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Verification of Arsenic Mitigation Technologies and Field Test Methods

Report of an Intercountry Consultation
Kolkata, India, 9-12 December 2002

WHO Project: ICP PHE 001

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Annexes

1. BACKGROUND AND OBJECTIVES

The consultation was convened by the WHO Regional Office for South-East Asia in Kolkata, India, between 9-12 December 2002. It was hosted by the Government of India and the State Government of West Bengal. The objectives of the meeting were the following:

General Objectives

- To provide technical guidance on the development of verification protocols for arsenic removal technologies and field testing methods for arsenic in drinking water.

Specific Objectives

- To present findings of recent externally-supported assessments/ evaluations of arsenic removal technologies and field testing methods in SEAR countries;
- To present internationally recognized verification protocols for arsenic removal technologies and field testing methods, which have been developed and widely applied by competent international development partners; and
- To develop guidelines for developing appropriate verification protocols for arsenic removal technologies and field testing methods at national level.

Participants included senior government officials and water supply experts from Bangladesh, India, Nepal, Myanmar and Thailand as well as a number of experts from outside the SEA Region. The programme of the meeting, and the list of participants is given in Annexes 1 and 2 respectively.

2. INAUGURATION

The consultation was inaugurated by the Hon'ble Goutam Deb, Minister of Public Health and Housing, Government of West Bengal. Mr Meenakshisundaram, Secretary, Department of Drinking Water, Ministry of

Rural Development, Government of India, presided. In his inaugural address, Mr Deb emphasized the importance of safe drinking water for the protection of human health and socioeconomic development. Citing as an example the challenges facing West Bengal, he stressed the importance of developing indigenous and other low-cost solutions appropriate to the social, economic and cultural characteristics of countries of the South-East Asia Region. He looked forward to an exchange of information among experts of the participating countries. Mr Meenakshisundaram urged participants to appreciate the demand of consumers for safe drinking water at affordable cost.

The address of the WHO Regional Director, Dr Uton Muchtar Rafei, was read by Mr Terrence Thompson. It set forth SEARO's objective of strengthening the capacity of Member countries to independently verify the performance of arsenic mitigation technologies and field test methods.

Participants were welcomed to the consultation by Mr Sumar Chowdury, Principal Secretary, Public Health Engineering Department, GoWB. Mr P.K. De, Chief Engineer, PHED/GoWB, moved a vote of thanks. Prof M. Feroze Ahmed presented arsenic contamination issues in Bangladesh in the inaugural session.

Dr Ramesh Panda was elected Chairman of the meeting, Dr A.H. Khan, Co-Chair and Mr Robin Lal Chitrakar, Rapporteur.

3. PLENARY SESSION: TECHNOLOGIES FOR ARSENIC MITIGATION

Following a brief introduction by Mr Han Heijnen on the regional situation with respect to arsenic exposure, presentations were made on recent externally supported assessments of arsenic mitigation technologies in West Bengal and Bangladesh. Mr Christian Beinhoff, UNIDO, presented the findings of a rapid assessment of community-based and household-based arsenic removal technologies in West Bengal. The study considered technical, social, financial and institutional aspects of various arsenic removal technologies and made a comparative assessment. Dr David Sutherland, reported on a DFID-supported rapid assessment of seven specific household-level arsenic removal technologies in Bangladesh. The intensive six-month study provided an independent comparative assessment with transparent results, and recommended four technologies for application in that country.

Dr Pitsanu Bunnaul reviewed current research and development activities in the area of arsenic mitigation technologies being carried out by several universities in Thailand. Arsenic contamination of drinking water is a concern only in the district of Ronphibun where the origin is the “tailings” of tin and tungsten mine operations. In practice, arsenic in drinking water has been mitigated in Ronphibun by encouraging rainwater harvesting and by disposing mine “tailings” in a secure landfill.

Mr Roy Boerschke introduced the theme of technology verification and explained the importance of developing national programmes and protocols to help independently verify the performance of arsenic mitigation technologies and field test methods. He briefed participants on ongoing efforts to establish a reference laboratory in Bangladesh for the purpose of implementing a national arsenic technology verification programme.

During discussions, participants recognized the importance of verifying the performance of arsenic removal technologies and field test methods in order to support arsenic mitigation programmes. The efforts made by various researchers to assess a limited number of technologies were appreciated. However, participants also agreed that countries of the Region needed to strengthen their national capacities to independently verify technology performance. Well-developed protocols were required for this purpose.

4. PANEL DISCUSSION ON FIELD TEST KITS FOR ARSENIC DETECTION

Mr Robin Lal Chitrakar, Prof Arunabha Mazumdar, and Mr Han Heijnen discussed recent advances in the development of arsenic detection field kits. Arsenic field test kits initially could only be used for qualitative or semi-quantitative measurements. WHO, UNICEF, USEPA, and Mahidol University have tested several kits recently and the kits had improved considerably. Several models are now able to reliably measure arsenic in drinking water at levels of 10 ug/l. Quality assurance and quality control procedures are necessary to ensure validation of field results by laboratory-based measurements. A recent evaluation of the 15-thana project in Bangladesh indicated that 3% of field tests are false negatives and 8% are false positives. Kits will remain important for large-scale, rapid tubewell screening programmes and long-term decentralized screening services. Their continued improvement needs to be encouraged and monitored.

5. VIDEO CONFERENCE ON USEPA ENVIRONMENTAL TECHNOLOGY VERIFICATION PROGRAMME

A digital video conference was held with officials of the U.S. Environmental Protection Agency in Cinncinnati, Ohio. Ms. Teresa Harten gave an overview of the USEPA Environmental Technology Verification (ETV) Programme and Mr Jeff Adams described the specific protocols developed by USEPA for verification of specific arsenic removal technologies.

The main points discussed during the video conference were the following:

(1) The USEPA Environmental Technology Verification (ETV) Programme was established under a mandate given by the executive branch of the federal government.

(2) USEPA collaborates actively with international partners to promote and develop the concept of ETV in many other countries. USEPA believes that it is important to work cooperatively in this regard.

(3) On average, a single ETV exercise in the United States costs about $100,000. Although costs are decreasing as experience is gained, the cost may nonetheless be prohibitive if the USEPA model is applied in many developing countries. It was noted that ETV is not a self-sustaining programme in the USA: about 25% of costs are covered through revenue generation and 75% by the federal government.

(4) Social and fiscal factors are not normally components of ETV exercises in the United States although these may be major concerns when verifying technologies in countries of the WHO South-East Asia Region. Of late, however, USEPA has begun to integrate cost components in some verification proceedings.

Prior to the video conference, a presentation on verification of portable analyzers/test kits for drinking water was made by Dr Arun Gavaskar. Dr

Gavaskar presented results from 2001 verification tests of four measurement technologies. He discussed the test parameters: accuracy, operator bias, precision, rate of false positives and false negatives, linearity, method detection limit and matrix interference. A further round of verification tests is planned for early 2003.

6. NATIONAL PROTOCOLS FOR VERIFICATION OF ARSENIC MITIGATION TECHNOLOGIES AND FIELD TEST METHODS

Mr Roy Boerschke presented draft guidelines for the development of national technology verification protocols for arsenic removal technologies (Annex 3) and, separately, for field test methods (Annex 4). The objective of the protocols was to establish systematic evaluation procedures that allow flexibility in testing procedures while ensuring that the various technologies and test methods are assessed and validated in an equivalent manner. The draft guidelines advocate that national protocols be developed through a participatory process involving all stakeholders. They also outline the main components of the verification process and envisage that social considerations and costs should be evaluated in addition to technical performance.

7. FIELD TRIP

Participants visited several arsenic mitigation projects in diverse locations in West Bengal organized by the Public Health Engineering Directorate, GoWB. Of particular interest was the Arsenic Technology Park, funded by the Indo-Canadian Environmental Facility and implemented by the All India Institute of Hygiene and Public Health and the School of Fundamental Research, where community level arsenic removal technologies have been evaluated through an ongoing programme of field testing.

8. CONCLUSIONS AND RECOMMENDATIONS

Working groups reviewed the draft guidelines for the development of national technology verification protocols for arsenic removal technologies and field test methods and made specific recommendations for modifying them.

(1) Participants agreed that arsenic-affected countries in the Region needed to strengthen their national capacity to verify the performance of arsenic removal technologies and field test methods, although the urgency of strengthening this capacity may vary with the nature and extent of the arsenic problem in individual countries. Apart from Bangladesh, none of the SEAR countries has defined protocols for verification of these technologies.

(2) It was agreed that governments would be justified in allocating national resources to the planning and implementation of technology verification programmes for arsenic removal and testing, but that generic protocols should be developed in the first instance as an intercountry initiative with WHO support. Generic social and fiscal protocols should be developed in addition to a generic technical one. Individual countries may then tailor the generic protocols to suit national conditions.

(3) The objective of technology verification programmes for arsenic removal and field testing methods should be to ensure safe, environmentally responsible and sustainable treatment and monitoring of drinking water and to provide quality assured objective data to enable transparent decision-making.

(4) The objectives of protocols for the verification of arsenic removal technologies and field test methods are to assess and independently verify the performance claims of the proponents for arsenic removal technologies and field test kits.

(5) Participants generally agreed with the components of Technology Specific Test Plans (TSTP) as per USEPA protocols (see Annex 3) but felt that protocols developed for use in SEAR countries should also include fiscal and social components, such as affordability and acceptability by the user communities. Another social component should identify when and how communities should replace media after breakthrough has occurred.

(6) In order to evaluate users' acceptability vis-à-vis social, cultural and gender concerns, the indicators to be used should be: ease of operation; frequency of maintenance; level of skill required for operation and maintenance; capital and recurring costs; energy requirements; materials

used in fabrication; availability of spares, replacement parts and consumables; taste and odour; and quantity of water produced.

(7) Formal, reciprocity agreements among SEAR countries could be advantageous to minimize costs of technology verification exercises, to save time and avoid duplication of effort. Such agreements, however, would need to be negotiated directly between interested governments. WHO may be requested to facilitate such negotiations.

(8) Ongoing technical and financial support would be needed from external support agencies such as WHO and others for training and developing the laboratory infrastructure necessary to implement technology verification programmes.

The meeting agreed to encapsule the main recommendations of the consultation in a declaration, termed the Kolkata Declaration on Verification of Arsenic Removal and Field Testing Technologies, (Annex 5).:

9. CLOSING

In closing, Mr Terrence Thompson thanked the Government of India and the Government of West Bengal for hosting the consultation. Dr A.H. Khan, Co-Chair of the consultation, expressed satisfaction with the outputs of the meeting and thanked participants for their hard work and valuable contributions. Dr R.C. Panda, Chairman, thanked WHO for its initiative in convening this important consultation which, he predicted, would be seen as a landmark event in the history of arsenic mitigation in the WHO South-East Asia Region. He called on all participants to follow-up on the actions outlined in the Kolkata Declaration and urged WHO to convene a similar intercountry event to monitor progress towards implementation of the recommendations made.

Annex 1

PROGRAMME

9 December 2002

08.00-09.00 hrs	Registration
09.00-10.00 hrs	Inaugural session
10.00-11.00 hrs	Presentation on present status of problems due to arsenic in drinking water in SEAR countries - Dr Harry Caussy, WHO/SEARO
11.00-13.00 hrs	Plenary Session
	Rapid Assessment of Community based and Household based Arsenic Removal Technologies in West Bengal." Dr Christian Beinhoff, UNIDO
	Development of ETV capacity for chemical water supply treatment technologies for Arsenic removal in Bangladesh," -- Presentation by Roy Boerschke based on GoB, BAMWSP, BCSIR and CIDA Study
	Rapid assessment of Household level Arsenic removal technologies." Presentation on BAMWSP/DFID/ WaterAid Study in Bangladesh. David Sutherland, DFID.
14.00-14.30 hrs	"Research and Development of Arsenic Mitigation Technologies in Thailand." Dr Pitsanu Bunnaul, Prince of Songkla University
14.30-15.15 hrs	Field Test Kits for Arsenic Detection. Dr M V Nanoti, NEERI
15.15-19.00hrs	USEPA Environmental Technology Verification Program: Portable Analyzers/Test Kits for Drinking Water. Dr Arun R Gavaskar, Batelle Research Institute
19.00-20.30hrs	Digital Video Conference: USEPA Environmental Technology Verification Program. • Overview of ETV program and process. Ms Teresa Harten, Director, USEPA ETV Program • Requirements of all studies; verification of ion exchange, coagulation/filtration, and adsorption media technologies for arsenic mitigation. Mr Jeff Adams, USEPA

10 December 2002

09.00-10.00 hrs	"Draft Guidelines for Development of Appropriate National Protocols for Verification of Arsenic Removal Technologies and Field Test Methods." Presentation by Roy Boerschke. Discussions.
10.00-10.30 hrs	Formation of Working Groups on Guidelines for Development of Appropriate National Protocols
10.30-13.00 hrs	Discussions in Working Groups
14.00-15.45 hrs	Discussions in Working Groups (Continued)
15.45 hrs	Discussions in Working Groups (Continued)

11 December 2002

09.00-11.15 hrs	Discussions in the Working Groups and finalization of recommendations
11.15-13.00 hrs	Plenary Session
	Presentation of findings of the Working Groups and discussions.
14.00 hrs	Presentation of recommendations of the workshop and Closing Session

12 December 2002 Field visit to Arsenic Technology Park

Annex 2

LIST OF PARTICIPANTS

Bangladesh

Dr M Feroze Ahmed
Department of Civil Engineering
Bangladesh University of Engineering and Technology (BUET)
Civil Engineering Building, 3rd Floor
Dhaka 1000
Phone: 880 2 966 3693 (Direct)
Fax: 880 2 9663695
E- mail: itn@dhaka.agni.com,
fahmed@ce.buet.edu, itn@agni.com

Mr Al-Mahmood
Superintending Engineer
Ground Water Circle, DPHE Bhavan
14, Shaheed Capt. Mansul Ali Sarani
Dhaka 1000
Phone: 880 2 9343359
Fax: 880 2 9343375

Dr M Nuruzzaman
Environmental Specialist
Bangladesh Arsenic Mitigation
Water Supply Project, DPHE Bhaban
14 Shaheed Capt. Mansur Ali Sarani
Dhaka 1000

Dr A H Khan
Professor of Analytical Chemistry
University of Dhaka
Dhaka 1000
Phone: 880 2 500137
e-mail: ahkhan@du.bangla.net

India

Dr Ramesh Chandra Panda
Joint Secretary & Mission Director
Rajiv Gandhi National Drinking Water Mission
Department of Drinking Water
9th Floor, Paryavaran Bhawan
CGO Complex, Lodi Road
New Delhi – 110 003
Phone: 436 1043

Mr V B Rama Prasad
Adviser (PHEE)
Ministry of Urban Development and Poverty Alleviation,
Department of Urban Development
Room No. 646, A-Wing, Nirman Bhawan
New Delhi – 110 011
Phone: 301 7482
Fax: 3017482
E-Mail: ramprasad@nb.nic.in

Prof K J Nath
Chairman
Government of West Bengal Arsenic State Taskforce, Amrita Apartments
32/1F, Gariahat Road (S)
Kolkata – 700 031

Dr D P Mukhopadhyay
Scientist, Central Pollution Control Board (CPCB)
Ministry of Environment and Forest
Eastern Zonal Office, CIT Market, 1st Floor
247, Deshpran Sashmat Road
Kolkata – 700 033
Phone: 033 – 4730210, 4720439
Fax: 033-4731102

Mr Abhijit Roy
Senior Hydrogeologist
Central Ground Water Board (CGWB)
Eastern Region
Bhujalika, Block CP-6, Sector-5
Salt Lake, Kolkata – 700 091
Phone: 033 – 3673080
Fax: 033 – 3673081

Mr Arunabha Mazumdar
Professor of Environmental Sanitation
All India Institute of Hygiene and Public Health
110, Chittaranjan Avenue
Kolkata – 700 073
Phone: 033 – 2413831
Fax: 033 – 2418508

Dr Anirban Gupta
Professor of Civil Engineering
Bengal Engineering College
Environmental Engineering Laboratory
Howrah – 711103, West Bengal
Phone: 033 – 6684561
Fax: 033 – 6684564
E-Mail: guptaanirban@hotmail.com

Mr P K De
Chief Engineer (Water Quality Management)
PHE Directorate
Government of West Bengal
New Secretariat Building, Sixth Floor
1 K S Roy Road
Kolkata – 700 001
Phone: 033 – 2481813
Fax: 033-2103993

Dr D N Guha Mazumdar
Department of Gastroenterology|
Institute of Postgraduate Medical Education and Research
244, Athya J C Bose Road
Kolkata – 700 020
Phone: 033 – 4787493
Fax: 033 – 2232178

Dr Dipankar Chakraborty
Director
School of Environmental Study
Jadhavpur University
Kolkata – 700 032
Phone: 033 – 4735233
Fax: 033 – 4734266
E-Mail: dcsoesju@vsnl.com

Nepal

Mr Robin Lal Chitrakar
Chief Water Quality Section
Department of Water Supply & Sewerage
Pani Pokhari, Kathmandu

Mr Upendra Poudyal
Engineer for Arsenic Treatment Technologies
Environment and Public Health Organization (ENPHO)
Kathmandu
Email : **enpho@enviro.mos.com.np**
Phone : 977-1-491052 , 491376

Thailand

Mr. Chetpan Karnkaew
Director
Bureau of Environmental Health
Department of Health
Ministry of Public Health
Tiwanon Road, Nonthaburi 11000
Phone: (66) 2590 4351; 2590 4352
Fax: (66) 2590 4321; 2591-8171

Dr Preeda Parkpian
Associate Professor
Urban Environmental Engineering Programme
Asian Institute of Technology
P.O. Box 4, Klong Laung, Pathumthani 12120
Phone: (66-2) 524 5635 (or) (66-2) 524 5642-3
Fax: (66-2) 524 5625
E-Mail: preeda@ait.ac.th

Resource Persons

Mr David Sutherland
DFID
Dhaka, Bangladesh

Dr Roy Boerschke
C/o Environmental Health Unit
WHO Bangladesh

Dr Pitsanu Bunnaul
Associate Professor
Head, Dept. of Mining and Materials Engineering, Faculty of Engineering
Prince of Songkla University
P.O. Box 2, Kohong
Hatyai 90112, Thailand
Tel./Fax 66-074-212897
Mobile Phone: 01-9638449
Email: bpitsanu@ratree.psu.ac.th

Arun R Gavaskar
Deputy Product Line Manager
Environmental Business Sector
Battelle, 505, King Ave.
Columbus OH 43201, USA
Tel: 614-424-3403
Fax: 614-424-3667
Email: gavaskar@battelle.org

Observers

Dr Bhanu Maharaj
Ramakrishna Mission Lokasiksha Parishad
Narendrapur, Kolkata – 700 103
India
Tel: 033-477 2207

Dr Biplab Bhusan Basu
School of Fundamental Research
29, Prakapaditya Road, Kolkata – 700 026
India
Tel: 033-463 0307

Mr David Nunley
Country Director
International Development Enterprises
House No. 15, Road No. 7
Dhanmondi, Dhaka – 1205
Bangladesh
Tel: 880 2 861 4485 (or) 9258
Fax: 880 2 861 3506
E-Mail: dbnunley@agni.com

Prof Dr Md Amjad Hossain
Chairman
Bangladesh Council of Scientific and Industrial Research
Dr Kudrat-e-Khuda Road
Dhanmondi, Dhaka 1205
Bangladesh
Tel: 880 2 966 9886

UN and Bilateral Agencies

Dr. Sudhanshu Sinha, Ph.D
Senior Project Officer
India-Canada Environment Facility (ICEF)
86, Paschimi Marg, Vasant Vihar,
New Delhi – 110057
India
Telephone: 6144051, 6146074, 6146653
Fax: 6147827, 6146236, 6146079
E-mail: ssinha@delhi.icco.net

Mr Jan-William Roosenboom
Project Officer (Arsenic)
UNICEF
Dhaka
Bangladesh

WHO Secretariat

Mr Terrence Thompson
Regional Adviser on Water, Sanitation and Health
Regional Office for South East Asia
World Health Organization
New Delhi
India

Mr Han Heijnen
Environmental Health Adviser
Office of the WHO Representative
G P O Box 250
Dhaka
Bangladesh

Mr Jan Speets
Environmental Health Adviser
Office of the WHO Representative
P O Box 108
Kathmandu
Nepal

Mr A.K. Sengupta
National Professional Officer (Environmental Health)
Office of the WHO Representative
Rooms 533-535, ‘A’ Wing
Nirman Bhawan
New Delhi 110011
India

Annex 3

NATIONAL ENVIRONMENTAL TECHNOLOGY VERIFICATION (ETV) PROTOCOLS FOR ARSENIC REMOVAL TECHNOLOGIES

1. INTRODUCTION

The objective of an Environmental Technology Verification (ETV) Protocol for Arsenic Removal Technologies would be to assess and independently verify the performance claims of arsenic removal technologies, thereby ensuring government, implementing agencies, developers, users and consultants have objective and quality assured data upon which to base their decisions. This document outlines the basic elements of an ETV Protocol for Arsenic Removal. These elements are drawn from similar Protocols for Arsenic Removal Technologies developed by the EPA and the CIDA- funded ETV-AM Project. Although the two protocols have differences with respect to specific components associated with the evaluation, the principles upon which both documents are based are similar, and should be used as guides for creating a global ETV Protocol for Arsenic Removal Technologies[1,2].

The verification protocol should be flexible enough to allow verification testing of performance claims for a variety of arsenic removal technologies. Evaluation of the technologies should recognize that one cannot account for all possible scenarios within an evaluation programme for a range of technology types and operating environments. Therefore, the protocol should provide a complete test design, but also allow for modifications of procedures given the variation in technology types and water quality parameters that may impact technology performance. In addition, as the test parameters set will define potential performance over a given range of environmental situations, clear statements regarding the potential application range of the technology must be made. The objective of the Protocol for Arsenic Removal Technologies is to establish a systematic evaluation procedure that allows

[1] *Protocol for Equipment Verification Testing for Arsenic Removal*, (2001), U.S.EPA.
[2] *ETV-AM Testing Protocol for Arsenic Removal*, (2002), OCETA.

flexibility in testing procedures, based upon operating environment and technology type, while ensuring the various technologies are assessed and validated in an equivalent manner.

The Protocol for Arsenic Removal Technologies should outline the verification processes for technologies based upon the following physical/chemical principles:

- Coagulation and filtration;
- Lime softening;
- Ion Exchange;
- Activated Alumina;
- Reverse Osmosis; and
- Electrodialysis.

Independent of the technology type, testing organizations (either alone or in association with the proponent) should establish a Technology-Specific Test Plan (TSTP) that outlines the following components for testing:[3,4]

(1) Roles and responsibilities of the verification testing participants;

(2) Laboratory procedures governing verification testing activities such as equipment operation and process monitoring; sample collection, preservation and analysis; and data collection and interpretation;

(3) Experimental design;

(4) Data analysis and control;

(5) QA/QC procedures for conducting the verification testing and for assessing the quality of the data;

(6) Evaluation for inherently generated chemical and/or biological compounds (i.e. process chemical residues, microbial contamination, etc.) above applicable water quality standards or guidelines;

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[3] Protocol for Equipment Verification Testing or Arsenic Removal, (2001), Usepa
[4] Boerschke, R.K., Stewart, D.K. (2001) "The Evaluation Arsenic Mitigation Technologies for Use in Bangladesh"

(7) Health and safety measures relating to electrical, mechanical and other physical hazards;

(8) Health and environmental concerns relating to chemicals used in the normal operation of the technology; and

(9) Health and environmental concerns relating to the disposal of biological and/or chemical waste byproducts.

The Protocol for Arsenic Removal Technologies will be designed to outline the procedures for implementing an evaluation of specifically designed TSTPs for removing arsenic from water, thereby providing arsenic safe water. The protocol will not be designed to address potential mitigation of secondary constituents. Additional performance claims with respect to removal of secondary constituents could be integrated into a more generic water mitigation protocol, given that the fundamentals with respect to monitoring, assessment and validation would be based upon a similar framework (but would require extensive modification of the TSTP). The Arsenic Removal Technology Protocol should provide objective and quality-assured performance data, within a specific operating range, for arsenic removal technologies, so that users, developers, regulators, and consultants can make informed decisions about these technologies.

2. DEVELOPMENT OF PROTOCOL

Development of the ETV Protocol for Arsenic Removal Technologies should be undertaken using a partnership approach involving standards and testing organizations; stakeholder groups that consist of buyers, vendor organizations, and permitters; and technology developers. The development of the protocol should be undertaken using a three step principle:

(1) Establishment of a network to share information on procedures for evaluating and verifying technology performance claims;

(2) Development of standard protocols for demonstrating, evaluating and verifying arsenic removal technologies; and

(3) Performance of peer review of the protocol.

In addition to developing the formal protocol, mechanisms must be established through which the verification activities could be undertaken within a given country or region. Clear direction with respect to the roles and responsibilities of the various participants in the ETV process should be outlined. The following represents a brief outline of entities within the ETV process, and a brief outline of proposed roles:

Government/Regulatory Body

The role of government/regulatory bodies is to ensure that the performance requirements of arsenic removal technologies, over a predetermined range of operation, are verified using a systematic mechanism of evaluation that adequately tests and verifies performance claims put forward by proponents. With respect to ETV Protocol for Arsenic Removal Technologies, **evaluation** of a technology is defined as:

A detailed, independent third-party assessment and validation of a process performance claim of a technology, using rigorous protocol,

and **verification** of a technology is defined as:

Confirmation of a technology performance claim through evaluation.

A technology that has its performance claim confirmed by the evaluation is *verified.*

The government/regulatory body should also perform systematic audits of all levels within the ETV process to ensure that the integrity of the process is maintained. A critical aspect with respect to the success or failure of any ETV activity is assurance that the “transparency” of the process is maintained.

Verification Organization

Verification of technologies should be undertaken by an independent, third-party Verification Organization (VO) with expertise in the development and/or use of arsenic removal systems. The VO should be responsible for the validation of data and information that support performance claims of an arsenic removal technology. Third-party verification organizations can come from government, academia, specialized organizations, and the private sector.

Stakeholder Group

The development of country/region-specific protocols should be undertaken involving suitable stakeholder groups with technical expertise in arsenic removal technologies, as well as input from social experts involved with water quality issues. Participation in the stakeholder groups should be inclusive, involving representatives from within government, academia, specialized institutions, proponents and end-users. The role of stakeholder groups is to work in association with the Verification Organizations in developing country/region-specific protocols for evaluating technologies for the removal of arsenic from drinking water. In addition to providing input into the development and critical review of the protocol, stakeholders should play a major role in disseminating the verification process.

Technology Proponents

Technology proponents may be categorized as having developed and/or proposed technologies, or as entities that have obtained licenses for manufacturing the technology. Proponents are responsible for submitting technologies to an independent third party testing agency for evaluation/verification according to the protocol.

Independent Testing Agency

An independent testing agency is an organization qualified to conduct studies and testing of the arsenic removal technologies in accordance with protocols and test plans, under the oversight of the VO. The role of the testing organization is to arrange for or conducts the evaluation of the arsenic removal technologies as required by the protocol.

3. COMPONENTS OF VERIFICATION

Verification is traditionally based upon evaluating the performance of a specific technology against a criterion. The verification process is based upon a specific protocol, designed to test the technology under a given set of conditions. The Protocol for Arsenic Removal Technologies will be based upon performance criteria. However, critical secondary issues should also be considered during the verification procedures.

2.1 Experimental Design

The verification process for arsenic removal technologies should be designed to challenge the fundamental mechanisms of removal and the equipment under varying operating conditions. The Protocol for Arsenic Removal Technologies should evaluate technologies in the following areas:[5,6]

- Performance relative to proponents' stated range of the technology objectives;
- Impact of feed water quality variations on technology performance;
- Cycle duration estimation;
- Logistical, human, and economic resources necessary to operate the technology;
- Reliability, ruggedness, cost, range of usefulness, and ease of operation.

The areas listed above should be evaluated through a series of modular processes, each designed to address a specific component of the verification. The verification of arsenic removal technologies can be separated into three basic units: technical, social, and fiscal. Each component is composed of numerous subcomponents, which may be broken down even further.

2.2 Technical Components

Performance

The efficacy of arsenic removal technologies should be evaluated to determine if performance claims put forward by proponents are accurate. Verification of the efficacy of technologies should be evaluated with respect to variations in both the feed water concentration of arsenic, as well as variation in other water quality parameters. In particular, the verification should determine the impact of potential interfering species on performance of the technology. Critical performance factors that should be evaluated with a given level of confidence are:

[5] *Protocol for Equipment Verification Testing for Arsenic Removal*, (2001), U.S.EPA.
[6] *ETV-AM Testing Protocol for Arsenic Removal*, (2002), OCETA.

- Efficiency of arsenic removal under varying conditions of feed water quality;
- Flow rate of treated water, whether it be continuous flow or batch;
- Estimated volumes of treated water per unit time;
- Potential impact of interfering species on quantity and quality of treated water;
- Mechanisms for estimating cycle duration of the technology under various water quality scenarios;
- Variation in cycle to cycle efficacy for technologies involving media regeneration, and power requirements.

Principles Behind Analysis

Knowledge of the fundamental principles upon which the technology is based is critical in ensuring that evaluation of the technology is undertaken using appropriate sampling regimes (i.e. operation within determined concentration ranges, recognition of potential interfering species, and operator bias, etc.). For technologies that are not based upon a known mechanism, requirements should be in place for the proponent to submit literature and/or other documentation to assist in determining the regime under which the technology should be tested. In addition, proponents advancing technologies based upon previously untested mechanisms should provide models upon which performance claims have been based. No black-box technologies should successfully complete the verification process.

Chemicals

Proponents should list all chemicals required by the arsenic removal technologies, including the chemical names and formulas. Information should be provided with respect to dosage requirements per unit volume of water and/or with respect to unit of time. They should also describe the use of each chemical within the system, the storage requirements, shelf life, safe handling requirements, other information pertinent to health risks, quality or grade requirements and a regional supplier, and attach material safety data sheets (MSDS).

Byproducts

All arsenic removal technologies will have at least one waste stream containing arsenic; however, other waste streams may also be produced. Proponents should be required to provide a plan for disposal of all wastes associated with the technology. In addition, they should be required to identify the concentration of arsenic, and concentrations of any other potentially toxic constituents, in the waste. Disposal options should also be identified for any waste generated, safe handling requirements, and other information pertinent to health risks associated with the byproducts.

Operations and Maintenance

Proponents should indicate procedures required to operate and perform (if necessary) maintenance on the technology, such that it operates within design parameters. They should also indicate the following operation and maintenance requirements with respect to proposed technologies:

- Number of operational steps required to treat the water;
- User time required to treat water during normal operation;
- Level of knowledge required to operate the technology and time required for training;
- Predictability and frequency of maintenance;
- Ease of maintenance;
- Logistical support required for maintenance, and
- Level of knowledge and time for maintenance and maintenance training.

Hardware

Verification should include an evaluation of hardware associated with the arsenic removal technology. Major components of verification with respect to hardware are:

- Fragility;
- Lifespan;
- Replacement parts;
- Installation, and
- Shipping requirements.

2.3 Social Evaluation

Arsenic removal technologies are designed for the delivery of a fundamental human requirement, water, therefore it is critical that social considerations with respect to the technology be assessed. Indicators of acceptability within the Protocol should reflect possible social, cultural and gender concerns, which will enable the identification of a technology's sociological strengths and weaknesses. The Protocol for Arsenic Removal Technologies should have a standard process through which arsenic mitigation technologies are evaluated with respect to social acceptability. Data should be collected through personal interviews with the main technology users (using a pre-designed interview form) and should provide the basis for making a statement regarding the social acceptability of a technology.

2.4 Cost

The Protocol for Arsenic Removal Technologies should include a detailed fiscal evaluation of proposed technologies to provide an estimate of the true cost to the end user by determining all costs incurred during the expected economic life of a technology. The fiscal component of the Protocol should be a standard process through which the direct and indirect costs of arsenic removal technologies can be evaluated. The procedure requires consideration of capital costs (cost of acquisition), installation/start-up costs, operation and maintenance costs, and waste disposal costs associated with the technology. The dependence of the true cost of the technology on parameters such as arsenic concentration or other water quality parameters should also be explored through the fiscal evaluation. Information from the fiscal evaluation will provide the basis for a statement regarding estimated technology costs.

3. MATERIALS AND EQUIPMENT

The materials and methods for the Protocol for Arsenic Removal Technologies should be drawn from reference material previously generated and tested. Development of additional, and/or modification to specific, components with respect to the materials and methods used can be undertaken, but a clear understanding as to why and how the alterations impact the potential verification should be presented.

4. PROCEDURES

The procedures presented in the proposed Protocol for Arsenic Removal Technologies should be drawn from reference material previously generated and tested. Development of additional, and/or modification to specific components with respect to the procedures can be undertaken, but a clear understanding as to why and how the alterations impact the potential verification should be presented.

5. DATA ANALYSIS AND REPORTING

The technical requfiirements that are integrated into the Protocol for Arsenic Removal Technologies should result in a variety of data being generated. Methods for collecting, analyzing, and reporting all data that will be generated during the testing of a technology should be identified in the TSTP. The Protocol for Arsenic Removal Technologies should provide details with respect to the methods for statistical analysis that will be used to evaluate the data generated from the test programme. The objective of the data analysis is to test statistical hypotheses regarding performance of the arsenic removal technology, thereby allowing for a performance claim for the arsenic removal technology to be made. In addition, format with respect to the reporting of data and the results of the statistical evaluation should be included in the Protocol for Arsenic Removal Technologies.

6. QUALITY ASSURANCE/QUALITY CONTROL

All ETV protocols must have sound quality assurance/quality control (QA/QC) procedures as part of any test plan. All evaluation is susceptible to a variety of errors, and procedures must be in place to ensure potential variations in the verification process are identified and corrected. Components of QA/QC programme within the Protocol for Arsenic Removal Technologies should include:

- QA/QC objectives;
- Sampling and sample tracking procedures;
- QA/QC control procedures;
- Validation, reporting and management of data;
- Quality assessment and corrective actions, and
- QA/QC reporting.

7. IMPLEMENTATION

Fundamentally, programme for implementing arsenic removal technologies should be developed such that they can be undertaken in a technically sound, and reproducible manner. In addition, programme for implementing arsenic mitigation options should be aware of the benefits in relation to proposed costs. The impact of implementation of arsenic mitigation activities should also be weighed in relation to other health, social and economic priorities.

Programme for implementing arsenic mitigation should undertake an overall assessment process that evaluates socio-economic and cultural issues. Implementation of technologies that cannot be technically, socially or financially sustained should be avoided. Implementation of verified arsenic removal technologies that ensure technical performance at a given confidence level, and which recognize social and fiscal realities in relation to potential operating environments, should be part of integrated water management programme through which safe water delivery is guaranteed.

8. WAYS FORWARD

Development of a generic Protocol for Arsenic Removal Technologies should be undertaken recognizing the experience and knowledge of organizations such as the USEPA. Currently, two sets of protocol have been established to evaluate arsenic removal technologies. Although differences exist regarding the structure of the documents, the fundamentals upon which the protocols are based are similar. Future efforts with respect to developing the Global Protocol for Arsenic Removal Technologies should attempt to move forward based upon previous experience and knowledge that currently exists.

Annex 4

NATIONAL ENVIRONMENTAL TECHNOLOGY VERIFICATION (ETV) PROTOCOLS FOR ARSENIC FIELD TEST METHODS

1. INTRODUCTION

The objective of a generic Environmental Technology Verification (ETV) protocol for Arsenic Field Test Kits would be to assess and independently verify environmental technology performance claims, thereby ensuring government, implementing agencies, developers, users and consultants have objective and quality assured data upon which to base their decisions. This document outlines the basic elements of a generic ETV protocol for Arsenic Field Test Kits. The completed protocol should follow a format similar to the "*Generic Verification Protocol for Portable Water Analyzers for Metals and Other Inorganics"* prepared by Battelle for the US Environmental Protection Agency (USEPA), which is currently the most comprehensive protocol for evaluating Field Test Kits.

The generic protocol for Arsenic Field Test Kits will recognize that two fundamental categories of technology exist: "(1) portable analyzers that provide quantitative measurements of metals and other inorganic contaminants in water, and (2) portable test kits that provide qualitative or semi-quantitative measurements. The quantitative analyzers consist of a portable electronic instrument that often requires a specific reagent solution. Typically the reagent and the water sample are mixed, and the mixture is inserted into the analyzer and probed, either photometrically or electrochemically, to provide a quantitative determination of the target contaminant. Results are reported by a digital display or electronic output signal. Technologies that provide only qualitative results are typically test strips or reagent solutions that, when exposed to the water sample, indicate the presence of the analyte through a visible colour change. These approaches are designed primarily to indicate the presence or absence of the target analyte relative to some regulatory or health-based concentration level. Semi-quantitative results can be obtained using these same technologies by comparing the colours to those of standards run with the samples or to a colour comparison chart provided by the manufacturer. These comparators typically have discrete colour levels that indicate different analyte concentrations, and the results are based on subjective visual comparisons made by the user. In some cases, quantitative results can be obtained by submitting the samples to a laboratory and analyzing them with a colourimeter. Both quantitative and qualitative analyzers are designed to be operated by non-technical users. The analyzers, whether quantitative or qualitative, may detect a variety of aqueous analytes, including dissolved metals and other inorganic cations and anions."[7]

The generic protocol is designed to outline the procedures for implementing an evaluation of portable analysis technologies for measuring the concentration of arsenic in water (referred to from this point forward as "test kits"). The purpose of the generic protocol is to provide objective and quality-assured performance data on arsenic field test kits, so that users, developers, regulators, and consultants can make informed decisions about these technologies.

2. DEVELOPMENT OF PROTOCOL

Development of an ETV protocol for arsenic test kits should be undertaken using a partnership approach involving standards and testing organizations; stakeholder groups that consist of buyers, vendor organizations, and permitters; and technology developers. The development of the protocol should be undertaken using a three step principle:

(1) Establishment of a network to share information on procedures for evaluating and verifying technology performance claims.

(2) Development of standard protocols for demonstrating, evaluating and verifying arsenic field test kits, and

(3) Performance of peer review of the protocols.

In addition to developing the formal protocol, mechanisms must be established through which the verification activities can be undertaken within a given country or region. Clear direction with respect to the roles and responsibilities of the various participants in the ETV process should be

[7] *Generic Verification Protocol for Portable Water Analyzers for Metals and Other Inorganics* (2002), Battelle/U.S.EPA.

specified. The following represents a brief outline of entities within the ETV process, and a brief outline of proposed roles:

Government/Regulatory Body

The role of government/regulatory bodies is to ensure the performance of arsenic field-test kits utilizing a systematic mechanism of evaluation that adequately tests and verifies performance claims put forward by proponents. With respect to ETV programme, **evaluation** of a technology is defined as:

A detailed, independent third-party assessment and validation of a process performance claim of a technology, using rigorous protocol,

and **verification** of a technology is defined as:

Confirmation of a technology performance claim through evaluation.

A technology that has its performance claim confirmed by the evaluation is *verified.*

The government/regulatory body should also perform systematic audits of all levels within the ETV process to ensure that the integrity of the process is maintained. A critical aspect with respect to the success or failure of any ETV activity is assurance that the "transparency" of the process is maintained.

Verification Organization

Verification of technologies should be undertaken by an independent, third-party Verification Organization (VO) with expertise in the development and use of technologies for the field-testing of water samples. The VO should be responsible for the validation of data and information that support performance claims of an arsenic field-testing technology. Third-party verification organizations can come from government, academia, specialized organizations, and the private sector.

Stakeholder Group

The development of country/region-specific protocols should be undertaken involving a suitable stakeholder groups with expertise in field-testing for arsenic in water. Participation in the stakeholder groups should be inclusive, involving representatives from within government, academia, specialized institutions, proponents and end-users. The role of the stakeholders group is to work in association with the verification organizations in developing a protocol for evaluating technologies for field-testing for arsenic. In addition to providing input in the development and critical review of the protocol, stakeholders should play a major role in disseminating the verification process.

Technology Proponents

Technology proponents may be categorized as having developed or proposed technologies for analyzing arsenic concentrations in water under field conditions. Proponents may be categorized as the original developers of a technology, or as entities that have obtained licenses for manufacturing the technology. Proponents are responsible for submitting technologies to an independent third party testing agency for evaluation/verification according to the protocol.

Independent Testing Agency

An independent testing agency is an organization qualified to conduct studies and testing of arsenic field-test technologies in accordance with protocols and test plans, under the oversight of the VO. The role of the testing organization is to arrange for or conducts the evaluation of the arsenic field-test kits as required by the protocol.

3. COMPONENTS OF VERIFICATION

Verification is traditionally based upon evaluating the performance of a specific technology against a criteria. The verification process is based upon a specific protocol, designed to test the technology under a given set of conditions. Verification of technologies using the generic protocol for arsenic test kits will be based upon performance criteria. However, critical secondary issues should also be considered during the verification procedures.

3.1 Performance

Performance of arsenic test kits under a given set of conditions will be the basis for verification. The critical parameters of performance for arsenic test kits will be the same as those identified in the "*Generic Verification Protocol for Portable Water Analyzers for Metals and Other Inorganics"*[8]:

[8] *Generic Verification Protocol for Portable Water Analyzers for Metals and Other Inorganics, (2002), Battelle/U.S.EPA*

"The quantitative (and semi-quantitative) analyzers measure analyte concentrations and should be evaluated in terms of:

- Accuracy
- Precision
- Linearity
- Method detection limit
- Matrix interference effects
- Operator bias
- Inter-unit reproducibility

The qualitative analyzers indicate only the presence or absence of a colour change associated with a given analyte. The colour change can be semi-quantified by comparing it to a colour chart. As such, the performance of these analyzers should be verified in terms of:

- Rate of false positives/false negatives
- Lowest calibration concentration producing a positive response
- Highest calibration concentration producing a negative response
- Matrix interference effects
- Operator bias
- Inter-unit reproducibility"

The methods with respect to evaluation of the parameters should correspond closely to those outlined in the Battelle/USEPA[2] document. The integration of performance criteria from existing protocols is necessary to ensures consistency is maintained between verification activities in different countries/regions.

3.2 Principles Behind Analysis

Knowledge of the fundamental principles upon which the technology is based is critical in ensuring that evaluation of the technology is undertaken using appropriate sampling regimes (i.e. operation within determined concentration range, recognition of potential interfering species and operator bias, etc.). For technologies that are not based upon a known mechanism, requirements should be in place for the proponent to submit literature and/or other documentation to assist in determining the regime under which the technology should be tested. In addition, proponents advancing technologies based upon previously untested mechanisms should provide models upon which performance claims have been based.

3.3 Chemicals

Proponents should list all chemicals required by the field test kits, including the chemical names and their formulas. They should provide information with respect to dosage requirements per unit application. They should also describe the use of each chemical within the system, the storage requirements, shelf life, safe handling requirements, other information pertinent to health risks, quality or grade requirements and a regional supplier and attach material safety data sheets (MSDS).

3.4 Byproducts

Test kits producing a waste byproduct should provide a plan for disposal of all waste associated with the technology. In addition, proponents should be required to identify the concentration of arsenic, and concentrations of any other potentially toxic constituents, in the waste. Proponents should also identify Disposal options should also be identified for any waste generated, safe handling requirements, and other information pertinent to health risks associated with the byproducts.

3.5 Operations and Maintenance

Proponents should indicate procedures required to operate and perform (if necessary) maintenance on the technology, such that it operates within design parameters. They should also indicate the required frequency of user maintenance events, and estimate the average time requirement per event.

3.6 Hardware

Proponents should identify potential performance issues associated with the physical nature of the arsenic test kits. Issues such as fragility, lifespan (if applicable), replacement parts, shipping, should also be indicated.

3.7 Cost

Proponents should estimate the cost to use the arsenic field test kits, including, but not restricted to: operating and maintenance costs (including chemicals, reference standards, etc), associate transport costs (if applicable), and costs for proper disposal of waste materials. The sum of these costs will represent the overall system cost and can be expressed per test basis.

4. MATERIALS AND EQUIPMENT

The materials and methods for the proposed protocol for evaluating arsenic field test kits should be drawn from reference material previously generated and tested. Development of additional, and/or modification to specific, components with respect to the materials and methods used can be undertaken, but a clear understanding as to why and how the alterations impact the potential test programme should be presented.

5. PROCEDURES

The procedures presented in the proposed protocol for evaluating arsenic field test kits should be drawn from reference material previously generated and tested. Development of additional, and/or modification to specific, components with respect to the procedures can be undertaken, but a clear understanding as to why and how the alterations impact the potential test programme should be presented.

6. DATA ANALYSIS REPORTING

The data acquired will be dependent upon the methodologies employed. However, to ensure credibility and transparency of the process, mechanisms should be established for providing supporting documentation, as well as electronic data used for the data analysis, generated by the testing agencies throughout the verification process.

A data base should be designed in such a manner that information obtained through the verification process, as well as subsequent analysis and reporting are consistent with pre-existing programs, both nationally and internationally. With respect to the data handling and reporting in the evaluation of arsenic field test kits, the USEPA "*Generic Verification Protocol for Portable Water Analyzers for Metals and Other Inorganics*" (2002) should be considered as a template.

7. QUALITY ASSURANCE/QUALITY CONTROL

All programme related to monitoring water quality, including ETV protocols for arsenic field test kits, must have sound quality assurance/quality control

(QA/QC) procedures as part of any test plan. All analytical methods are susceptible to error, and procedures must be in place to ensure potential variations in monitoring are identified and corrected. Data generated during the evaluation of arsenic field test kits should be substantiated by approved laboratory methods for measuring arsenic in water.

The EPA approved methodologies, the MDLs, some of the advantages and disadvantages of each method and the estimated cost of analysis are shown in the table below[9]:

Approved Analytical Methods (and Method Updates) for Arsenic (CFR 141.23)				
Methodology	**Reference Method**	**MDL (µg/L)**	**Advantages**	**Disadvantages**
Inductively Coupled Plasma Atomic Emission Spectroscopy (ICP-AES)	200.7 (EPA) 3120B (SM)	8 5	Multi-Analyte	Not widely used Higher MDL than other methods
Inductively Coupled Plasma Mass Spectroscopy (ICP-MS)	200.8 (EPA)	1.4 (0.1)[1]	Multi-Analyte Low MDL Demand Increasing	High capital cost
Stabilized Temperature Platform Graphite Furnace Atomic Absorption (STP- GFAA)	200.9 (EPA)	0.5 (0.1)[2]	Widely Used Low MDL	Single Analyte
Graphite Furnace Atomic Absorption (GFAA)	3113B (SM) D-2972-93C (ASTM)	1 5	Widely Used Low MDL	Single Analyte
Gaseous Hydride Atomic Absorption (GHAA)	3114B (SM) D-2972-93B (ASTM)	0.5 1	Low MDL	Single Analyte

[1] In 1994, EPA approved the use of selective ion monitoring with ICP-MS. ICP-MS with this modification is capable of achieving a method detection limit of 0.1 µg/L ("Methods for the Determination of Metals in Environmental Samples - Supplement I," EPA/600/R-4/111, USEPA, 1994). Advantages include a short analysis time, lower detection limits and multi-analyte capabilities. However, instrument acquisition can be costly and the analysis for arsenic is subject to interference from the formation of an argon chloride in high chloride water samples.

[2] In 1994, EPA approved the use of multiple depositions with STP-GFAA. The use of multiple depositions with STP-GFAA is capable of attaining a method detection limit of 0.1 µg/L ("Methods for the Determination of Metals in Environmental Samples - Supplement I," EPA/600/R-4/111, USEPA, 1994).

[9] *Arsenic in Drinking Water: Analytical Methods*, (1999), USEPA

8. IMPLEMENTATION

Fundamentally programme for monitoring should be developed such that they can be implemented in a technically sound, and reproducible manner. In addition, programme for monitoring water quality should be aware of the benefits in relation to proposed costs when considering the application of any monitoring technology. To monitor arsenic at levels which cannot be obtained using existing technology and/or is such that it renders a monitoring programme financially unsustainable, should be avoided. A monitoring programme should be part of the integrated processes through which assurance of safe water delivery is guaranteed. Therefore, the verified technologies should reflect the realities of the overall process.

Given that the Maximum Contaminant Level (MCL) for arsenic will differ among countries, it is important to establish standards and implement monitoring programs that are economically and technologically feasible. The arsenic field test kits must therefore be such that they insure compliance with the established MCL. In addition, QA/QC and test procedures must reflect the ability to determine MCL using existing infrastructure or (under certain conditions) proposed infrastructure. Determination of the MCL will be dependent on the ability of laboratories involved in the QA/QC to reliably measure the contaminant, the health risks, and the costs and benefits associated with arsenic at the proposed MCL level[10].

In considering analytical methods for use in compliance monitoring, evaluation of the overall sensitivity of the techniques should be considered. The EPA programme, upon which many monitoring programme have been established, uses two measures of analytical capability: the Method Detection Limit (MDL) and the Practical Quantification Level (PQL). “The MDL is a measure of an individual laboratory's sensitivity and is defined as "the minimum concentration of a substance that can be reported with 99% confidence that the analyte concentration is greater than zero." MDLs can be operator, method, laboratory, and matrix specific. Because MDLs are derived under research-type conditions, they are not necessarily reproducible within a laboratory or between laboratories due the day-to-day analytical variability that can occur.

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[10] *Generic Verification Protocol for Portable Water Analyzers for Metals and Other Inorganics*, (2002), Battelle/U.S.EPA.

In an effort to integrate this analytical chemistry data into regulation development, the PQL is used to estimate or evaluate the minimum, reliable quantification level that can be expected to be met during day-to-day operations. PQL is defined as "the lowest concentration of an analyte that can be reliably measured within specified limits of precision and accuracy during routine operating conditions." A PQL is either determined through the use of interlaboratory studies or, in the absence of sufficient information, through the use of a multiplier of 5 to 10 times the MDL. In the U.S., the EPA routinely conducts large water supply (WS) performance evaluation (PE) studies twice a year to certify drinking water laboratories, provide large-scale evaluation of analytical methods, a database for method validation, demonstrate method utilization by a large number of laboratories, and to provide PQL data. Using graphical or linear regression analysis of the WS data, the PQL is set at a concentration where at least 75% of the laboratories could perform within an acceptable level of precision and accuracy."[11]

9. CONCLUSION

As stated at the onset, the objective of the generic Environmental Technology Verification (ETV) protocol for arsenic field test kits is to assess and independently verify environmental technology performance claims, thereby ensuring government, implementing agencies, developers, users and consultants have objective and quality assured data upon which to base their decisions. However, the generic protocol should reflect the ETV experiences obtained thus far. The USEPA "*Generic Verification Protocol for Portable Water Analyzers for Metals and Other Inorganics"* provides a sound basis from which the development of a generic protocol can be established. The document presents a sound mechanism through which the evaluation of performance-based components can be tested. However, as indicated, important secondary issues, which although not included in the EPA protocol, require integration into the overall process.

[11] *Guidelines Establishing Test Procedures for the Analysis of Pollutants Under the Clean Water Act; National Primary Drinking Water Regulations; and National Secondary Drinking Water Regulations; Methods Update; Final Rule* (2002), U.S.EPA.

Annex 5

KOLKATA DECLARATION ON VERIFICATION OF ARSENIC MITIGATION TECHNOLOGIES AND FIELD TEST METHODS

Whereas, for more than 15 years, arsenic has been detected and confirmed in ground water in several countries of the South-East Asia Region (India, Bangladesh, Nepal, Thailand and Myanmar) exposing millions of people to unacceptable levels of arsenic in drinking water;

Whereas, the health consequences of exposure to excess arsenic in drinking water are grave, with clinical signs appearing after 5 to 10 years through skin lesions, and ultimately resulting in internal cancers;

Whereas, it is acknowledged that without effective and timely interventions, the health, social and economic consequences for the affected people in these countries in the Region will be severe;

Whereas, rational understanding of the gravity of the problem has led to increased attention for arsenic mitigation, requiring screening of affected water sources through field test measurement and the implementation of arsenic removal technologies;

Whereas, several test kits and removal technologies have been developed and subsequently used in countries of the SEA Region; and

Whereas, there is need for Environmental Technology Verification (ETC) of the existing and new technologies for arsenic mitigation in the Region,

Therefore, WHO-SEARO convened the Intercountry Consultation on Verification of Arsenic Mitigation Technologies and Field Test Methods in Kolkata, India, and brought together experts from five affected SEAR countries and several specialized institutions in an effort to address the emerging issues associated with arsenic removal technologies and test kits and verification of these technologies.

The Intercountry Consultation took place between 09 and 12 December 2002, and identified Environmental Technology Verification as a mechanism for ensuring safe, environmentally friendly and sustainable treatment and monitoring of drinking water technologies, which can provide quality assured objective data to enable transparent and confident decision-making at national and sub-national levels.

The Intercountry Consultation adopted the following declaration:

(1) To ensure the delivery of arsenic safe drinking water to millions of people exposed to arsenic concentrations exceeding national water quality standards, available technologies in the participating countries may undergo formal verification based upon nationally recognized protocols. The ETV Protocol would ensure that appropriate resources would be applied in assessing and validating arsenic removal technologies and detection, measurement and monitoring technologies.

(2) We urge Governments in the participating countries to take necessary initiatives for formalizing ETV and implementing programmes to ensure that arsenic removal technologies and field test technologies meet the necessary requirements with the desired goal of the delivery of arsenic-safe drinking water.

(3) The development of common generic protocols, for verification of arsenic removal and field test technologies, involving interested regional countries, in partnership with WHO, should be undertaken. Participating countries should then undertake the development of country specific protocols based upon the principles outlined in the generic protocol.

(4) To achieve the objectives outlined in clauses 1 to 3 above, national governments may develop the necessary capacity for undertaking all components associated with verification activities. Partners requiring assistance in the development and implementation of ETV programmes, should establish international collaboration to meet the needs of the country.

(5) Development of the generic protocol should be completed by WHO in partnership with national governments and stakeholders by December 2003 and development of country specific protocols by national governments by December 2004.

(6) It was also resolved that WHO should facilitate an annual consultation for exchange of intercountry experiences in achieving the goals set herein.