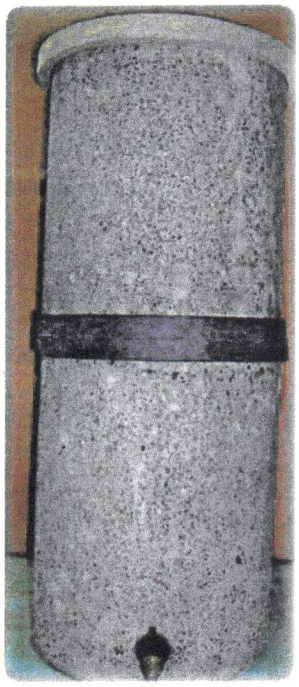
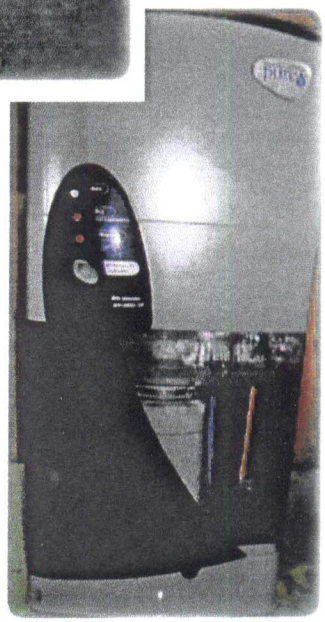
Final Report

Evaluation and Standardization of Domestic Arsenic Removal Units

Sponsor
UNICEF, Kolkata





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FOREWORD

Groundwater is the primary source of drinking water for the inhabitants of rural West Bengal. Arsenic contamination in groundwater is a major public health issue in the State and exposure to arsenic through drinking water leads to a wide range of health problems including skin cancer, gangrene of the limbs, vascular diseases, conjunctivitis, central nervous system damage and hyperkeratosis. Recognizing the enormity and severity of the problem of arsenic poisoning the United Nations Children Fund (UNICEF), as part of its support programme aimed at mitigating the problem through provision of domestic arsenic removal units. National Environmental Engineering Research Institute (CSIR-NEERI), Nagpur, was engaged by UNICEF, Kolkata, for evaluating the domestic arsenic removal units for effectively removing arsenic and to develop guidelines for their usage in the arsenic affected areas.

The report presents the results of the laboratory and field evaluation of the domestic arsenic removal units based on the criteria of filter design, capacity, presence of essential media, time required to obtain arsenic safe water (at first installation), arsenic removal capacity, occupational hazards and cost. Salient features of these domestic arsenic removal units, protocol for laboratory and field evaluation, and also the experience of users with the units are included in the report. Suggestions for further improvement in domestic arsenic removal units have also been delineated.

The initiative taken by the Chairman, Arsenic Task Force Core Committee, Government of West Bengal and inputs received from UNICEF, Kolkata in steering these studies is gratefully acknowledged.

(S. R. Wate)

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Contents

List of Tables

List of Tables

1. Preamble

The occurrence of arsenic in ground water from the vast tract of alluvial aquifers in the Bengal Delta plains covering the eastern part of West Bengal , Assam, Jharkhand and parts of Chhattisgarh in India and Bangladesh has been one of the most recent and major environmental issues in the subcontinent. The criticality of the situation created by the incidence of arsenic in ground water can be judged by the fact that ground water is the only drinking water source for the vast rural populace. It has been estimated that about 50 million people in Bangladesh and 38 million in West Bengal have been affected by the incidence of arsenic in ground water.

A major constraint experienced in the provision of potable water to millions of rural population is the non availability of adequate infrastructure for removal of high concentrations of arsenic from water supply sources subsequent to monitoring of contaminant levels in water supplies to ensure public health safety. The problem is being addressed by various agencies for short term as well as long term solutions. Several domestic / household arsenic removal units have been developed by various agencies. Recognizing the enormity and the severity of the problem of arsenic poisoning the Chairman, Core Committee, Arsenic Task Force, Government of West Bengal aimed at mitigating the problem; in consultation with the Chief Engineer, Planning and Water Quality Management, PHED, Government of West Bengal (GoWB), approached the National Environmental Engineering Research Institute (NEERI), Nagpur to undertake the task of 'Evaluation and Standardization of the Domestic Arsenic Removal Units' to be made available commercially in near future in the arsenic affected areas, for their capabilities and accuracy and in the light of the findings, develop guidelines for their usage, and recommend generic specifications which could form the basis for indigenous manufacture of domestic arsenic removal units in the arsenic affected countries. GoWB intends to provide safe drinking water to communities at risk of consuming arsenic contaminated water and improve access to short-term mitigation options. To standardize available options GoWB requested UNICEF to support for the evaluation and standardization of five types of domestic arsenic removal technologies/options presently available, which may further be

4. Methodology

4.1 Field Visit

A team of NEERI scientists visited arsenic affected areas in West Bengal accompanied by a UNICEF official for familiarising with the technological options used for arsenic removal and gather information on users' perception and experiences. UNICEF, Kolkata had arranged the visit during May, 2010 to villages of Gaighata, Paripara, etc in North 24 Parganas and Nadia districts of West Bengal. The team visited about 12-15 households. Some houses had RSM Filter with Activated Alumina Technology - Domestic Arsenic Removal Filter produced and promoted by Rural Sanitary Mart (RSM), developed with technical assistance from Bengal Engineering Science University (BESU) with UNICEF support while some had SONO Arsenic Mitigation Filters developed by Manab Sakti Unnayan Kendra, an NGO, Kustia, Bangladesh installed in their houses. Almost all were using water from these filters. In most of the houses women responded to the queries made by the scientists. They were happy using these filters. However, it was observed that few women were using water from the public stand posts in these filters instead of water from tube wells adjacent to their houses. Persons appointed by local NGO were found to be regularly monitoring working of these filters and actively engaged in the operation and maintenance of these units. The household where Sono filters were installed were happy that addition of any chemical is not required in these filters; however, they expressed their dissatisfaction for not getting cool water during hot season because of the plastic body of Sono filters. They were definitely found to have the feeling of gratitude that some agency cared for their well-being.

The team also visited the Rural Sanitary Mart where two RSM Filters with Activated Alumina Technology were randomly selected to carry out their evaluation at NEERI, Nagpur. During their visit the team also picked up one set of SONO Arsenic Mitigation Filter developed by Manab Sakti Unnayan Kendra, an NGO, Kustia, Bangladesh from an NGO's office at Thakur Nagar in Gaighata for transportation to NEERI, Nagpur for its evaluation.

4.2 Procurement of Domestic Arsenic Removal units

As per the information provided by the Chairman, Core Committee, Arsenic Task Force the following five suppliers were identified for procurement of arsenic removal units;

i. RSM Filter with Activated Alumina Technology- Domestic Arsenic Removal Filters promoted by RSMs developed under GoWB-UNICEF Joint Plan of Action
ii. Household Water Filter developed by Naval Materials Research Laboratory (NMRL), DRDO, Ministry of Defence, Government of India
iii. SONO Arsenic Mitigation Filter developed by Manab Sakti Unnayan Kendra, an NGO, Kustia, Bangladesh
iv. Pureit arsenic cum germ removal filter, developed by Hindustan Unilever Limited
v. Pureit arsenic cum germ removal sachet, developed by Hindustan Unilever Limited

Two RSM Filters with Activated Alumina Technology were purchased from Rural Sanitary Mart; West Bengal while another set of SONO Arsenic Mitigation Filter developed by Manab Sakti Unnayan Kendra, an NGO, Kustia, Bangladesh was supplied by an NGO working in the rural arsenic affected areas of West Bengal. One stainless and one polypropylene Household Water Filter each developed by Naval Materials Research Laboratory (NMRL), DRDO, Ministry of Defence, Government of India were procured from Save Environment, an NGO in Kolkata. These units were transported to Nagpur by staff, Kolkata Zonal Laboratory NEERI, through cargo. Pureit arsenic cum germ removal filter, developed by Hindustan Unilever Limited (two units) was procured from Hindustan Unilever Ltd., Mumbai. These filters were received at NEERI, Nagpur on July1, 2010.

Pureit arsenic cum germ removal sachet, developed by Hindustan Unilever Limited could not be procured as the manufacturer informed that the sachet was under development and hence, expressed their inability to supply immediately.

Thus in all four arsenic removal units developed by different institutions/vendors as listed below have been evaluated in the laboratory at NEERI, Nagpur.

i. RSM Filter with Activated Alumina Technology- Domestic Arsenic Removal Filters promoted by RSMs developed under GoWB-UNICEF Joint Plan of Action
ii. Household Water Filter developed by Naval Materials Research Laboratory (NMRL), DRDO, Ministry of Defence, Govt. of India
iii. SONO Arsenic Mitigation Filter developed by Manab Sakti Unnayan Kendra, an NGO, Kustia, Bangladesh
iv. Pureit arsenic cum germ removal filter, developed by Hindustan Unilever Limited

4.2.1 Salient Features of Arsenic Removal Units

A brief description of each of the arsenic removal units under study and their salient features as delineated by the manufacturers /suppliers are given in the following paragraphs.

4.2.1.1 RSM Filter with Activated Alumina Technology

The filter is made of ferro-cement body with outer surface finished with mosaic. The filter has two parts. The upper part is placed over the lower part. The two parts are connected firmly with the help of a circular rubber gasket. Raw water is placed in the upper chamber for filtration. There is a cover over this chamber. The iron removal candle is fixed to the floor of the upper chamber. The candle is made of burning soil and rice husk. There is a valve in the lower part of the filter through which the flow of water can be controlled. The sachet of activated alumina is connected with the valve and placed in the upper portion of the lower chamber of the filter. The sachet can easily be fixed or detached with or from the valve. After treatment by the iron removal candle, the iron free water passes through the sachet. Finally the filtered water is stored in the lower chamber of the filter. Treated water can be collected with the help of a tap fitted at the lower part of the chamber. It is claimed that the filter can remove dissolved iron, fluoride and arsenic in water. It

also removes other suspended and colloidal substances including bacterial contamination.

Salient Features

- Total capacity of the filter 23 litres
- Ferro-cement body with outer surface mosaic-finished. The candle is made of burning soil and paddy husk.
- Trained sanitary mart
- Can remove dissolved iron, fluoride and arsenic in water very efficiently. It also removes other suspended colloidal substances including bacterial contamination to a great extent.
- Life of the filter is very long. Every two years, the filter candle and the sachet of activated alumina are to be replaced.
- Every six months the activated alumina is to be regenerated.

4.2.1.2 NMRL-DRDO Household Water Filter

Arsenic removal filter has been designed and fabricated both in polypropylene andin stainless steel. The filter comprises of three chambers. The first chamber contains reactant material enclosed in a fine cloth bag. In the second chamber fine cloth bag containing treated sandis placed. The third chamber simply acts as a collector chamber for treated water. Arsenic contaminated water is allowed to enter the first chamber of the filter at a predetermined flow rate from where it passes down to the second chamber and finally gets collected in the third chamber. The arsenic removal filter works on the simple principle of co-precipitation of arsenic with iron and adsorption of this precipitate on iron oxy-hydroxides, followed by further retention of this precipitate in treated sand. Sodium salts of arsenite and arsenate get ionized in the water medium. The arsenite and arsenate ions are removed further by co-precipitation as $FeAsO_4$ and $FeAsO_3$ and by adsorption of these oxides onto ferric oxy-hydroxide solids. The filter material and sand is to be replaced periodically as per usage. This filter is capable of purifying arsenic contaminated water to internationally accepted purity levels for drinking water.

Salient Features

- Most suitable for household use
- Requires no power (electricity or battery)
- Environment-friendly
- Easy to operate and maintain
- Easy available reactant material
- Flow rate 15 L/h
- Filter water quality as per WHO/EPA drinking water standard
- Waste utilization in the form of non-leachable M-25 grade cement bricks
- Cost Effective

4.2.1.3 SONO Arsenic Mitigation Filter

The primary active material used in this filter is the composite iron matrix (CIM), a mass made up of iron turnings. The filter consists of two chambers made up of plastic buckets. The upper chamber comprises of a tap fitted with flow control junction with a plastic pipe which enters the second chamber. The upper chamber consists of layers of brick chips, and CIM sandwiched between two layers of coarse sand. The lower chamber is filled with brick chips as the lowest layer followed by fine sand, on the top of which is spread wood charcoal followed by the top layer of coarse sand. The CIM removes inorganic arsenic species quantitatively. The process does not require pre-treatment of water with external oxidizing agents. Further the filter does not require any special maintenance other than replacement of the upper sand layers when the apparent flow rate decreases. The filter can produce potable water for at least 5 years.

Salient Features

- Treats 20-30 litres water per hour
- No pre-treatment of water is necessary; a completely non chemical filtration system
- No backwashing or regeneration is necessary

- Removes iron, manganese, heavy metals, nitrate, nitrite and many anions quantitatively
- Life: 5 Years Minimum
- Maintenance: Very low
- Cost effective
- Waste: Completely nontoxic ,passed TCLP

The filter media can be disposed on top soil because the media turns into soil after this period or their properties are very close to normal soil. Leaching tests show no environmental contamination from the waste.

4.2.1.4 Pureit Arsenic cum Germ Removal Filter

The purifier has key parts which include top chamber for filling and storage of untreated water; pre-filtration system – the stored water from top chamber is first filtered through a 2-stage pre-filtration system consisting of sediment filter which removes particle impurities up to 10 micron particle size, the water from the sediment filter then gets filtered through a specially designed compact carbon trap (cct) which can remove particulate matter up to 3-5 micron size. The purifier works on the principle of continuous chlorination and filtration through activated carbon. A special attachment with activated alumina is used to remove arsenic. It can work without electricity and without inline water supply. Arsenic is removed to EPA specifications of 10 ppb for drinking water.

Salient Features

- Removes visible dirt, kills all harmful viruses and bacteria, and removes parasites and pesticide impurities besides arsenic giving safe water as boiled water
- Has unique 'Germkill Indicator' which gives indication of getting safe or unsafe filtered water
- It works with worst quality drinking water
- It meets international germkill standards

- Does not need any power

4.3 Laboratory Evaluation of the Domestic Arsenic Removal units

Prior to the laboratory studies, arsenic removal filters procured by NEERI were unpacked and thoroughly checked for breakages, if any. The units were installed in the laboratory as per the instructions given in the users' manual. These units have been evaluated in the laboratory for their performance using drinking water of various concentrations ranging from 100 ppb to 3000 ppb. The results of these tests are presented in subsequent tables and the findings are discussed hereunder.

4.3.1. Protocol for Laboratory Evaluation of Domestic Arsenic Removal Units

Evaluation of domestic arsenic removal units were undertaken in the laboratory and also under field conditions. Following protocol is used for the evaluation

4.3.1.1 Preparation of Synthetic water

- Prepare primary stock solution of 1000 ppm of arsenate As(V) by dissolving Loba chemie GR Sodium arsenate ($Na_2HAsO_4,7H_2O$) in tap water
- Prepare primary stock solution of 1000 ppm of arsenate As(III) by dissolving Sigma-Aldrich sodium arsenite ($NaAsO_2$)
- Use these stock solutions for preparing synthetic water of different concentrations i.e. 100 ppb to 3000 ppb of As (V) and As (III)
- Fill-up upper chamber of the arsenic removal units with synthetic water of varying concentrations of synthetic solutions
- Collect treated water at 0, 2, 4 and 24 hours interval (Evaluation and Standardization of Domestic Arsenic Removal Units Report)
- Carry out analysis of treated water as per Standard Methods i.e. SDDC (Silver Diethyldithiocarbamate) spectrophotometric method

4.3.1.2 SDDC (Silver Diethyldithiocarbamate) method for analysis of arsenic in water

In this method the inorganic arsenic is reduced to arsine by zinc in acid solution in an acid generator. The arsine is then passed through a scrubber containing glass wool