

Sustained Applications of Pesticides and Fertilizers in Sugarcane, Cotton and Wheat Cultivated Areas Causes Ground Water Arsenic Contamination - District Rahim Yar Khan, Pakistan

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Abstract: Due to over all water scarcity situation, more reliance is made on local groundwater sources for drinking and other human needs /purposes. Most of the boreholes or shallow wells are confined to upper aquifers which are exposed to contamination from all sorts of wastewaters and run-off from agricultural field etc. Water quality monitoring from these ground water sources remained irregular, as main focus was on surface water quality monitoring . Information on seasonal water quality changes in surface and ground water was generally lacking. Natural factors facilitating introduction of arsenic into water are related to geomorphology, tectonic activities and chemical components of water bearing formations (Tong, 2002; Htay, 2004, Fengthong, 2004). Keeping in view the prevalence of arsenic in district Rahim Yar Khan , a confirmatory arsenic testing was carried out and it was revealed that out of 45 samples, tested for arsenic contamination, 57.78 % were having more than 100 ppb arsenic contamination and 35.56 % were having arsenic contamination more than 50 ppb, which were higher than the WHO limits. During 2006, UNICEF installed some kind of arsenic removal technologies in the area, which were not sustainable due to lack of technical know and resources essentially needed during post project periods . At the same time no endeavors were made to ascertain the causes of arsenic prevalence for having sustainable alternative arsenic free water sources. The areas was rich for agricultural activities, with sustained use of pesticides and fertilizers . A well planned soil investigation process was carried out upto the depth of 387 feet to find out the existence of arseno-pyrites, the major cause of arsenic contamination. All the soil samples were analyzed in the laboratory by using XRD & XRF equipment. The soil investigation analysis, clearly indicated the absence of arseno-pyrites which could have been responsible for ground water arsenic contamination in the area. This very fact indicates that arsenic contamination was due to leaching of pesticides and chemicals , as cotton, being a major cash crop of Pakistan, consumes more than 70 % pesticides being used in the country and at least a dozen spray sessions are made during a single harvesting season September to November. Therefore keeping in view the above findings, a deep bore hole was installed up to the depth of 387 feet and arsenic contamination at 240 feet depth, was 5-10 ppb, which is within the permissible limits. The deep bore hole was monitored for complete one year and arsenic contamination was found to be within the limits. Thus, deep bore holes are one of the safe alternative drinking water sources, provided soil strata in arsenic hit areas is investigated prior to installing any arsenic removal technologies.

Keywords: Arsenic, Application, Aquifer, Contamination, Fertilizers, Ground Water, Pesticides, Quality, Deep Wells

1. Introduction

Ground water arsenic contamination has emerged as serious public health concern all over the world and arsenic is the twentieth most common natural element present in

atmosphere, soils, rocks, organisms and groundwater. It is widely distributed throughout the earth's crust. Though toxic and carcinogenic, arsenic when present in water has no color, smell or taste even in high concentrations. Humans are inevitably exposed to the arsenic compounds present in

drinking water, in food items, and sometimes in air particles. Normally, the daily dose of total arsenic in the range of 10-50 µg appears to be no threat to human health.

Worldwide more than 130 million people consume arsenic-contaminated drinking water, which sometimes far exceeds that of the WHO as acceptable classified arsenic amount (10 g / L in groundwater). Estimates show that up to 77 million people in Bangladesh alone are directly affected by a fluctuating release of arsenic into the groundwater (UNICEF, 2008 WHO, 2013). Although arsenic cannot be smelled, tasted or seen in contaminated food or water, long-term exposure can lead to serious health consequences, collectively called arsenicosis, symptoms of which include skin lesions such as Hypo pigmentation (white spots), Hyper pigmentation (dark spots), collectively called Melanosis by some physicians, and keratosis (break up of the skin on hands and feet), skin cancer, internal cancer affecting bladder, kidney and lungs, hypertension, heart disease and diabetes etc (Shresta et al., 2004). The photograph of arsenic bearing pyrite and its adverse impacts on human health, hyper pigmentation on palms are shown in figure-1, below



Figure 1. The magnified glimpse arsenopyrites sediment and its impacts, hyper pigmentation, on human body

Natural factors contributing arsenic into water are connected/linked to geomorphology, tectonic activities and chemical components of water bearing formations (Tong, 2002; Htay, 2004; Fengthong, 2004). Arsenic is a transitional reactive element that forms chemical and organic complexes together with other metals, like iron, carbon, sulphur, and oxygen and contaminates water sources naturally and artificially. When arsenic minerals break down by weathering, they get oxidize, which can release arsenic into water. Arsenic is assumed to be released into groundwater when iron oxides find themselves under reduced conditions. Anaerobic bacteria may mediate this process. It is believed that this process is enhanced by the presence of organic matter, such as peat, which is found in young, shallow sediments (Shrestha et al., 2004).

There may be some other quaternary aquifers with high groundwater arsenic concentrations that have not yet been identified, but since awareness of the arsenic problem has grown substantially over the last few years, these are likely to be on a smaller scale than those already identified. Many of the health consequences resulting from contaminated groundwater have emerged in relatively recent years as a result of the increased use of groundwater from tube wells for drinking and irrigation. In terms of numbers of groundwater

sources affected and populations at risk problems are greatest in Bangladesh, but have also been identified in India (West Bengal, and more recently Assam, Arunachal Pradesh, Bihar, Manipur, Meghalaya, Nagaland, Tripura and Uttar Pradesh), China, including Taiwan, Vietnam, Thailand, Cambodia, Myanmar, and Nepal. Occasional high-arsenic ground waters have also been found in Pakistan, although the occurrences appears to be less widespread due devoid awareness. Now, there is a need to develop sustainable arsenic removal technologies, alongwith finding the causes of arsenic contamination, whether it is naturally occurring or due to increased anthropogenic activities. This is the very theme of this paper for un-earth area specific causes of arsenic contamination and finding sustainable solutions for arsenic free water sources, may deep boring etc.

2. Literature Review

Inorganic Arsenic is relatively most toxic to the human as compared with lead and fluoride. The toxicity and mobility of arsenic species differ with their chemical forms and oxidation states (NRC (National Research Council-1999 and Thomas et al., 2001). Generally, inorganic forms are more toxic and mobile than organoarsenical species, while arsenites is considered to be more toxic and mobile than arsenate (Gulens et al., 1979, Squibb and Fowler, 1983, Xu et al., 1988 and Lambly and Hill, 1996). Gulens et al. (1979) reported that As(III) is 5 to 8 times more mobile than As(V) in a non-adsorbing sandy loam.

In India, the parliamentary committee on estimation, chaired by member parliament, Mr. Murli Manohar Joshi, in its first report on arsenic in ground water, has revealed prevalence of alarming levels of ground water arsenic contamination in Indian states. The parliamentary committee has criticized the central government for neglecting this serious public health related issue that impacts at least 70 million people across six states (water network research, 2014- Times of India, 29 Dec, 2014).

Occurrence of arsenic in natural water is dependent on the local geology, hydrogeology and geochemical characteristics of the aquifer, and climate changes as well as human activities. The main anthropogenic activities that may release arsenic into the environment include nonferrous metal mining and smelting, fossil fuel processing and combustion, wood preserving, pesticide production and application, and disposal and incineration of municipal and industrial wastes (Popovic et al., 2001 and Prosun et al., 2002). It has been observed that anthropogenic activities release of arsenic are to land or soil, primarily in the form of pesticides or solid wastes, through leaching process (USDHHS, 2000). The use of arsenical pesticides presents a non-point anthropogenic source of arsenic contamination. The mainly used arsenical pesticides include lead arsenate $[Pb_3(AsO_4)_2]$, calcium arsenate $[Ca_3(AsO_4)_2]$, magnesium arsenate $[Mg_3(AsO_4)_2]$, zinc arsenate $[Zn_3(AsO_4)_2]$, zinc arsenite $[Zn(AsO_2)_2]$, and Paris green $[Cu(CH_3CCOO)_2 \cdot 3Cu(AsO_2)_2]$. (Martin et al., 2000).

Industrial wastes/drainage and pesticides & fertilizers, composed of various arsenate compounds are contributing towards arsenic contamination through leaching process. In these scenarios, arsenic free water can be found at deeper depths. The deep boring options for arsenic free water are practiced in Burma and Bangladesh (Wegler et al, 2004)

3. Objectives

The salient objectives are:

- 3.1 To ascertain ground water arsenic concentration at various depths through atomic absorption spectrometer (AAS) and Merck field testing kit in the cultivated area.
- 3.2 To carry out soil investigation and analysis to find out its ingredients and composition by XFR and XRD equipment.

3.3 To analyze cropping pattern and application/use of various pesticides and fertilizers.

3.4 To explore the possible causes of ground water arsenic contamination and exploring arsenic free deep bore holes as an alternative water supply option.

4. Methodology

4.1. Location and Socio-Economic Environments of Study Area

The research was focused on area, situated towards river Indus (Eastern side of the city of Sadiqabad and Rahim Yar Khan) as shown in Figure-2, below;

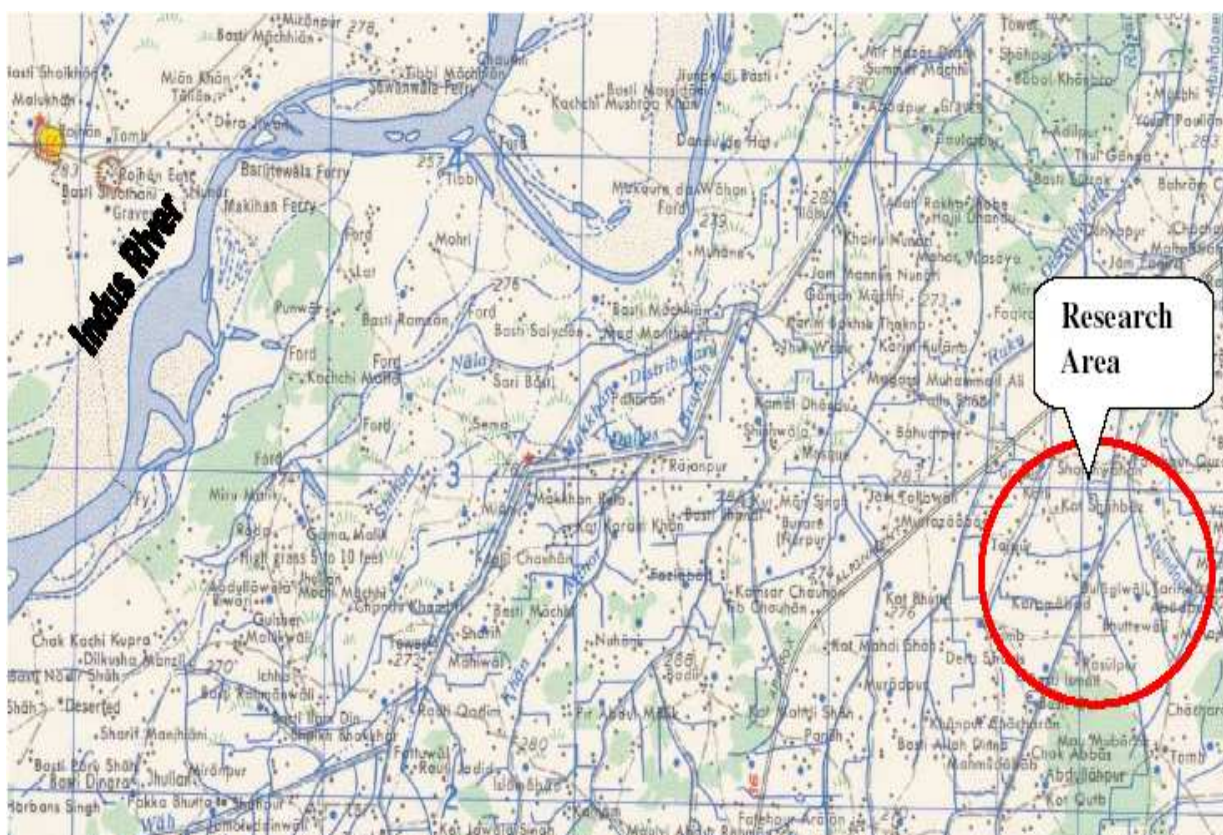


Figure 2. Research area- Rahim Yar Khan, Basti Rasul pur

4.2. Review of Secondary Data/ Reports on Arsenic Survey-PAKISTAN

Extensive review of the secondary data, pertaining to arsenic contamination survey and resting was carried out. During the process it was revealed that, during the national arsenic contamination survey, conducted in 2007, district Rahim Yar Khan, Punjab province - Pakistan, was found to be most affected area. Alarming levels of ground water arsenic contamination have been observed and report highlights the various arsenic concentration levels as shown in figure-3, below;

4.3. Socio-Economic Conditions and Livelihood Generation Practices

The area posses rich tribal culture and traditions with the literacy rate around 35-40 %, being a remote rural area. Livelihood generation depends on mix of agro businesses, cottage industries and some industrial units. This reveals domination of agro-based economic and business activities. The other research area characteristics are;

- a located at a distance of 5-7 km from the left bank of River Indus, which originates from Himalayan ranges in the northern parts of Pakistan.

- b Livelihood reliance on agriculture and main crops are cotton, sugarcane, wheat, rice and fruit orchards of mangos and oranges.
- c Indiscriminate and excessive uses of fertilizers and pesticides for getting increased crop yields.
- d Agriculture activities and irrigation practices are dependent on ground water, consisted of mushroomed net work of tub wells. Extensive ground water abstraction cum ground water mining culture are the haul mark of irrigation practices.
- e Complete dependence/reliance on ground water both for agriculture and for drinking purposes, by human and animals.
- f Water table in the area is about 25 feet. and for domestic use, rotor and hand pumps are installed, having average depth of 40 to 70 feet.

4.4. Industrial Set up

The main industrial units comprises of group of fertilizers (Fauji Fertilizer Companies) which produces various types of products and is the largest fertilize production units in South-Asia. The textile industry, medicine and other cottage industries in the area also provide sizeable livelihood to the

inhabitants. The leachate of chemical compounds causes massive ground water contamination.

4.5. Agriculture and Application of Pesticides and Fertilizers Pattern

The area is very fertile for all types of agricultural activities and main crops are cotton, wheat and sugar cane besides many other less significant crops. The main use of pesticides in Pakistan is for cotton crops (60%), followed by paddy(7%) , cereals (4%), sugarcane (2%) and other crops use pesticides @ 27%. (Shehzad Ahmad Kang-2013) . Currently, three major groups of pesticides, including Organophosphate, Pyrethroid and Organochlorine are being widely used in Pakistan. Additionally, 108 types of insecticides, 30 kinds of fungicides, 39 types weedicides and six different types of rodenticides are being used in the agricultural sector of the country. Local landlords and farm owners were interviewed regarding use of pesticides and fertilizers and accordingly the summary of uses pattern is shown in Table-1, 2, below;

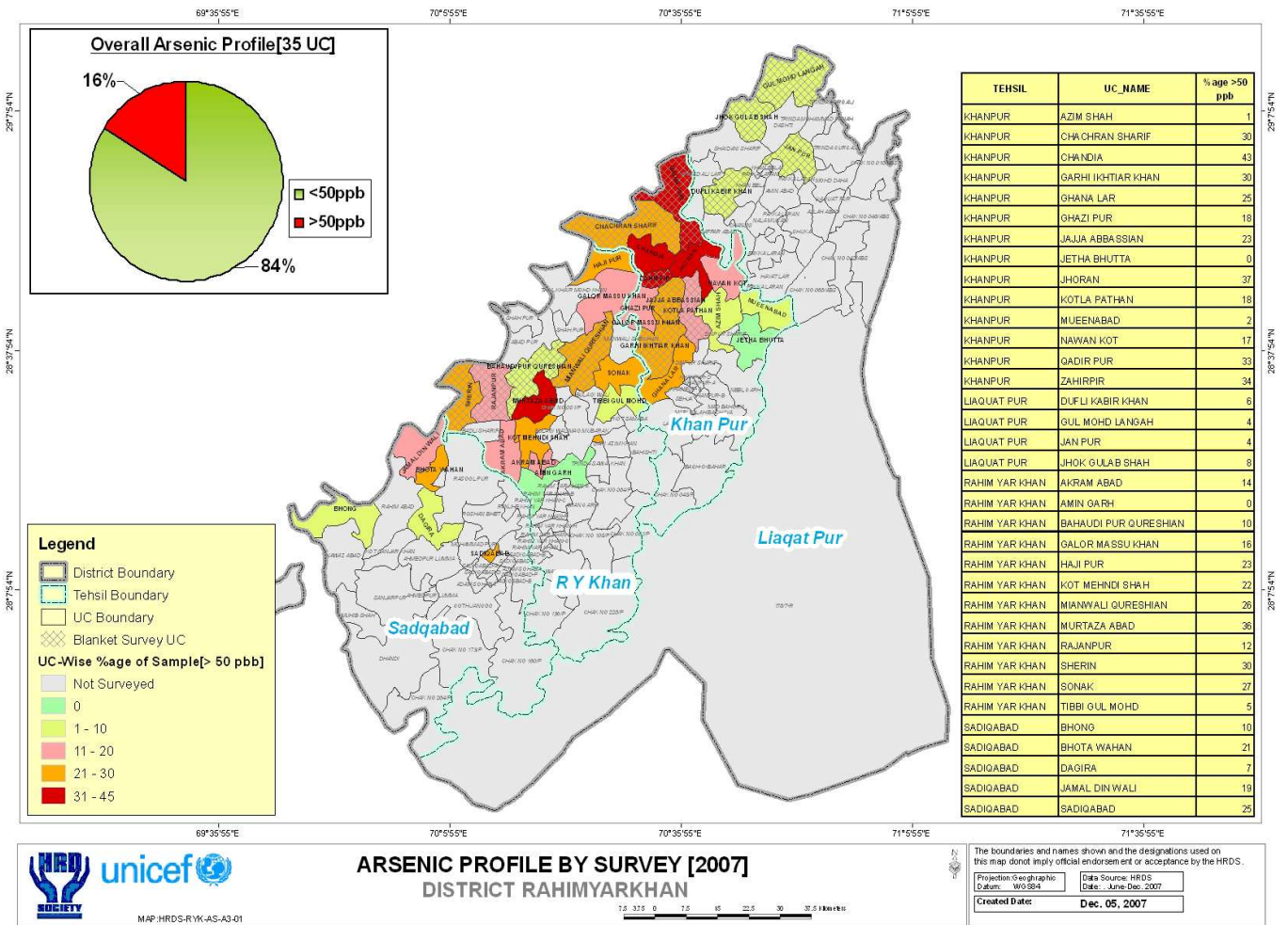


Figure 3. Map showing status of Arsenic contamination in Pakistan

Table 1. Pesticides and fertilizers application pattern on various crops

S. No	Owner's Name	Crop	Pesticide Used	Fertilizer Used
1.	Khalil Ahmad	Brassica	Cyper Methrine, Methamedophas Karate (1 Liter/Acer) twice / year	DAP+ Sona Urea
2.	Malik Jumma	Mango + Brassica	Cyper Methrine, Methamedophas Karate (1 Liter/Acer) twice / year	DAP+ Sona Urea
3.	Malik Yaqoob	Sugarcane	Karate (1 Liter/Acer) twice in a year	DAP+ Sona Urea
4.	Sadiq Qureshi	Cotton	Cyper Methrine, Methamedophas Karate (1 Liter/Acer)	DAP+ Sona Urea
5.	Bibi Hijani	Mango + Sugarcane	Karate (1 Liter/Acer) twice in a year	DAP+ Sona Urea

The prolonged/sustained use of excessive pesticides and fertilizers can cause ground water contamination during seepage process. Environment Protection Agency - USA(EPA), in its 2006 Re-registration Eligibility Decision (RED) concluded that all uses of the organic arsenical herbicides were ineligible for re-registration. Following application, these pesticides convert over time to a more toxic form in soil, inorganic arsenic, and potentially contaminate drinking water through soil runoff (US EPA 2006).

Likewise, the sustained application / use of phosphate fertilizers cause arsenic contamination of the soil which ultimately during run-off leaches into the ground water aquifer (Hartley et al, 2013). The constituent composition of fertilizers being used and pesticides applications in the area are shown in table-2, & figure-4, below;

Table 2. Nutrient Composition of Individual Fertilizers

Fertilizer	% Nutrient Composition
Ammonium Nitrate	34% N
Calcium Nitrate	15.5% N, 19% Ca
Diammonium Phosphate	16% N, 46% P ₂ O ₅ (20.1% P)
Monopotassium phosphate (MKP)	52% P ₂ O ₅ (22.7% P), 34% K ₂ O (28.2% K)
Nitrate of Soda Potash	15% N, 14% K ₂ O, (11.6% K)
Potassium Chloride (muriate of potash)	60% K ₂ O (49.8% K)
Potassium Nitrate	13.75% N, 44.5% K ₂ O, (36.9% K)
Sodium Nitrate	16% N
Urea	46% N



Figure 4. Indiscriminate use of pesticides on cotton crop-Pakistan

4.6. Ground Water Arsenic Contamination Testing Process

The study of secondary data has revealed arsenic prevalence in ground water , but again arsenic trace level analysis, both for arsenic (III) and arsenic (V) speciation to 0.02 ug/L was carried out by continuous hydride generation (HG) interfaced with inductively coupled plasma-mass spectrometry (ICP-MS). The atomic absorption spectrometer was used for detecting the arsenic contamination. Samples were taken from the field in ½ lt. PET bottles following the standards sample collection procedures, preserved by adding 2ml of reagent grade, arsenic free concentrated Nitric acid per 1000ml of water sample. All the samples were marked with proper code and sampling date and thereafter samples were analyzed on atomic absorption spectrometer (AAS) by using hydride generation mode and with field kit and results are shown in table-3, as shown, below;

The analysis of above samples shows that out of 45 samples, tested for arsenic contamination, 57.78 % are having more than 100 ppb As contamination and 35.56 % are having arsenic contamination more than 50 ppb. Both the values are higher than the WHO limits. During the water samples analysis process, it was revealed that there is lot of variations in the results, performed with Merck field kit and AAS, as mentioned below;

- a Values measured with field Kits are more consistent as compared to AAS which is due to interpretation of color coding. Therefore, the result accuracy with field testing kits may be misleading.
- b Field testing Kit results remains between 50 to 100 ppb while AAS represent a wide range of arsenic concentration variations (sample ID 11 shows lowest value of 21 ppb while sample ID 13 shows largest value of 128 ppb) as compared with the filed kits results.
- c 14 samples out of 26 represent the larger value of Arsenic measured with AAS.
- d Only three values measured with AAS are below the range shown by field Kits (50 to 100 ppb).
- e It is therefore, suggested that better AAS be used as long as possible. The only advantage of the field testing kit is of its workability, handiness and quickness in the field. The results variations are shown in figure-5, below;

Table 3. Confirmatory arsenic contamination test results, carried out with Merck field kit and AAs

Arsenic (ppb) Merck field testing kit	Arsenic (ppb) with AAS	E.C.	TDS	pH
100	120	1260	781	7.38
50-100	99	1120	694	7.22
50-100	46	840	462	7.32

Arsenic (ppb) Merck field testing kit	Arsenic (ppb) with AAS	E.C.	TDS	pH
50-100	108	1570	973	7.27
100	40	1320	818	7.29
100	87	1020	632	7.50
50-100	91	1250	775	7.19
100	90	900	495	7.43
100	114	1170	725	7.36
100	75	950	522	7.31
50-100	21	1020	632	7.18
100	98	830	456	7.15
100	128	1040	644	7.0
100	122	800	440	7.26
50-100	109	970	533	7.22
50-100	72	990	544	7.16
100	124	960	528	7.15
50-100	84	860	473	7.33
50-100	76	1040	645	7.35
50-100	97	1290	780	7.36
50-100	92	1290	800	7.29
50-100	93	1530	979	7.31
50-100	96	1060	657	7.44
50-100	67	880	484	7.51
100	72	1060	657	7.44
100	71	1050	651	7.20

4.7. Soil Investigation

In the light of prevalence of arsenic in the area, there was a need of having geo-chemical analysis of the soil strata to ascertain the arsenic contamination causes. This will give arsenic bearing soil strata (pyrites). Therefore, a series of deep borings was planned for soil analysis by energy dispersive X-Ray fluorescence Spectrometer (XRF) Equipment

The soil profiling strata shows sandy soil predominately with clay layer at the depth of 85 & 240 feet The deeper strata is consist of sand layers. The graphical representation is shown in Figure-6 & 7, below;

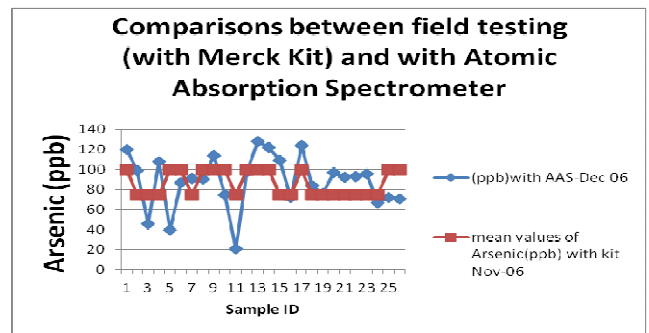


Figure 5. Graphical representation of arsenic testing by AAS and by Merck field testing kit

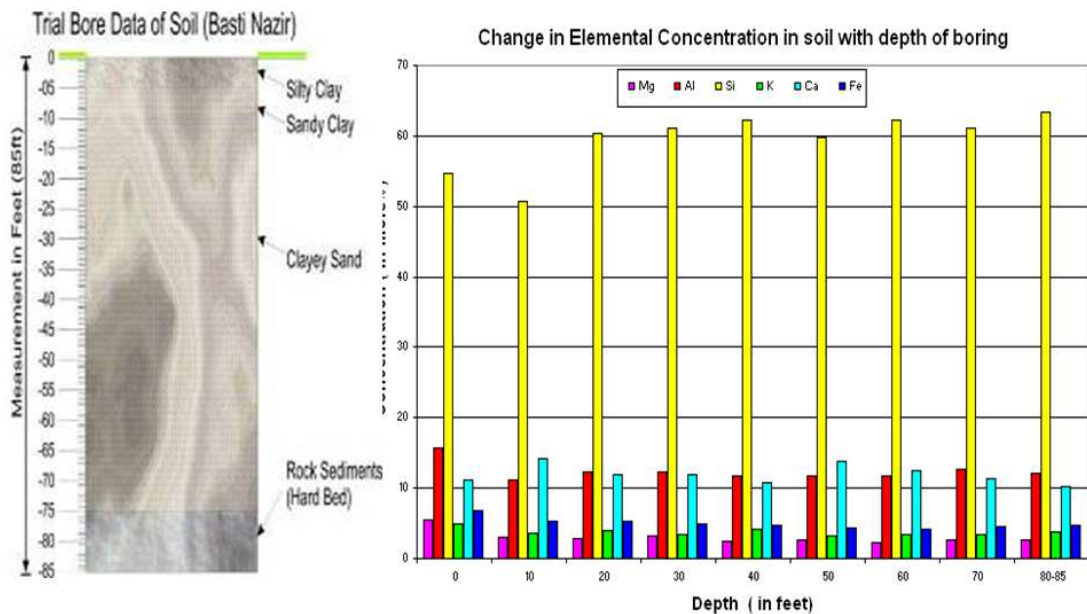


Figure 6. The soil strata showing various configurations of soil constituents upto depth of 85 feet

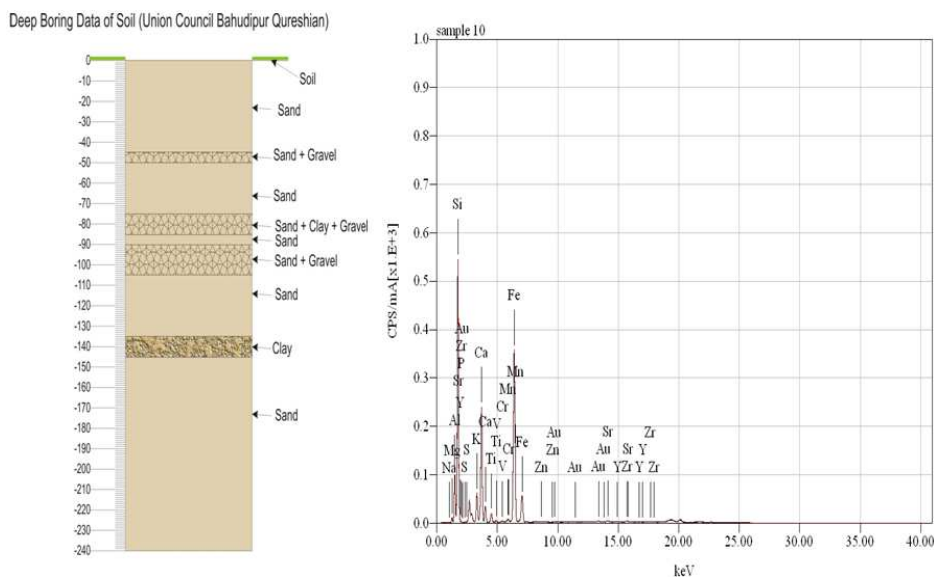


Figure 7. The soil strata showing various soil of constituents up to the depth of 240 feet

A total of 11 samples were analyzed on XRD, the mineral composition of soil samples are shown in Figure-8, below;

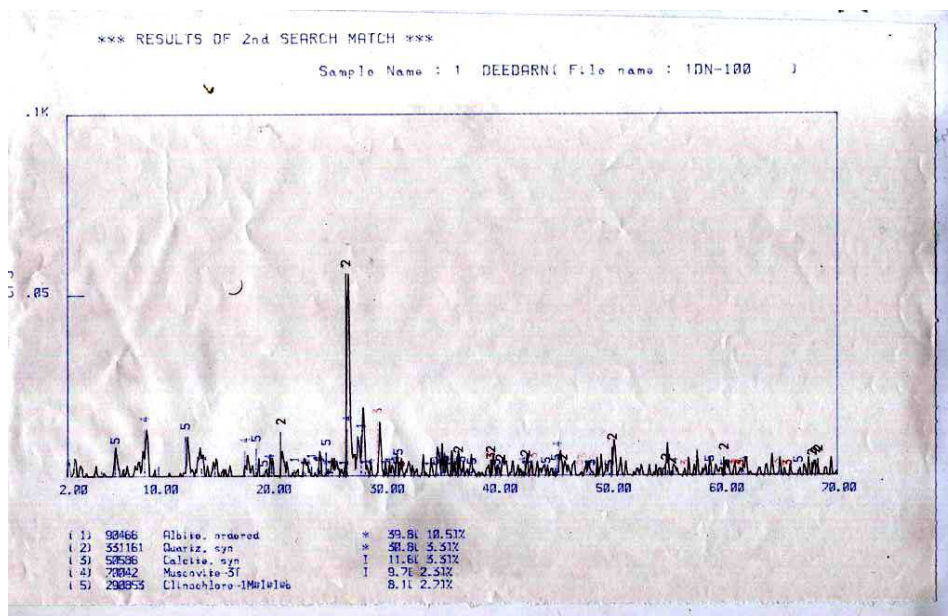


Figure 8. XRD test results , showing mineral composition of the soil sample

The analysis by XRD , following mineral composition of soil samples was recorded as shown in Table-4, given below;

Table 4. Mineral Identification of the soil samples - XRD

Serial no.	Sample configuration	Mineral Identified
A	A- surface soil	Quartz, Calcite, Clinocllore, Muscovite
B	B-surface soil	Quartz, Muscovite, Kaolinite
C	C-surface soil	Quartz, Clinocllore, Muscovite, Albite
D	D-surface soil	Quartz, Albite, Calcite Clinocllore, Muscovite
E	E-surface soil	Quartz, Calcite Clinocllore, Muscovite. Albite,
1	At depth of 15 feet	Quartz, Albite, Clinocllore, Muscovite
2	30	Quartz, Albite, Clinocllore, Muscovite
3	45	Quartz, Albite,
4	60	Quartz, Albite, Calcite, Muscovite
5	75	Quartz, Albite, Calcite Clinocllore, Muscovite
6	90	Quartz, Albite, Calcite , Muscovite

Total of 5 Soil samples from River Indus bed were collected (UC Banbla Acha, Mouza Kacha Chuhan, Basti Akbar Munishi, district Rahim Yar Khan to investigate the presence of pyrites (arsenic bearing rocks). The results so obtained through XRF analysis are shown in Table-5 and Figure- 9, below;

Table 5. Sediments samples taken from Indus River bed at various depths

Sr. #	Sample Code	Sample Depth (FT)	Sample Status
	River (A)	01 FT	Sand
	River (B)	01 FT	Sand
	River (C)	01 FT	Sand
	River (D)	01 FT	Soil + Sand
	River (E)	01 FT	Sand

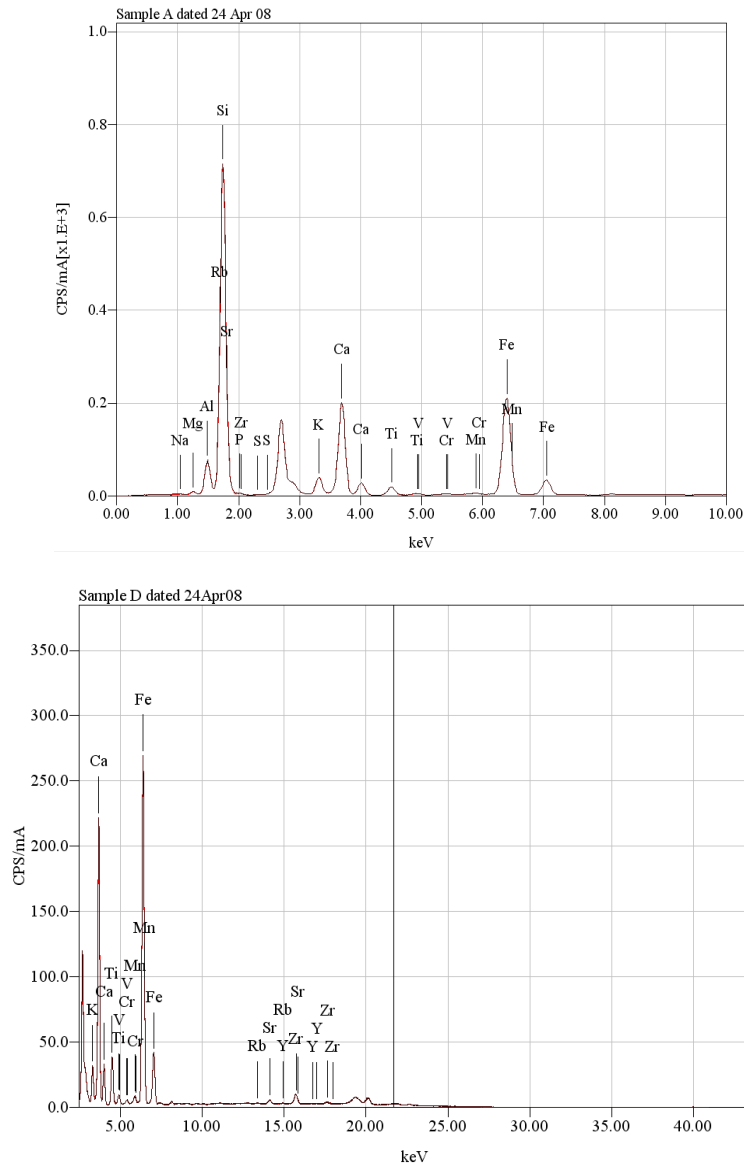


Figure 9. Soil constituents of soil samples

The soil investigation through XRD and XRF equipment in the lab showed absence of arsenic bearing pyrites which implies that presence of arsenic contamination in ground water is not because of naturally occurring arsenic bearing sediments or due to oxidation of arseno- pyrites .

The main anthropogenic activities that may release arsenic into the environment include nonferrous metal mining and smelting, fossil fuel processing and combustion, wood preserving, pesticide production and application, and disposal

and incineration of municipal and industrial wastes (Popovic *et al.*, 2001 and Prosun *et al.*, 2002). The use of arsenical pesticides presents a non-point anthropogenic source of arsenic. The mainly used arsenical pesticides include lead arsenate $[Pb_3(AsO_4)_2]$, calcium arsenate $[Ca_3(AsO_4)_2]$, magnesium arsenate $[Mg_3(AsO_4)_2]$, zinc arsenate $[Zn_3(AsO_4)_2]$, zinc arsenite $[Zn(AsO_2)_2]$, and Paris green $[Cu(CH_3CCOO)_2 \cdot 3Cu(AsO_2)_2]$. (Martin *et al.*, 2000). Therefore, in this area the arsenic prevalence look like due to

excessive use of pesticides and other anthropogenic activities etc.

Hence in the backdrop of above analysis, there is a possibility of presence / availability of arsenic free water at deeper aquifer depths.

4.8. Deep Boring upto 400 Feet Depth

Deep boring, upto the depth of 387 feet, was carried out to

explore the possibility of getting arsenic free water. Water and soil samples at the interval of 5 meter depth was taken and water and soil samples were investigated with XRD & XRF equipment and no arsenic bearing sediments were found and water testing results showed decrease of arsenic contamination with increase in depth. The deep boring process and arsenic contamination results are shown in figure-10 & table-6 , below;



Figure 10. Deep bore hole upto the depth of 387 feet, which 10 ppb arsenic contamination which is within the WHO drinking water standard limits

Table 6. Ground water arsenic contamination concentration recorded during deep boring

Sample Code	Depth	Arsenic	Alkalinity	HCO3	Ca	Cl	EC	Hardness	Mg	Na	SO4	TDS	Fe	No3
1	50	100	320	390	68	45	950	290	29	101	110	598	0.58	1.2
2	60	80	320	390	68	45	950	290	29	101	110	598	0.58	1.2
3	70	80-100	320	390	68	44	940	290	29	98	106	590	0.59	1.2
4	80	80-100	320	390	66	42	910	280	28	92	100	574	0.59	1.1
5	90	60	315	384	64	42	890	280	29	88	94	559	0.51	1.1
6	100	50	310	378	62	39	850	270	28	80	84	531	0.45	1
7	110	40	300	366	62	35	800	270	28	68	76	499	0.39	1.1
8	120	30	300	366	60	30	780	260	27	65	69	482	0.37	0.99
9	130	20	295	360	60	26	750	250	24	60	60	457	0.38	0.99
10	140	20	295	360	60	23	730	250	24	56	55	444	0.35	0.98
11	150	20	290	354	58	20	700	240	23	54	49	428	0.35	0.98
12	160	10-20	285	348	58	20	680	240	23	50	45	415	0.28	0.98
13	170	10	285	348	62	18	660	240	21	47	40	408	0.24	0.97
14	180	10	285	348	60	16	650	240	22	46	38	401	0.18	0.97
15	190	10	280	342	58	15	630	230	21	44	36	390	0.11	0.97
16	200	5-10	275	335	56	12	620	220	19	44	34	390	0.07	0.96
17	210	5-10	270	329	56	13	610	210	17	42	33	370	0.04	0.96
18	220	5-10	260	317	56	13	590	210	17	41	33	362	0.00	0.96
19	230	5-10	260	317	56	13	590	210	17	41	33	362	0.00	0.96
20	240	5-10	260	317	56	13	590	210	17	41	33	362	0.00	0.96

The samples analysis showed in decrease of arsenic concentration with the increase in depth which implies that ground water arsenic contamination is due to leaching phenomenon of sustained application of pesticides and

fertilizers in the area (Sharma, A.K., 2006). The relationship between arsenic concentration verses various depths is shown in Figure-11, below;

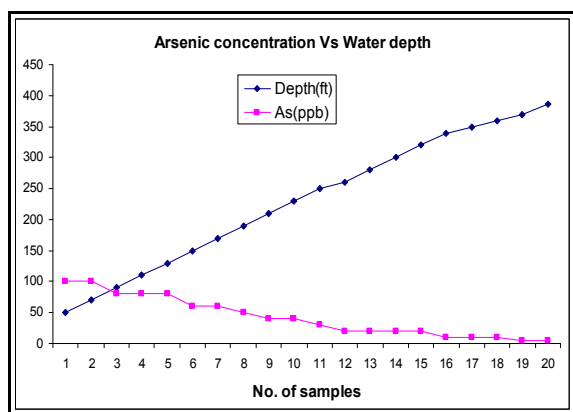


Figure 11. The graphical representation of arsenic contamination during deep boring

5. Result and Discussion

The confirmatory arsenic testing survey conducted in the study area reveals prevalence of arsenic in ground water beyond acceptable limits. Arsenic concentration in ground water survey results are inconformity with the arsenic survey results, conducted by various organizations.

In the light of literature review, it was found that generally ground water arsenic contamination takes place due to oxidation of arseno-pyrites. Therefore, comprehensive surface and sub-surface soil strata was investigated on XRF & XRD equipment in the laboratory of National University of Science and Technology (NUST), Rawalpindi and in geo-tech laboratory, Islamabad.

The soil investigation analysis, performed on XRF and XRD, has clearly indicated the absence of arseno-pyrites which could have been responsible for ground water arsenic contamination in the area. This very fact indicates arsenic contamination is due to leaching of pesticides and chemicals which are abundantly used in the area since ages.

The test results has also indicated heavy iron and arsenic ground water contamination. Higher iron concentration imparts color to water and changes in water usage habits due to high iron would indirectly lead to reduced exposure to arsenic. This could also be viewed as beneficial as the storage with higher iron concentrations would result in oxidation and removal of arsenic and iron and hence people were indirectly protected against As exposure. (Sharma, A.K., 2006) Storing groundwater for few hours with such a high iron concentration can remove over 50% of arsenic. (Khan, A.H., et al. 2000)

The release of arsenic may be correlated to one of the three most established theories:

- 1 Release of arsenic due to phosphates due of application of phosphatic fertilizers.
- 2 Desorption of arsenic due to reductive dissolution of metal oxy-hydroxides;
- 3 Oxidation of pyrite. In this case, XRF Elemental analyses of the soil strata at various depths showed no elemental arsenic implying the absence of arseno-pyrite.

Therefore oxidation theory of arseno-pyrite may be ruled out. However, positive correlation between arsenic and iron

concentration supports the reductive dissolution theory.

In the research area, pesticides and fertilizers are being used on cotton and sugarcane crops. Phosphatic fertilizers are extensively used in the area. In many studies, elevated arsenic concentrations in groundwater have been found due to application of phosphatic fertilizers (Campos, V., 2002, Davenport, J.R. & Peryea, F.J. 1991). Water quality survey conducted by PCRWR in the study area revealed higher PO_4 concentration in the study area (water quality status in Pakistan, 2003). Hence preferential adsorption of phosphate on sediments can also be held responsible for the release of arsenic.

6. Conclusion

Ground water arsenic contamination has emerged as a proven public health issue and problem which is growing exponentially in scope and complexity, particularly in developing world. Both natural phenomenon and anthropogenic activities tangibly contributes towards arsenic contamination. In developing worlds, without ascertaining the causes, heavy investments are being made in developing the arsenic removal technologies. In majority of the cases, these arsenic removal technologies become un-sustainable, as these are not marketable items, particularly, the media which is used to precipitate the arsenic. Therefore, it is important that before going for any technological solution, the arsenic contamination causes be ascertained and the sustainable solutions be sought. As in the case of research of area in district Rahim Yar Khan, Pakistan, during soil investigation, no arsenic bearing pyrites were observed. Therefore, deep boring for arsenic free alternative water supply option was resorted to which is sustainable, cost-effective, environment & people friendly and compatible with the socio-economic environments of the local population.

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