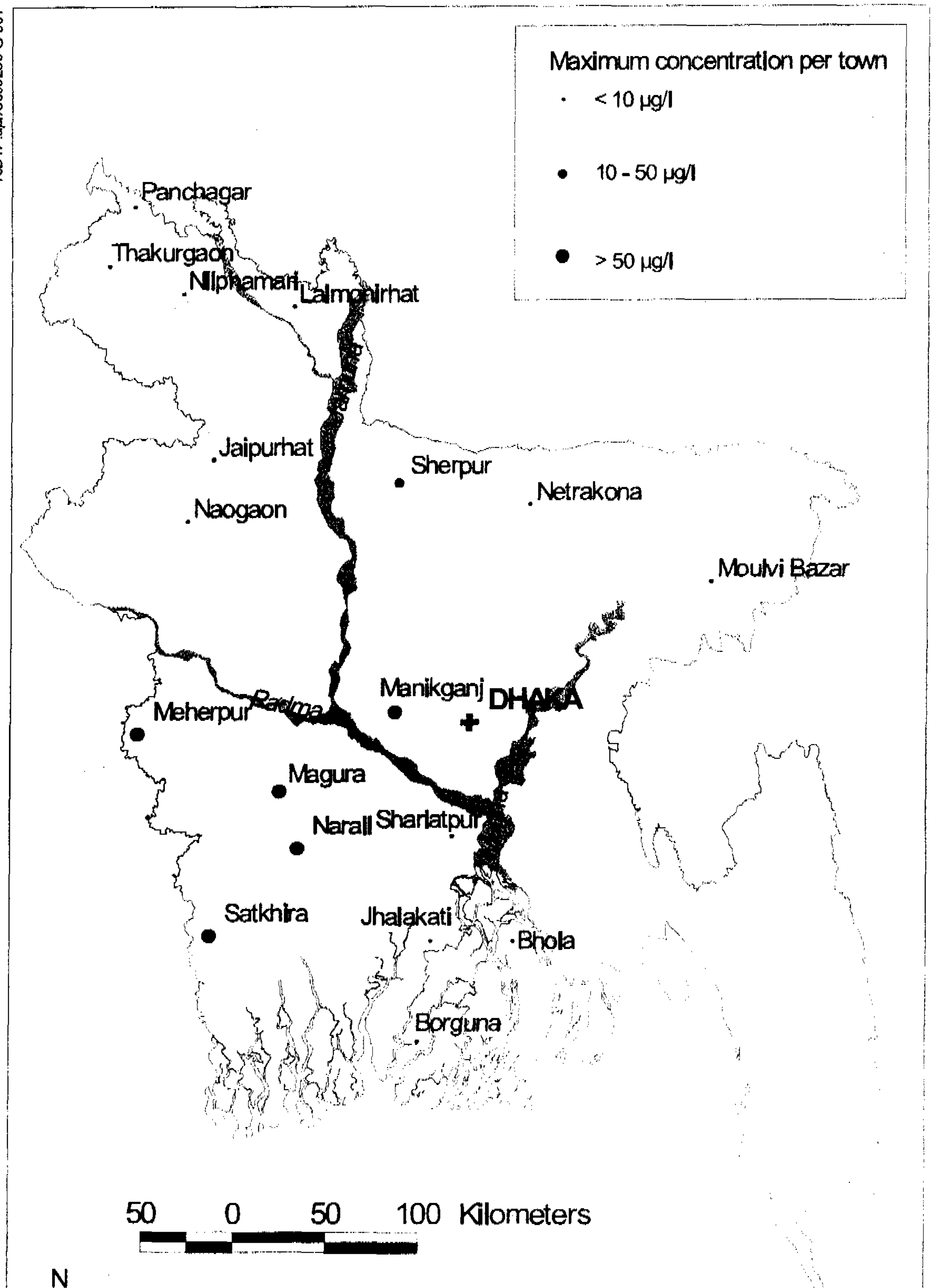


2 Arsenic in groundwater, theoretical background

2.1 Chemistry

In natural waters soluble arsenic is present in two valences: in the form of arsenate As(V) and in the form of arsenite As (III). The valency in which arsenic exists is a function of both pH and Eh (oxidation-reduction potential):

- in surface water and in oxygenated groundwater arsenic is predominantly found in its pentavalent state [As(V)] as protonised arsenates: $H_2AsO_4^-$ below pH 6.9 and as $HAsO_4^{2-}$ above pH 6.9;
- in reducing (anaerobic) conditions which are common in deep groundwater (with low Eh), arsenic is predominantly present in its trivalance state As (III), as arsenious acid species of H_3AsO_3. In extremely reducing environments the trivalent form can be found as AsS_2^- (Ferguson & Gavis, 1972).

Although both the organic and inorganic form exist, organic species (methylated arsenic) are rarely present at concentration > 1 µg/l and are generally considered of little importance compared with the inorganic species in drinking water (Anderson & Bruland, 1991).

The form and the oxidation state in which arsenic is present is called its speciation. The speciation of arsenic specifies the environment as well as the form in which arsenic has been dissolved.

> Because the different forms differ in solubility and consequently in mobility, the speciation of arsenic plays an important role in the mobilisation and the transport of arsenic in ground water. In the arsenite form, arsenic is more soluble and consequently more mobile than when arsenic is present as arsenate Deuel & Swoboda, 1972).

In soil, arsenates are mostly adsorbed to iron(III)(hydr)oxides (e.g. FeOOH) or to a lesser extent to aluminium(hydr)oxides. These (hydr)oxides can be present as discrete particles or as layers around other minerals like clays. Arsenite is hardly adsorbed by iron(III)(hydr)oxides (Pierce and Moore, 1982) and is consequently more mobile than arsenate. Apart from iron(III)(hydr)oxides, arsenic has got a strong affinity with pyrite, an iron(II)sulphide-mineral(FeS_2), which can include As in its mineral structure (Huerta-Diaz & Morse, 1992). Also arsenic can be adsorbed directly on clay minerals (Ferguson & Gavis, 1972) and on organic material (O'Neill, 1990).

In case of adsorption by pyrite, arsenic may be mobilized when the mineral is oxidized by oxygen or nitrate. This may lead to high arsenic concentrations in the groundwater. Another mobilization mechanism for arsenic is through mobilization of

iron(II)(hydr)oxides. Arsenic adsorbed to the iron(II)(hydr)oxides will be mobilized as well.
The presence of phosphates in groundwater may lead also to elevated levels of arsenic as phosphates compete with arsenic for adsorption places to iron(II)(hydr)oxides. An increased in phosphates may therefore result in desorption of arsenic and higher concentrations in the groundwater (Van Rossum, 1996).

2.2 Effects om public health

Elevated intake of arsenic may result in to the so-called black foot disease, visible in blackening of fingers and toes, and induces a general lethargy in the patient. Chronic intake of excessive concentrations may result in cancer. Arsenic poisoning may result from chronic ingestion of 150-3300 µg As/day in drinking water and food prepared in such water. For adults a dose of 80 mg As/kg body weight results in arsenic intoxication (Morris et al, 1974), while children are already affected by 1 mg As/kg body weight.

Elevated arsenic concentrations are commonly associated with sediments partially derived from volcanic rocks of intermediate to acid composition (Welch et al, 1988) and are also frequently found in water that also contains appreciable Fe-concentrations (Appelo & Postma, 1993) and are often associated with the presence of pyrite in the subsurface. Pyrite is a common mineral in clayey and peaty sediments which are often found in deltaic environments. A good example is the Netherlands where high arsenic concentrations in groundwater have been reported throughout the country, mostly in peaty and clayey environments (concentrations up to 850 µg/l, see Van Rossum, 1996). Lowering of the groundwater tables has resulted in higher levels of arsenic in parts of the Netherlands.

3 Arsenic in groundwater in the 18DTP

3.1 Set-up of the investigations

In the framework of the baseline study on arsenic in groundwater in 18-DTP, 149 water samples for analyses on arsenic have been collected from 126 wells in 4 subsequent phases:

- in December 1995, the situation in Meherpur was checked with 10 groundwater samples. The results where unambiguous: in 9 out of 10 samples the arsenic concentration was above the WHO guideline of 10 µg/l;
- in August 1995 53 groundwater samples in 9 other 18-DTP towns near the River Padma (Ganges) were collected. In 4 of these towns, (Shatkira, Narail, Magura and Manikganj) the arsenic concentration was above the WHO guideline level in at least one well;
- in October 1996 3 groundwater samples were collected in the town of Panchagarh. In none of the samples the arsenic concentration exceeded the detection limit;
- in December 1996 (the current mission), the towns which were not yet checked, were visited to collect water samples. The towns where previously elevated As concentration in groundwater was detected were visited again to collect additional groundwater samples to verify the previous results (83 samples).

All groundwater samples were submitted to the Environmental laboratory of IWACO in the Netherlands. Identification of the sample locations is presented in Appendix 2.

Sampling strategy

The first batch of groundwater samples were collected in the towns in the period December 1995 - October 1996. At this stage the objective of the sampling was to measure whether arsenic was present in groundwater in the area near the West Bengal border and if so, to assess the order of magnitude of the concentrations in deep and in shallow groundwater.

The results of the first batch indicated that arsenic is present in groundwater at levels exceeding the WHO guideline in 5 towns (Meherpur, Shatkira, Narail, Magura and Manikganj). Based on these results it was decided to sample the groundwater in production wells and hand tubewells in every town under 18-DTP.

In the towns of Meherpur, Shatkira, Narail, Magura and Manikganj, where the results of the first batch of samples indicated that the arsenic concentration in ground water was above the WHO guidelines of 10 µg/l, a second batch of samples was collected with the aim to:

- to verify the previous results;

- to check the arsenic concentrations in time;
- to provide some information about the relation depth versus arsenic concentration in groundwater;
- to check the influence of surface water bodies on the arsenic concentration;
- see whether abstraction of groundwater by production wells has any impact on the arsenic concentration in the vicinity. This in view of the postulation that the enlarged aerated zone around production wells, caused by the drawdown of the water table, may enhance pyrite oxidation which in turn may result in higher concentration of arsenic in the groundwater.

Sampling methodology
In order to allow comparison of the results of the analyses, all samples were collected using the same protocol. Groundwater was sampled from the outflow of the production wells and handpumps. The groundwater was stored without filtration in polyethane bottles of 0.25 l. All samples were acidified, to pH less than. Sampling protocol and sample conservation are in accordance with the Dutch "Water quality sampling guidelines part III; guidance on the preservation and handling of samples" and ISO 5667.

During the first sampling rounds, pH and Electric Conductivity (EC) were not measured. During the sampling of December 1996 a pH meter and an EC meter were taken into the field for measurements. Unfortunately the equipment was defective, so no pH and EC measurements could be performed.

All samples were analyzed by the IWACO laboratory in Rotterdam. A description of the analytic protocol is given as Appendix 3. Samples from the December 1996 sampling batch were also analysed on Iron and Sulphate in case Arsenic levels were between 2 and 10 µg/l or above 100 µg/l for towns with elevated arsenic levels.

3.2 Results

The results of the laboratory analyses of all analyses on arsenic are presented in annex 1. Table 1 gives an overview of the results of the analyses by town.
As can be seen from Table 1, arsenic levels exceeding the WHO guideline value for drinking water of 10 µg/l are found in some of the samples in the towns of Sherpur, Manikganj, Magura, Narail, Shatkira and Meherpur (for location of towns see Figure 1).

Table 1 also indicates that in all 6 towns with relatively high arsenic levels at least some groundwater samples do not exceed the WHO guideline. At least one sample in each of these towns even has arsenic concentrations below the detection limit of 2 µg/l. This may indicate that the arsenic contamination of the groundwater is not present everywhere in the aquifer, but rather that the elevated arsenic levels occur locally, probably influenced by the local hydrogeological situation and human activities.

Table 1:Inventory of arsenic investigations in 18-DTP

Town	Detected As concentrations						No. of wells sampled twice
	< 2 µg/l	2-10 µg/l	10-50 µg/l	50-100 µg/l	> 100 µg/l	Total	
Netrakona	1	4	-	-	-	5	-
Sherpur	1	3	2	-	-	6	-
Manikganj	1	3	10	3	-	17	4
Moulavibazar	4	1	-	-	-	5	-
Magura	2	4	5	2	-	13	4
Narail	2	2	9	-	1	14	5
Shatkira	1	0	8	5	1	15	3
Meherpur	1	2	12	4	4	23	7
Jhalokati	6	-	-	-	-	6	-
Bhola	5	-	-	-	-	5	-
Shariatpur	6	-	-	-	-	6	-
Barguna	5	-	-	-	-	5	-
Panchagarh	3	-	-	-	-	3	-
Lalmonirat	2	2	-	-	-	4	-
Nilphamari	-	4	-	-	-	4	-
Joypurhat	6	-	-	-	-	6	-
Naogaon	6	-	-	-	-	6	-
Thakurgaon	1	5	-	-	-	6	-
All samples	53	30	46	14	6	149	23

Figure 1 shows that most of the towns with high arsenic levels in the groundwater are found in the southwest of the country. However, the elevated levels in Manikganj and Sherpur indicate that arsenic contamination of the groundwater may occur also in other parts of Bangladesh.

3.3 Evaluation of the results

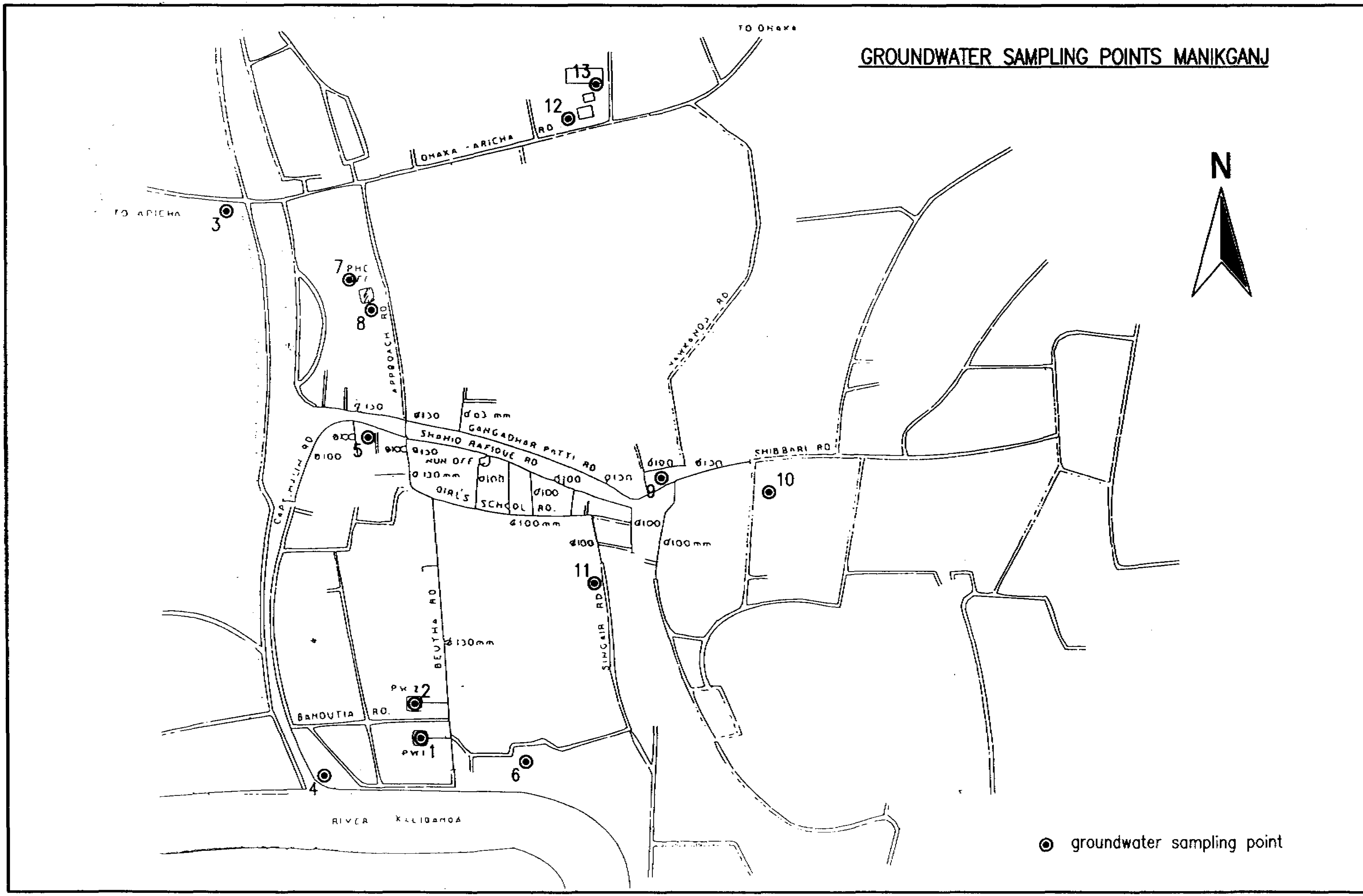
In this section of the report the results of the chemical analyses will be examined in relation with depth of the well, proximity of surface water bodies and production wells and with time. To this purpose the results will be discussed first for each town separately. In chapter 5 a more generalized evaluation of the results will be given.

Manikganj

In the town of Manikganj 6 groundwater samples were taken in August 1996 and 11 wells were sampled in December 1996; four wells were sampled during both sampling rounds (see Appendix 1). The location of the wells is shown in the figure on the following page.

Figure 2 shows the relationship between the depth of the well and the concentration of arsenic in the groundwater for Manikganj. For the data collected in August 1995, arsenic contents seems to increase with depth, but no such relationship is present for the December 1996 samples. None of the samples of December 1996 has an arsenic concentration exceeding 45 µg/l.

Wells that were sampled twice had significant lower arsenic levels in December 1996. Whether this is a reflection of an annual fluctuation of the arsenic level is unclear.


GROUNDWATER SAMPLING POINTS MANIKGANJ
N
TO DHAKA
TO ARICHA
DHAKA - ARICHA RD
APPROACH RD
SHAHID RAFIQUE RD
GANGADHAR PATTI RD
GIRL'S SCHOOL RD.
SHIBBARI RD
BEUTHA RD
SINGAIR RD
BANOUTIA RD.
RIVER
PHC
PW 2
PW 1
1
2
3
4
5
6
7
8
9
10
11
12
13
groundwater sampling point

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Considering the depth of most wells an annual fluctuation caused by seasonal influences is unlikely.

The highest arsenic levels in the groundwater are found in the two production wells in the south of Manikganj and in well number 3, near the Dhaka-Aricha highway. Low levels (< 10 µg/l) are found in wells 13, 10 and 6 at the eastern side of the town.

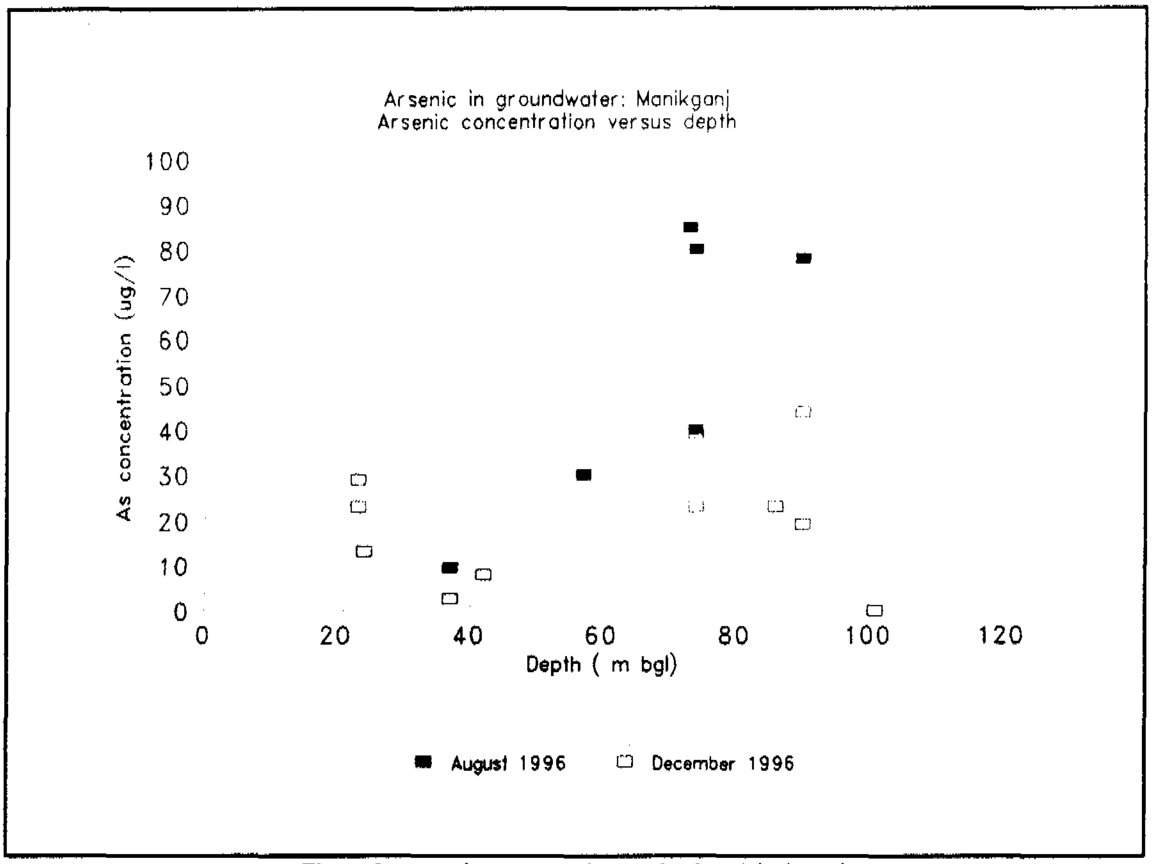


Figure 2: Arsenic concentration vs depth in Manikganj

When looking at the available data, there appears to be no relationship between the arsenic concentration of the groundwater and any of the following parameters:

- depth of the well;
- distance to the river or other open water bodies.
- year of construction of the well;
- type of well (hand tubewell, production tubewell or observation well);
- distance to production tubewells.

The production wells for the water supply of Manikganj showed relatively high values, ranging between 19 and 80 µg/l. The exceeding of the WHO limit is cause for concern, although the levels do probably not pose a direct threat to public health. The haphazard distribution of high- and low- arsenic groundwater and the small amount of data makes it impossible to identify an alternative location for a safer production well.

It is **recommended** that the production wells in Manikganj are sampled regularly and analyzed on arsenic. The recommended minimum frequency of sampling is once per month. Sampling and analysis should be conducted according to a well described protocol. The obtained data may be used to identify which well yields the best water quality throughout the year.

Meherpur

In the town of Meherpur 10 groundwater samples were taken in December 1995 and 13 wells were sampled in December 1996; seven wells were sampled during both sampling rounds (see Appendix 1). The location of the wells is shown in the figure on the following page.

Figure 3: Arsenic concentration vs depth in Meherpur

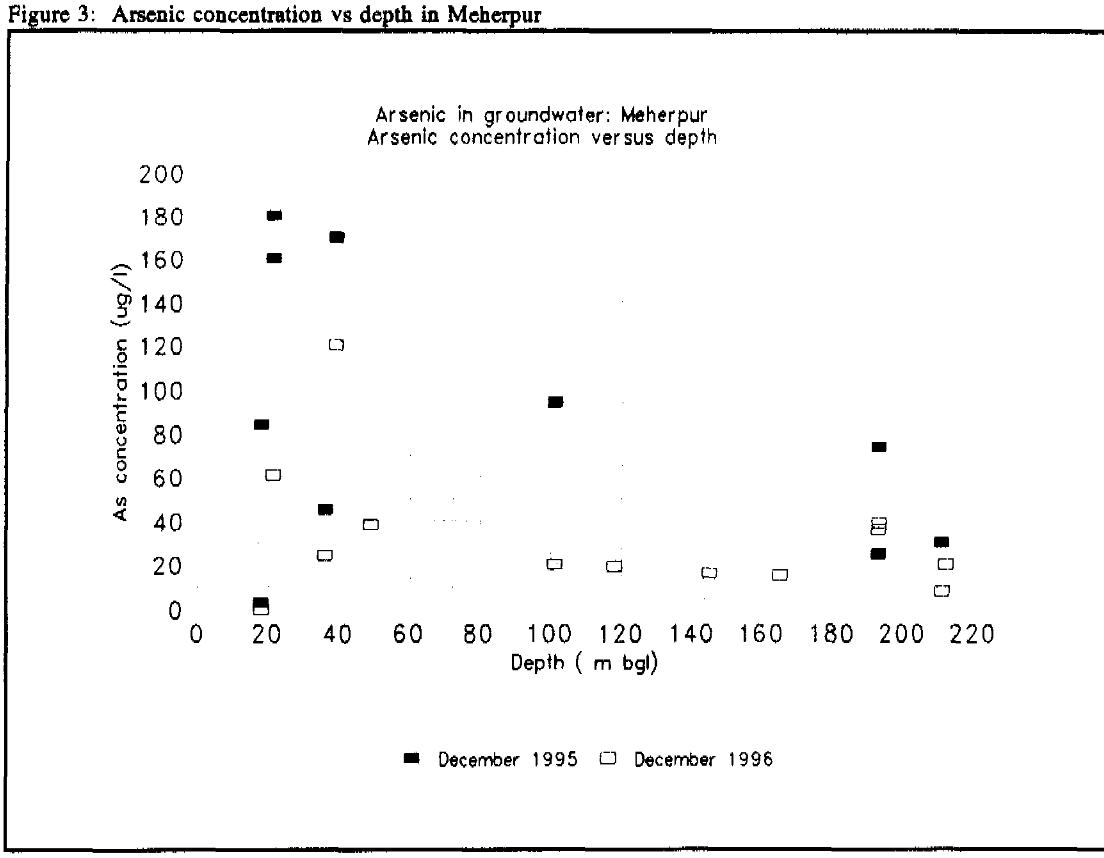
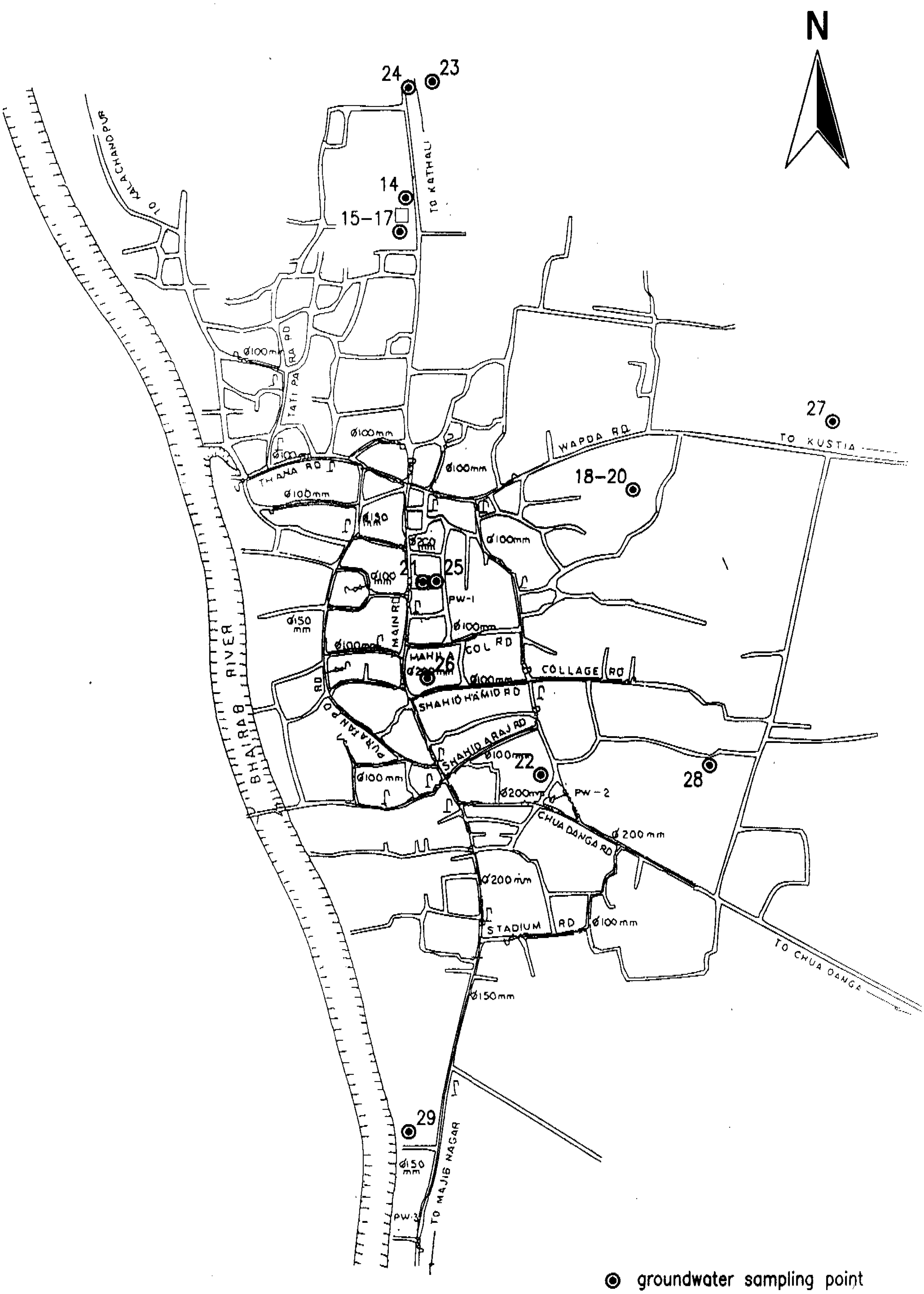


Figure 3 shows the relationship between the depth of the well and the concentration of arsenic in the groundwater for Meherpur. The highest arsenic concentrations are found in shallow wells: all concentrations over 100 µg/l are measured in samples taken from wells less than 40 m deep. However, the relationship between depth and arsenic content of the groundwater does not appear to be significant. Even in the deepest wells (> 200 m) arsenic levels of 20-75 µg/l are found. At the same time one shallow well yields groundwater containing less than 10 µg/l.

GROUNDWATER SAMPLING POINTS MEHERPUR



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In wells that were sampled twice, the samples from December 1995 generally have a higher arsenic concentration than the samples from December 1996. Exceptions are wells 16 (lower in 1995) and 26 (no change).

As is the case in Manikganj, no connection can be established between the arsenic content of the groundwater and other parameters, such as the depth of the well, the distance to the river or other open water bodies, the year of construction of the well, the type of well (hand tubewell, production tubewell or observation well) or the distance to production tubewells.

The production wells for the water supply of Meherpur showed relatively high values, ranging between 20 and 94 µg/l. The exceeding of the WHO limit is cause for concern, although the levels do probably not pose a direct threat to public health. The haphazard distribution of high- and low- arsenic groundwater and the small amount of data makes it impossible to identify an alternative location for a safer production well.

It is recommended that the production wells in Meherpur are sampled regularly and analyzed on arsenic. The recommended minimum frequency of sampling is once per month. Sampling and analysis should be conducted according to a well described protocol. The obtained data may be used to identify which well yields the best water quality throughout the year.

Magura
In the town of Magura 6 groundwater samples were taken in August 1996 and 7 wells were sampled in December 1996; four wells were sampled during both sampling rounds (see Appendix 1). The location of the wells is shown in the following page.

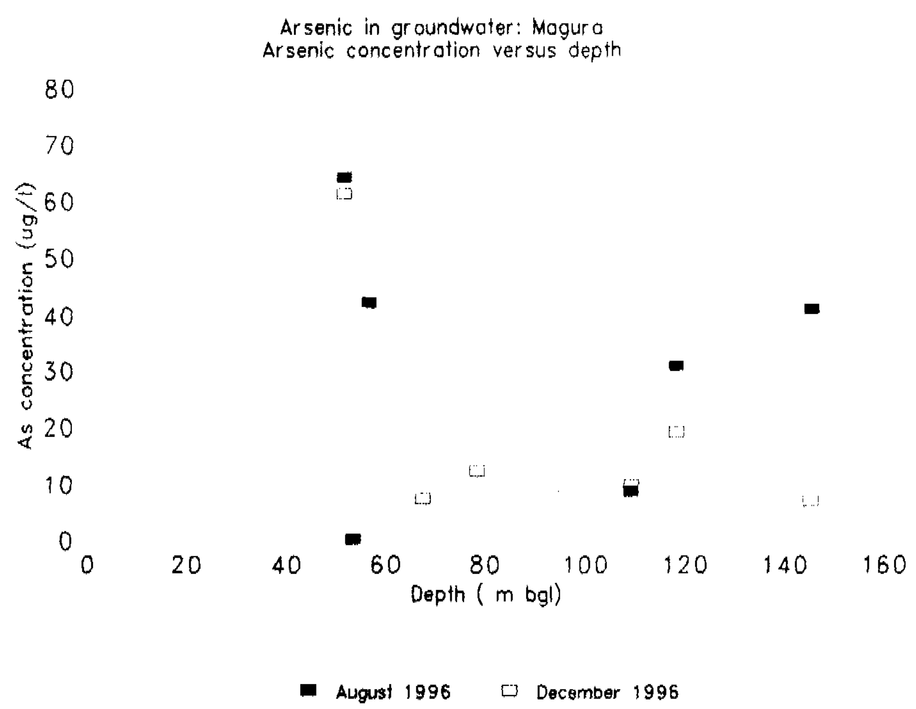
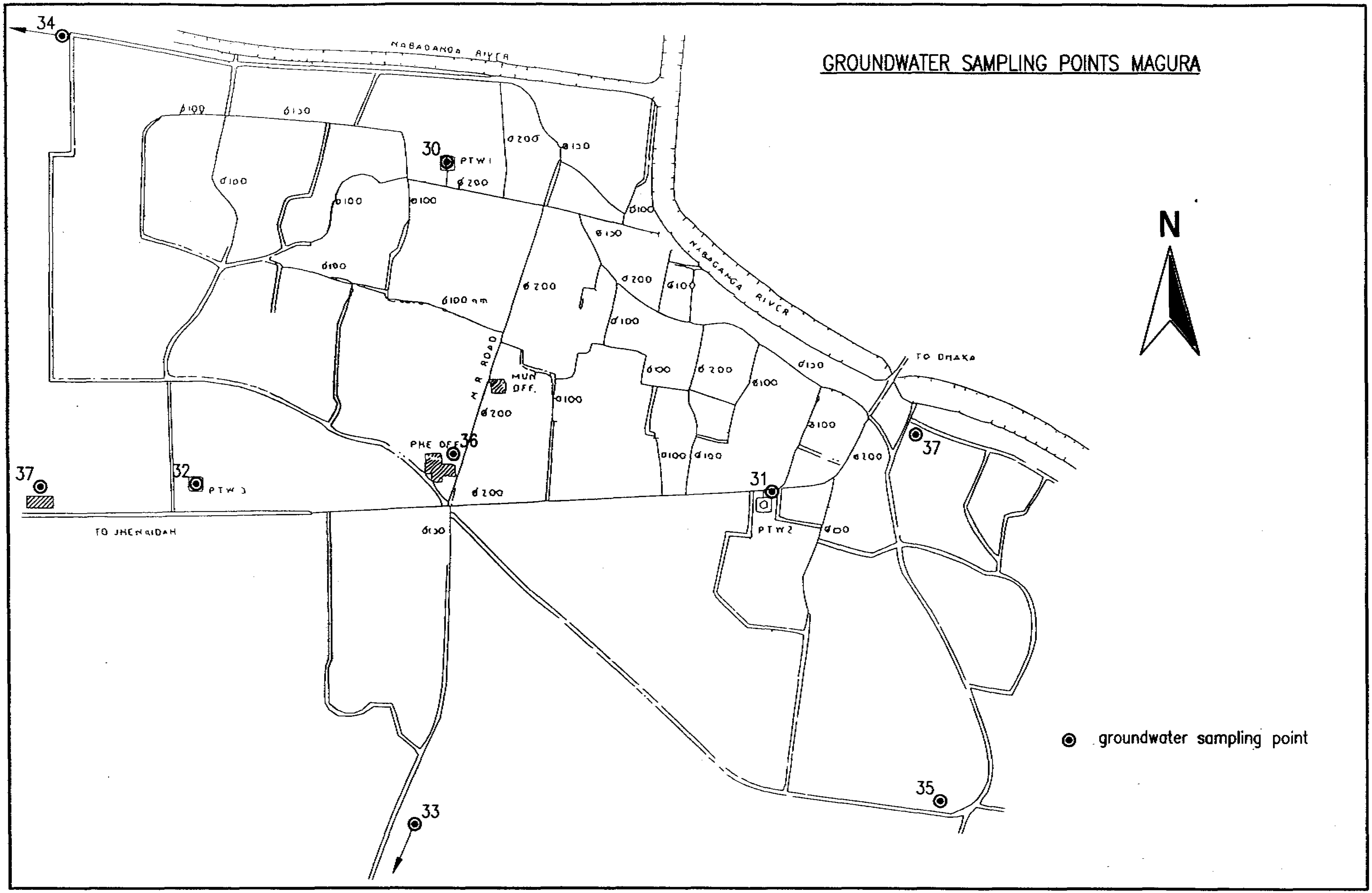


Figure 4: Arsenic concentration vs depth in Magura

Figure 4 shows the relationship between the depth of the well and the concentration of arsenic in the groundwater for Magura. There is no apparent relationship between well depth and arsenic level in the groundwater. Of the wells that were sampled twice, two wells (nos 30 and 31) show considerable higher levels of arsenic in December 1996 than in August 1995. In two wells (nos 32 and 34) the levels are similar for both sampling rounds.

GROUNDWATER SAMPLING POINTS MAGURA



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The highest levels of arsenic were detected in wells 30, 31, 34 and 35. Two of these wells are water supply production wells, the other two are hand tubewells. The water from the third water supply well contained low levels of arsenic and so did the samples from the other hand tubewells.

Also for Magura no connection could be established between the arsenic content of the groundwater and other parameters, such as the depth of the well, the distance to the river or other open water bodies, the year of construction of the well, the type of well (hand tubewell, production tubewell or observation well) or the distance to production tubewells.

The production wells for the water supply of Magura showed low to medium values of arsenic, ranging between 6.7 and 41 µg/l, not exceeding the 'old' WHO limit of 50 µg/l. The exceeding of the 1993 WHO limit in half of the samples taken from production wells is cause for concern. However, there seems to be no direct threat to public health.

It is recommended that the groundwater for the town of Magura as much as possible will be produced through production well number 3. This well apparently yields the best water quality. In addition it is recommended that all production wells in Magura are sampled regularly and analyzed on arsenic. The recommended minimum frequency of sapling is once per month. Sampling and analysis should be conducted according to a well described protocol. The obtained data may be used to identify which well yields the best water quality throughout the year.

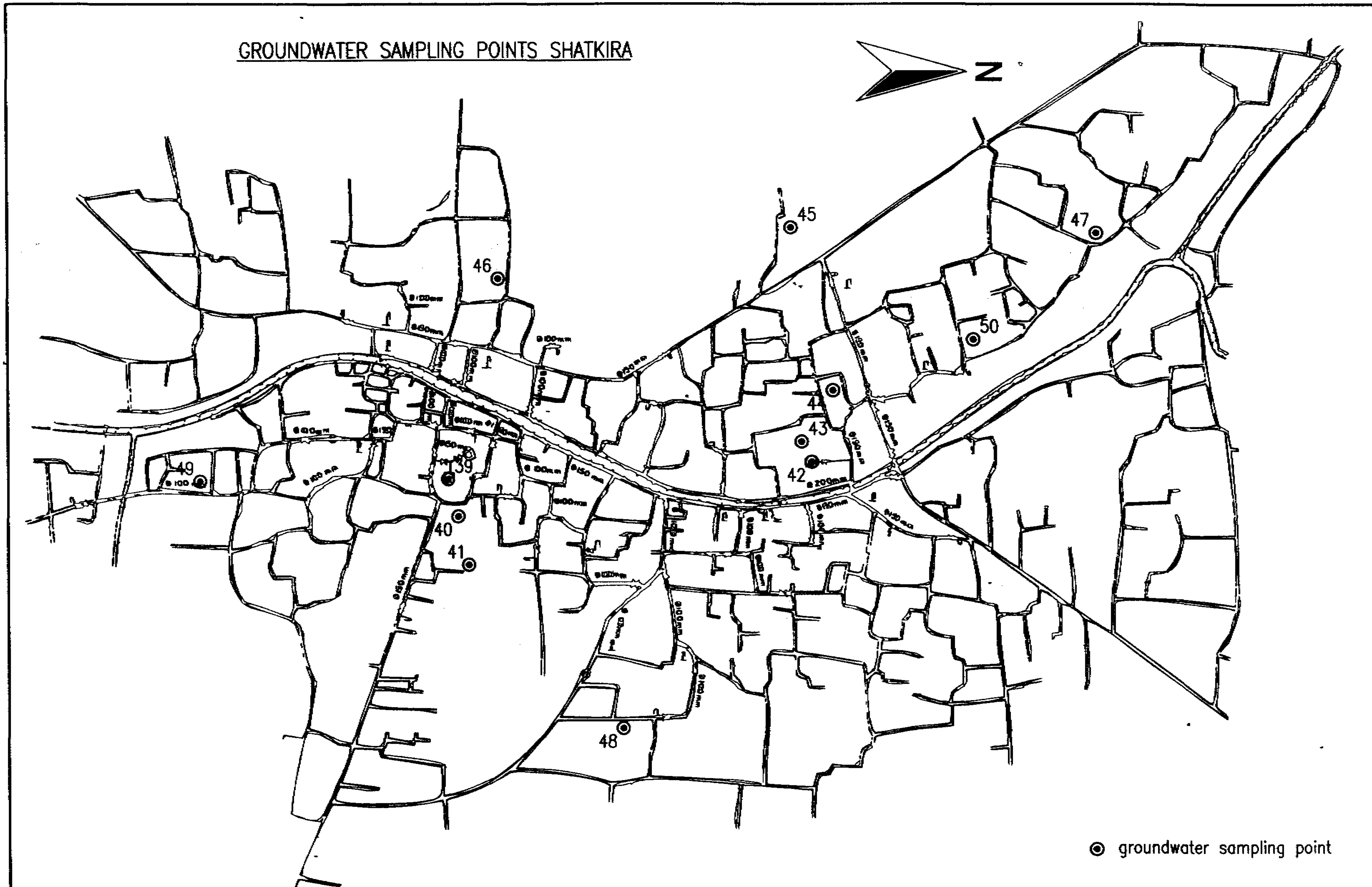
Satkira

In the town of Shatkira 7 groundwater samples were taken in August 1996 and 9 wells were sampled in December 1996; three wells were sampled during both sampling rounds (see Appendix 1). The location of the wells is shown in the following page.

Figure 9 shows the relationship between the depth of the well and the concentration of arsenic in the groundwater from the well for Shatkira. Again there is no apparent relationship between well depth and arsenic level in the groundwater.

All three wells that were sampled twice contain less arsenic in the December 1996 samples than in the August 1996 samples, but only for well 42 the difference is significant.

GROUNDWATER SAMPLING POINTS SHATKIRA



For Shatkira no connection could be established between the arsenic content of the groundwater and other parameters, such as the depth of the well, the distance to the river or other open water bodies, the year of construction of the well, the type of well (hand tubewell, production tubewell or observation well) or the distance to production tubewells.

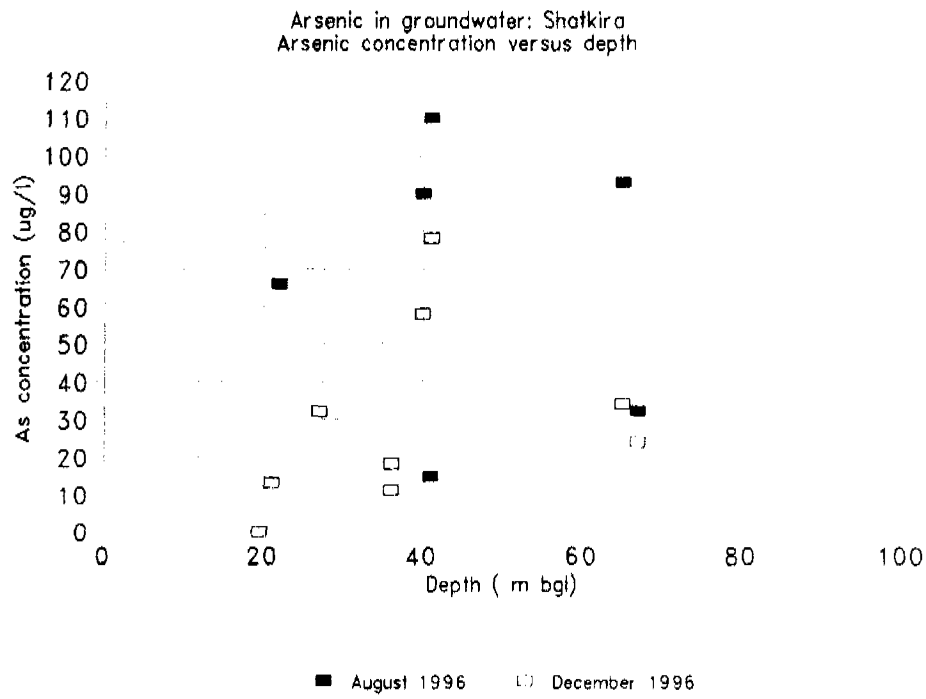


Figure 9: Arsenic concentration vs depth in Shatkira

The production wells for the water supply of Shatkira Meherpur showed relatively high values, ranging between 24 and 93 µg/l. The exceeding of the WHO limit is cause for concern, and the levels may pose a threat to public health on the long term. The haphazard distribution of high- and low- arsenic groundwater and the small amount of data makes it impossible to identify an alternative location for a safer production well.

It is recommended that the production wells in Meherpur are sampled regularly and analyzed on arsenic. The recommended minimum frequency of sampling is once per month. Sampling and analysis should be conducted according to a well described protocol. The obtained data may be used to identify which well yields the best water quality throughout the year.

Narail

In the town of Narail 6 groundwater samples were taken in August 1996 and 8 wells were sampled in December 1996; five wells were sampled during both sampling rounds (see Appendix 1). The location of the wells is shown on the following page.

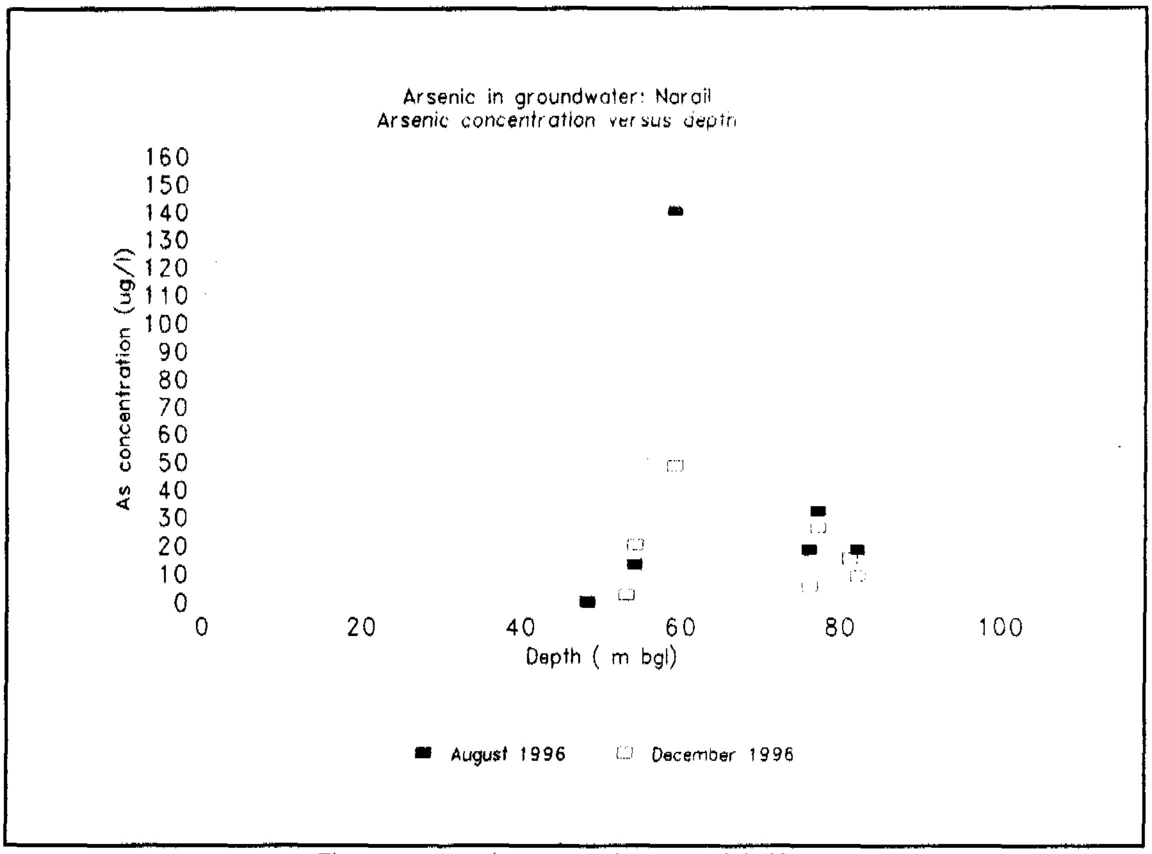
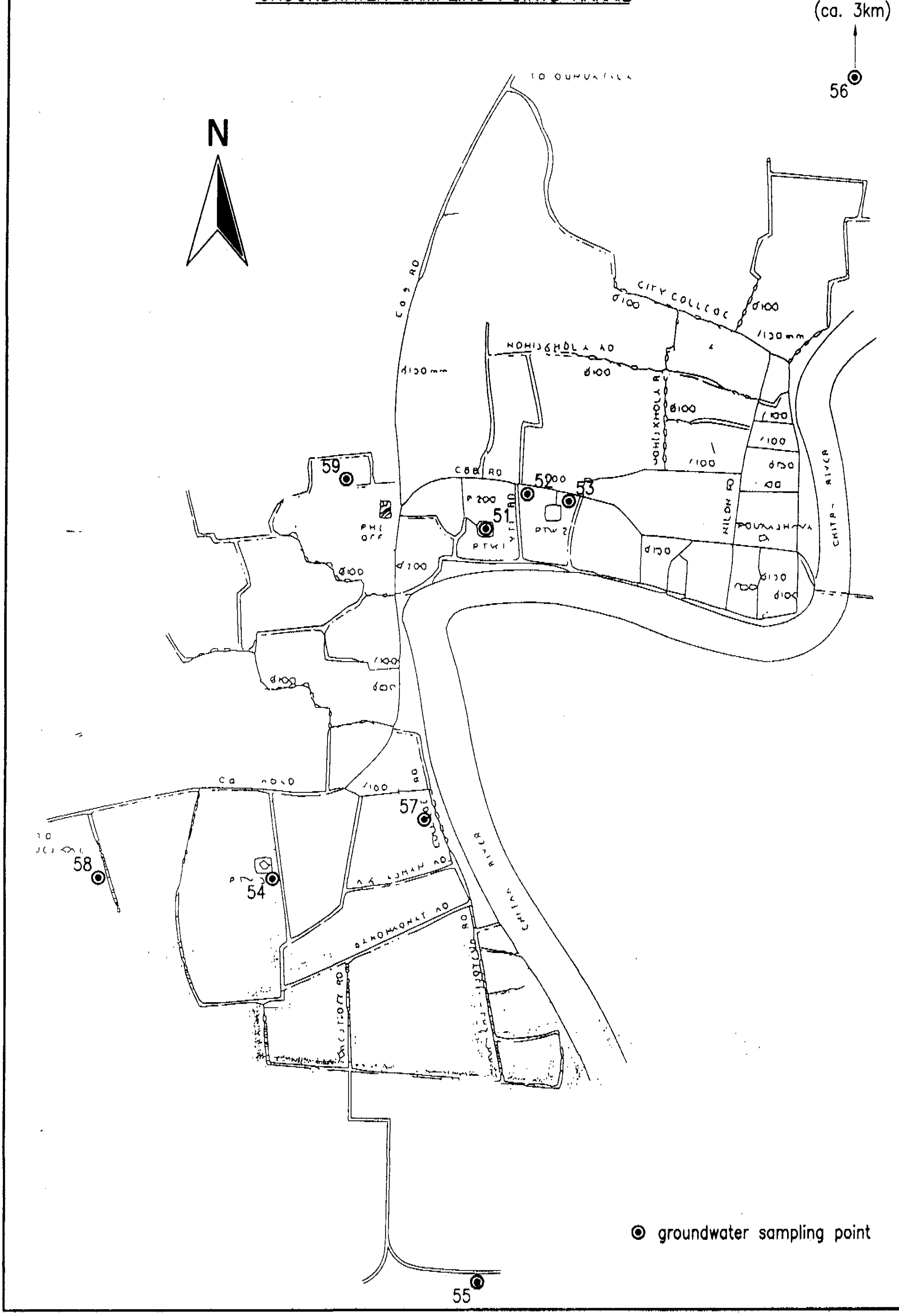


Figure 11: Arsenic concentration vs depth in Narail

Figure 11 shows the relationship between the depth of the well and the concentration of arsenic in the groundwater from the well. Again there is no apparent relationship between well depth and arsenic level in the groundwater.

GROUNDWATER SAMPLING POINTS NARAIL



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The lowest levels of arsenic were detected in groundwater from wells 53 and 48 at the southern and western fringes of the town (less than 3 µg/l), the highest values were found in well 55 in the north. In the other wells the arsenic concentrations range between 10 and 32 µg/l. Insufficient data are available to maintain that this distribution is part of a (sub)regional pattern of decreasing values in southward direction.

The production wells for the water supply of Narail showed low to medium high values, ranging between 5 and 32 µg/l. The exceeding of the WHO limit is cause for concern, although the levels do probably not pose a direct threat to public health.

It is **recommended** that the groundwater for the town of Narail as much as possible will be produced by using production wells number 1 and 2. These wells apparently yield the best water quality. In addition it is **recommended** that all production wells in Magura are sampled regularly and analyzed on arsenic. The recommended minimum frequency of sampling is once per month. Sampling and analysis should be conducted according to a well described protocol. The obtained data may be used to identify which well yields the best water quality throughout the year.

Sherpur

Five groundwater samples were taken in Sherpur in December 1996. Two of the samples showed arsenic levels of about 30µg/l, thus exceeding the WHO limit (well nos 105 and 107, both hand tubewells). Arsenic levels in the other three wells (including the production wells of the town's water supply) are below this limit. An explanation for the elevated levels in the two hand tubewells is not available.

The water supply wells in Sherpur contain less arsenic than the WHO limit and there is, therefore, no threat to the public health. However, the arsenic levels in the two production wells were above the detection limit and there is some cause for concern.

It is **recommended** that all production wells in Sherpur are sampled regularly and analyzed on arsenic. The recommended minimum frequency of sampling is once per month. Sampling and analysis should be conducted according to a well described protocol. The obtained data may be used to confirm that the production wells continue to yield water of safe quality throughout the year.

Other towns

In 12 towns the concentration of arsenic in the groundwater samples did not exceed the WHO limit of 10 µg/l: Shariatpur, Bhola, Jhalokati, Panchagarh, Naogaon, Joypurhat, Moulavi bazar, Netrakona, Lalmonirhat, Thakurgaon, Nilphamari and Barguna. In many of these towns the arsenic concentration exceeded the detection limit in at least one sample, indicating that some groundwater contamination with arsenic is present (Moulavi bazar, Netrakona, Lalmonirhat, Thakurgaon and Nilphamari).

In these towns the groundwater quality is good and safe as far as arsenic is concerned. It is **recommended** that all production wells in these towns are sampled for analysis on arsenic regularly. The recommended **minimum** frequency of sampling is once per six months.

4 Measures taken by the Bangladesh authorities

4.1 Introduction

In order to find out in what way the Bangladesh authorities anticipated on the threads to the public health by the elevated arsenic concentrations in ground water, a number of institutes and persons were visited:

Bangladesh Water Development Board, Mr.Md.Mizanur Rahman, Director GW Circle II; Department of Public Health Engineering, Ground Water Circle, Research and Development, Mr.Ihteshamul Haque , XEN; Department of Environment, Mr.M.Khan.

May be due to the unofficial status of the mission. It seemed impossible to arrange appointments with the relevant representatives (assigned for the As problem) of WHO and UNICEF.

An outline of the discussions and interviews with the above mentioned persons are presented hereafter.

4.2 Set Up of the Organization on a National Level

In 1995 a National Steering Committee was created. In order to anticipate adequately on the threads to public health by elevated arsenic concentrations in ground water. In view of the importance of the health aspects, the Chairman of this Steering Committee is the Director General of Health Service and the members are representatives from DPHE, BWDB, DGHS, DOE, BUET, GSB, WHO, UNICEF and NIPSOM (see acronyms). Initially three sub-committees were created and assigned for specific tasks and responsibilities (see Table 4.1). Every sub-committee prepared a plan of action. In February 1996, the concepts of the Terms of References from the three sub-committees were blended into a TAPP by NIPSOM and forwarded to the Government of Bangladesh. Recently, in December 1996, the approval of this TAPP has been stopped by Prof.J.M.Dave (assigned as technical consultant for the 3 sub-committees) and the tasks of the sub-committees were formulated and reshuffled and an additional "Research Committee" was created.

4.3 Investigation Realized So Far by the Sub-Committees

Sub-committee for Geo-hydrology

The intention of the sub-committee of Hydrogeology (Bangladesh Water Development Board and Geological Survey of Bangladesh) is to investigate in 30 locations the source of arsenic in ground water. To realize this programme of investigations, the BWDB needs a budget of 1.55 million Btk. So far the budget has not been made available and apart from 20 water points which have been sampled and analyzed no further field activities or investigations have been realized.

Sub-Committee for water quality standard analysis

The sub-committee for water quality standard analysis (DPHE, Ground Water Circle, Research and Development) has collected and analyzed (in close collaboration with the WHO) more than 200 ground water samples. Recently the results have been reported. Due to budgetary constraints large sampling campaigns are not to be occupied.

Sub-committee for Health Hazard

This committee is according to DPHE not (yet) functioning properly due to non availability of facilities. Also for this committee counts that no money has been allocated, to realize the action plans.

It is obvious that until and unless the TAPP for the activities of the sub-committees will be approved by the Government of Bangladesh investigations and actions will be limited or even come to a standstill due to budgetary constraints. The institutes concerned can not allocate budget to realize these "additional" activities.

Table 2:Sub-committees involved in investigations on Arsenic in ground water

Sub-committee	Organized by	Principle tasks of sub-committee
Sub-committee for water quality standard analysis	DPHE	- Identification of potential hazardous areas; - Organize water analysis campaigns in areas with potential As-hazard; - Sealing of affected water sources and organize alternative water supply; - Recommend measure to control As in ground water
Sub-committee for Health Hazard	NIPSOM	- Development of a surveillance team for identification, treatment and follow up of cases; - Nation wide survey to detect patients affected with arsenic intoxication; - Establishment of a 10 bedded in patient service for management of the complicated cases; - Nation wide training of doctors and Health personnel to disseminate knowledge on arsenicosis; - Involvement of media of AEC material for awareness development; - Development of inter-pectrol cooperation both with National and International Agencies.
Sub-committee for Geo-hydrology	BWDB & GSB	- to develop the source of arsenic in ground water; - to determine the background of the accumulation of arsenic in groundwater; - to determine the vertical and lateral extent of As in As-affected aquifers; - to realize detailed investigations in a number of pre-selected sites; - to carry out spot investigations in different parts of the country whenever required.
Research Committee	IAEH-Lab	

List of acronyines

AAN	Asian Arsenic Network
DGHS	Directorate General of Health Services
DOE	Department of Environment
DPHE	Department of Public Health Engineering
BWDB	Bangladesh Water Development Board
BUET	Bangladesh Technical University in Dhaka

GSB	Geological Survey of Bangladesh
NIPSOM	National Institute of Preventive and Social Medicine

5 Conclusions

In this baseline study 149 groundwater samples were taken from 126 wells in 18 towns. This is a relatively small data set, and overall conclusions based on these data should be formulated with caution. Some conclusions are given below.

1. In six towns of the 18-DTP project, the groundwater concentrations of arsenic exceed the WHO guideline of 10 µg/l. These towns are Manikganj, Meherpur, Magura, Shatkira, Narail and Sherpur. Except in Sherpur, the pre-1993 guideline of the WHO (50 µg/l) is exceeded in each of these towns in at least one well.

2. In each town, including the six towns mentioned under 1., at least one well has arsenic levels below the 10µg/l level. More remarkable even is that in each town (except Nilphamari) at least one sample was found without arsenic (arsenic below detection limit of 2 µg/l). This is an indication that the groundwater contamination is very heterogeneous.

3. In none of the towns where elevated concentrations of arsenic are present a relation could be established between the depth of the well and the arsenic level. This is confirmed in Figure 12 showing a graph of the arsenic concentration versus depth for all sampled wells. Note that the highest values for arsenic indicated in Figure 12 are those for hand tubewells in Meherpur. It should be emphasized here, that no effort was made to make detailed hydrogeological schematization for the six towns with high arsenic levels. It is recommended that this be done.

4. In none of the towns a relation could be established between the arsenic concentration of the groundwater and one of the following parameters:

   - distance to open water bodies such as rivers or lakes;
   - year of construction of the well;
   - type of well;
   - distance to production wells.

5. Most wells that were sampled twice had considerable lower concentrations of arsenic in December 1996 than in August 1995. It is not clear if this could be caused by any seasonal influences.

6. The effect of changes in groundwater levels on the arsenic contents of the groundwater is difficult to establish. Groundwater level monitoring is conducted in Bangladesh by the Groundwater Circle of the Bangladesh Water Development Board (BWDB-GWC). Data from BWDB-GWC do not show a decline in the towns of the 18-DTP project (BWDB, 1995). Based on data from BWDB-GWC the National Minor Irrigation Project reports the occurrence of groundwater decline in rural areas of Bangladesh (NMIDP, 1996). The declines are in the

order of 1-3 meter over the last ten years and occur in areas with intensive groundwater irrigation. It should be clearly noted here, that the decline of groundwater levels does occur only during the irrigation season. Recharge of the aquifers in the rainy season is abundant and sufficient.

7. Arsenic concentrations of groundwater exceed the WHO limit in water supply production wells of Meherpur, Manikganj, Magura, Shatkira and Narail. In Magura and Narail water supply wells exist with low arsenic levels; it is strongly recommended to use those wells as much as possible for the water supply of the towns.

8. For Meherpur, Manikganj and Shatkira the raw water for the water supply will not meet the WHO standards of 1993. As arsenic-free groundwater is not available in those towns, treatment of water to remove the arsenic should be seriously considered.

9. As the available data are limited in number, it is recommended to start an arsenic monitoring programme in all towns. Sampling and analysis on arsenic should be **at least** monthly in towns where elevated levels of arsenic are reported and at least bi-annually in the other towns. Sampling should include all production wells in the towns. In addition a selection of other wells might be selected for regular sampling and analysis. During water sampling field values for pH and EC should be collected. Groundwater samples should be analyzed on major elements (Ca, Mg, K, Na, CO_3, HCO_3, SO_4, Cl, NO_3), arsenic and iron.

10. The effect of filtration of the samples on the arsenic content should be investigated. This may be done by collecting a number of filtrated and non-filtrated samples from various high-arsenic wells. Filtration may be realized by using 45 µm manual filtration equipment.

11. Treatment of arsenic-rich groundwater might be possible by using sunlight, see Appendix 5.

Arsenic in groundwater in the 18DTP

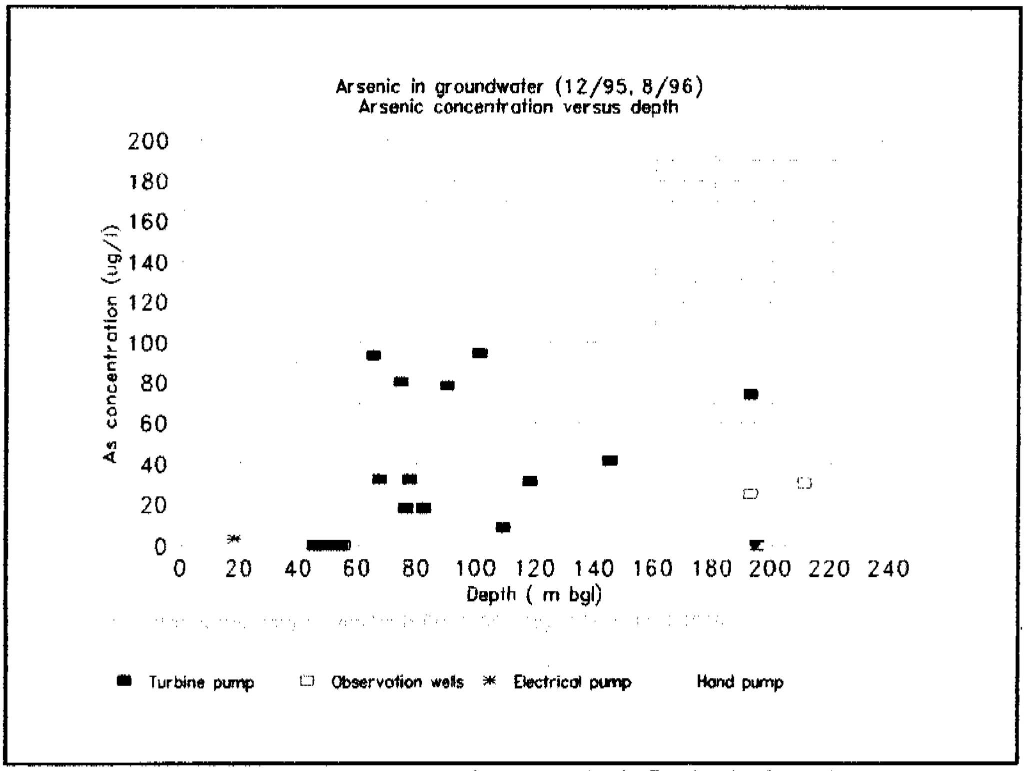

Figure 12a: Arsenic concentration versus depth; first batch of samples

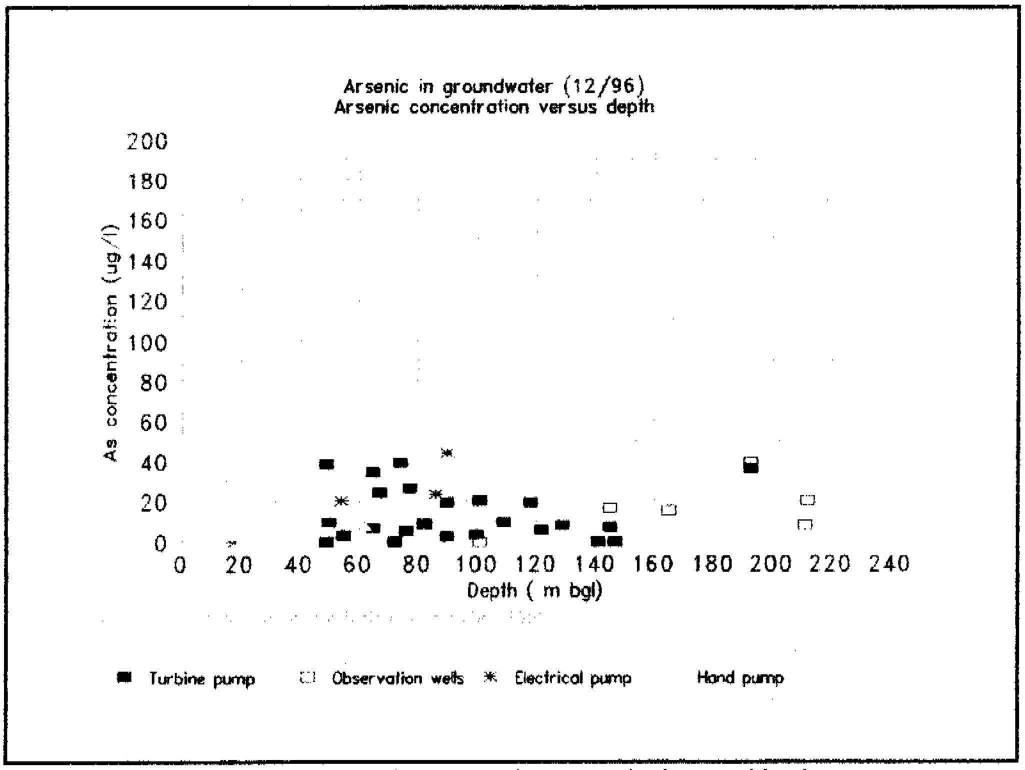

Figure 12b: Arsenic concentration versus depth: second batch

6 Recommendations

In the previous chapters already some recommendations have been given. Based on the results and the conclusions this chapter summarizes the recommendations with respect to the elevated arsenic levels found in groundwater in some towns.

The recommendations of this report fall into three categories:

a. Immediate and urgent recommendations, to be implemented by 18-DTP;
b. Mid-term and important recommendations, moderately urgent, to be implemented by 18-DTP;
c. Mid- to long-term recommendations to be implemented in cooperation with other projects and organizations.

The immediate and urgent recommendations are as follows:

1. Arsenic concentrations of groundwater exceed the WHO limit in water supply production wells of Meherpur, Manikganj, Magura, Shatkira and Narail. In Magura and Narail water supply wells exist with low arsenic levels; it is strongly recommended to use those wells as much as possible for the water supply of the towns.

2. For Meherpur, Manikganj and Shatkira the raw water for the water supply will not meet the WHO standards of 1993. As arsenic-free groundwater is not available in those towns, treatment of water to remove the arsenic should be seriously considered. Research into cheap and easy arsenic removal processes is required and should be initiated. An evaluation of possible treatment processes for water supply systems as well as for hand pumps should be made. Appendix 5 contains a recent copy of an article from the New Scientist that may be of help.

3. As the available data are limited in number, it is recommended to start an arsenic monitoring programme in all towns. Sampling and analysis on arsenic should be **at least** monthly in towns where elevated levels of arsenic are reported and at least bi-annually in the other towns. Sampling should include all production wells in the towns. In addition a selection of other wells might be selected for regular sampling and analysis. During water sampling field values for pH and EC should be collected. Groundwater samples should be analyzed on major elements (Ca, Mg, K, Na, CO_3, HCO_3, SO_4, Cl, NO_3), arsenic and iron.

4. The effect of filtration of the samples on the arsenic content should be investigated. This may be done by collecting a number of filtrated and non-filtrated samples from various high-arsenic wells. Filtration may be realized by using 45 μm manual filtration equipment.

5. The interaction between the aquifer material and the groundwater needs more thorough investigation, both laterally and with depth. Investigations in this respect will be a matter for the medium to long term, and should be implemented through the existing inter-ministerial committees. However, some investigations should be started immediately in the framework of the 18-DTP project.

- it is recommended to install a multi-filter sampling well close to (about 20 m distance) a production well in Manikganj and Meherpur (one well in each town). These wells will contain 10 to 20 so-called mini-filters that allow groundwater sampling at various depths. The depth of the wells should be the same as the depth of the production wells. Through a multi-channel datalogger the groundwater levels in the minifilters should be monitored during the abstraction of the groundwater for the towns's water supply. This will show the detailed groundwater flow patterns near the production wells;
- during the drilling of the wells soil samples should be taken for mineralogical analyses and analysis on the arsenic contents;
- those soil samples should be analyzed that were taken at the same level as the position of the mini filters; analysis of samples of clayey and peaty horizons is also recommended.

Recommendations on the mid-term are:

6. The distribution and extent of the contamination of groundwater should be investigated. In this respect the distribution of polluted water in Meherpur, Manikganj, Magura, Shatkira and Narail. In Magura and Narail should be further investigated. Before a detailed sampling programme is initiated, the hydrogeological situation should be mapped using available bore logs. In addition an inventory of existing industries in these towns should be made. Based on this information, the preferred location and depth of new sampling sites should be determined.

Recommendations on the mid- to long-term should be directed to further research. This research should not be carried out in the framework of 18-DTP alone. Other projects on water supply, urban as well as rural, should investigate the matter. If required other institutions could be involved in the investigations, such as DPHE, the Geological Survey of Bangladesh, GWDB- groundwater Circle, BUET, Dhaka University and others.

Mineralogy of the aquifer needs more thorough investigation, both laterally and with depth. The model concentration of pyrite in particular needs to be assessed. Chemical analysis of minerals, notably pyrite, clay minerals and iron oxides needs to be carried out, especially for arsenic (e.g. by electron microprobe). Whole-rock analyses of sediments also need to be made, for major elements and arsenic. This would be achieved best by obtaining sediment from newly-drilled boreholes in both high-arsenic and low-arsenic areas in the Quaternary aquifer.

Chemical analysis of porewater extracted from newly-cored sediments would help to relate aqueous geochemistry to sediment composition in discrete horizons and would constrain the mineral sources and mobilisation processes. Dry drilling, hence percussion methods would need to be carried out to achieve this.

Further regional surveys of quality of water pumped from existing tubewells should incorporate other elements and parameters of relevance to arsenic mobility, notably redox potential, dissolved oxygen, pH, major elements (particularly sulphate and nitrate), iron manganese, phosphorus and other trace elements such as antimony. It is paramount that the redox environment (Eh) and pH variations in the aquifer are ascertained as these are crucial to the mobilisation of arsenic.

Since pesticides and/or phosphate fertilisers were postulated as a possible source of arsenic contamination, it is necessary to ascertain composition and application rates of such materials and to measure concentrations of anthropogenic pollutants in the groundwater (e.g.pesticides, phosphorus, nitrate, potassium, sulphate, ammonium).

If overabstraction and induced pyrite oxidation is the mechanism of arsenic mobilisation much more investigation needs to be made of historical water-level changes and abstraction rates.

a. Investigation of the potential for deep drilling for alternative low-arsenic water sources should incorporate analysis of the aquifer's physical properties, such as vertical and horizontal variation in permeability to assess the likelihood of induced vertical flow of shallower high-arsenic water to deeper levels and to asses whether dewatering of deeper layers is likely to result. Prediction of the impact of pumping from deeper levels should be carried out by groundwater-flow (computer) modelling.

b. If arsenic-producing zones appear to be concreted in distinct horizons in the aquifer, boreholes should be modified to seal such horizons or to case out problem layers.

c. Investigation of the potential of shallow groundwater with low arsenic concentrations (close to the water table) for drinking-water supply should be carried out. Improved ground water yields from shallow depths may be necessary (large-diameter wells, horizontal drilling).

d. If pyrite is the cause of the high arsenic concentrations, prudent aquifer management would include maintaining the water levels as high as possible: whilst pyrite oxidation can proceed in aerobic groundwater by reduction of dissolved oxygen (and nitrate), the effect will be **much** more pronounced in the presence of atmospheric oxygen introduced by periodic dewatering.

Appropriate technology treatment methods at community or domestic level are a reasonable short-term strategy for mitigation of the arsenic problem but are not a long-term solution. Provision of safe, good-quality groundwater is in my opinion preferable to treatment of existing groundwater or to regional water schemes. Solutions will not be found overnight and require longer-term research initiatives on the key hydrogeological and hydrogeochemical process pertaining to the aquifer.

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Appendix 1

List of the results

Annex 1. Arsenic in groundwater 18 District Towns, results of the laboratory analyses

No		Depth	Constr. yr	type	date	As	date	As
1	Manikganj	90	1981	p	+8/8/96	78	+10/12/96	19
2	Manikganj	74	1982	p	+8/8/96	80	+10/12/96	39
3	Manikganj	73	1995	h	+8/8/96	85		
4	Manikganj	74	1994	h	+8/8/96	40	+10/12/96	23
5	Manikganj	57	1981	h	+8/8/96	30		
6	Manikganj	37	1995	h	+8/8/96	9.6	+10/12/96	2.6
7	Manikganj	24	1981	h			+10/12/96	13
8	Manikganj	90	1981	m			+10/12/96	44
9	Manikganj	23	1988	h			+10/12/96	29
10	Manikganj	42	1988	h			+10/12/96	7.8
11	Manikganj	23	1991	h			+10/12/96	23
12	Manikganj	86	1980	m			+10/12/96	23
13	Manikganj	101	1992	o			+10/12/96	0
14	Meherpur	36	1995	h			+11/12/96	24
15	Meherpur	212	1991	o			+11/12/96	20
16	Meherpur	193	1991	o	+8/12/95	25	+11/12/96	39
17	Meherpur	165	1991	o			+11/12/96	15
18	Meherpur	211	1991	o	+8/12/95	30	+11/12/96	7.8
19	Meherpur	145	1991	o			+11/12/96	16
20	Meherpur	118	1991	o			+11/12/96	19
21	Meherpur	101	1979	p	+8/12/95	94	+11/12/96	20
22	Meherpur	193	1993	p	+8/12/95	74	+11/12/96	36
23	Meherpur	21	1980	h	+8/12/95	180	+11/12/96	61
24	Meherpur	49	1981	i			+11/12/96	38
25	Meherpur	18	1979	h	+9/12/95	84		
26	Meherpur	18	1995	m	+9/12/95	2.8	+11/12/96	< 2.0
27	Meherpur	39	1994	h	+9/12/95	170	+11/12/96	120
28	Meherpur	36	1994	h	+9/12/95	45		
29	Meherpur	21	1971	h	+9/12/95	160		
30	Magura	145	1982	p	+12/8/96	41	+11/12/96	6.7
31	Magura	118	1983	p	+12/8/96	31	+11/12/96	19
32	Magura	109	1987	p	+12/8/96	8.6	+11/12/96	9.6
33	Magura	53	1992	h	+12/8/96	< 2.0		
34	Magura	51	1992	h	+12/8/96	64	+11/12/96	61
35	Magura	56	1995	h	+12/8/96	42		

Type: p:production well; o:observation well; h: handpump

Annex 1. Arsenic in groundwater 18 District Towns, results of the laboratory analyses

36	Magura		78	1975	h			+11/12/96	12
37	Magura		67	1996	h			+11/12/96	7.2
38	Magura	?		1990	m			+11/12/96	< 2.0
39	Shatkira		67	1982	p	+11/8/96	32	+12/12/96	24
40	Shatkira		21	1984	h			+12/12/96	13
41	Shatkira		36	1984	h			+12/12/96	18
42	Shatkira		65	1979	p	+11/8/96	93	+12/12/96	34
43	Shatkira		27 --		h			+12/12/96	32
44	Shatkira		19.5 --		h			+12/12/96	< 2.0
45	Shatkira		41	1995	h	+11/8/96	110	+12/12/96	78
46	Shatkira		40	1993	h			+12/12/96	58
47	Shatkira		36	1994	h			+12/12/96	11
48	Shatkira		40	1995	h	+11/8/96	90		
49	Shatkira		22	1991	h	+11/8/96	66		
50	Shatkira		41	1995	h	+11/8/96	15		
51	Narail		76	1983	p	+11/8/96	18	+13/12/96	5
52	Narail		81	1995	h			+13/12/96	15
53	Narail		82	1985	p	+11/8/96	18	+13/12/96	8.6
54	Narail		77	1987	p	+11/8/96	32	+13/12/96	26
55	Narail		59	1992	h	+11/8/96	140	+13/12/96	48
56	Narail		48	1991	h	+11/8/96	< 2.0	+13/12/96	< 2.0
57	Narail		54	1992	m			+13/12/96	20
58	Narail		53	1993	h			+13/12/96	2.4
59	Narail		54	1992	h	+11/8/96	13		
60	Shariatpur		195	1994	p	+21/8/96	< 2.0		
61	Shariatpur		184	1985	h	+21/8/96	< 2.0		
62	Shariatpur		197	1987	h	+21/8/96	< 2.0		
63	Shariatpur		245	1995	h	+21/8/96	< 2.0		
64	Shariatpur		192	1993	h	+21/8/96	< 2.0		
65	Shariatpur		245	1995	h	+21/8/96	< 2.0		
66	Bhola		257	1983	p	+19/8/96	< 2.0		
67	Bhola		279	1995	h	+19/8/96	< 2.0		
68	Bhola		280	1990	p	+19/8/96	< 2.0		
69	Bhola		267	1995	h	+19/8/96	< 2.0		
70	Bhola		283	1990	p	+19/8/96	< 2.0		
71	Jhalokati		263	1986	p	+20/8/96	< 2.0		
72	Jhalokati		296	1993	p	+20/8/96	< 2.0		

Type: *p:production well; o:observation well; h: handpump*

Annex 1. Arsenic in groundwater 18 District Towns, results of the laboratory analyses

73	Jhalokati	291	1994	p	+20/8/96	< 2.0		
74	Jhalokati	289	1994	h	+20/8/96	< 2.0		
75	Jhalokati	296	1995	h	+20/8/96	< 2.0		
76	Jhalokati	276	1994	h	+20/8/96	< 2.0		
77	Panchagari	55	1990	o	+16/10/96	< 2.0		
78	Panchagari	23	1993	h	+16/10/96	< 2.0		
79	Panchagari	18	1988	h	+16/10/96	< 2.0		
80	Noagon	53	1982	p	+12/8/96	< 2.0		
81	Noagon	45	1983	p	+12/8/96	< 2.0		
82	Noagon	28	1993	h	+12/8/96	< 2.0		
83	Noagon	33	1994	h	+12/8/96	< 2.0		
84	Noagon	20	1994	h	+12/8/96	< 2.0		
85	Noagon	22	1993	h	+12/8/96	< 2.0		
86	Joypurhat	49	1982	p	+14/8/96	< 2.0		
87	Joypurhat	54	1983	p	+14/8/96	< 2.0		
88	Joypurhat	28	1993	h	+14/8/96	< 2.0		
89	Joypurhat	26	1994	h	+14/8/96	< 2.0		
90	Joypurhat	19	1993	h	+14/8/96	< 2.0		
91	Joypurhat	19	1994	h	+14/8/96	< 2.0		
92	Moulavibaz	72	1995	p			+18/12/96	< 2.0
93	Moulavibaz	141	1995	p			+18/12/96	< 2.0
94	Moulavibaz	147	1990	p			+18/12/96	< 2.0
95	Moulavibaz	60	1993	h			+18/12/96	< 2.0
96	Moulavibaz	114	1993	h			+18/12/96	2.6
97	Netrakona	50	1982	p			+21/12/96	9.3
98	Netrakona	65	1984	p			+21/12/96	6.4
99	Netrakona	58	1996	h			+21/12/96	< 2.0
100	Netrakona	56	1994	h			+21/12/96	2.9
101	Netrakona	63	1993	h			+21/12/96	6.7
102	Sherpur	122	1982	p			+20/12/96	5.5
103	Sherpur	129	1985	p			+20/12/96	7.8
104	Sherpur	14	1978	h			+20/12/96	4.4
105	Sherpur	20	1980	h			+20/12/96	29
106	Sherpur	26	1970	h			+20/12/96	< 2.0
107	Sherpur	45	1978	h			+20/12/96	31
108	Lalmonirha	55	1984	p			+19/12/96	3.0
109	Lalmonirha	49	1985	p			+19/12/96	< 2.0

Type: p:production well; o:observation well; h: handpump

Annex 1. Arsenic in groundwater 18 District Towns, results of the laboratory analyses

110	Lalmonirha	16	1996	h	+19/12/96	2.9
111	Lalmonirha	13	1985	h	+19/12/96	< 2.0
112	Thakurgan	100	1983	p	+20/12/96	3.4
113	Thakurgan	100	1985	p	+20/12/96	3.2
114	Thakurgan	90	1985	p	+20/12/96	2.6
115	Thakurgan	14	1985	h	+20/12/96	< 2.0
116	Thakurgan	14	1985	h	+20/12/96	2.5
117	Thakurgan	14	1985	h	+20/12/96	2.1
118	Nilphamari			p	+20/12/96	2.5
119	Nilphamari	17	1992	h	+20/12/96	2.7
120	Nilphamari	18	1986	h	+20/12/96	2.5
121	Nilphamari	20	1986	h	+20/12/96	3.0
122	Bargunna	275	1985	p	+21/12/96	< 2.0
123	Bargunna	285	1990	p	+21/12/96	< 2.0
124	Bargunna	282	1994	h	+21/12/96	< 2.0
125	Bargunna	285	1994	h	+21/12/96	< 2.0
126	Bargunna	283	1994	h	+21/12/96	< 2.0

Type: p:production well; o:observation well; h: handpump

Appendix 2

Identification of the sampling wells

Annex 2. Arsenic in groundwater 18 District Towns

No	Town	Well	Location	Care taker
1	Manikganj	Production well no 1	Beutha	DPHE / PWSS
2	Manikganj	Production well no 2	Beutha	DPHE / PWSS
3	Manikganj	HTW	Near canal	Shahera Khatun
4	Manikganj	HTW 03-185	Bandatia	Fuljan
5	Manikganj	HTW unicef	Bandatia	Momin Miah
6	Manikganj	HTW 03-304	Bandatia	Shabia Khatun
7	Manikganj	HTW DPHE	DPHE compound(office SAE-r	
8	Manikganj	MTW DPHE	DPHE compound(behind XEN	
9	Manikganj	HTW 01-116		Headmaster-Primary school Po
10	Manikganj	HTW 02-169		Ratish Nag
11	Manikganj	HTW 02-70	Singair road	Chamar house
12	Manikganj	PW-pol.line	Police line	Police line
13	Manikganj	Expl1.1 pol.line	Police line	Project: rehabilitation needed
14	Meherpur	HTW-mosque	End of Kathali road	mosque at Kathuali road
15	Meherpur	Exp2.1 (1strp)	Besides mosque at Kathuali roa	Project: rehabilitation needed
16	Meherpur	Exp2.2 (2strp)	Besides mosque at Kathuali roa	Project: rehabilitation needed
17	Meherpur	Exp2.3 (3strp)	Besides mosque at Kathuali roa	Project: rehabilitation needed
18	Meherpur	Exp1.1 (1strp)		Project: rehabilitation needed
19	Meherpur	Exp1.3 (3strp)		Project: rehabilitation needed
20	Meherpur	Exp1.4 (4strp)		Project: rehabilitation needed
21	Meherpur	Production well no 1	PWSS compound	PWSS
22	Meherpur	Production well no 2	near bus stand	
23	Meherpur	HTW Kathali road 400 m after mosque		Private
24	Meherpur	Irrigation well 20 m apart from No 23		Shahidul Islam
25	Meherpur	HTW PWSS	PWSS compound	
26	Meherpur	Mtw chairman	Shahid Hamid road	Chairman
27	Meherpur	HTW Wapda rd*	WAPDA road	Karmena Khatun
28	Meherpur	HTW Shabdar rd	Sabdar road, Mallik para	Taslima Khatun
29	Meherpur	HTW, prod w3	Small road leading to river	Rejaul Hoque
30	Magura	Production well no 1	Treasury office	DPHE / PWSS
31	Magura	Production well no 2	PWD office	DPHE / PWSS
32	Magura	Production well no 3	Stadium para	DPHE / PWSS
33	Magura	HTW Sardar	Sardar para	Chapala Rani
34	Magura	HTW Shrimbur	Shibrumpur para	Shiuli, wife of Azizur Rahman

Type: p:production well; h:handpump; o:observation well

35	Magura	HTW Nir Para	Mir para	Rahman Mirdha
36	Magura	HTW DPHE		
37	Magura	HTW Wabda mosq		
38	Magura	PW-police line		
39	Shatkira	Production well no 3	Razzak park	
40	Shatkira	HTW at 50 m pw3		
41	Shatkira	HTW at 250m pw3		
42	Shatkira	Production well no 2	Palashpole	
43	Shatkira	HTW at 50 m Pw2		
44	Shatkira	HTW at 250 m Pw2		
45	Shatkira	HTW no 214	Polashpole	Amena Katun
46	Shatkira	HTW no 312		
47	Shatkira	HTWRusselHgschool		
48	Shatkira	HTW no 15	Katia Shorkar para	Begum Lufti Ara
49	Shatkira	HTW no 132	Sultanpur	President of the club
50	Shatkira	Prod. well 2	Rosulpur area	Sabitri
51	Narail	Prod. well 1	Charaghat Aladatpur	
52	Narail	HTW at 100 PW1		
53	Narail	Production well no 2	Upazila compound	
54	Narail	Production well no 3	Natun Gohat	
55	Narail	HTW No 7	Betbaria area	Madhuri, wife of Robin Sarkar
56	Narail	HTW Barasula	Barasula area	Razzak Mollah
57	Narail	MTW Library		
58	Narail	HTW No 20		
59	Narail	HTW Voakali	Voakhali area	Jahanara, wife of Kashem Shei
60	Shariatpur	Prod well1	DPHE office compound	
61	Shariatpur	HTW Pala bazar	Mosque compound*	Mosque
62	Shariatpur	HTW Toulashar	Toulashar	Shalam Fakir
63	Shariatpur	HTW Baluchara	Baluchara	Shilpi Akter**
64	Shariatpur	HTW Angaria bazar	Angaria Bazar	Azzizul Hoque Mullah
65	Shariatpur	HTW Modhu para	Behind Zamindar House	Beauty Rani Shova
66	Bhola	Production well no 1	Jughirgol	
67	Bhola	HTW No 22	Kalibari road	Renu Begum
68	Bhola	Production well no 5	Near Stadium	
69	Bhola	HTW Bapto rd	Ellsia bus stand	Nurjahan Begum
70	Bhola	Production well no 4	Western para	
71	Jhalokati	Production well no 2	Katpatti	

Type: p:production well; h:handpump; o:observation well

72	Jhalokati	Production well no 3	PWD compound	
73	Jhalokati	Production well no 4	New College road	
74	Jhalokati	HTW Umeshganj	Umeshgonj	Suratunnessa
75	Jhalokati	HTW Bikna	Bikna	Khodeza Begum
76	Jhalokati	HTW Krisnokalthi	Krishnokalthi	Shazeda Begum
77	Panchagarh	Testwell 1		
78	Panchagarh	HTW No 231 market		
79	Panchagarh	HTW No 156 graveyard		
80	Noagon	Production well no 1	DPHE office compound	
81	Noagon	Production well no 3	Kalitola Police Fari	
82	Noagon	HTW Chalk prashad v	Chalk Prashad South para	Maleka Begum
83	Noagon	HTW Mayda para w3	Boalia	Delwara Begum
84	Noagon	HTW South para w2	Chalk Prashad South para	Ebarat Mandal
85	Noagon	HTW Jagatsingpara w	Jagathsinghapur	Rehana Begum
86	Joypurhat	Production well no 1	Mashua Bazar	
87	Joypurhat	Production well no 2	Upazila Parishad	
88	Joypurhat	HTW CSC compound	CSC compound	Supervisor
89	Joypurhat	HTW sugar mill/mosk	Sugar Mill	Secretary, Sugar Mill
90	Joypurhat	HTW shikhpara ward2	Shikhpara ward-2	M.Akkas Ali
91	Joypurhat	HTW Masterpara ward	Masterpara Ward-1	Mosarraf Hossain
92	Moulavibazar	Production well no 1	Court road(Govt. school field)	
93	Moulavibazar	Prod. well7 DPHE	DPHE compound	
94	Moulavibazar	Prod. well 8 PWSS	PWSS compound	
95	Moulavibazar	HTW MBazar w1	Shayerpur	
96	Moulavibazar	HTW DhargaMohalla	Dhargah Mohalla	
97	Netrakona	Production well no 1	Ukil para DPHE office	
98	Netrakona	Production well no 2	Muktar para	
99	Netrakona	HTW no 8	Satpai Ward-1	Abdul Gani Master
100	Netrakona	HTW no 182 ward no	Nikhilnath road ward-2	
101	Netrakona	HTW no 431 ward no	Nagra	Sabekun Nahar
102	Sherpur	Production well no 1	Bananti para	
103	Sherpur	Production well no 2	Purangurhat	
104	Sherpur	HTW no 17 ward no 1	Nabinagar ward-1	
105	Sherpur	HTW no 50 ward no 1	Dhakal hati ward-1	
106	Sherpur	HTW no 206 ward no	Kasba Khathgar ward-2	
107	Sherpur	HTW no 378 ward no	Digar par ward-3	
108	Lalmonirhat	Production well no 1	DPHE campus	

Type: p:production well; h:handpump; o:observation well

109	Lalmonirhat	Production well no 2	Near Giasuddin High school	
110	Lalmonirhat	HTW East Thanapara	East Thana para TNO road	Md.Shafiqul Islam
111	Lalmonirhat	HTW refugee colony	Refugee colony	Dulal Miah
112	Thakurgan	Production well no 1	Kalibari, PWSS compound	
113	Thakurgan	Production well no 2	Sarkar para	
114	Thakurgan	Production well no 3	College para	
115	Thakurgan	HTW No 8 collegepar	College para ward-3	Hazera Banu
116	Thakurgan	HTW No 25 Goalpara	Goal para ward-2	Sahera Khatun
117	Thakurgan	HTW Nischintapar w3	Nishchintapur ward 3	Tultuli Begum
118	Nilphamari	Production well no 1		
119	Nilphamari	HTW 109 ward 2	Shahipara ward-2	Ashiya Khatun
120	Nilphamari	HTW 237 ward 3	Khuka para ward-3	Ashma Alem
121	Nilphamari	HTW 45 ward 3	Sharker para ward-3	Razia
122	Barguna	Production well no 1	DPHE / PWSS	
123	Barguna		Zila Pastesd	Zila Pastesd
124	Barguna	HTW No 69	Abdul Kader road	Aisha Begun/Naya Mia Howlad
125	Barguna	HTW no 116	Gagou school	Lyli Begun
126	Barguna	HTW no 54	Sader road	Rabea Begun+Abdul Mannan

Type: p:production well; h:handpump; o:observation well

Appendix 3

Analytic protocol for Arsenic

Analytic protocol for the analysis of Arsenic in water

Analytic technique: AAS-hydride

Measurement of concentrations of metals in solutions by means of Atomic Adsorption technique. By adding sodiumboronhydride to the sample, the element to be measured is converted to a gaseous hydride compound. The hydride is driven from the solution after which the atomic adsorption is measured in the vapour. This adsorption is a measure for the concentration of the element in the solution. Internal accuracy:

Arsenic (µg/l)	Repeatability (%RSD)	Reproducibility (%RSD)
0.4 - 2	5.3	
2 - 5.5	5.7	
15 - 50	7.7	
20		7

The analytic protocol has been derived from NVN 6432.

The analytic protocol at IWACO has been STERLAB certified.

Appendix 4

Water sampling procedures

1. Indicate the well on the map

2. Fill in the data of the well
   * location - WARD / STREET

   * Name of Caretaker

   * Depth and year of Installation

   * Sample Number

3. Production wells should be running for at least 10 minutes before you can collect the sample.

4. Also Hand Tube Wells should be pumped also at least 10 minutes before you can collect the sample.

5. Open the bottle of mineral water, empty the bottle, rinse the bottle at least 3 times with well water (also the cap).

6. Fill the bottle as full as possible than add 1 pipet of acid.

   Be Careful with the Acid !

7. Screw the cap carefully on the Plastic bottle.