Can Water Storage Habits Influence the Cancer Risk of Drinking Arsenic Contaminated Water?

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Abstract

The removal of Arsenic from well water by co-precipitation with indigenous Iron was studied in 4 villages of West Bengal, India. A correlation exists between concentrations of Arsenic and Iron, and the Fe/As ratio (W/W) present was above 10 in all of the studied tube wells. The Arsenic concentration was in the range of 0-220 μg/l. The study showed that the actual risk of getting various cancers is 11% less than calculated if water was taken straight from the tube well, and the risk can be reduced by 77% if the water is allowed to stand for 24 hours and filtered. The literature review shows that there is a need for risk evaluation at lower Arsenic concentration levels (less than 170 μg/l).

INTRODUCTION

Countries like Bangladesh *(4)*, and India (West Bengal) *(8)* are facing major drinking water problems due to elevated concentrations of Arsenic in pumped ground water. Incidences of elevated Arsenic concentrations have also been reported from Argentina *(21)*, Mexico *(10)*, Taiwan *(33)*, USA *(17, 31, 37)*, and Vietnam *(3)*. The problem in the Ganges delta (Bangladesh and India) is by far the largest with approximately 40 million people potentially exposed to Arsenic concentrations of 0-3200 μg/l *(28)*.

   Arsenic being the 20th most abundant element in the Earth's crust (approximately 2-5 mg/kg) *(36)*, also occurs naturally in most of the

reported incidences. Arsenic is present as inorganic Arsenic in the ground waters and may occur in the oxidation states +3 (Arsenite) and +5 (Arsenate). Only Arsenate is present as oxyanion in the neutral pH range. The pKa values of Arsenic acid (As(V)) are 2.2, 7.1 and 11.5, whereas for Arsenous acid (As(III)) they are 9.2, 12.3, and 13.4. Even though As(III) is more predominant under reducing conditions and (As(V)) is more predominant under oxidising conditions, both species can occur in both conditions depending on the environmental circumstances. For example, the reduction of As(V) to As(III) is very slow, resulting in presence of As(V) in reducing environments. Moreover low steady-state concentrations of As(III) in oxic waters may be maintained by biological reduction of As(V) *(11)*.

Roots of Human Exposure

The routes of Human exposure to Arsenic can be through food, water and air. The general values of exposure through air, water and food are shown in Table 1 *(35)*.

Table 1: Intake of inorganic and organic Arsenic compounds in the general population

Source	Inorganic Arsenic (mg/d, p)	Organic Arsenic compounds (mg/d ,p)
Air	0.05	-
Food	5-20	5-1000
Water	<1-10	-
Smoking	1-20	-

Air: Normally the concentrations of Arsenic in air are in the range of 0.4-$30*10^{-3}$ µg As/m^3 *(39)*. 30-85% of the inhaled Arsenic can be absorbed and USEPA has estimated that the general public's intake of Arsenic would be in the range of 0.04-0.09 µg/d *(22)*. People living near smelters, power plants using coal and oil with high Arsenic concentrations, and households using coal with high concentrations of Arsenic can get exposed to Arsenic concentrations as high as 1 µg/m^3 resulting in a real intake of 6-17 µg/d (assuming that an adult inhales 20 m^3 of air per day). Liu et al. *(19)* reported an incidence of indoor air Arsenic concentrations in the range of 20-400 µg/m^3 in China, where people used coal with high Arsenic concentration for preparation of food.

Food: The Arsenic intake through food is widely varied depending on the type of food consumption. Based on the market basket survey of total

Arsenic the US food and Drug administration has estimated that adults ingest on average about 53 µg As/d from the diet *(22)*. A Japanese study showed a daily intake of Arsenic at 182 µg, which is very high compared to the other mentioned studies, and is largely attributed to the consumption of seafood by Japanese. In a Dutch study the daily intake of total Arsenic range between < 5 to 950 µg/d. According to WHO the mean daily intake of Arsenic through food by adults is in the range of 17-129 µg *(39)*. Generally it is only the inorganic Arsenic which is considered toxic to humans, while the organic forms appear virtually non-toxic.

Water: Arsenic concentration in most natural waters generally varies between 1-2 µg/l resulting in an arsenic intake of 2-4 µg/d assuming that an adult consumes 2 L of water per day *(39)*. This value is very low compared to the exposure through food. But as mentioned before elevated concentrations up to 3200 µg/l of Arsenic occur in some parts of the world and the arsenic concentration varies widely, resulting in very high exposure to Arsenic concentrations.

The importance of the various routes of exposure depends on the actual concentration. Usually in places where the Arsenic concentration in the groundwater is less (1 µg/l) and there is no pollution of air due to industries, the major route of Exposure to Arsenic would be through food. But in places like Bangladesh and India where the Arsenic concentration in the ground water can be up to 3200 µg/l with a water consumption of 3.5 l, the intake through drinking water will be much higher than the intake through food. Raychowdhury et al. *(24)* estimated that the average intake of drinking water per day for adult male is 4 l and for females it is 3 l. With a mean concentration of 133 µg/l in one of the studied blocks they found that the average daily intake of Arsenic from drinking water by an adult is 532 µg and the average intake of inorganic arsenic through food it is 86 µg/d assuming that 50% of total Arsenic in food is inorganic Arsenic. In this case the inorganic Arsenic intake through food accounted for around 14% of the total Inorganic Arsenic intake.

Health Effects and Risk Assessment

Arsenic is a known carcinogen and incidences of populations suffering from Blackfoot disease due to long term exposure to Arsenic concentrations (0.1-0.9 mg/l) are reported in the literature *(33)*. Acute dosages of 1.5 mg Arsenic (di-arsenic trioxide)/kg of body weight can lead to death. The most common symptoms of long-term low level Arsenic exposure are variations in skin pigments, hyperkeratosis, and ulcerations. There is documentation that Arsenic can cause kidney,

bladder, skin, lung, and liver cancer. The health effects of Arsenic vary for each individual depending on genetic conditions, nutrition level, amount of exposure, duration of exposure etc *(5,22,36)*.

Usually when establishing a guideline value for maximum intake of a substance, results from animal studies are extrapolated to define the guideline values. In case of Arsenic until so far no animal studies are available that show for certain that exposure to Arsenic causes skin and other internal cancers. On the other hand there are studies where evidence of cancer among human with exposure to high levels of Arsenic is available. The studies are from Taiwan *(33, 39)*, Mexico *(7)*, India *(25)* and Bangladesh *(1, 23)*. One of such studies from Taiwan is the extensive work done by Tseng et al in 1966 *(33)*, where the authors collected data on the exposure to Arsenic and prevalence of skin cancer in a population of 40,421 in Taiwan. The study showed that there were 428 cases of skin lesions among the studied population and there were no reported cases of skin lesions for people under the age of 20 years. Prevalence rate increased with an increase in the age. Higher skin cancer rate was reported in males compared to females, whereas there was no difference between the sexes when hyper pigmentation and keratosis were taken into consideration.

There were also studies, which showed that at lower exposure levels there was no excess risk of getting cancer. These studies are from the Oregon, Utah Study *(16)*, Belgium, and Finland. The study from Utah showed that there was no observed excess incidence of death due to cancer and high Arsenic concentrations in drinking water. The Arsenic concentrations in the water ranged between 14-166 µg/l.

When comparing studies several factors may influence the results. One observation is that between the studies showing correlation for cancer incidence appears to be at high concentrations compared to the studies without correlation where Arsenic concentrations in drinking water were lower. Another observation is that the exposure group with correlation is from developing countries with poor nutritional state, whereas the exposure group without correlation is from industrialised countries with good nutritional diet. A third observation is that the studies with cancer correlation are from villages, where usually most of the dietary products consumed are produced in the village, probably using highly Arsenic contaminated water for plant growth. A recent study shows that the food products grown in Taiwan contained high amounts of Arsenic. This indicates that the Arsenic through food products also contributed to the high incidence of skin cancer in the Tseng et al., 1966 study *(33)*. According to Tsuda et al., *(34)* there is synergism between

ingested Arsenic through drinking water (> 50 µg/l) and smoking in developing lung cancer in an exposed population in Japan.

Risk assessment studies for skin cancer and internal cancers are available in the literature. Table 2 presents the excess risk of getting skin cancer by intake of Arsenic concentration obtained by USEPA *(40)* and Brown et al. 1989 *(6)* presenting the reanalysis of skin cancer used for USEPA.

One of the drawbacks of the data in the Tseng study *(33)* is that the data was grouped in wide concentration intervals: 0-299; 300-599, and above 600 µg/l with mean concentrations of 170 µg/l; 470 µg/l and 800 µg/l respectively. Table 3 presents the excess risk of getting Bladder cancer based on the calculation made by National Research Council (NRC)*(2)* and Smith et al. *(29)*, for an American population consuming 2 l of water with an Arsenic concentration of 50 µg/l. Table 2 and 3 are used to estimate the span in risks of getting skin cancer and bladder cancer in the present study.

Table 2: Calculated lifetime excess risk of skin cancer

Author	Sex	Life time excess risk of skin cancer per 1 mg/kg, d
USEPA (40)	Male	$2.45 * 10^{-3}$
	Female	$1.05 * 10^{-3}$
Brown et al. (6)	Male	$1.3*10^{-3}$
	Female	$0.6*10^{-3}$

Table 3: Lifetime excess risk of bladder cancer

Author	Life time excess risk of bladder cancer consuming 2 l of water with 50 mg/l Arsenic
NRC (2)	1/1000
Smith et al. (29)	7.4/1000

Background and Aim of the Present Study

One of the remediation methods for preventing exposure to high Arsenic concentrations is to remove Arsenic from drinking water. The available removal methods listed in the literature are primarily based on 4 principles: Coagulation/Co-precipitation *(9,12)*, adsorption onto surfaces *(13, 14, 16)*, membrane processes *(16)* and ion exchange *(15, 16, 20)*. In case of coagulation/co-precipitation Iron and Aluminium salts are added to oxidising conditions. In the pH range of 6-8 As(V) is removed better compared to As(III). Activated Alumina, Granulated Ferric hydroxide,

Hematite, Activated Carbon are studied for their adsorption of As(III) and As(V) and the studies show that adsorption of As(V) is better than adsorption of As(III). Reverse osmosis, electrodialysis and colloidal flotation are some of the membrane processes studied, and the results show that removal of As(V) is better than As(III), the same is true in case of ion exchange processes.

The groundwaters in Bangladesh and West Bengal contain high concentrations of Iron, and data from investigations by BGS 1999 in Bangladesh show that high concentrations of Arsenic usually occur together with high concentrations of Iron. Since one of the efficient removal methods is based on the principle of coagulation with Iron salts, the naturally occurring Iron can be used in removing the Arsenic. WHO has estimated that there are around 2.5 million tube wells in Bangladesh, but the unofficial estimate is 10 million *(30)*. These estimates also show that many people are not connected with centralised water supply systems. The estimates further show that most families do not have a tube well in their backyard to supply drinking water. This indicates that many families fetch drinking water from a distant tube well or from a nearby surface water source. As it is impractical to fetch the water whenever the need arises, it is usual practice to fetch the water once or twice a day and store it in containers.

The hypothesis of this study is that the concentrations of Arsenic are usually correlated with concentrations of Iron. It is further expected that people usually store the water from tube wells and use it for drinking and cooking purpose for several hours, instead of fetching water when the need arises due to the inconvenience. This mode of storing water with high concentrations of Iron and Arsenic results in removal of Arsenic along with the precipitated Iron-(hydr)oxides. The aim of this study is to conduct a field survey and estimate the excess risk of getting skin cancer and other cancers based on the Arsenic concentrations in drinking water in the study area, and to investigate whether the habit of water storage has any effect on these estimates and whether a slight change in the habits can substantially reduce the risk of getting cancer.

THE CHEMISTRY OF ARSENIC REMOVAL WITH IRON

The expected reactions occurring during storage of water initially with high concentrations of Arsenic and Iron may be best described as concurrent oxidation and co-precipitation of Iron and Arsenic. The more detailed sequence may have the following steps:

Since the pumped groundwater is anoxic and under reducing conditions, Iron and Arsenic are present as Fe^{2+} and As(III). Since Fe^{2+} gets easily oxidised in presence of oxygen, when water is exposed to air after pumping, Fe^{2+} gets oxidised to Fe^{3+}, which in turn at pH above 2 gets hydrolysed to form $Fe(OH)_3$.

$$Fe^{2+} + \tfrac{1}{2}O + \tfrac{1}{2}H_2O \rightarrow Fe^{3+} + OH^-$$
$$Fe^{3+} + 3(OH^-) \rightarrow Fe(OH)_3$$
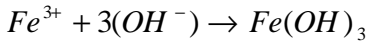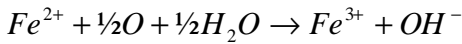
The oxidation of Fe^{2+} depends on the concentration of O_2, pH and Fe(II) concentrations according to the following reaction *(32)*.

$$-\frac{d(Fe(II))}{dt} = \frac{(K_H(O_2(aq)))}{(H^+)^2}(Fe(II))$$

The hydrolysis of Fe^{3+} and subsequent removal of Fe^{3+} as Iron hydroxide ($Fe(OH)_3$) depends on pH and presence of different ions. The literature review shows that Iron hydroxides are capable of removing As(V) and As(III) from water, with the removal of As(V) being much better than As(III).

The oxidation of As(III) to As(V) in presence of Fe^{3+} is thermodynamically favourable, and the literature shows results where both the occurrence of oxidation of As(III) in presence of Fe(III) and the absence of this reaction. The laboratory results also shows that the oxidation of As(III) takes place in presence of Fe(III) (these results are not shown here). The possible overall reactions in the removal of Arsenic from water are:

Fe(III) + As(III) = As(V) + Fe (II)
$Fe(OH)_3$ + As(V) = $Fe(OH)_3As(V)$.
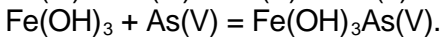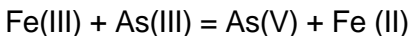
The above reactions are not balanced and the complicated oxides and hydroxides of iron formed in water are only denoted as $Fe(OH)_3$. The Oxidation of As(III) and subsequent removal of Arsenic depends on pH, As(III)/As(V) ratio, initial Arsenic and Iron concentration. The removal of Arsenic also depends on the presence of phosphate, silicate, and bicarbonate. The effect of these ions in the field conditions is described in a conference paper by the authors *(27)*.

METHODOLOGY

A field study was conducted in 4 villages from Deganga and Barasat II block of North- 24 Paraganas in West Bengal, India, where 41 families

were interviewed for their habits on usage of drinking and cooking. Water and tube well waters from these families were analysed for Arsenic and Iron concentrations. Water samples were also collected, if the family had stored water in their household for family usage. Experiments were conducted to investigate the % Arsenic removal by simple sedimentation. The samples were analysed for Arsenic (hydride-generation AAS) *(40)* and Iron (flame-AAS) *(41)*.

RESULTS AND DISCUSSION

Arsenic and Iron concentration in the different tube wells from the surveyed area are shown in Figure 1, which shows that the occurrence of Arsenic is correlated with occurrence of Iron in the surveyed villages and a Fe/As molar ratio of above 10 is present in all the surveyed tube wells. The total Arsenic concentration was in the range of 0-220 µg/l.
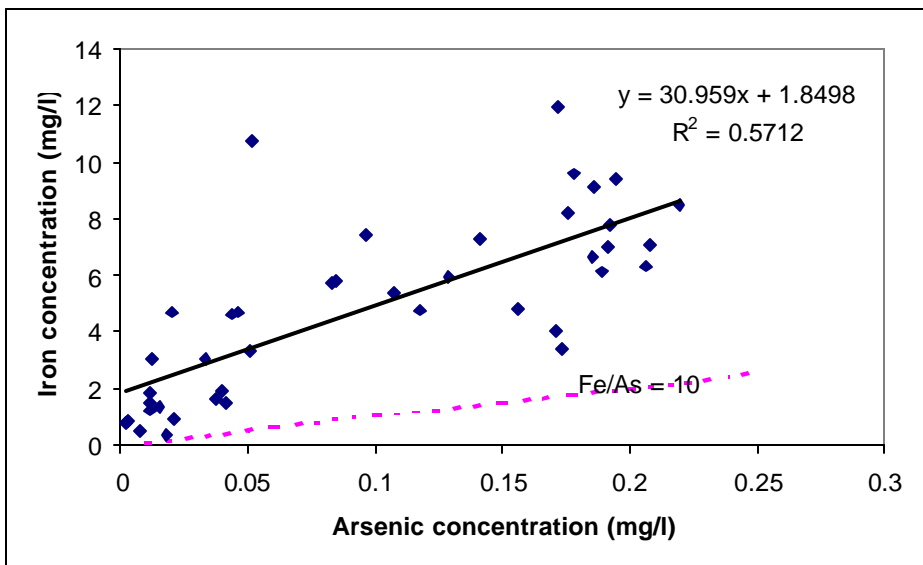
Figure 1: Co-occurrence of Iron and Arsenic in the 4 studied villages

According to an estimate from the people who live in the villages there are around 340 tube wells of which around 38 are deep tube wells (more than 400ft deep) and are installed by the Government and the rest are shallow individual tube wells. Of the surveyed tube wells 80% of them were installed between 1-10 years back and all the deep tube wells are installed within 1-10 years. Altogether 41 tube wells were surveyed

including 7 deep tube wells. Arsenic concentration in the deep tube wells was in the range of 10-30 µg/l. The population in the surveyed village is approximately 10000 with a male to female ratio of 1.1:1. Regarding the water storage and water usage, the following patterns are observed:

- Before installation of tube wells in their backyard, people used to fetch the water and store it.
- People living near by the tube well fetch water whenever they need it.
- People living some distance away from the tube well fetch the water once or twice a day and store it.
- If the water contains high concentrations of Iron then people do not use the water for cooking or drinking purpose. They use the nearby pond water for cooking purpose and/or store the water for some time to remove the iron and use it for cooking purpose. For drinking purpose they fetch the water from a tube well where there is no Iron.
- Most of the interviewed people mistake Iron for Arsenic and do not drink the water containing high concentrations of Iron.
- The recent discussion in the media has created awareness in people and people have started fetching the water from the nearby deep tube wells.

The results on estimation of risks are divided into the following 3 scenarios: (i) Scenario 1: Excess risk of getting cancer when the tube well water was consumed directly; (ii) Scenario 2: Excess risk of getting cancer with peoples present water related habits; (iii) Scenario 3: Excess risk of getting cancer if the people store the water for 24 hours and filter it before consumption.

The following Assumptions are made to calculate the risk:

- It is assumed that the Arsenic concentration which the population in these villages is exposed to is proportional to the distribution in the measured tube well concentration.
- The population in Taiwan for which epidemiological data are available is comparable to the population in West Bengal, since the majority in both the population groups depends on agriculture. The body weight of 55 kg for men and 50 for women is assumed.
- The weather is hot in both the situations leading to the assumptions that the water consumption in both the situations will be same, i.e., 3.5 L for men and 2 L for women as assumed by other authors. The difference in the water consumption between

male and female is due to the fact that male work in the fields and thereby consume more water compared to the female. The water consumption in cooking is not taken into consideration.

- When applying the data directly from the Tseng et al. *(33)* study it was assumed that there is no threshold of getting skin cancer i.e., there is no expected skin cancer cases at 0 µg/l of Arsenic, whereas even a slight exposure can lead to skin cancer. This assumption may lead to higher risk estimates at lower exposure levels, but very little is known about exposure to low level Arsenic concentrations.
- Since there are no industries, which emit Arsenic in the studied area, the intake of Arsenic through air is neglected. The main diet of people living in West Bengal and Bangladesh is rice and vegetables.

Scenario 1: Directly from the Tubewell Water

Table 4 shows the distribution of Arsenic concentration in the tube wells. According to Table 4, 29% of the population are exposed to a mean concentration of 0.034 mg/l and 54% are exposed to a mean concentration of 0.16 mg/l. Table 5 summarises the excess number of people that has a risk of getting skin cancer. Depending on the model used the calculated excess risk of getting skin cancer varied between 53 and 98 cases. The calculated excess risk of getting bladder cancer using the NRC estimates *(2)* and smith et al. *(29)* is shown in Table 6.

Table 4: Arsenic concentration in the three different scenarios

Conc. (mg/l)	% Tubewells			Mean concentration (mg/l)		
	Scenarios			Scenarios		
	1	**2**	**3**	**1**	**2**	**3**
< 10	17	17	32	8	8	1
10-50	29	29	61	34	34	28
> 50	54	54	7	161	140	56

Scenario 2: Water Stored as it is Done Now

Of the surveyed 34 shallow tube wells there were 11 families, which had water stored in containers. Both filtered and unfiltered samples from the containers were collected. The storage time ranged between 5 and 56 hours and the % Arsenic removal ranged between -8 to 71% in the unfiltered samples and 17 to 82% in the filtered samples (See Fig. 2 and Table 4). The figure also shows the corresponding % removals in the

experiments. The % removals obtained in the experiments (Scenario 3) are generally higher than the % removals obtained in the households. One of the reasons for the difference in the % removal obtained in the households and in the experiments could be that the water in the households is disturbed, when water is taken from the containers for consumption. The resulting Arsenic concentrations are shown in Table 3. It can be seen from the table that the distribution of the tube wells in the 3 concentration intervals did not change while the mean concentration in the concentration zone > 50 µg/l decreased from 161 to 140 µg/l. Table 5 and 6 shows the excess risk of getting skin and bladder cancer respectively. It can be seen from the table that both the cancer risks are reduced by around 11%.
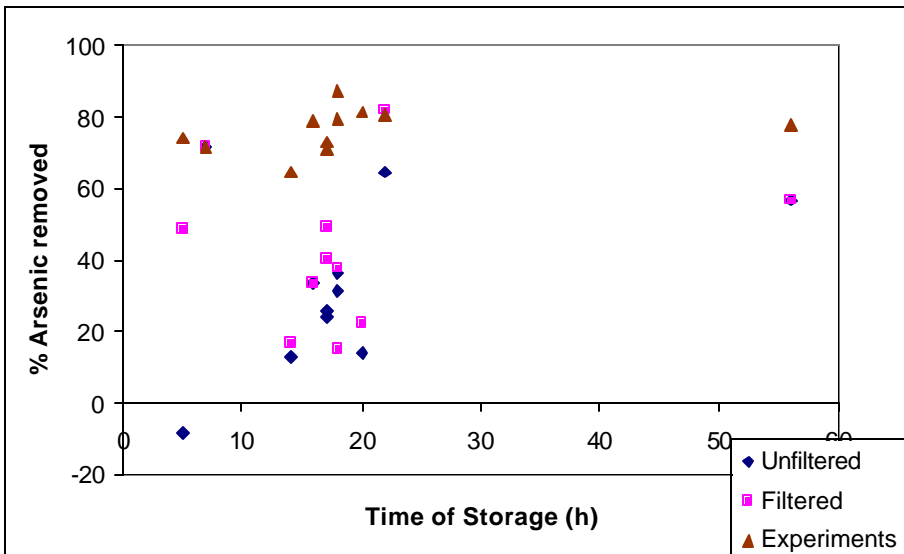

Figure 2: % Arsenic removal with storage time at household level

Scenario 3: Water Stored for 24 Hours

Experiments were conducted where the collected water containing Arsenic and Iron from all the tube wells was allowed to stand and the supernatant was collected and Arsenic concentration was measured in the supernatant. The resulting Arsenic concentration is shown in Table 4. The highest concentration that was present in the supernatant was 0.062 mg/l. Figure 3 shows the initial Arsenic concentration vs. final Arsenic concentration in the experiments and the fitted linear regression shows that the about 78% Arsenic was removed and the correlation coefficient

(R^2) was 0.8082. The calculated skin cancer and bladder cancer risks are shown Table 5 and 6 respectively. It can be seen from the table that expected number of skin cancer and bladder cancer were reduced by around 77%.

y = 0.2166x
R^2 = 0.8082
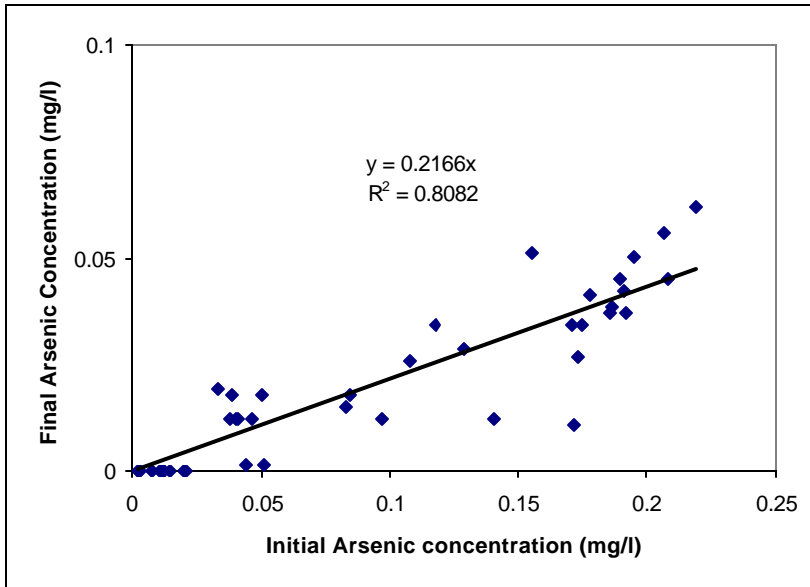
Figure 3: Initial vs. final arsenic concentration in experiments

The experiments conducted in the field showed that a time period of 24 hours is necessary to remove the maximum possible Arsenic from the water. The experiments also showed that even though the supernatant looks free from Iron (hydr)oxide particles, which are responsible for the removal of Arsenic, the water even after 24 hours may contain a small fraction of these particles leading to higher concentration of Arsenic in the water compared to filtered water.

Table 5: Expected number of skin cancer cases using different models in the three different scenarios

Author	Expected number of skin cancer		
	Scenario 1	**Scenario 2**	**Scenario 3**
Brown et al. (6)	53	47	12
USEPA	98	87	22

Table 6: Expected number of bladder cancer cases in the three different scenarios

Author	Expected number of bladder cancer		
	Scenario 1	Scenario 2	Scenario 3
NRC (2)	48	43	10
Smith et al. (29)	354	315	77

Observed Cases in the Villages

Of the 41 interviewed families none of them were suffering from Cancer. There was one man of age around 50, who was having Black spots on hands and he said that it was diagnosed that it is Arsenicosis. There is no one else in the family suffering from any skin lesions. The family was moved from another village around 30 years back and already at that time this man was suffering from these skin lesions. The Arsenic concentration in the tube well was 80 µg/l. They store the water before using it for cooking purpose and drinking purpose.

There was one female of age 30 was suffering from rough hands. She moved to this village after her marriage and suffering from the skin lesions for the past 5 years. The Arsenic concentration in the tube well was 15 µg/l. There was one female of age 18 years was suffering from skin lesions for the past 10 years. Arsenic concentration in the tube well was 190 µg /l. Recently they have installed a filter in the house. She is the only one suffering in the family.

The above three are the only cases that were observed during the visit. In the first case the concentration of Arsenic that caused the effect is unknown. An exposure to 80 µg /l had until now no effect on the people in that family. This could be due to that they store the water before using it. In the second case the Arsenic concentration in the tube well water was only 15 µg/l, and it is not for certain that the effects are due to Arsenic. It was not possible for the visited team to classify the symptoms. But it is unlikely that the symptoms are due to Arsenic.

In the third case it is likely that the symptoms are due to Arsenic, but as in the second case it is not certain, since the skin lesions could also be a kind of allergy. The skin lesions are more prevalent during summer than during winter.

General Discussion

The above presented risk analysis is an attempt to describe how the risk can be reduced if just the water containing Arsenic along with Iron is allowed to stand for 24 hours. It is difficult to give an exact estimate for

the excess risk of getting skin cancer or other cancers since the models used for calculations uses different assumptions. One of them is the assumption about the daily consumption of water. In the recent risk analysis USEPA uses an estimate of 4.5 L of water in case of Taiwanese instead of 3.5 l, with the argument that during the preparation of Taiwanese food (Rice and sweet potatoes) approximately 1 l of water is used. Maybe the water Arsenic intake is even higher in case of populations in West Bengal and Bangladesh, since the main food items is rice and Daal (lentils), both of them uses large amount of water. The people in West Bengal and Bangladesh also consumes large amount of tea. If all these things are taken into account then the total daily water consumption may be around 5.5 l. If these figures are used instead of 3.5 l, then the excess risk of getting cancer will increase by a factor of around 1.6. But it is also possible that the consumption of ground water is only 3.5 l and not 5.5 l, since people use pond water for cooking purpose. Raychowdhury et al. *(24)* stated that the average consumption of drinking water in one of the villages of West Bengal was 4 l for men and 3 l for women.

The other main assumption is that the intake of Arsenic is only through drinking water. With the evidence that food products also contain inorganic Arsenic the exposure through food may have a significant effect. Recent studies have shown that the sweet potatoes grown in the Arsenic endemic area also contain high concentrations of Arsenic *(26).*

The calculated results show that there is a difference between the expected number of skin cancer cases or bladder cancer cases depending on the model used. This is due to the uncertainty of effect of Arsenic in the lower concentration range and hence the extrapolation into the lower concentration zone. The Arsenic concentration in the available studies is divided into 3 ranges 0-300, 300-600 and above 600 µg/l with mean concentrations of 170 µg/l, 470 µg/l and 800 µg/l respectively. There is no data available for mean concentrations below 170 µg/l.

As mentioned earlier most of the tube wells installed in the surveyed villages are only 10 years old. This could be one of the reasons why there are not so many cases of Arsenicosis observed in the villages. This is due to the fact that when there were longer distances to the tube well, people used to fetch the water only once or twice a day and store it. This storage of water with high concentrations of Iron could have resulted in substantially lower the Arsenic concentrations in the consumed water. It may even be possible that there were no tube wells earlier and hence no Arsenic load to the villagers.

When calculating the risk of getting cancer in Scenario 2 it was assumed that the % reduction in the Arsenic exposure was proportional to

the number of samples collected from the household. This is could be an overestimation of the risk, because approximately 30 people share one tube well and since it is installed with one family the rest will fetch the water once or twice a day, which means that there will be higher % of people storing the water compared to the assumed number here.

One of the features observed in the literature was that the prevalence of skin cancer was higher in men compared to women. One of the explanations for this could be that women do not work in the fields as hard as men and therefore their water consumption is low. When estimating the risk it was assumed a daily water consumption of 2 l in case of women compared to men. Other reasons could be that since women do not work in the field but stay at home they drink the water from the stored containers, and this will result in lower exposure to Arsenic compared to men who drinks the water directly from the tube wells. If this is true then children may also be more exposed, since they play outside all day and drink water directly from the tube well. If the assumption of 2 l drinking water for women is not true then higher risks can be expected in the population.

The short literature survey showed that most of the risk assessment studies carried out so far are based on the population study from Taiwan, while the guideline values established are meant for the American population. The differences between the population in US and the population in West Bengal and Bangladesh in terms of average weight and nutritional status are considerable. Thus the guideline values for the American population are not sufficiently protective in case of West Bengal and Bangladesh. If we assume an average body weight of 70 (or more) kg for an American compared to 55 kg for a Bangladeshi, and 2 l water consumption by an American compared to 3.5 l for a Bangladeshi, then the provisional guideline value set at 10 µg/l by WHO should rather be 4.5 µg/l in case of a Bangladeshi to have the same risk as calculated by WHO. If the water consumption is higher then this value should be even lower. If these risk estimates are true then there should be more cases Arsenicosis in West Bengal and Bangladesh compared to what is seen now. One of the reasons could be that the age of most of the tube wells is between 1 and 10 years and since it takes time to develop the symptoms, the expected number of cases are not yet seen at present. The other reason could be the co-occurrence of Arsenic with Iron giving colour to water and bad taste, which may lead to either discarding of the water with high concentrations of Iron, or to let the water stand for some time to remove the Iron. Many villagers are doing this. This will result in lower exposure to Arsenic and thus the risks, than what may be calculated

based on the number of tube wells and the Arsenic concentrations found in the tube wells.

Despite the obvious advantages of storing tube well water, there are drawbacks of the method. The lengthy storage of water with high concentrations of iron may encourage bacterial growth and this may be harmful for the people. For the method to be fully effective the water may have to be filtered otherwise high concentrations of colloidal Arsenic can be present in the water.

The literature survey showed that even though there is evidence of cancer incidence due to exposure to Arsenic, there is lack of knowledge in the lower concentration range, i.e., below 170 µg/l. Since these data are used to evaluate the guideline value there will be a high uncertainty in the estimated absolute risks. Since many people in West Bengal and Bangladesh have been exposed to concentrations in this range for the past 10 years, a well-planned data collection and health survey in this region can lead to good understanding about the effects of Arsenic in the lower range.

CONCLUSIONS

- It is concluded that high Arsenic concentrations in ground water are correlated with high Iron concentrations in the studied villages.
- The risk of getting skin and internal cancer can be reduced by 77% if the water containing high concentrations of Iron and Arsenic are allowed to stand for 24 hours and then filtered properly.
- People's habit of storing the water for drinking and cooking purpose may be one of the reasons for observed highly variable effects of Arsenic. This could be also one of the reasons why no cancer patients are observed in the villages.
- The time span for constructing the tube wells with high Arsenic concentrations is short in comparison to the time for health effects to appear fully.
- The opportunity of conducting epidemiological studies in the lower range < 170 µg/l is present in West Bengal and Bangladesh. This opportunity should be utilised to obtain better knowledge about the effects of Arsenic exposure in the lower range. This would also lead to establishment of better guideline values.

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