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Article

Feasibility study on fluoride removal in drinking water in Mehsana, India

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The problem of fluoride contaminated water has been reported to affect many parts of Gujarat especially in Mehsana District causing severe causes of fluoride related diseases. Although there are varying standards on the acceptable fluoride concentrations around the world; the general consensus is that fluoride above 1.5 mg/L will be detrimental to health. As such, a feasibility study on the drinking water in Mehsana is undertaken to decide if a project by Engineers-Without-Borders on fluoride removal in drinking water is feasible in Mehsana. Water testing was further conducted in University of Oxford to validate the results that were obtained in Mehsana. The paper will then conclude with the current concentration of fluoride in selected villages in Mehsana and the recommended future directions EWB-Oxford should be taken for the project.

Key words: Engineers-Without-Borders, Gujarat, Mehsana district, drinking water.

INTRODUCTION

Fluoridation in water has remained controversial because too much or too little of fluoride in our drinking water will have harmful effects to our health. According to studies on varying fluoride concentrations in water, concentrations lower than 0.5 mg/L has shown to intensify the risk of tooth decay while those exceeding 1.5 mg/L pose a risk of dental fluorosis as well as skeletal fluorosis and osteoporosis (AbuZeid and ElHatow, 2008). This is especially an important issue since fluoride standards in many parts of the world differ. In the 3rd edition of the World Health Organisation's (WHO) guidelines on drinking water, it maintains its guideline on the appropriate fluoride concentration at 1.5 mg/L (WHO, 2008). However, WHO suggests in setting a National standards based on several considerations such as the total intake of fluoride by the population and the climatic conditions of the nation. Until now, there has not been a single clear criterion or test to conclude the exact amount of fluoride required for each country's drinking water. Hence, for the purpose of the feasibility study, we will take the appropriate fluoride level in drinking water to be between 1.0 mg/L (lower limit) and 1.5 mg/L (upper limit) according to the approved levels in India (Bureau of Indian Standards, 2010). Perhaps, it is not immediately obvious to many people that the problem of fluoride-contaminated drinking water comes a long way in India before standards and technologies were introduced. Thus, many villagers who lived on fluoride contaminated water for most part of their lives have suffered serious consequences ranging from different extents of dental fluorosis to skeletal fluorosis. This problem has since attracted the attention of the relevant governmental organisations in India, which eventually culminated in the formation of Water and Sanitation Management Organisation (WASMO) in May 2002 to facilitate decentralised community-managed water programmes in Gujarat. Although prior efforts were made to create and maintain water supplies in the state, it was soon evident that the system itself was not sustainable as the users

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were unwilling to pay for the services and the entire system became financially unviable (WASMO, 2008). Besides the structure of the organisation that was not sustainable, the inherent problem of fluoride-contaminated drinking water was more urgent. The challenge was then to make known to the villagers that water with high levels of fluoride is unfit for drinking. This is made even tougher given that fluoride is colourless and odourless, thereby making it difficult to convince villagers of the detrimental effects of drinking such water. Furthermore, the effects of drinking fluoride contaminated water are long term and can only be obvious after a number of years (Grobler et al., 2009). Hence, the objective of WASMO was then to create a demand driven decentralised water supply system that will be partly created, operated and maintained by the users.

The water quality monitoring and surveillance programme (WQSMP) was launched in 2006 to bring user participation in building safe water for everyone. One of the districts that were focused on was Mehsana district which is situated in the North of Gujarat. With a population of 2,027,727 with an estimated land area of 4,382 km^2 (Government of India, 2011), it is also home to numerous large-scale petroleum and chemical industries. Thus, WQSMP was launched in Mehsana to determine the number of affected villages and the extent of fluoride contamination. Along with the implementation of this programme, initiatives were also introduced by the state government since 1985. These initiatives include defluoridation based Nalgonda technique at various levels, setting up of defluoridation plants and introducing new sources of water. The problem of fluoride contaminated water source may be due to a number of factors. One of them is the presence of naturally occurring fluoride content in the environment. Except for the presence of evaporates, fluoride is the most abundant halogen in the sedimentary rocks (Wedepohl, 1975). Although the amount of naturally occurring fluoride depends on the location, the fluoride contamination of groundwater is partly due to its environment. Furthermore, industrial plants manufacturing hydrofluoric acid, aluminium, super-phosphate, enamel, bricks and industries consuming high sulphur non-coking coal like thermal power plants are the main sources of fluoride pollution (Griffin et al., 1980; Deshmukh et al., 1995). This is true as Mehsana district is home to numerous large scale industries in which the industrial effluent containing fluoride may contaminate the groundwater if not treated carefully. During the field trip to the different villages in Mehsana, it was observed that defluoridation plants were common sights along the roads to the villages. Also, source of water from the Narmada River has been made accessible to the villages in addition to the Bore-well Submersible water under the Narmada Canal based water supply schemes. Villages of east and central Mehsana are covered under a regional water supply scheme based on water of Dharoi Dam (WASMO, 2008). Hence, the purpose of the trip is to determine the current fluoride concentration in selected villages in Mehsana and determine if the situation has been improved after the aforementioned initiatives were implemented by the state government.

This feasibility study will then affect the direction EWB-Oxford will take for its branch project in future.

EXPERIMENTAL METHODS

As part of the collaboration between EWB-Oxford and one of our local partners, Aqua-plus, a water test kit has been provided by Prerana laboratory. The methodology for the water testing is based on the Zirconium-Alizarin Visual Method, a method which compares the colour of the water samples with the protocol given. However, colour comparison is discrete in nature, making it difficult to distinguish the precise differences of the fluoride concentration for all the test samples. Hence, this method used was found to be subjective and lacked the accuracies and reliability of a commercial fluoride meter. Water tests were then done in a total of 22 different sites in Mehsana District with tests being done on different water sources in a single site depending on the sources that were available to the inhabitants in that site. The sources of water being tested were also being recorded whenever it was possible as well as the population at that site. In the data collation process, the fluoride concentration of the different water sources in a site is then averaged and compared with the average fluoride concentrations from different sites. This approach was taken because different villagers in a site were gathering water from different sources and it will be difficult to assess the impact of a single source of water to all the villagers in that site.

Three water samples were collected at random from different water sources in India and brought back to be tested in a research facility at the Department of Engineering Science, University of Oxford. This is due to the limitations in taking all samples back due to aviation regulations.

Testing methodologies

The test for fluoride in the ground tests was based on a commonly-known chemical reaction between Alizarin-S, Zirconium and fluoride. Firstly, Alizarin-S combines with Zirconium to give red Zirconium-Alizarin S complex. By adding drops of the testing liquid to the water samples, the presence of fluoride then removes Zirconium to form colourless Zirconium Hexafluoride leaving the yellow Alizarin. Similarly, as stated in the protocol given together with the testing kit, the higher the concentration of fluoride in the water samples, the more yellowish the colour of the water will be. As part of the protocol given, drops of the testing reagent were added to the water samples (given in standard-sized tubes) and colour comparison was made after approximately 10 min of mixing the reagent with the water sample. Colour comparisons were all made by the same tester in order to ensure consistency since such method tends to be subjective to the visual perception of the tester. As for the water tests at the Department of Engineering Science, Oxford University, three tests were conducted for a single water sample and then the average value was taken for each of the three water samples in addition to the standard deviation calculated. The testing procedure is as follows: firstly, 5 ml of water sample is pipette into a cuvette

Table 1. Test results collated from ground tests in Mehsana district using zirconium-alizarin visual method.

Village	Fluoride concentration (ppm)			
	Unknown source	Narmada source	Bore well submersible water	Average conc.
Heduva	1.00	-	-	1.00
Heduva (farming)	0.50	-	-	0.50
Devivura	1.00	-	-	1.00
Mitha	1.00	-	-	1.00
Balol	1.00	-		1.00
Nugar	1.00	-	-	1.00
Gilosan	1.00	-	-	1.00
Bodela	1.00	-	-	1.00
Maguna	1.00	-	-	1.00
Street shops packaged drinks	0.75	-	-	0.75
Kaloda	-	1.25	1.50	1.38
Serludeva	-	-	1.50	1.50
Ralela	-	1.00	1.50	1.25
Dadrda	-	1.00	-	1.00
Ganeshpura	-	1.00	-	1.00
Gabhu	-	1.00	-	1.00
Mohera	-	1.00	1.00	1.00
Pachok	-	1.00	1.50	1.25
Deloger	-	-	1.00	1.00
Lanva	-	1.00	-	1.00
Pipolo	-	1.00	-	1.00

which is then closed and inverted.

The outside of the cuvette is then thoroughly cleaned and evaluated after 1 min, with 1 blank-value cuvette being prepared with 5 ml of distilled water. The test cuvette is then evaluated by using DR2800 (barcode programme).

RESULTS AND DISCUSSION

Test results from ground tests in Mehsana district

It was found that the maximum concentration of fluoride present in any water sample collected from the 22 sites is 1.50 mg/L (Table 1). This is a surprising result as it was initially thought that the fluoride concentration will be higher and above the standards of 1.5 mg/L (upper limit) according to the approved levels in India (Bureau of Indian Standards, 2010). However, it was found through the water test kit that none of the sites had water samples that violated such a standard and in particular, the water standards that is set by World Health Organisation. A few reasons are identified to justify these surprising results. Firstly, WASMO has been effective with dealing with the fluoride problem in these regions (if any) and the water source from Narmada river source has been a reliable source in terms of low fluoride concentration. As compared to existing water from the Bore well (1.00 to 1.50 ppm), the Narmada River provides water with a lower fluoride concentration in the range between 1.00 to 1.25 ppm (Table 1). Secondly, the 22 different sites that were surveyed may not be the areas that have been affected by the fluoride problem. Prior to the feasibility study, not much was known about the areas, the areas that were surveyed are chosen based on the knowledge of local partners which could be inaccurate as well.

Thirdly, the water test kit may be producing inaccurate results causing the anomalies. This reason may be plausible as the visual method was deemed subjective as mentioned previously. Hence, three water (Table 2) samples from different sites and sources were taken back to be tested using more reliable testing methodology and equipment.

Test results by Department of Engineering Science, University of Oxford

The water test results from the Department of Engineering Science showed equally surprising results. The fluoride concentrations of the water samples displayed even lower values as compared to the results

Table 2. Classification of the three samples brought back for testing.

Test samples
Sample A: Maguna, Mehsana (underground water source)
Sample B: Bore well or Submersible source
Sample C: Ralela, Mehsana (Narmada river source)

Table 3. Fluoride concentration results equivalent of ppm conducted on three samples.

Sample No.	Test 1 (mg/L)	Test 2 (mg/L)	Test 3 (mg/L)	Standard deviation	Average (mg/L)
A	0.326	0.329	0.338	0.0062	0.331
B	1.24	1.18	1.22	0.0306	1.21
C	0.334	0.341	0.345	0.0056	0.340

from the visual method (Table 3). Hence, this confirmation test shows that the inaccurate testing method was not a valid reason and the conclusion could only be due to either an absent of fluoride problem in the sites that were surveyed or that WASMO might have been successful in dealing with the fluoride problem. In light of these issues, a literature review has been done to understand more about the past fluoride concentrations for some of the sites that were surveyed. It was found that Ganeshpura for instant recorded a fluoride concentration of 3.35 ppm for its water source as of February 1997 (Gupta and Deshpande, 1998). However, when fluoride test in that site was conducted again in December 2010, its fluoride concentration was 1.00 ppm. Hence, at this moment we can only conclude that WASMO efforts in dealing with the problem have been effective for the sites that were surveyed.

Conclusions

It was found that WASMO efforts in reducing fluoride concentration in parts of Mehsana region surveyed have indeed been successful. Fluoride concentrations in the 22 sites that were surveyed were within the approved levels in India and the World Health Organisation. In fact, by taking into account the fluoride concentrations that were collected by the Department of Engineering Science, there is actually an offset that reduces the values obtained by the visual method. In addition, it was found that through the Narmada Canal based water supply schemes, some of the sites have been introduced to lower concentration of fluoride compared to Bore well water which showed higher concentration of fluoride. As the fluoride problem in these surveyed villages has been solved, one of the future direction of EWB-Oxford will be to move on to other areas that are affected by the fluoride problem. Given the uncertainties on the areas that are affected, it is proposed that consultation with WASMO and more partners must be sought to ensure that the targeted areas must be plagued by high fluoride concentration before conducting any field trips. Also, it is highly advisable that another feasibility trip should be made before the project is committed to any specific areas or villages. However, this feasibility study is successful in the aspects of gaining experiences in field testing work and establishing connections with local partners and WASMO. Also, visits to local industry such as Ionex Engineers were conducted on the last day of the trip to understand more about the water issues concerning India and the market for technologies that were required to solve such problem. Additionally, EWB-Oxford could move on to shift its focus to a more general direction of safe access to drinking water. This area possibly requires less technical expertise and can attract more help at an undergraduate level.

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