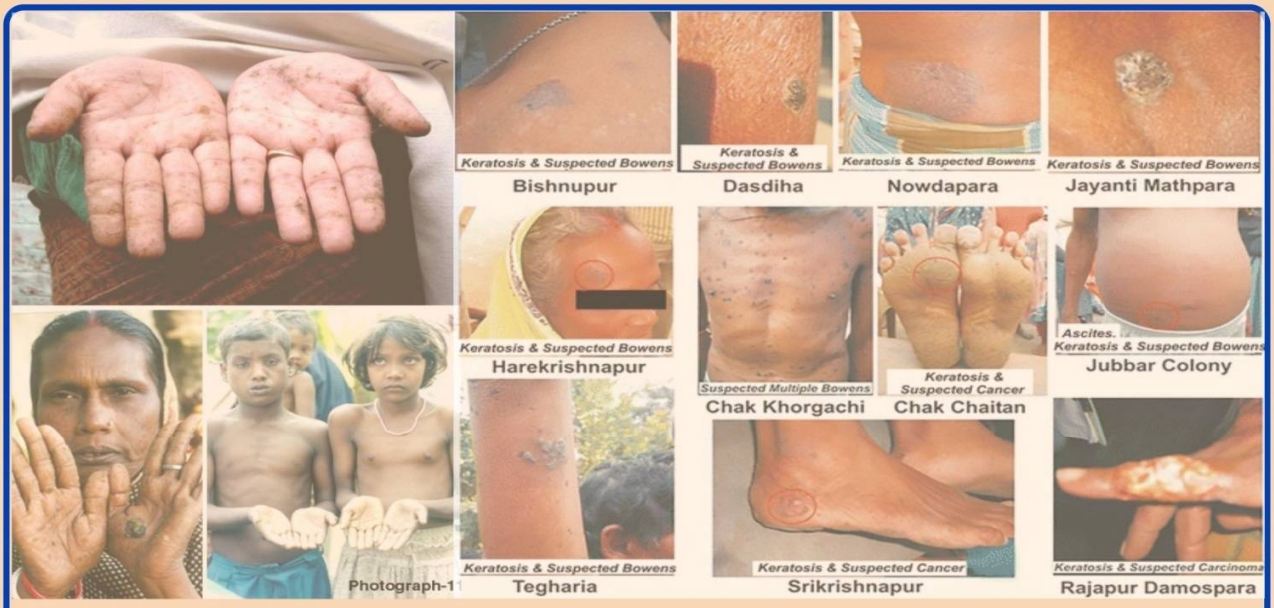

PROJECT COMPLETION REPORT

(G-77/PGTF Project No. INT/20/K01 Project Code: 124567)

Reducing Arsenic Exposure from Food and Water in Developing Countries – A Road Map for Technological Solutions for the Future

Centre for Science & Technology of the
Non-Aligned and Other Developing Countries (NAM S&T Centre)
[An Intergovernmental Organisation]
New Delhi

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Table of Contents

1. Introduction
2. About the Project
3. Aims and Objectives
4. Project Deliverables
5. Implementation Strategy
   - 5.1 Implementing Agency
   - 5.2 Partner Institutions
   - 5.3 Participatory Developing Countries (PDCs)
   - 5.4 Expert Advisory Committee
6. Implementation of the Project
   - 6.1 International Workshop on "Water Purification Technologies, Arsenic Removal from Groundwater and Integrated Water Management"
   - 6.2 International Training Programme on "Low Cost Technologies for Arsenic Removal from Groundwater"
   - 6.3 State-of-the-Report: Publication of Book
7. Financial Summary
8. Project Outcome

Annex – I: Workshop Report

Annex – II: Training Programme Report

1. Introduction

Sustainable Development Goal–6 aims to achieve universal and equitable access to safe and affordable drinking water for all by 2030 and improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials. The Goal also calls for implementation of integrated water resources management at all levels, including through trans-boundary cooperation and to expand international cooperation and capacity building support to developing countries in water-and sanitation-related activities and programmes.

In this connection, it is important to note that the use of water contaminated with Arsenic for drinking, food preparations and irrigation of crops poses great danger to public health. The risk of Arsenic contamination in groundwater continues to increase in many parts of the world, especially in the developing countries. Its sources and effects are multiple and its diffusion in natural resources including food and groundwater requires a multipronged assessment, technological interventions and appropriate policy initiatives for its mitigation.

Chronic arsenic exposure is associated with many human health risks, including skin lesions and cancers of the liver, lung, bladder and skin. It is also associated with many non-cancer health conditions, such as cardiovascular diseases, adverse reproductive outcomes, neurological disorders and impaired cognitive development in children. Cardiovascular effects in humans resulting from drinking arsenic contaminated water include black foot disease, atherosclerosis, cerebro-vascular diseases and ischemic heart disease.

Due to the lack of awareness about the problem, the silent presence of higher arsenic content in groundwater which is left unnoticed created a latent magnification of the problem in the Asian, African as well as in many other developing countries. However, the sources and effects of arsenic contamination are multiple and diffused in nature and require a detailed assessment, technological interventions and formulation of the required policies.

In the areas where the groundwater contains unsafe levels of arsenic [Arsenic concentration in water beyond 10 parts per billion (ppb)], the immediate solution is to find an alternative source for safe drinking water or removing arsenic from the contaminated source. If the safe water source cannot be established, the short-term goal is to reduce the arsenic levels from the existing water sources. So far, a very few efforts have been made on the removal of arsenic from groundwater in developing countries. While a number of technologies for arsenic removal have been developed, variations in the sources and characteristics of arsenic polluted groundwater must be considered to develop appropriate and cost-effective technological solutions. In addition, differences in the socio-economic and literacy conditions of people must to be taken into account. Based on the assessment, efforts should be made for improving the effectiveness of arsenic removal, reducing the cost of the system, making the technology user friendly, overcoming maintenance problems and resolving the toxic sludge management issues.

2. About the Project

In order to address the above issues, the Centre for Science and Technology of the Non-Aligned and Other Developing Countries (NAM S&T Centre), New Delhi submitted a proposal to the Group of 77 (G-77) Secretariat, New York for the implementation of a collaborative project entitled

"Reducing Arsenic Exposure from Food and Water in Developing Countries – A Roadmap for Technological Solutions for the Future".

It was proposed to implement the Project with a total estimated budget of US$95,000, out of which financial support of US$ 30,000 was requested from G-77 as a grant from the Perez-Guerrero Trust Fund for South-South Cooperation (PGTF), while the balance amount was to be arranged by the implementing agency - NAM S&T Centre from its internal resources and through partnership with other institutions.

The Executive Secretariat of the G - 77 vide its letter No N-094/2019 dated October 23, 2019 conveyed the approval on the Project based on the decision taken during the 43rdAnnual Meeting of Ministers for Foreign Affairs of the Member States of G-77 held in New York on 27th September 2019 with partial financial support under the Perez-Guerrero Trust Fund for South-South Cooperation (PGTF) of G-77. As the Fund Manager for PGTF, the UN Office for South-South Cooperation (UNOSSC), New York vide its letter No. SSC/2020/3/001 dated 3rd March 2020 addressed to the UNDP India Office, New Delhi confirmed the allocation of a PGTF Grant of US$30,000 and sought its assistance for Project implementation and disbursal of the allocated funds to the NAM S&T Centre. However, due to certain administrative issues, it was later decided by UNOSSC to handle the Project directly from UNOSSC Office in New York.

Thereafter, the Project was implemented by the NAM S&T Centre from January 2022 to December 2023.

3. Aims and Objectives

The aims of the Project were to cope with the serious consequences of arsenic contamination of groundwater in developing countries and provide a roadmap for low cost technological solutions for the removal of arsenic from the groundwater in order to minimize the exposure of people to this toxic element through food and water.

The objectives of the Project were:

- Understanding the complexity and status of the arsenic contamination of groundwater in the developing countries;
- To identify the best practices and lessons learned from the experiences in other countries in the area of arsenic contamination of groundwater and appropriate low cost treatment technologies available to minimize arsenic exposure to the population;
- To create awareness among the policymakers in the developing countries about the danger of arsenic exposure in its population;
- Capacity building through human resource development and transfer of technologies, e.g. Subterranean Arsenic Removal (SAR) technology and other relevant technologies for remediation of arsenic contaminated groundwater;
- Promoting a mechanism of exchange of scientific information and technical cooperation among the developing countries with regard to low-cost technologies for removal of arsenic from the groundwater;

- Documentation and dissemination of the current status of arsenic contamination of groundwater in the developing countries, prevailing remediation methods and practices and a set of intergovernmental policy recommendations on various technological options for arsenic removal from groundwater.

4. Project Deliverables

Considering the grave danger to public health posed by arsenic contamination in domestic water and water for irrigation of food crops, it was proposed to undertake this collaborative project with participation of various developing countries under which water technology professionals and policymakers would be trained on survey and assessment of arsenic contamination of groundwater and application of low-cost technologies for removal of arsenic. Further, a "State-of-the-art Report" would be prepared based on the deliberations in an International Workshop. Information collected from various countries would lead to development of a roadmap for technological solutions for the future towards reducing arsenic exposure in the developing countries. Thus, the project would have a multiplier effect in the developing countries and large sections of the population in the rural and semi urban areas would be benefited by minimizing arsenic exposure from the food and water chain and ensuring sustainable supply of drinking water with safe level of arsenic according to WHO guidelines. As such, the Project would complement the efforts of the developing countries to achieve the SDG–6 to *ensure universal and equitable access to safe and affordable drinking water for their population*.

The above objectives were sought to be achieved through the following activities:

a) Organisation of an International Workshop on "Integrated Water Management and Arsenic Removal from Groundwater" with participation of scientists and experts from various developing countries working on the arsenic remediation of groundwater and the technology developers from the NAM S&T Centre's partner institutions to discuss the problem of the arsenic contamination and its technological remedial measures.

b) Organisation of a Training Programme on "Low Cost Technologies for Arsenic Removal from Ground Water" to provide exposure to the scientists and policymakers dealing with water purification and supply systems, water technologists and public heath engineers from developing countries and empower them to identify appropriate mitigation technologies specific to their countries.

c) Preparation of a 'State-of-the-Art Report' comprising the status papers and scientific articles presented by the representatives of the developing countries during the International Workshop and also other invited experts - on the extent and severity of the problems of Arsenic contamination and various technological options for arsenic remediation.

   The report would be published and disseminated to various NAM and other developing countries which would help them in taking appropriate policy measures to tackle the problem of arsenic exposure to their population.

5. Implementation Strategy

5.1 Implementing Agency

The Project was implemented by the Centre for Science and Technology of the Non-Aligned and Other Developing Countries (NAM S&T Centre) with technical support from its partner institutions. The NAM S&T Centre is an Inter-governmental Organisation established by the Non-Aligned Movement (NAM) in 1989 for the promotion of South-South Cooperation in Science and Technology. The Centre has 47 Member Countries from the African, Middle Eastern, Asian, Latin American and European regions. Currently, Mauritius is the President of the Centre and the offices of the three Vice-Presidents are being held by Egypt, Palestine and South Africa. In order to achieve its objectives, the Centre holds a variety of International Workshops and Training Programmes/Training Courses on various S&T subjects, undertakes collaborative projects and offers short-term fellowships in partnership with the S&T institutions/agencies and Centres of Excellence in various countries. In the past, the Centre has successfully completed three collaborative projects partially supported by Perez-Guerrero Trust Fund (PGTF) of the Group of 77 on : (i) Low-cost Housing Technology (1998–2003), (ii) Bio-Control of Pests and Weeds (2001–2003) and (iii) Rain Water Harvesting and Groundwater Recharge – HRD and Technology Transfer (2008–2011) with participation of a number of developing countries.

5.2 Partner Institutions

Many institutions of excellence in India, such as R&D laboratories under the Council of Scientific & Industrial Research (CSIR), Universities, Indian Institutes of Technology (IITs) etc. have developed technologies for removal of arsenic from groundwater. Various treatment methods such as ion exchange, adsorption, ultra-filtration, reverse-osmosis, and adsorption–co-precipitation by metals (predominately ferric chloride) followed by coagulation are in practice for removal of arsenic from the groundwater. The most common technique for treatment of arsenic contaminated water is based on chemical treatment or adsorption. Each of the processes has its own advantages, disadvantages and limitations. In addition, researchers have recently developed the *"In-situ Treatment Process"* which is chemical free and also free from over the ground generation of toxic sludge.

The Queen's University, Belfast, UK in collaboration with the CSIR-National Metallurgical Laboratory (NML), Jamshedpur, India and other partner institutions had developed an "In-situ Treatment Process" [also known as Subterranean Arsenic Removal (SAR) Process] for Arsenic removal of groundwater. Other two institutes under the CSIR, the Central Glass and Ceramic Research Institute (CGCRI), Kolkata and Central Salt and Marine Chemical Research Institute (CSMCRI), Bhavnagar have respectively developed adsorption based and reverse osmosis (RO) based technologies for arsenic removal from groundwater.

The NAM S&T Centre obtained technical support from some such Indian research institutions and technology developers and also the UK based research team for implementing the project, particularly for conducting the training programme for the water management professionals nominated by the developing countries.

5.3 Participating Developing Countries (PDCs)

At the time of submitting the project proposal to G-77, 13 Member Countries of the NAM S&T Centre - Bhutan, Egypt, India, Iran, Malaysia, Myanmar, Nepal, Nigeria, Palestine, South Africa, Sri Lanka, Togo and Zimbabwe agreed to participate in this Project. During the course of implementation of the Project, delegates/experts from many other countries also participated. Many of these Participating Developing Countries (PDCs) were unaware about the levels of arsenic contamination in their groundwater and the grave danger that it poses to the health of their populations.

5.4 Expert Advisory Committee

An Expert Advisory Committee (EAC) was constituted to advise the NAM S&T Centre on the implementation of the project from time to time. The EAC explored various options and suggested guidelines for the execution of mitigating measures especially with the low-cost arsenic removal technologies. The EAC reviewed the progress of the project periodically to ensure that the deliverables were achieved as per the project objectives within the approved timeline.

6. Implementation of the Project

The Project was executed over a period of two years – from January 2022 to December 2023. The following three activities were carried out under the Project:

6.1 International Workshop on "Water Purification Technologies, Arsenic Removal from Groundwater and Integrated Water Management" during 28-30 June, 2022 in Bhavnagar (Gujarat), India

The NAM S&T Centre in partnership with the CSIR - Central Salt and Marine Chemicals Research Institute (CSIR-CSMCRI), Bhavnagar, India successfully organized an International Workshop on "Water Purification Technologies, Arsenic Removal from Groundwater and Integrated Water Management" during 28-30 June 2022 in Bhavnagar (Gujarat), India in Hybrid Mode.

The Workshop aimed to discuss water purification technologies, integrated water management and the status of arsenic contamination of groundwater in developing countries including its sources, process development, technological interventions and impacts on the human health. It facilitated understanding and exchange of knowledge on contamination of groundwater with arsenic and other heavy metals. It also generated information and materials through status reports and scientific papers that were presented during the Workshop by the participants, which were used for preparing a *State-of-the-Art Report* - that was one of the deliverables of this G-77 sponsored Project.

The International Workshop organised over a period of three days consisted of an Inaugural Lecture, 8 Invited Lectures and 26 paper presentations by the participants. In addition, around 50 poster presentations were made by the young scientists and students who attended the event.

Altogether 139 researchers, scientists, experts, academicians and policymakers from 20 countries including Bhutan, Burkina Faso, Egypt, Ethiopia, India, Indonesia, Kenya, Madagascar, Malaysia, Malawi, Mauritius, Mongolia, Myanmar, Nepal, Palestine, South Africa, Sri Lanka, Togo, United Kingdom and Zambia participated in the Workshop. It included invited speakers, scientists and experts, and nodal officers for the G-77 project from the participating developing countries. Students

and young researchers from various Indian universities and research institutions also attended the Workshop.

A copy of the report of the Workshop including the list of participants that was disseminated to all the participants and other stakeholders is enclosed at **Annex – I.**

6.2 International Training Programme on "Low Cost Technologies for Arsenic Removal from Groundwater" during 5-6 September, 2023 in Cairo, Egypt

The 2nd activity under the project was an International Training Programme on "Low Cost Technologies for Arsenic Removal from Groundwater" which was organized by the NAM S&T Centre in partnership with the Academy of Scientific Research and Technology (ASRT), Egypt during 5-6 September, 2023 in Cairo, Egypt.

The Training Programme was held in order to facilitate the exchange of knowledge and expertise on arsenic contamination of groundwater and capacity building in developing countries for transfer of low-cost technological solutions for removal of arsenic and other heavy metals from groundwater.

The Training Programme was attended by over 155 participants from 14 countries including India, Indonesia, Malaysia, Mauritius, Mexico, Myanmar, Palestine, South Africa, UAE, United Kingdom, Vietnam, Zambia and Zimbabwe and the host country Egypt. The overall Training Programme was divided into – an Inaugural Session, 4 Technical Sessions, a Panel Discussion and the Closing Session. Under the technical sessions, 6 Keynote Training Lectures, 9 Scientific Papers and 3 Country Status Reports were presented.

It was discussed that presence of elevated levels of arsenic in groundwater has become a major concern for most of the countries globally. Although, arsenic contamination of water sources have been reported in a number of developing countries, the contamination scenario in some of the South East Asian and African Countries appears to be worse than the others, both in terms of area and the population affected. Arsenic pollution of groundwater is particularly challenging for these countries since water extracted from shallow aquifers using tube-wells is the main source of drinking water for majority of their population. There are many treatment technologies available for removal of arsenic from groundwater including – membrane technology, co-precipitation, reverse osmosis, oxidation and ion exchange, adsorption, Subterranean Arsenic Removal (SAR) technology etc. However, further research is needed to improve the real time field testing and monitoring of the drinking water sources to develop new and cost-effective technologies for the treatment of chronic arsenic toxicity.

It was concluded that expanding international cooperation and extending capacity building support to developing countries in water related programmes such as desalination, efficient water treatment processes, wastewater treatment, recycling and reuse technologies will help the arsenic affected communities against its detrimental impacts on human health and environment as well as to achieve SDG-6 on access to safe and clean drinking water.

A copy of the report of the Training Programme including the list of participants that was disseminated to all the participants and other stakeholders is enclosed at **Annex – II.**

6.3 State-of-the-Art Report – Publication of Book

The last deliverable of the Project was to prepare a State-of-the-Art (SOTA) Report. In compliance of this objective, a Book on "Reducing Arsenic Exposure from Food and Water through Technological Interventions: Perspectives from Developing Countries" is being published by the NAM S&T Centre comprising papers contributed by scientists and experts from various countries. Considering the scientific quality of the papers, the book proposal submitted by the NAM S&T Centre has been accepted by the globally renowned publisher, **Springer Nature, Singapore**, and the book is expected to be released by December 2024.

The salient features of the publication are described hereunder.

Title of the Book

Reducing Arsenic Exposure from Food and Water through Technological Interventions: Perspectives from Developing Countries

Brief Summary of the Book

The use of water contaminated with arsenic for drinking, food preparations and irrigation of food crops poses a serious threat to public health. The risk of arsenic contamination in groundwater continues to increase in many parts of the world, especially in developing countries. Its sources and effects are multiple and its diffusion in natural resources including food and groundwater requires a multipronged approach and appropriate policy initiatives for its mitigation.

While several technologies for arsenic removal have been developed in different parts of the world, variations in sources and characteristics of arsenic-polluted groundwater should be considered to find appropriate and cost-effective technological solutions for affected communities. In addition, differences in the socio-economic conditions and literacy rate of people in developing countries also need to be considered. Based on the current assessment, efforts should be made to improve the effectiveness of arsenic removal, make the technology user-friendly, overcome maintenance problems, reduce cost, and resolve toxic sludge management issues.

In addition, technologies developed and adopted for cost-effective arsenic remediation of groundwater must lead to the formulation of appropriate national policies dealing with reducing arsenic exposure in food and water in the developing world.

This book consisting of 22 chapters intends to explore the challenges faced by developing countries to understand and manage the risks of arsenic pollution of groundwater and resultant contamination of food and water by highly toxic arsenic. The book brings together scientific communities from 9 countries namely Burkina Faso, India, Indonesia, Malawi, Mexico, Myanmar, Palestine, United Kingdom, and Zimbabwe to share their expertise in different aspects of managing arsenic contamination of groundwater and reducing arsenic exposure of food and water through technological interventions.

Editors: **Prof. Bhaskar Sen Gupta,** OBE, Professor in Water Technology, School of Energy, Geoscience, Infrastructure and Society, Heriot-Watt University, Edinburgh, Scotland, United Kingdom; and **Prof. Nadia Martínez-Villegas**, Professor, Applied Geoscience Division at IPICYT, Mexico, and President of the National Institute of Geochemistry (INAGEQ), Mexico.

Table of Contents

Section I – Sources of Arsenic Contamination of Groundwater

Chapter 1: **The Contamination of Water and Soil from the Dissolution of As-Bearing Mineral Waste in Matehuala, Mexico** - Nadia Martínez-Villegas*, Gerardo Hernández-Bárcenas, Margaret Suárez, Esther Salazar Amador, René Loredo-Portales, Francisco Castillo-Rivera, Israel Razo-Soto, Patricia González-Hernández, Diana Meza-Figueroa, Mario Villalobos and Bhaskar Sen Gupta **(Mexico)**

Chapter 2: **Arsenic Contamination in Indonesia** - Ahmad Shoiful **(Indonesia)**

Chapter 3: **Assessment of Arsenic Contamination in Groundwater in the Ayeyarwaddy Region of Myanmar: A Study by Irrigation and Water Utilization Management Department of Myanmar** - Phyo Wai***** and Mya Thandar Khin **(Myanmar)**

Chapter 4: **Assessing Hazards of Arsenic Leakage in Multi-Layered Aquifer System in a Part of Middle Ganga Plains, Northern India** - N.C. Mondal***,** L. Surinaidu**,** S. Ahmed, and V.M. Tiwari **(India)**

Chapter 5: **Systematic Review of Arsenic Contamination, Toxicity and Remediation Techniques in Malawi** - Ibrahim Chikowe*****, Bonface Mwamatope, Ulemu Kankwatira, Henry Phiri, George Chirambo and Collins Edward Jana **(Malawi)**

Chapter 6: **Groundwater Arsenic Contamination in Karimpur-I Block, District Nadia, West-Bengal and Investigation for Safe Water Option** - Bhaskar Das*****, Somil Thakur and Sanjana Chakraborty **(India)**

Chapter 7: **Arsenic Contamination of Water Sources in Southern Africa: Role of Artisanal and Small Scale Mining Sector** - Xavier Poshiwa **(Zimbabwe)**

Chapter 8: **Source Apportionment of Heavy Metal(loid)s in the Surface Soils of Cerrito Blanco, Mexico: A Comparative Study of Three Receptor Models (APCS-MLR, PMF, and UNMIX Model)** - Arnab Saha*****, Bhaskar Sen Gupta, Sandhya Patidar and Nadia Martínez-Villegas **(United Kingdom)**

Section II – Process Development for Arsenic Removal from Groundwater

Chapter 9: **Polymer Nanofilm Composite Membranes for Ionic and Molecular Separation: History, Challenges and Future Perspectives** - Pulak Sarkar and Santanu Karan***** **(India)**

Chapter 10: **Novel Cellulose-Based Hectocycle Nanopolymers for Arsenic Removal from Groundwater** - Bayan Khalaf*****, Shehdeh Jodeh and Subhi Samhan **(Palestine)**

Chapter 11: **Investigation of Physicochemical Characteristics for Alumina Selection for Fluoride and Arsenic Removal** - Rajendra S. Thakur*****, Payal A. Kaneriaa, Anil R. Gupta and Saroj Sharma **(India)**

Chapter 12: **Arsenic Remediation from Water in Burkina Faso Using Local Materials as Adsorbents: Overview, Mitigation and Prospects** - Yacouba Sanou **(Burkina Faso)**

Section III – Technological Interventions

Chapter 13: **Arsenic and Iron Removal from Groundwater using Indigenously Developed Ceramic Membranes –** Swachchha Majumdar*****, Subhendu Sarkar, G.C. Sahoo, Sudhendu Sensarma and Sibdas Bandyopadhyay **(India)**

Chapter 14: **An Overview of the Strategies to Mitigate Arsenic in Deltaic Aquifers** - Surajit Chakraborty*****, Utsab Ghosal and Srijita Ghosh **(India)**

Chapter 15: **A Chemical and Waste-Free Community Plant for Treating Arsenic-Contaminated Water in Tepul Village, North 24 Parganas, West Bengal** - Bhaskar Sen Gupta*****, Isita Sen Gupta, Soumyadeep Mukhopadhyay, Joey Sen Gupta, Nibedita Chatterjee and Chanchal Majumder **(United Kingdom)**

Chapter 16: **Performance Evaluation of a Subterranean Arsenic Removal (SAR) Community Water Treatment Plant: A Sustainable Long-term Approach to Removing Arsenic from Drinking Water** - Bhaskar Sen Gupta*****, Soumyadeep Mukhopadhyay, Sumona Mukherjee, Isita Sen Gupta, Debra Helen Phillips, Amitava Bandopadhyay and Arup K. Sen Gupta **(United Kingdom)**

Section IV – Arsenic Contamination in Water and Food Chain

Chapter 17: **Remedial Approaches to Arrest Arsenic in Soil-Plant System to Prevent its Entry in Rice Grain: A Review** - Urvashi Lama, Sharmistha Majumder, Deepanjan Mridha and Tarit Roychowdhury*** (India)**

Chapter 18: **Arsenic in Groundwater: A Threat to Agriculture and its Mitigation Measures to Protect the Food Chain** - Mariya Naseem, Richa Raghuwanshiand Pankaj Kumar Srivastava***(India)**

Chapter 19: **Arsenic Contamination in Groundwater and Food and Remediation Measures in Myanmar** - Mya Thandar Khin***** and Phyo Wai **(Myanmar)**

Chapter 20: **Arsenic Toxicity: Contamination through Groundwater and Food-Chain and Role of Genetic Factors** - Payel Singh, Subhamoy Bhowmick, Debashis Chatterjee and Sreemanta Pramanik***(India)**

Chapter 21: **Food Toxicity Caused by Transfer of Arsenic through Groundwater Irrigation: A Review** - Shepherd Manhokwe*****, Victor Nyanhete, Rudo Natasha Mugadza, Ruth Nyoka and Patience Marume **(Zimbabwe)**

Section V – Effect of Arsenic Contamination on Human Health

Chapter 22: Arsenic Contamination of Groundwater and its Impact on Health - Kunal Kanti Majumdar **(India)**

After the release, the NAM S&T Centre will submit the copies of the book to the UNOSSC and other concerned authorities in the G-77 Secretariat.

7. Financial Summary

The total estimated cost of the Project was US $95000, of which US $30,000 was requested from PGTF while only US $27,402 was released for implementing the project. The remaining amount was arranged from the internal resources of the NAM S&T Centre and other sources. A break-up of cost for various activities proposed under the Project is given below:

Description	1st Year (2022) Source of Funding	
	PGTF (in US$)	Others (NAM S&T Centre) (in US$)
Project Personnel	--	8,345
Correspondence with Focal Points of PDCs, Identification and Selection of National Level Coordinators and Related Activities	640	--
Preparations and Organization of International Workshop (3-Day Workshop in June 2022)	4,380	--
Correspondence with Partner Institutions and Expert Trainers and Finalization of Training Programme Schedule	682	
Identification and Correspondence with Resource Persons and Planning for Training Programme Structure and Content	1700	818
Total Expenses	**7,402**	**9,163**
Total Grant Received	**9,900**	**--**
Balance Carried Forward	**2,498**	

Description	2nd Year (2023) Source of Funding	
	PGTF (in US$)	Others (NAM S&T Centre) (in US$)
Project Personnel	--	11,535
Correspondence with Partner Institutions and Expert Trainers and Finalization of Training Programme Schedule	247	--
Identification and Correspondence with Resource Persons and Planning for Training Programme Structure and Content	651	--
Preparation for Training Programme	1,000	--
Preparation of Course Material by the Resource Persons	604	--
Preparation for Organizing Training Programme	12,442	4,551
Preparation of Course Material by the Resource Persons	2,276	--
Collection of Information from Expert Trainers and Partner Institutions	1,618	--
Completion of “State-of-the-Art Report” and “Handbook & Training Manual”	1,337	1,007
Preparation of the Final Project Completion Report	1,098	1,098
Submission of Final Report to UNDP and Circulation of Final Report to Member Countries	800	1,000
Contingencies		1,712
Total Expenses	**22,073**	**20,903**
Total Grant Received (2498+17502)	**20,000**	**--**
Balance	**-2,073**	

8. Project Outcome

The Project has been able to create sufficient awareness among large section of policymakers and water management professionals of the developing countries about the danger of arsenic exposure and the prevailing remediation methods and practices. Capacity building of participating developing countries was done through human resource development and knowledge transfer on technologies for remediation of arsenic from contaminated groundwater. Further, circulation of the book after its publication will help in propagating the scientific information about the current status of arsenic contamination, adverse impact of consuming arsenic contaminated water on human health and sustainable and cost effective technologies for removal of arsenic from water.

It is hoped that the participants of the International Workshop and Training Programme organized under the Project will disseminate the scientific information and knowledge acquired by them - to the personnel engaged in public water supply and related areas in their respective countries thereby the Project would have a multiplier effect in the participating countries and a large section of the population in these countries will be benefited by minimizing arsenic exposure of food and water chain and ensuring sustainable supply of drinking water with safe level of arsenic.

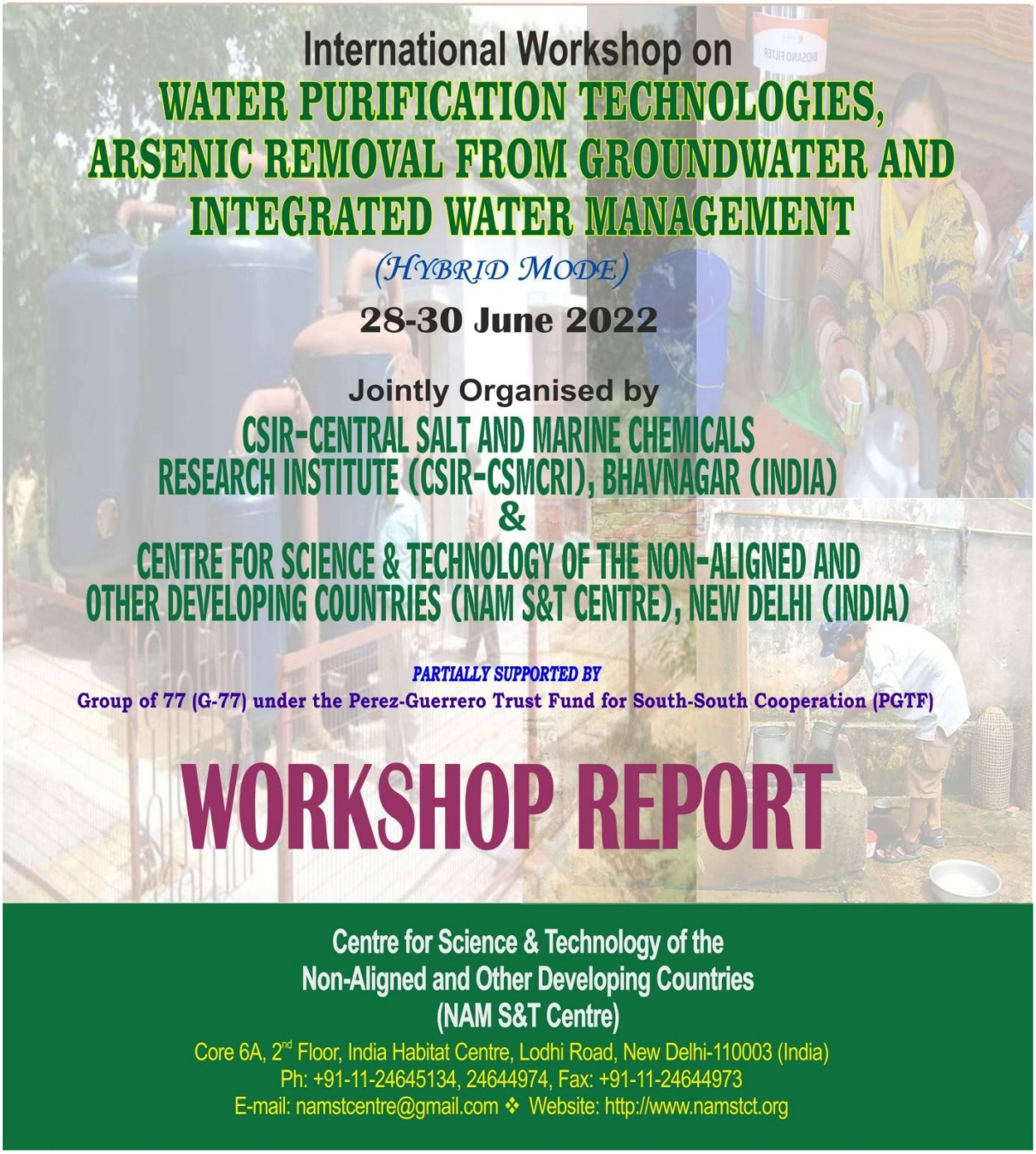
As such, the Project will complement the efforts of the developing countries to achieve the Sustainable Development Goal – 6 (SDG–6) to ensure universal and equitable access to safe and affordable drinking water for the population.

******

Annex 1

Centre for Science & Technology of the
Non-Aligned and Other Developing Countries
(NAM S&T Centre), New Delhi (INDIA)

CSIR-Central Salt and Marine
Chemicals Research Institute
(CSIR-CSMCRI), Bhavnagar (INDIA)



International Workshop on
WATER PURIFICATION TECHNOLOGIES, ARSENIC REMOVAL FROM GROUNDWATER AND INTEGRATED WATER MANAGEMENT

(HYBRID MODE)

28-30 June 2022

Jointly Organised by

CSIR-CENTRAL SALT AND MARINE CHEMICALS RESEARCH INSTITUTE (CSIR-CSMCRI), BHAVNAGAR (INDIA)

&

CENTRE FOR SCIENCE & TECHNOLOGY OF THE NON-ALIGNED AND OTHER DEVELOPING COUNTRIES (NAM S&T CENTRE), NEW DELHI (INDIA)

PARTIALLY SUPPORTED BY

Group of 77 (G-77) under the Perez-Guerrero Trust Fund for South-South Cooperation (PGTF)

WORKSHOP REPORT

Centre for Science & Technology of the
Non-Aligned and Other Developing Countries
(NAM S&T Centre)

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TABLE OF CONTENTS

1. Workshop Report 3

2. Programme Schedule 16

3. List of Participants 23

The Sustainable Development Goal (SDG) – 6 aims to achieve universal and equitable access to safe and affordable drinking water for all by 2030 and improve water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials. The Goal also calls for implementation of integrated water resources management at all levels, including through trans-boundary cooperation, and to expand international cooperation and capacity-building support to developing countries in water- and sanitation-related activities and programmes.

In this connection, it is important to note that the use of water contaminated with Arsenic for drinking, food preparations and irrigation of food crops poses the greatest threat to public health. The risk of Arsenic contamination in groundwater continues to increase in many parts of the world, especially in the developing countries. Its sources and effects are multiple and its diffusion in natural resources including food and groundwater requires a multipronged assessment and appropriate policy initiatives for its mitigation.

Chronic Arsenic exposure is associated with many human health risks, including skin lesions and cancers of the liver, lung, bladder and skin. It is also associated with many non-cancer health conditions, such as cardiovascular diseases, adverse reproductive outcomes, neurological disorders and impaired cognitive development in children. Cardiovascular effects in humans resulting from drinking Arsenic contaminated water include black foot disease, atherosclerosis, cerebro-vascular diseases and ischemic heart disease.

Due to the lack of awareness about the problem, the silent presence of higher Arsenic content in groundwater is left un-noticed which creates a latent magnification of the problem in the Asian, African as well as in many other developing countries. However, the sources and effects of Arsenic contamination are multiple and diffused in nature and require a detailed assessment and formulation of required policies.

In the areas where the groundwater contains unsafe levels of Arsenic, the immediate concern is to find a safe source of drinking water. There are two main options: finding a new safe source or removing Arsenic from the contaminated source. If an Arsenic safe water source cannot be established, the short-term goal is to reduce the Arsenic levels in the exiting sources. So far, very few efforts have been made on the removal of Arsenic from groundwater in many developing countries. While a number of technologies for Arsenic removal have been developed in different countries, we must consider variations in sources and characteristics of Arsenic polluted groundwater to find an appropriate cost effective technological solution for the same. In addition, differences in the socio-economic and literacy conditions of people also need to be considered. Based on the assessment, efforts should be made for improving the effectiveness of Arsenic removal, reducing the cost of the system, making the technology user friendly, overcoming maintenance problems and resolving the toxic sludge management issues.

In order to address the above issues, the Centre for Science and Technology of the Non-Aligned and Other Developing Countries (NAM S&T Centre) is implementing a collaborative project entitled "Reducing Arsenic Exposure from Food and Water in Developing Countries – A Roadmap for Technological Solutions for the Future" with partial financial support under Perez-Guerrero Trust Fund (PGTF) of G-77. The project aims to cope with the serious consequences of Arsenic contamination of groundwater in developing countries and provide a roadmap for low cost technological solutions for the removal of Arsenic from the groundwater in order to minimize the exposure of people to this toxic element through food and water. The implementation of the project is being monitored by the UN Office for South-South Cooperation (UNOSSC), New York.

As a part of the Project, the NAM S&T Centre organized an International Workshop on "*Water Purification Technologies, Arsenic Removal from Groundwater and Integrated Water Management*" in partnership with the CSIR-Central Salt and Marine Chemicals Research Institute (CSIR-CSMCRI), Bhavnagar, India during 28-30 June 2022 (in Hybrid Mode).

The International Workshop was organized over 3 day's period with an Inaugural Lecture, 8 Invited Lectures, and 26 presentations made by other participants. Further, around 50 Poster presentations were made by young scientists and students attending the event.

Altogether 139 researchers, scientists, experts, academicians and policy makers from 20 countries including Bhutan, Burkina Faso, Egypt, Ethiopia, India, Indonesia, Kenya, Madagascar, Malaysia, Malawi, Mauritius, Mongolia, Myanmar, Nepal, Palestine, South Africa, Sri Lanka, Togo, United Kingdom and Zambia had participated in the Workshop. This included invited speakers, guests, nodal officers for the G-77 project from the participating developing countries, and scientists and experts from other countries. Around 50 students and young researchers from various Indian universities and research institutions had also attended the Workshop and made their Poster presentations.

The Workshop Inaugural Session was initiated with the lighting of a ceremonial lamp followed by felicitation of the dignitaries and honorable Chief Guest, Padma Shri Prof. T. Pradeepfrom the Indian Institute of Technology Madras, Chennai, India.

At the outset, Dr. V. K. Shahi, Chief Scientist/Divisional Chair, Membrane Science & Separation Technology Division, CSIR-CSMCRI, Bhavnagar, India welcomed the invited delegates and other participants, and said that it is a privilege to organize the International Workshop on such an important topic to address the issues of the developing countries suffering from Arsenic contamination of groundwater. He pointed out that the membrane technologies are playing a pivotal role in water purification and some of the membrane-based approaches that are currently adapted at an industrial scale include membrane based desalination (by reverse osmosis, electrodialysis, nano-filtration, or bioreactors) for production of pure water. He further added that recent developments in advanced membrane forming materials with improved performance and practical life, prompted the CSMCRI and NAM S&T Centre to bring membrane researchers and technologists, academicians and industry personals on a single platform to share their views for solving the problems for safe drinking water.

Dr. Amitava Bandopadhyay, Director General, NAM S&T Centre, in his address, welcomed the distinguished speakers, special invitees, and other participants from various NAM and other developing countries, and spoke about the importance and need of conducting this Workshop. He indicated that amongst many of the toxic pollutants, Arsenic contamination of groundwater and use of Arsenic contaminated water in drinking, food preparation and irrigation of food crops pose the

greatest threat to public health. According to an estimate, nearly 100 million rural people are affected by exposure to Arsenic in the food chain and drinking water in Asia. The areas that have the worst documented contamination of groundwater by Arsenic are in South Asia, and the toxin poses a severe problem in Bangladesh, India and Nepal. Arsenic contamination in groundwater and food beyond permissible limits has also been reported in many other countries but sufficient data is not available due to lack of proper scientific studies. He also pointed out the sources and effects of Arsenic contamination in groundwater on human health, and since the contamination is on the rise in the developing world, the NAM S&T Centre has taken up the collaborative project with a view to prepare a roadmap of reducing arsenic exposure through food and water as a part of the commitment to achieving "Clean Water and Sanitation for All" (SDG-6), and the Workshop is an integral part of the project. He also described in brief Submerged Arsenic Removal (SAR) treatment technology, *in-situ* and *ex-situ* treatment, and expressed hope for fruitful deliberations in the Workshop.

This was followed by an address by Dr. Kannan Srinivasan, Director, CSIR-CSMCRI, Bhavnagar, India who warmly welcomed all the experts and participants from India and various other countries. He pointed out the need for all the countries, especially the developing world, to become aware of the technologies available and gaps that need to be bridged regarding access to potable water which is one of the indispensable requirements for mankind's survival. He added that there is a widespread disparity in distribution of water and it becomes important to understand that the problem is extremely location and problem centric and it is important to know when, where and which technology should be deployed. He then thanked the NAM S&T Centre for collaborating with his institute on such an important topic and wished everyone good takeaways from the workshop.

Prof. T. Pradeep, a renowned researcher from the Indian Institute of Technology Madras, Chennai, India,inhis remarks said that the value of globally connected water network is estimated to be 50 trillion dollars and total wealth is estimated around 13 trillion dollars, with India's market being about 1 trillion dollars, and thus enormous opportunities are there in wealth creation through water. He then talked about the relations between science and nature, and said that water is a possible adventure into advanced science, with a lot of difficulties but with tremendous opportunities. He, being passionate about water connected it with wealth, opportunity, chemistry, physics, literature, and peace. He also emphasized on the importance of studying water as a separate branch of engineering which is now buried under environmental engineering. In this context, he said that it is also necessary to address issues of human resources, otherwise this would remain an issue even after 2030, and to overcome this problem, water has to be accessed properly and water literacy should be encouraged.

After a short tea break, an Inaugural Lecture was delivered by Prof. Pradeep on '*Affordable clean water using advanced materials*'. He elucidated on how water is neither created nor destroyed (roughly even after the molecular exchange between the Earth and the Space) whereas water is involved in everything we do. He elaborated on this with the example of a vehicle sent by NASA to explore the Solar System which when reached Uranus showed "The pale Blue Dot" picture that indicates possible availability of water, thus a possibility of life. He stated that the World Health Organization (WHO) set the upper limit on Arsenic in drinking water at 50 ppb in 1963, and the U.S. Environmental Protection Agency decreased the limit to 10 ppb in 2002. A primary reason for decreasing contaminant limits has been an enhanced understanding of the effects of contaminants on human health. However, the limited availability and high cost of remedial technologies have kept governments from implementing these standards. Moreover, the actual safe limit is expected to be further below the present WHO limit. This is because the Arsenic intake per capita per day is much higher than that assumed by the WHO in the Arsenic-affected tropical regions of India due to

unaccounted sources of Arsenic intake, such as food crops. However, the dreams to reduce Arsenic exposure become reality with advanced materials through sustainable nanotechnology that has made substantial contributions in providing contaminant-free water to humanity. Nano-materials are now atomically precise and therefore, can solve real problems. He further talked about the current nanotechnology frontiers in diverse areas of the clean water space with an emphasis on applications in the field and provided suggestions for future research. He mentioned how he along with his research group has developed environment-friendly 'water positive' nano-scale materials which are affordable, sustainable and efficient in rapid removal of arsenic from drinking water. He discussed technologies including "Biopolymer-reinforced Synthetic Granular Nano-composites for Affordable Water Purification Aid", and 'Silver' technology. He talked about his dream to use raw water to produce energy and get clean water at the same time. He emphasized that by understanding the global environmental challenges and exploring remedies from emerging nanotechnologies, sustainability in clean water can be realized.

The lecture was followed by a short *Question-Answer Round.*

Followed by a lunch break, the first Session of Day-1 of the International Workshop was chaired by Prof. D. Mohan, Anna University, Chennai, India. The Session consisted of 3 Keynote Lectures given by Dr. Pradip K. Tewari, Professor & Chair, Department of Chemical Engineering, Indian Institute of Technology (IIT), Jodhpur, India on '*Sustainable Water: Challenges and Opportunities*'; Dr. Dipankar Saha, Former Member, Central Groundwater Board, Ministry of Jal Shakti, Government of India, New Delhi, India on '*Aquifer-based water supply in groundwater dependent arsenic contaminated areas'*; and Dr. Pawan Kumar Labhasetwar, Chief Scientist & Head, Water Technology and Management Division, CSIR-National Environmental Engineering Research Institute, Nagpur, India on '*The Conundrum of Water Treatment – Reality and Priority*'.

Dr. Pradip, in his lecture talked about sustainable water and how water is the ultimate source of happiness. He explained that water sustainability involves – water harvesting and conservation; water purification; water recycle and reuse, and brackish water desalination. He also pointed out the challenges that are faced in the process - affordability, simple and robust technology, technological innovations that are simple, sustainable and replicable by local technicians especially in rural areas; and the need for indigenous development. He then explained various programs/technologies developed by his institute. He further talked about the need for low carbon water purification technologies, development and appropriate selection of technology and integrating the ancient water technologies that (are usually slow) with new technologies (present day knowledge) can have high impact (hybrid technologies) to achieve SDGs.

Dr. Dipankar Saha talked about how Arsenic in groundwater is a difficult problem, especially in areas covering Indo-Gangetic-Brahmaputra flood plains covering India, Pakistan and Bangladesh. These areas have the most intrinsically extracted groundwater in the world and are hugely Arsenic contaminated. According to a Geo-physical Survey, Arsenic groundwater contamination is reported in more than 70 countries and 6 continents and suspicion is that the Himalayas are the reason.. He then explained the different types of aquifers present currently. He also discussed the shallow alluvial stratigraphy according to which there are zones where the water is still Arsenic free even in the most affected areas. He also described a study on alteration of different grades of mud, sand and clay and which aquifer should be used based on it.

Dr. Pawan Kumar Labhasetwar, in his lecture, discussed the framework and guidelines for safe drinking water provided by the World Health Organization (WHO). He mentioned that safe drinking water can be achieved through a preventive approach using a water safety plant which helps

in contaminant removal from various water treatment units, or using conventional water treatment plants. He also explained the advancement in adsorption technology for Fluoride using membrane based technologies and RO membrane based point-of-use water treatment system.

This was followed by Session 2 chaired by Dr. Pawan Kumar Labhasetwar, consisting of 4 virtual lectures.

The first lecture was delivered by Ms. Mya Thandar Khin, Assistant Director, Environmental Conservation Department, Ministry of Natural Resources and Environmental Conservation, Myanmar on '*Arsenic contamination in groundwater and food and remediation measures in Myanmar*'. In her presentation, she spoke about the adverse impacts on human health due to Arsenic contamination in groundwater and food. She gave the current status in Myanmar on this problem and researches being undertaken in the country. She further talked about challenges faced by Myanmar in this area that includes - short/ long term training needs for capacity building, advanced techniques and machines for Arsenic removal, financial resources, need to increase public awareness especially for local people, and need of strong cooperation and collaboration among the related organizations.

Then a paper titled 'Water Pollution in Malaysia' was presented by Mr. Zulhelmi Bin Kasim, Senior Executive, Ministry of Environment and Water, Malaysia. He said that Arsenic contamination in water is rare in Malaysia but in January 2019, Malaysians were stunned by the news of Arsenic contamination in the river, the first such case that occurred in Malaysia. The pH level taken from water samples showed the presence of heavy metals, particularly a small amount of Arsenic. The cause of the pollution was said to be a 100-year-old mine which releases Arsenic due to poor maintenance apart from agriculture, logging and construction carried out in the area. Although the concentration of Arsenic was 8µg/L, less than the limit according to WHO standard (10 µg/L), the authorities ordered stopping the operation of nearby water treatment plants to protect water users from Arsenic contamination. He concluded by stating that it becomes a global responsibility to provide clean, Arsenic-free water to everyone.

A joint paper by Dr. Subhi Abed Al-kaderSamhan, Director, Research and Development, Palestinian Water Authority, Palestine; Dr. Bayan khalaf, Assistant Professor – Chemistry, Arab American University, Jenin, Palestine; and Prof. Shehdeh Jodeh, Professor An-Najah N University, Palestine on 'Novel Cellulose-Based Hectocycle Nanopolymers for Arsenic Removal from Groundwater' was presented by Dr. Bayan Khalaf . She explained a project that they have been working on, in which cellulose-based derivatives with heterocyclic moieties were synthesized by reacting cellulose with 2-amino pyridine (Cell-N), furan-2-carbonyl chloride (Cell-F) and pyridine-2, 6-dicarbonyl dichloride (Cell-P). The derivatives were evaluated as adsorbents for Arsenic removal from aqueous solution. To maximize the adsorption efficiency of Arsenic removal, the optimum conditions of contact time, pH, temperature, adsorbent dose, and initial concentration of adsorbate were determined. The results proved having promising percentages of removal of Arsenic from groundwater to drinkable degree.

This was followed by a presentation on '*Arsenic in Water, Soil and Food in Sri Lanka*' by Dr. A.G. Piyal Aravinna, Head, Chemical & Environmental Section, Central Engineering Consultancy Bureau (CECB), Sri Lanka. He mentioned that levels of Arsenic in soil and groundwater in Sri Lanka are very low compared to other Asian countries such as Bangladesh, India, and China. Even though Arsenic is naturally available in trace levels in the Sri Lankan environment, anthropogenic activities are responsible for the slight enrichment of their levels in soil and water. Based on some scientific data published in the last decade, some researchers speculated that Arsenic exposure from food and water is a root cause of kidney disease. However, the data published in 2019 shows that the levels of

Arsenic in rice are below the maximum permissible level for the husked rice (0.35 mg/kg), proposed by the CODEX Alimentarius committee. He however pointed out that most of the studies are limited to the level of total Arsenic in the environment. However, further studies are essential to evaluate the levels of organic and inorganic varieties of Arsenic in both environment and the human body to understand the relationship between their levels and non-infectious diseases in the country, and since the level of Arsenic in water resources is relatively low in the county compared to other countries, the interest for the development of Arsenic removal technologies is relatively less among the Sri Lankan scientists.

Day 2 of the Workshop commenced with Session 3, chaired by Mr. Swachchha Majumdar, CSIR-Central Glass &Ceramic Research Institute (CGCRI), Kolkata, India which had 6 lectures.

A paper titled '*Emerging Membrane Technology processes in Water Desalination with reduced Carbon footprint*' was presented by Prof. D. Mohan, Anna University, Chennai, India. He talked about the relationship between Water, Energy and Food. He further pointed out how water shortage is affecting 3 billion people worldwide and how billions will face hunger as a result. In order to overcome this, desalination can help meet UN SDG 6. He spoke on the development of water treatment technologies and requirements of further improvement e.g. high flux membrane at low operating pressure, and more effective energy recovery which helps in optimization of the whole process. He also highlighted some limitations of the Reverse Osmosis (RO) process: high energy requirement, membrane fouling (by increasing the turbulent flow), concentration polarization, life of membranes, and rejection management. He then elaborated on some challenges faced during membrane separation. He also explained membrane fouling and its different types: organic fouling, bio fouling, micro plastics fouling, colloidal fouling, and precipitate fouling (scaling).

Following this, a lecture was delivered by Dr. Sridhar S., Chief Scientist, Indian Institute of Chemical Technology, Hyderabad, India on '*Innovations in Membrane Science & Technology for Combating Water Scarcity and Covid-19 Pandemic*'. During his lecture, he talked on membrane technology: industrial growth, social welfare, academic progress, and said that the focus of his studies is to find solutions to eradicate Fluorosis and water borne diseases in India and the world. He explained with the help of a video presentation on medical grade water and how it is obtained. He showed another video on mitigation of water scarcity through a hand pump operated ultra-filtration system and talked about atmospheric water generators – ultra filtration post treatment + re-mineralization. Dr. Sridhar also said that RO sucks away all the minerals thus making it very bad for health. He then discussed remineralized ROs, industrial effluent treatment methods, prevention of bio-fouling, and defluoridation of groundwater.

A paper titled '*Understanding Water Safety with Focus on Membrane/Reverse Osmosis based Plants and Water ATMs for Drinking Water Supply*' was presented by Dr. Atul Maldhure, Water Technology & Management Division, CSIR-National Environmental Engineering Research Institute, Nagpur, India. In his presentation, he said that in order to provide safe water, RO has emerged as an important solution as it reduces chemical contaminations and removes bacterial load. The technology is well established and is perceived to deliver safe water. However, like every technology, RO has its limitations like the higher fixed and recurring cost, and requirement of higher TDS in water for efficient functioning and generation of reject water. Currently, there are no established criteria or specifications for the installation of the RO plants. According to a study by an expert committee based on the 4 districts of Maharashtra, it was noted that RO technology is not required for places that have provision for piped water supplies from rivers, lakes, or surface water supplies. It is also noted that deficiency of minerals is caused by the RO. During the study it was observed that around 50%

RO Plants are installed in the locations where the TDS is less than 500 mg/L and at no location the TDS is more than 2000 mg/L. The TDS of the treated water ranges between 19 mg/L to 159 mg/L. The operational efficiency based on flow rate ranges between 14 to 44%. According to the household survey, the water-borne diseases are not completely eliminated; however, the perception survey indicates that the health and quality of water consumed are improved.

This was followed by a keynote lecture given by Dr. Kunal Kanti Majumdar, Professor of Public Health, KPC Medical College, Kolkata, India on '*Arsenic contamination of groundwater and its impact on Health*'. He explained that Arsenic contamination in drinking water has been reported from many countries like Taiwan, China, Argentina, Chile, Mexico, Cambodia, Thailand, Myanmar, Nepal, and the USA, but the severity of this contamination in India and Bangladesh is unprecedented. The common symptoms of chronic Arsenic toxicity due to prolonged drinking of Arsenic contaminated water are pigmentation, keratosis, cancer of skin along with variety of systemic manifestations. If Arsenic poisoning occurs over a brief period of time, symptoms may include vomiting, abdominal pain, encephalopathy, and watery diarrhea that contains blood. Long-term exposure can result in thickening of the skin (keratosis), darker skin (pigmentation), abdominal pain, anemia, heart disease, chronic cough, liver disease, numbness, and cancer. . He further added that primary prevention by raising levels of awareness among primary care providers of the local region about signs and symptoms of arsenicosis and available intervention can definitely help to mitigate this important public health problem. It is therefore an urgent need to make arrangements for availability of safe water sources among the Arsenic affected people (taking example of the West Bengal Region in India). He elaborated further on Arsenic toxicity and gave some recommendations for health administrations to overcome lack of awareness, and focus on issues that need to be immediately addressed.

A lecture was then given by Prof. Anurag Mudgal, Pandit Deen Dayal Energy University, Gandhinagar, Gujarat, India on '*Feasibility and parametric studies of thermal energy driven MED and RO systems for brackish water treatment*'. He explained in detail the Multi Effect Distillation (MED) and RO module using low-grade thermal energy. He also talked about thermal energy storage: schemes and its applications. He said that a wide range of steam driven RO mechanisms may be designed as per the requirement and availability of steam pressure, and if the system is scaled up to produce hundreds of cubic meters of drinking water, the product cost further reduces.

Dr. Santanu Karan, Membrane Science and Separation Technology Division, CSIR-CSMCRI, Bhavnagar, India presented a paper titled '*Polymer Nano-film Composite Membranes for Ionic and Molecular Separation*'. He talked about composite nano-filtration membranes with ultrahigh ion selectivity and liquid permeance that are desirable to increase water recovery and process efficiency in nano-filtration and water desalination. The ultra-selective and highly water permeable nano-film composite membranes were fabricated via interfacial polymerization with precise control of the kinetics of the interfacial polymerization reaction by maintaining the stoichiometric equilibrium of the monomers at the interface and by a post-solvent-washing and post-heating of the nascent nano-film formed at the interface.

After a short lunch break, the Workshop recommenced with Session 4, chaired by Dr. Sridhar S., Chief Scientist, Indian Institute of Chemical Technology, Hyderabad, India, consisting of 5 lectures delivered virtually by experts.

A keynote lecture was given by Prof. David Polya, Department of Earth and Environmental Sciences and Williamson Research Centre for Molecular Environmental Sciences, School of Natural Sciences, Faculty of Science and Engineering, University of Manchester, United Kingdom on

'*Groundwater Arsenic in India – Distribution, Impacts & Remediation Perspectives*. In his lecture, he described various features of a Manchester - India groundwater arsenic project, and pointed out that whether drinking more or low Arsenic water, both have harmful effects. He then differentiated between acute versus chronic Arsenic poisoning; and also explained different health effects caused due to it. While giving the details of the project between the two slides, he pointed out that Rice is the main route for Arsenic in India. He also talked about the remediation of Arsenic contamination, such as, developing a framework for selecting the best options and improving drinking water quality resulting in better quality of life - in a cost effective way. He concluded by saying that removing exposure to Arsenic can result in public health benefits of the order of $US 750 million to $US 3,400 million.

Following this, a keynote lecture on '*DST's water interventions and its impacts*' was given by Dr. Neelima Alam, Scientist - F/Director (Technology Missions), Department of Science & Technology (DST), Ministry of Science & Technology, Government of India. She mentioned that realizing the need for Research and Development (R&D) to address various issues in providing safe water, the DST, Government of India launched a Water Technology Initiative (WTI) in the year 2007-08, with an aim to design and develop low cost solutions for domestic use of safe drinking water, referencing of technologies to social context, capacity building of water managers and encouraging new research ideas. In order to develop holistic and viable research and technology-based solutions for tackling problems of water quality and water scarcity, the Department promoted activities so as to address issues related to drinking water in terms of purification, availability, reuse and recycling under the aegis of Technology Mission "Winning, Augmentation and Renovation (WAR) for Water". For Arsenic remediation, indigenous technologies such as cost-effective gravity-fed water purification units (Arsenic and Metal Removal by Indian Technology- AMRIT), adsorption of metal ion-based water filtration devices, laterite based Arsenic filters and zero valent iron based filters have been developed and deployed in real field conditions under the aegis of WTI.

This was followed by a presentation of a paper titled '*Biogeochemistry of arsenic cycling-translating microbial responses towards As free potable water*' by Prof. Punyasloke Bhadury, Centre for Climate and Environmental Studies & Department of Biological Sciences, Indian Institute of Science Education and Research, Kolkata, India. He started by pointing out that the Bengal Delta Plains encompassing parts of India and Bangladesh are reeling from severe Arsenic (As) contamination in groundwater, agricultural lands and in staple foods including rice. Microbial communities involved in key steps of Arsenic cycling such as in aquifers offer cues that can be integrated towards development of cost-effective approaches to provide Arsenic free water as well as rice. Based on robust biogeochemical measurements and genomic approaches, it has been observed that Arsenic oxidizing bacteria along with diazotrophic cyanobacteria possess metabolic capabilities to transform forms of As present in groundwater as well as in agricultural fields. The information from the microbially mediated cues is being integrated to develop cost-effective approaches for providing As-free potable water and bioremediate As contaminated agricultural lands. These approaches can ultimately provide long-term solutions to achieve As-free resources and contribute to the goals of UN-SDGs.

A paper titled '*Current researches of Arsenic removal in water – A review*' was presented by Dr. P. S. Navaraj, Former Principal, Annai Fathima College, Madurai and Former Dean, Yadava College, Madurai, India. He talked about the active research efforts that are being made to remove Arsenic (As) contamination from water and Iron-based adsorbents were found to be promising for Arsenic removal.

Following this, Dr. Lalit Mohan Sharma, Principal Scientist, Water Research and Training Water Researcher, S M Sehgal Foundation, Gurugram, India presented a paper on '*Arsenic Removal in Groundwater*'. He pointed out from a world health organization (WHO) report according to which 80% of diseases are waterborne. Contamination from the geological formations (termed geogenic contamination) is the major source of groundwater contamination. Geogenic contaminants originate through weathering of rocks/formations deposited in the aquifer naturally, soluble in water. Arsenic and Fluoride are such geogenic contaminants that possess a greater risk to human health and a major part of India suffers from it. He also said that the Bureau of Indian Standards (BIS) has set the desirable limit of Arsenic in drinking water to 10 ppb and consumption of Arsenic concentration above the desired limit affects health including respiratory and gastrointestinal systems along with an increase in the risk of cancer and skin diseases. He then talked about a study conducted by Indian Institute of Technology, Kanpur on Bio sand filters to evaluate the performance and feasibility of a Jal Kalp Bio sand filter in providing potable water to rural households in India affected by chronic Arsenic. The study proves that Jal Kalp removes Arsenic by adsorption on rusted iron nails with an efficiency of 95-99% and microbial contamination through the addition of germicidal properties of copper. Sehgal Foundation innovated the sustainable Bios and Filter technology and named the model "JalKalp". Household water filter 'Jal Kalp', is capable of addressing microbial, iron, and manganese contamination. Its design is also optimized for natural oxidation to oxidize As (III) into As (V). Integration of Zero Valent Iron (ZVI) technology makes it perfect for removal of Arsenic via adsorption of As (V) on Hydrous Ferric Oxide (HFO) produced by ZVI placed in a diffuser. Put together; this low-cost innovation aimed at resolving one of the gravest developmental issues that decelerate the impact of other developmental solutions can be a game-changer.

After a short tea break, the workshop recommenced with Session 5 consisting of 3 lectures, chaired by Dr. Kunal Kanti Majumdar.

Dr. Eng Ahmad Shoiful, Junior Engineer, Research Center for Environmental and Clean Technology, the National Research and Innovation Agency (BRIN), Indonesia presented a lecture on '*Arsenic contamination in Indonesia*'. He talked about a study that found out that Arsenic concentration in submarine mine tailings deposited in Buyat Bay, North Sulawesi, was 1.54 μg/L and 3.13 mg/kg wet weight, in seawater bottom and fish tissue, respectively. Arsenic was detected in coastal aquifers from big cities in the North Coast of Java, namely Jakarta, Semarang and Surabaya with concentration of 15.47 ± 18.79, 1.25 ± 2.05 and 0.59 ± 0.26 μg/L, respectively. A study of Arsenic concentration in foodstuff samples collected from Jakarta has been conducted. The highest concentration of Arsenic was detected in fish and fish products (452.51 ng/g fresh weight of sample), followed by steamed white rice (85.53 ng/g fw), common food ready to be served (80.95 ng/g fw), homemade of porridges (79.18 ng/g fw), while the concentration of Arsenic in tap water (PDAM) was 0.72 ng/L. According to the studies above, Arsenic was found in several cities in Indonesia. Hence, regular monitoring of Arsenic in foodstuffs or environmental samples in Indonesia is deemed necessary to protect human health and prevent global contamination.

Following this, Dr. Chander Kumar Singh, TERI School of Advanced Studies, New Delhi, India presented a paper on '*Business of Poison: Willingness of rural households to have their groundwater well tested for arsenic for a fee*'. He pointed out that the World Health Organization (WHO) has called the exposure to arsenic across South Asia "the largest mass poisoning of a population in history". Chronic exposure to arsenic by drinking groundwater at over 10 times the level of the current WHO guideline of 10 micrograms per liter has recently been shown to double all-cause deaths in a large cohort study conducted in Bangladesh. He also talked about a study conducted

in Bihar, India where people of the area are well informed about the adverse health impact that leads to people of even lower income category ready to pay a subsidy to get arsenic-free water.

This was followed by a paper presentation on '*Assessing hazards of arsenic leakage in multi-layered aquifer system in a part of Middle Ganga Plains, Northern India*' by Dr. N C Mondal, Principal Scientist, Earth Process Modeling Group & Assoc. Prof., Academy of Scientific & Innovative Research (AcSIR), CSIR – National Geophysical Research Institute (NGRI), Hyderabad, India. He pointed out that the severity of uncontrolled pumping has disturbed the multi-layered aquifer hydro-dynamics and that the major concern is the inter-aquifer leakage through the intervening clay layers of varying thickness which has been deduced by dense geophysical measurements. The heavy pumping from the deeper aquifer (largely uncontaminated) and reduced thickness of confining clay layer at places between the two aquifers, offer a possible threat of the leakage and the arsenic contaminated groundwater entering into the deeper aquifer, deteriorating the groundwater quality seriously. To overcome the issue, he talked about a project that has resulted in providing safe pumping rates at a micro-scale for the farmers and sites for the decision-makers to provide alternate supply of water.

The session and Day 2 ended with an open discussion/question-answer round and summarization of key takeaways by the Session Moderator followed by Poster Presentations.

Day 3 started with Session 6 comprising 6 lectures, chaired by Dr. Atul Maldhure.

Dr. Swachchha Majumdar, Membrane and Separation Technology Division, CSIR-Central Glass & Ceramic Research Institute, Kolkata, India presented a paper on '*Ceramic Membranes and applications purification of ground water for decontamination of Arsenic and Iron'*. He described the features of Ceramic membrane which is a separation device made up of inorganic materials, and explained its various applications. He further elucidated on the topic with pictorial representations and engaged the audience with help of short videos. He also discussed the structure of a ceramic membrane. He further added that using technology, the process for obtaining porous ceramic monolithic membranes was established and implanted based on the nature of the problem: Ground Water contamination – membrane based technology for liquid filtration, and also emphasized on the importance of the maintenance of the system. He also explained the CSP Techniques, and Nano-filtration method.

Dr. S. Rajamani, Technical Expert - Environmental Engineering, UNIDO; Chairman - Asian International Union of Environment (AIUE) Commission, Chennai, India presented a paper on '*State-of-the-Art Technology of Advanced oxidation process using Ozone in water and industrial wastewater treatment – A first of its kind treatment system in India*'. In his lecture, he talked about the technical and environmental challenges in water and wastewater treatment with contaminants such as high salinity, turbidity, colour, etc. that resulted in development of a new state-of-art advanced oxidation process, membrane system, and recovery of quality water for reuse. These technological developments also become necessary in meeting stringent environmental regulations including Total Dissolved Solids (TDS), Zero Liquid Discharge (ZLD) and integration with treated domestic wastewater for sustainable treatment, reuse and disposal of residual treated effluent by meeting all discharge norms. He elaborated on the different stages of the innovative treatment system.

Afterwards, a paper titled '*Advances in membrane distillation system for water purification with the development of a pilot model*' was given by Dr. Raju Abraham, Scientist-F, National Institute of Ocean Technology (NIOT), Chennai, India. Dr. Raju talked about Membrane Distillation (MD) method which is a promising and an emerging desalination technology during the last few

years for meeting the increasing global water demand. It combines the advantages of both membrane and thermal based desalination technologies and minimizes the harmful effects such as chemical treatment, CO2 emission, etc. at the same time producing better quality water.

After this, a paper titled '*Transforming Waste to Wealth through Membrane Processes in an Eco-Friendly Manner*' was given by Dr. S. Prabhakar, Visiting Professor, SRM Institute of Science and Technology, and Ex-Head, Separation Technology Section, Desalination Division, Bhabha Atomic Research Centre, Mumbai, India. He explained the role and types of membranes and also talked about ultra-filtration, membrane distillation, and forward osmosis: passive process.

This was followed by a presentation given by Dr. Mohan TC, Assistant Professor, Faculty of Life Sciences, Division of Biotechnology and Bioinformatics, JSS Academy of Higher Education and Research, Mysore, India on '*The Intervention of Phytohormones to Reduce Arsenic Accumulation in Rice Grains*'. He pointed out the very fact that Arsenic (As) is a highly toxic metalloid to all living organisms. It has been classified as a class-I human carcinogen by the International Agency Research on Cancer (IARC). The natural occurrence of arsenic in groundwater is a worldwide problem including in north-eastern parts of India. People worldwide are affected by arsenic poisoning primarily through arsenic-contaminated drinking water. Additionally, arsenic enters the food chain because arsenic-contaminated water is used for agriculture. Rice is the major crop grown in arsenic affected regions and rice accumulates more arsenic in the grains compared to other crops. Therefore, people who use rice as their staple food are under the threat of As poisoning. He also mentioned that plants have an inherent capacity to cope with arsenic stress by producing metal-chelating peptides called phytochelatins (PCs). PCs detoxify arsenic in plants by sequestering As to the vacuole and reducing the bioavailability of arsenic. So for overcoming this problem, he suggested Bio-molecular study that would help in development of arsenic-free plants which do not absorb arsenic and thus, activating of As tolerance mechanisms and increased production of phytochelatins, which are essential for arsenic detoxification.

A presentation on '*Arsenic in groundwater: a threat to agriculture and its mitigation measures to protect the food chain*' was made by Dr. Pankaj Kumar Srivastava, Principal Scientist, CSIR – National Botanical Research Institute (NBRI), Lucknow, India. He mentioned that Arsenic in agricultural products puts human health at risk of several diseases when consuming these arsenic-laden eatables. The temporal and spatial distribution of groundwater arsenic in irrigating cultivable fields is a serious concern worldwide, especially in South-East Asian countries. Therefore, developing countries should address some specific challenges in the context such as improving mitigation approaches regarding arsenic contamination in groundwater and irrigated ecosystems. The long-term solutions and strategies would require joint interdisciplinary R&D, capacity building, and effective awareness through a diverse and integrated regional network and partnership on the subject of tackling the groundwater arsenic threat in agriculture.

After a short question-answer round, followed by a short tea break, marked the beginning of Session 7 which was chaired by Dr. Hariom Gupta, CSIR-CIMAP, India, consisting of 2 important keynote lectures by Prof. Bhaskar Sengupta, Water Technology, School of Energy, Geoscience, Infrastructure and Society, Heriot-Watt University, Edinburgh Campus, UK; and Dr. Debapriya Mondal, Global Health Centre for Clinical Education, Institute of Medical and Biomedical Education, St George's University of London, UK.

Prof. Sengupta, in his lecture on "*Soil and Water pollution from historical mining activities in San Luis Potosi (SLP), Mexico*" outlined the history of mining, the scale of pollution and possible remedial measures to reduce arsenic exposure to the local population in SLP, Mexico. He taslked

about the tailings from metallurgical processes, deposited over many years which are inherently unstable leading to arsenic and other heavy metal pollution of soil and water.

Dr. Mondal delivered a lecture on "*Significant health risks of food-based arsenic exposure and remediation options*". She pointed out that among the different routes of arsenic exposure, the greatest threat to public health is perceived to be from contaminated groundwater in endemic areas. Despite crops being irrigated and food being prepared with arsenic contaminated water in India, impact of food-based exposure is largely overlooked. She focused on three basic areas: i) exposure assessment to understand the relationships between daily arsenic intake from both food and drinking water and health risks in Bihar, India; ii) evaluation of performance of existing remediation technologies implemented in Bihar for safe drinking/cooking water and iii) recommendation of potential remediation options to have safe rice cultivation.

Followed by a Lunch Break, the last Session of the day took place. Session 8 was chaired by Dr. A. B. Panda, CSIR-National Metallurgical Laboratory, India. The session contained 5 lectures.

Dr. Purnima Jalihal, National Institute of Ocean Technology (NIOT), Goa, India, Ministry of Earth Sciences, Govt. of India presented a paper on "*Moving Away From Water Stress – The Road Ahead*". She said that India was known to be the world's largest groundwater user but now this has changed. The huge utilization has affected aquifers and the water quality. Technical and scientific solutions can help alter the situation. Climate change has now been accepted by scientists as the real issue and this is visible with the effects on water availability, frequencies of hydrologic extremes like floods and droughts. The resulting water stress can be mitigated by water conservation. A holistic view of issues, solutions and maintenance with site specific needs is required for the long term alleviation of the water stress.

Prof. Surajit Chakraborty, Environmental Technology, Department of Environment Management, Indian Institute of Social Welfare and Business Management (IISWBM), Kolkata, India presented a paper on "*Capacity building for mitigation of arsenic pollution in groundwater of Bengal basin*". He said that groundwater in the Bengal Basin is badly polluted by arsenic (As) which adversely affects human health. To provide low-As groundwater for As mitigation, detailed hydro-geological study was carried out across 235 km^2 of central West Bengal, in the western part of Bengal Basin. Drilling indicated a surficial cover of organic-poor weathered clay, light brown silty clay and sandy silt followed at depth by three different sedimentary sequences. The palaoe-interfluve (PI) aquifers are overlain by shallow palaeo-channe (SPC) aquifers of grey sand in which groundwater is usually As-polluted and is highly exploited by the local people. The Last Glacial Maximum Palaeosol now protects the PI aquifers from downward migration of As-polluted groundwater from overlying SPC aquifers. The SPC and deep palaeo-channel groundwater are also widely contaminated by waste water derived from pit latrines, septic tanks, and other methods of sanitary disposal. He also pointed out that the ability to exploit this knowledge for mitigation exists among the local drillers in the communities, who know the stratigraphy of their areas.

Dr. Saroj Sharma, CSIR-CSMCRI, India presented a paper titled "*Quest for arsenic remediation technology of drinking water: Initiative of CSIR-CSMCRI*". She talked about the membrane science and separation technology Division of CSIR-CSMCRI that has been working in a variety of diverse and highly applied research areas focused on the primary issue of 'Water' for five decades. Significant contributions have been made to develop resins, adsorbents, charged membranes (ion exchange membranes), pressure driven membrane (RO, UF, MF, NF) and hollow fibre membranes to tackle water related issues.

The last two presentations were made by Ms. Prerana Sharma, CSIR-CSMCRI on "*An energy efficient and continuous electrochemical process using halophyte derived bio-adsorbent for selective trace removal of Hg2+/As3+/5+ from water system*"; and by Ms. J Juliana, National Institute of Technology, Calicut, Kerala, India on "*An integrated Nanofiltration-Membrane Distillation (NF-MD) process for the treatment of saline oily wastewater*".

In the Concluding Session, Dr. V.K. Shahi thanked Dr. Kannan Srinivasan, Director, CSMCRI and Dr. Amitava Bandopadhyay, DG, NAM S&T Centre for their efforts and inputs for giving everyone a platform to discuss on the very important topic of Arsenic Contamination. He especially thanked the NAM S&T Centre for this collaboration, due to which the CSIR-CSMCRI could organize its first scientific event in hybrid mode after the pandemic.

Dr. Bandopadhyay in his closing remarks thanked everyone who participated in the Workshop, specially the Chief Guest – Padma Shri Prof. T. Pradeep, and the Keynote and other Speakers for sharing their knowledge. He further expressed his gratitude and appreciation for Dr. Kannan Srinivasan, Dr. V. K. Shahi, Dr. Vaibhav, and other colleagues from CSIR-CSMCRI for successfully organizing the Joint International Workshop on such an important topic. He expressed his appreciation for Mr. Madhusudan Bandyopadhyay, Senior Adviser, Ms. Nidhi Utreja, Programme Officer (Coordinator – G-77 project), Mr. Rahul Kumra, Private Secretary to DG and other colleagues from the NAM S&T Centre for their dedication and hard work in ensuring participation of an impressive number of scientists and experts from developing as well as developed countries and making this Workshop a great success.

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INTERNATIONAL WORKSHOP

on

"Water Purification Technologies, Arsenic Removal from Groundwater and Integrated Water Management (IWWPT-2022)"

(Hybrid-Mode)

28-30 June, 2022

PROGRAM SCHEDULE

DAY 1: 28 June, 2022		
TIME [Indian Time] (GMT+ 5.5 hrs.)	**PROGRAMME**	
INAUGURAL SESSION		
11:00 AM - 11:10 AM	**Introduction and Welcome** by **Dr. Vinod K. Shahi**, Chief Scientist/Divisional Chair, Membrane Science & Separation Technology Division, CSIR-CSMCRI, Bhavnagar, India	
11:10 AM - 11:20 AM	**Welcome Address** by **Dr. Amitava Bandopadhyay**, Director General, Centre for Science & Technology of the Non-Aligned and Other Developing Countries (NAM S&T Centre), New Delhi, India	
11:20 AM - 11:30 AM	**Inaugural Address** by **Dr. Kannan Srinivasan**, Director, Council of Scientific and Industrial Research-Central Salt & Marine Chemicals Research Institute (CSIR–CSMCRI), Bhavnagar, India	
11:30 AM - 11:40 AM	**Address** by **Padma Shri Prof. Pradeep, T.**, Indian Institute of Technology Madras, Chennai, India	
TEA BREAK (11:40 AM - 12:00 AM)		
12:00 AM - 01:00 PM	**Inaugural Lecture** by **Padma Shri Prof. Pradeep, T.**, Indian Institute of Technology Madras, Chennai, India **Affordable clean water using advanced materials**	
LUNCH BREAK (01:00 PM -02:00 PM)		
SESSION–I **Keynote Lectures** ***Session Chair***: **Prof. D. Mohan**, Anna University, Chennai, India		
02:00 PM - 02:45 PM	**Dr. Pradip Kumar Tewari,** Visiting Professor, Indian Institute of Technology, Jodhpur, India	*Sustainable Water: Challenges and Opportunities*

02.45-03.30 PM	**Dr. Dipankar Saha**, Former Member, Central Groundwater Board, Ministry of Jal Shakti, Government of India, New Delhi, India	*Aquifer-based water supply in groundwater dependent arsenic contaminated areas*
03:30 PM - 04:15 PM	**Dr. Pawan Kumar Labhasetwar**, Chief Scientist & Head, Water Technology and Management Division, CSIR-National Environmental Engineering Research Institute, Nagpur, India	*The Conundrum of Water Treatment – Reality and Priority*
TEA BREAK (04:15 PM- 04:30 PM)		
SESSION–II ***Session Chair*** : **Dr. Pawan Kumar Labhasetwar**, CSIR-NEERI, Nagpur		
04:30 PM - 04:45 PM	**Ms. Mya Thandar Khin** Assistant Director, Environmental Conservation Department, Ministry of Natural Resources and Environmental Conservation, Myanmar	*Arsenic contamination in groundwater and food and remediation measures in Myanmar* **(Virtual)**
04:45 PM - 05:00 PM	**Mr. Zulhelmi Bin Kasim** Senior Executive, Ministry of Environment and Water, Malaysia	*Water Pollution in Malaysia* **(Virtual)**
05:00 PM - 05:15 PM	**Prof. Kissao GNANDI** Géologie - Géosciences Envir. et Hydrogéologie, Dpt de Géologie, Faculté des Sciences, Université de Lomé, Togo	*The contamination of Lake-Togo and Aného Lagoon complex (Southern Togo) by trace metal caused by the dumping of phosphorite mining wastes* **(Virtual)**
05:15 PM - 05:30 PM	**Dr. Yacouba SANOU** Enseignant-chercheur, University Joseph KI-ZERBO, EDST // LCAEBiO, Burkina Faso	*Arsenic Contamination from Water in Burkina Faso: Overview, Mitigation and Perspectives* **(Virtual)**
05:30 PM - 05:45 PM	**Prof. Enas Aboutaleb** Former Chief Executive Officer, Egyptian Environmental Affairs Agency (EEAA), Ministry of Environment; Prof. of Wastewater Treatment Technologies, Water Research and Pollution Control Department, Environmental Science Division, National Research Centre (NRC), Egypt	*Status of Arsenic in Groundwater in Egypt Aspect for Future* **(Virtual)**

05: 45 PM - 06:00 PM	***Joint Paper*** by – **Dr. Subhi Abed Al- kader Samhan** Director Research and Development Palestinian Water Authority, Palestine; **Dr. Bayan khalaf** Assistant Professor - Chemistry Arab American University , Jenin, Palestine; and **Prof. Shehdeh Jodeh** Professor An-Najah N University, Palestine	*Novel Cellulose-Based Hectocycle Nanopolymers for Arsenic Removal from Groundwater* (**Virtual**)
06: 00 PM - 06: 15 PM	**Dr. A.G. Piyal Aravinna** Chemical & Environmental Section CECBLS, Central Engineering Consultancy, Sri Lanka	*Arsenic in Water, Soil and Food in Sri Lanka* (**Virtual**)
DAY 2: 29 June, 2022		
TIME [Indian Time] (GMT+ 5.5 hrs.)	**PROGRAMME**	
SESSION–III ***Session Chair*** : **Mr. Swachchha Majumdar**, CSIR-CGCRI, Kolkata, India		
10:00 AM - 10:40 AM	**Dr. Sridhar S.** Chief Scientist, Indian Institute of Chemical Technology, Hyderabad, India	*Innovations in Membrane Science & Technology for Combating Water Scarcity and Covid-19 Pandemic*
10:40 AM - 11:20 AM	**Prof. D. Mohan** Anna University, Chennai, India	*Emerging Membrane Technology processes in Water Desalination with reduced Carbon foot print*
TEA BREAK 11.20-11.40 AM		
11:40 AM - 12:10 PM	**Dr. Kunal Kanti Majumdar** Professor of Public Health, KPC Medical College, Kolkata, India	*Arsenic contamination of groundwater and its impact on Health*
12:10 PM - 12:40 PM	**Prof. Anurag Mudgal** Department - Mechanical, School of Technology, Pandit Deendayal Energy University, Ahmedabad, India	*Feasibility and parametric studies of thermal energy driven MED and RO systems for brackish water treatment*
12: 40 PM - 01:10 PM	**Dr. Santanu Karan**, CSIR-CSMCRI, Bhavnagar, India	*Polymer Nanofilm Composite Membranes for Ionic and Molecular Separation*
OFFICIAL LUNCH (01:10 PM -02:00 PM)		
SESSION–IV ***Session Chair*** : **Dr. Sridhar S.**, CSIR-IICT, Hyderabad, India		

02:00 PM - 02:30 PM	**Prof. David Polya** FSE Associate Dean for Internationalisation, Professor of Environmental Geochemistry, Dept. of Earth and Environmental Sciences, The University of Manchester, UK	*Groundwater Arsenic in India – Distribution, Impacts & Remediation Perspectives* (**Virtual**)
02:30 PM - 03:00 PM	**Dr. Neelima Alam** Department of Science & Technology, Ministry of Science and Technology, India	*DST's water interventions and it's impacts* (**Virtual**)
03:00 PM - 03:30 PM	**Prof. Punyasloke Bhadury** Department of Biological Sciences, Centre for Climate and Environmental Studies, Indian Institute of Science Education and Research (IISER), Kolkata, India	*Biogeochemistry of arsenic cycling - translating microbial responses towards As-free potable water* (**Virtual**)
03:30 PM - 03:45 PM	**Dr. P. S. Navaraj** Former Associate Professor, Dean and Principal; Water Researcher, Global Care Foundation, Madurai, India	*Current researches of Arsenic removal in water – A review* (**Virtual**)
03:45 PM - 04:00 PM	**Dr. Lalit Mohan Sharma** Principal Scientist, Water Research and Training Water Researcher, S M Sehgal Foundation, Gurugram, India	*Arsenic Removal in Groundwater* (**Virtual**)
TEA BREAK (04:00 PM- 04:20 PM)		
SESSION–V **Presentations by Participants** ***Session Chair*** : **Dr. Kunal Kanti Majumdar**, Professor, KPC Medical College, Kolkata, India		
04:20 PM - 04:35 PM	**Dr. Eng Ahmad Shoiful** Junior Engineer, Research Center of Environment and Clean Technology, The National Research and Innovation Agency (BRIN), Indonesia	*Arsenic contamination in Indonesia* (**Virtual**)
04:35 PM - 04:50 PM	**Dr. Rabelani Mudzielwana** Senior Lecturer, University of Venda, South Africa	*Synthesis of inorgano-organo modified kaolin clay for As(III) and As(V) removal from groundwater* (**Virtual**)
04:50 PM - 05:05 PM	**Dr. Chander Kumar Singh** TERI School of Advanced Studies, New Delhi, India	*Business of Poison: Willingness of rural households to have their groundwater well tested for arsenic for a fee* (**Virtual**)

05:05 PM - 05:20 PM	**Dr. N C Mondal** Principal Scientist, Earth Process Modeling Group & Assoc. Prof., Academy of Scientific & Innovative Research (AcSIR), CSIR – National Geophysical Research Institute (NGRI), Hyderabad, India	*Assessing hazards of arsenic leakage in multi-layered aquifer system in a part of Middle Ganga Plains, Northern India* (**Virtual**)
05:20 PM - 05:35 PM	***Joint Paper*** by – **Ms. Dilini Saumya Samarahewa** Deputy Principal, Sanghamiththa Balika Vidyalaya, Wackwella Road, Galle, Sri Lanka; and **Dr. Chamila Dias** Senior Lecturer, Centre for Environmental Studies & Sustainable Development (CESSD), The Open University of Sri Lanka, Sri Lanka	*Desalination of Sea Water using various sources of Activated Carbon* (**Virtual**)
05:35- 06:30 PM	**POSTER PRESENTATIONS**	
DAY 3: 30 June, 2022		
TIME [Indian Time] (GMT+ 5.5 hrs.)	**PROGRAMME**	
SESSION–VI ***Session Chair*** : **Dr. Noel Jacob Kaleekkal**, NIT, Calicut, India		
09:30 AM - 10:05 AM	**Mr. Swachchha Majumdar** Membrane and Separation Technology Division, CSIR-Central Glass & Ceramic Research Institute, Kolkata, India	*Ceramic Membranes and applications purification of ground water for decontamination of Arsenic and Iron [Invited Lecture]*
10:05 AM - 10:40 AM	**Dr. S. Prabhakar**, Visiting Professor SRM Institute of Science and Technology, Ex-Head, Separation Technology Section, Desalination Division, BARC	*Transforming Waste to Wealth through Membrane Processes in an Eco-Friendly Manner [Invited Lecture]* - (**Virtual**)
10:40 AM-10:55 AM	**Dr. S. Rajamani** Technical Expert - Environmental Engineering, UNIDO; & Chairman - Asian International Union of Environment (AIUE) Commission, Chennai, India	*State-of-the-Art Technology of Advanced oxidation process using Ozone in water and industrial wastewater treatment – A first of its kind treatment system in India* (**Virtual**)

10:55 AM - 11:10 AM	**Dr. Raju Abraham** Scientist-F, National Institute of Ocean Technology (NIOT), Chennai, India	*Advances in membrane distillation system for water purification with the development of a pilot model* (**Virtual**)
11:10 AM - 11:25 AM	**Dr. Mohan TC** Assistant Professor, Faculty of Life Sciences, Division of Biotechnology and Bioinformatics, JSS Academy of Higher Education and Research, Mysore, India	*The Intervention of Phytohormones to Reduce Arsenic Accumulation In Rice Grains* (**Virtual**)
11:25 AM - 11:40 AM	**Dr. Pankaj Kumar Srivastava** Principal Scientist, CSIR – National Botanical Research Institute (NBRI), Lucknow, India	*Arsenic in groundwater: a threat to agriculture and its mitigation measures to protect the food chain* (**Virtual**)
TEA BREAK (11:40 AM- 12:00 AM)		
SESSION–VII ***Session Chair*** : **Dr. Hariom Gupta,** CSIR-CIMAP, Lucknow, India		
12:00 PM - 12:30 PM	**Prof. Bhaskar Sengupta** Water Technology, School of Energy, Geoscience, Infrastructure and Society, Heriot-Watt University, Edinburgh Campus, UK	*High Arsenic and Heavy Metal Remediation from Groundwater in Mining Areas: A Case Study of Matehuala Mines in Mexico* (**Virtual**)
12:30 PM - 01:00 PM	**Dr. Debapriya Mondal** Global Health Centre for Clinical Education, Institute of Medical and Biomedical Education, St George's, University of London, UK	*Significant health risks of food-based arsenic exposure and remediation options* (**Virtual**)
OFFICIAL LUNCH (01:00 PM -02:00 PM)		
SESSION– VII ***Session Chair*** : **Dr. A. B. Panda**, CSIR-NML, Jamshedpur, India		
02:00 PM - 02:30 PM	**Dr. Purnima Jalihal** National Institute of Ocean Technology (NIOT), Ministry of Earth Sciences, Govt. of India, India	*Moving Away From Water Stress – The Road Ahead* (**Virtual**)
02:30 PM- 02:45 PM	**Oral Presentations**	
02:45 PM- 03:00 PM		
03:00 PM - 03:15 PM		
03:15 PM - 03:30 PM		

03:30 PM - 04:00 PM	**Prof. Surajit Chakraborty** Environmental Technology, Department of Environment Management, Indian Institute of Social Welfare and Business Management (IISWBM), Kolkata, India	*Capacity building for mitigation of arsenic pollution in groundwater of Bengal basin* (**Virtual**)
04:00 PM - 04:30 PM	**Dr. (Mrs.) Saroj Sharma** CSIR-CSMCRI, India	*Quest for arsenic remediation technology of drinking water: Initiative of CSIR-CSMCRI*
04:30 PM - 05:00 PM	**CONCLUDING SESSION**	
HIGH TEA		

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Annex – II

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أكاديمية البحث العلمي والتكنولوجيا
Academy of Scientific Research & Technology

International Training Programme on Low Cost Technologies for Arsenic Removal from Groundwater

Cairo, Egypt
5-6 September 2023

TRAINING REPORT

A Part of the Multilateral Collaborative Project Entitled
"Reducing Arsenic Exposure from Food and Water in Developing Countries – A Roadmap for Technological Solutions for the Future"
with partial financial support from
G - 77 under the Perez-Guerrero Trust Fund (PGTF)



TABLE OF CONTENTS

1. Brief Report of Training Programme 2

2. Final Programme Agenda 9

3. List of Participants 13

   - Egyptian Participants and Other Local Attendees
   - NAM S&T Sponsored Foreign Participants
   - Online Invited Speakers
   - Organizers and Organizing Committee

INTERNATIONAL TRAINING PROGRAMME
ON
LOW COST TECHNOLOGIES FOR ARSENIC REMOVAL FROM GROUNDWATER

5-6 SEPTEMBER, 2023
CAIRO, EGYPT

BRIEF REPORT

Arsenic in drinking water is a widespread global concern. Chronic arsenic exposure is associated with many human health risks, including skin lesions and cancers of the liver, lung, bladder and skin and with many non-cancer health conditions, such as cardiovascular diseases, adverse reproductive outcomes, neurological disorders and impaired cognitive development in children. Due to the lack of awareness about the problem, the silent presence of higher arsenic content in groundwater left unnoticed and is creating a latent magnification of the problem in the many Asian, African and other developing countries.

Considering this serious problem of arsenic contamination of groundwater, a multilateral collaborative project entitled "Reducing Arsenic Exposure from Food and Water in Developing Countries – A Roadmap for Technological Solutions for the Future" is being implemented by the *Centre for Science and Technology of the Non-Aligned and Other Developing Countries (NAM S&T Centre), New Delhi, India* with partial financial support from G-77 under the Perez-Guerrero Trust Fund (PGTF) for South-South Cooperation. The project aims to cope with the serious consequences of arsenic contamination of groundwater in developing countries and suggest low-cost treatment technologies for the removal of arsenic from groundwater, in order to minimize its exposure through contaminated food and water sources. The implementation of the project is being coordinated by the UN Office for South-South Cooperation (UNOSSC), New York, USA.

Earlier, under the project, the NAM S&T Centre had successfully organized an International Workshop on "Water Purification Technologies, Arsenic Removal from Groundwater and Integrated Water Management" in partnership with the CSIR-Central Salt and Marine Chemicals Research Institute, Bhavnagar, India during 28-30 June, 2022 to discuss the status of arsenic contamination of groundwater and the remedial measures available for developing countries.

The second activity under the project was an International Training Programme on "Low Cost Technologies for Arsenic Removal from Groundwater" that was organized by the NAM S&T Centre in partnership with Academy of Scientific Research and Technology (ASRT), Egypt during 5-6 September, 2023 in Cairo, Egypt. The Training Programme was organized in order to facilitate the exchange of knowledge and expertise on arsenic contamination of groundwater and capacity building of developing countries for transfer of low-cost technological solutions for removal of arsenic from groundwater and other heavy metals.

The Training Programme was attended by over 158 participants from 14 countries including **India, Indonesia, Malaysia, Mauritius, Mexico, Myanmar, Palestine, South Africa, United Arab Emirates, United Kingdom, Vietnam, Zambia and Zimbabwe** and the host country **Egypt.**

The Overall Training Programme was divided into - an Inaugural Session, 4 Technical Sessions, a Panel Discussion and a Closing Session.

Under various technical sessions 6 Keynote Training Lectures, 9 Scientific Papers and 3 Country Status Reports were presented.

The Inaugural Session started with **Welcome Remarks** by **Prof. Dr. Gina Elfeky,** Supervisor of Cultural and Scientific Sector, Academy of Scientific Research & Technology (ASRT), Cairo.Prof. Dr. Elfeky, in her address, warmly welcomed the distinguished keynote speakers, various invited guests, participants from the NAM Members and other developing countries and other local attendees from Egypt.

Following this, **Prof. Dr. Enas AbouTaleb,** Professor of Wastewater Treatment Technologies, Water Research and Pollution Control Department, Environmental Science Division, National Research Centre, Cairo gave a brief about the **Training Programme** and outlined the origin and objectives of the same and broadly described the topics to be discussed.

The **Opening Remarks** was given by **Dr. Amitava Bandopadhyay**,Director General, NAM S&T Centre, who in his address, highlighted that as an esteemed Member Country of the NAM S&T Centre - **Egypt** has held the position of the President of the Governing Council of the NAM S&T Centre in the past and currently holds the office of one of its Vice Presidents. The Centre has successfully organized several scientific programs in diverse areas of S&T with ASRT in the past and would further wish to enhance the S&T cooperation in the areas of commonality and mutual interest in the future. He further outlined the role of NAM S&T Centre in promoting South-South Cooperation in Science, Technology and Innovation for collective self reliance of developing countries and helping its Member Countries in achieving *UN Sustainable Development Goals-2030*.

Prof. Dr. Mahmoud Sakr, President, Academy of Scientific Research & Technology, Cairogave the **Presidential Address.** Prof. Dr. Sakr highlighted that the Arab Republic of Egypt (ARE) is an active Member of the NAM S&T Centre, and especially is one of the founders of the Non-Aligned Movement. The Egyptian scientific and research community has been benefitted from the cooperation with the NAM S&T Centre through ASRT. The Academy plays a major role in maximizing the benefits to Egyptian scientists and researchers through the opportunities available as a result of Egypt's Membership with the Centre. He further mentioned that the Arab Republic of Egypt has participated in the activities of the NAM S&T Centre by hosting five scientific events of the Centre from the year 2014 to 2023. A total of 75 Egyptian professors and researchers from various disciplines have participated in the programmes organized by the NAM S&T Centre since 2014. In addition, 23 Egyptian researchers and professors have won the Centre's Fellowship grants. He further underlined the new important S&T cooperation between the ASRT and NAM S&T Centre through organization of this Training Programme.

A **Vote of Thanks** was given by **Mrs. Reham Sabry** from the Academy of Scientific Research & Technology, Cairo. Mrs. Sabry thanked the organizing committee and other volunteers for their support and help for successful organization of the event.

Technical Session I - Country Status Reports on Arsenic Contamination of Groundwater

The Keynote Training Lecture 1titled "Arsenic Contamination of Water Sources in Southern Africa: A Review" was given by **Prof. Dr. Xavier Poshiwa**, Great Zimbabwe University, Masvingo **[Zimbabwe]**. In his review paper, he gave a status of arsenic contamination in water sources in Southern Africa. He mentioned that research in Africa, has reported elevated levels of As in both surface and groundwater systems. High concentrations of arsenic of up to 1760 µg/L were reported in groundwater in South Africa, 188 µg/L reported in the surface water in Botswana, 96 µg/L in surface water in Eastern Zimbabwe and 119 µg/L in surface water in South Africa. He observed that the anthropogenic activities and geogenic sources are the major causes of elevated arsenic levels particularly in soils and water within the Southern Africa region, and more efforts are needed for removal of the metal from both surface and groundwater systems to curb the effects of arsenic toxicity.

The Country Status Report 1titled "Groundwater Pollution with Arsenic in Palestine: Sources, Adverse Effects and Purification Techniques" was presented by **Dr. Bayan Khalaf**, Arab American University, Jenin **[Palestine]**. In her presentation, Dr. Khalaf, indicated that the main sources of groundwater pollution in Palestine included agricultural activities, the discharge of untreated wastewater from domestic and industrial sources and non-engineered landfill sites. This can virtually affect all living organs including dermatologic, cardiovascular, hepatobiliary, nervous, renal, respiratory and gastrointestinal systems. Furthermore, arsenic accumulation can significantly increase standardized mortality rates for kidney, bladder, liver, and skin cancer. Many methods are suggested for purifying water from arsenic, including but not limited to, membrane technology, co-precipitation, reverse osmosis, oxidation and ion exchange. However, adsorption is considered to be one of the most promising techniques for arsenic removal.

The Country Status Report 2 titled "Removal of Arsenic Contamination in Water: Affordable and Low Cost Technologies for Developing Countries" was presented by **Dr. Shivaraju H.P.**, JSS Academy of Higher Education & Research, Mysuru, Karnataka **[India]**. In his presentation, Dr. Shivaraju, mentioned that most of the arsenic contamination of groundwater and surface water in Indian regions is by the alluvial terrain (90%), hard rock terrain and anthropogenic activities. Some of the low-cost and affordable technologies like solar oxidation and precipitation, coagulation and filtration, sorption processes, etc. (by using indigenous materials like lime, charcoal, sand, natural clay, etc.) can reduce the arsenic levels. Advanced arsenic removal technologies like ultra-filtration and nano-filtration, solar-based advanced oxidation, photocatalysis, bioremediation, etc. combined with the existing conventional treatment processes can be a possible technological framework to reduce arsenic poisoning in India.

A presentation on Country Status Report 3 titled "Challenges and Opportunities in Monitoring of Arsenic in Food and Water for Mauritius" was given by **Prof. Kishore Boodhoo**, University of Mauritius, Réduit **[Mauritius].** In his presentation, Prof. Boodhoo, addressed various factors related to: (a) sources of arsenic, including hotspots and actions taken by the government of Mauritius in terms of policies; (b) challenges of monitoring of arsenic in food and water in terms of access to equipment and training of personnel and (c) opportunities in overcoming arsenic contamination in terms of access to both knowledge and equipment as well as sensitizing the public to be able to reduce the risk of adverse effects associated with arsenic.

Technical Session II- Desalination and Water Treatment Technologies

The Keynote Training Lecture 2 titled "New Technologies for Water Desalination" was given by **Prof. Dr. Abdel-Hammed M. El-Asar**, Egypt Desalination Research Centre of Excellence (EDRC), Desert Research Centre **[Egypt].**

The Paper Presentation 1 titled "Fabrication of Low Cost Antibacterial Hybrids Based on Local Resources for Water Treatment" was given by **Prof. Dr. Hossam El Nazer**, National Research Centre, Cairo **[Egypt]**.The main objective of his research study was to use new advanced technologies to treat the polluted water. The study estimated the extent of groundwater pollution in Siwa Zone of Egypt based on the detection of heavy metals, organic compounds and bacteriological contaminants. Through the application of advanced methods of water treatment along with using environmentally friendly materials and oxidation treatment process, the water was treated.

The Paper Presentation 2 titled "Cost Effective Coagulation Clarification Using Iron-Based Polymeric Coagulant for Arsenic Removal from Water Resources" was given by **Prof. Dr. Hanan Ibrahim Abdel Rahman**, National Research Centre, Cairo **[Egypt]**. In her presentation, Prof. Dr. Ibrahim summarized that iron-based polymeric coagulant (IBPC) is a promising coagulant - as cost-effective material for decontamination of groundwater from arsenic. Further post-treatment could be employed with IBPC-based coagulation for obtaining USEPA and WHO arsenic standards for drinking water.

The Paper 3 titled "Innovative Water Solutions: Advanced Treatment Systems Shaping the UAE's Water Future" was presented by **Dr. Badr Mohamed,** Technology Innovation Institute (TII), Abu Dhabi **[UAE]**.In his presentation, Dr. Mohamed highlighted that water scarcity is a pressing global concern, particularly in arid regions like UAE. He discussed some innovative approaches and advanced technologies that the UAE has embraced to tackle its water scarcity challenges. Focusing on three key aspects - desalination, atmospheric water harvesting, and sludge management, he briefed on how these systems are reshaping the UAE's water landscape. By integrating these advanced systems, the UAE is demonstrating a holistic approach to water resource management.

The Paper Presentation 4 titled "Desalination Technology to Solve Africa's Water Crisis" was made by **Dr. Sumaya Clarke**, University of the Western Cape, Cape Town **[South Africa]**. Dr. Clarke summarized that the desalination technologies applied in the coastal towns of South Africa were sufficient to alleviate the effects of drought like conditions.Cape Town and many other cities in South Africa are adopting an integrated approach for water management including drilling of wellfields, managing aquifer recharge, water reuse - where aquifers are recharged with the treated wastewater and desalination, as an additional source.

Technical Session III - Arsenic Contamination of Food and Water: A Serious Global Public Health Risk

The Keynote Training Lecture 3 titled "Arsenic in the Food Chain: Causes and Health Risks" was virtually given by **Prof. Bhaskar Sengupta**, OBE, Heriot-Watt University, Edinburgh, Scotland **[United Kingdom]**.He highlighted that high levels of arsenic in crops grown in arsenic endemic areas of the world pose serious health risks to humans. The crops and dairy products produced in those areas are often sold globally resulting in health risks to other communities. Added to the health risks are lower crop yields and poor nutritional values of the crops. Hence, safe irrigation water and uncontaminated soil are essential for safe crop production.

The Paper Presentation 5 titled "Health Issues due to Arsenic Contamination" was given by **Prof. Dr. Aly Mohamed Ezz El-Arab Aly**, National Research Centre, Cairo **[Egypt]**. In his presentation, Prof. Dr. El-Arab, discussed the major health complications associated with arsenic toxicity. He indicated that long-term exposure to arsenic increases the risks of non-communicable diseases such as cardiovascular diseases, diabetes, skin lesions, pigmentation and cancer. Poor cognitive function and increased teenage mortality may arise from exposure to arsenic in early childhood. Due to the absence of safe and efficient therapeutic management, treating As-induced diseases is challenging. He concluded that plant origin and natural dietary compounds assume a positive role in arsenic detoxification without any side effects.

Technical Session IV – Low-Cost Treatment Technologies for Removal of Arsenic, Iron, Fluoride and Other Toxic Heavy Metals from Groundwater

The Keynote Training Lecture 4titled "Water Purification Technologies for Arsenic Remediation of Groundwater: Perspectives from Developing World" was virtually given by **Dr. Swachchha Majumdar**, CSIR – Central Glass and Ceramic Research Institute, Kolkata **[India]**. Dr. Majumdar summarized that several technologies have been attempted for arsenic remediation with varied degrees of success rate. However, apart from scientific and technological issues, there are several other factors which affect the practical applications and feasibilities of these technologies. Some of the technologies that are very pertinent to the developing countries can be: membrane technologies; nano-material based arsenic remediation, zero valent ion process etc. Membrane contactors can be a very good option for oxidation of Arsenite to Arsenate for easier remediation. Also nano-particle embedded nano-filtration process has got potential for becoming a successful arsenic remediation technology.

The Paper Presentation 6 titled "Remediation of Arsenic in Polluted Water Using Microalgae: Current Applications and Future Perspectives" was jointly given by **Prof. Dr. Sayeda Mohamed Abdo** and **Dr. Reda Mohamed Moghazy**, National Research Centre, Cairo **[Egypt]**. They togetherdiscussed "Algae" as a green technology for removal of heavy metals. Arsenic sorption by algae has a great potential in As-bioremediation in aquatic systems because it is environmentally-friendly and has high removal efficacy. Many species of Cyanobacteria and phytoplankton are tolerant against high levels of aqueous As species. Algae biomass, in general, is an efficient adsorbent of heavy metals. Bio-treatment with microalgae is particularly attractive because of their photosynthetic capabilities, converting solar energy into useful biomasses and incorporating nutrients such as nitrogen and phosphorus causing eutrophication. Also, algae based systems for the removal of toxic minerals such as lead, cadmium, mercury, scandium, tin, arsenic and bromine are also being developed. However, there are still some concerns and obstacles that need to be overcome in order to achieve commercial and economic success**.**

Paper Presentation 7 titled "The Potential of Vacuum Membrane Distillation Technology for the Removal of Arsenic from Water" was given by **Prof. Dr. Elham El Zanati**, National Research Centre**,** Cairo **[Egypt].** Prof. El Zanati spoke about vacuum membrane distillation (VMD) that allows complete removal of As from an aqueous solution. She also highlighted the recent developments in VMD designs, membrane modules, membrane materials and membrane preparation methods used for As removal. Limitations, challenges, and opportunities of VMD systems for As removal were also highlighted. It was concluded that using super hydrophobic polymeric membranes, the VMD systems can efficiently remove As (III) and As (V) with 100% As rejection.

The Paper Presentation 8 titled "Development of Low Cost Ceramic Membrane for Arsenic Removal from Water" was jointly given by **Dr. Mohd Riduan Bin Jamalludin** and **Dr. Siti**

Khadijah Hubadillah, Universiti Malaysia Perlis (UniMAP), Perlis **[Malaysia].** Together they introduced an integrated system of direct contact membrane distillation (DCMD) and microalgae bioremediation for green removal of arsenic from the polluted river water (Pengorak River, Pahang, Malaysia). The findings of their study showed that Botryococcus sp. successfully grew in the retentate with a common microalgae growth pattern during the 20 days test period, which indicated the potential and feasibility of this integrated system for the arsenic retentate management.

Paper Presentation 9 titled "Food Toxicity Caused by Transfer of Arsenic through Groundwater Irrigation: A Review" was given by **Dr. Shepherd Manhokwe**, Midlands State University, Gweru **[Zimbabwe].** Dr. Manhokwe provided a comprehensive review of the food toxicity caused by transfer of arsenic through groundwater irrigation. He discussed various species of arsenic, food systems and irrigation practices. In addition, he discussed the potential health risks associated with exposure to arsenic as well as the occurrence and consumption of arsenic in irrigated crops.

Keynote Training Lecture 5titled "Arsenic Remediation Technologies for Community-Level Water Supply" was virtually given by Prof. Bhaskar Sengupta, OBE, Heriot-Watt University, Edinburgh, Scotland **[United Kingdom]**. He highlighted that sustainable treatment of groundwater containing high arsenic concentrations poses a serious challenge. The common methods like adsorption, membrane filtration and ion-exchange methods produce waste streams containing much higher levels of Arsenic than those present in the feed stream. The lack of safe disposal facilities remains the key hurdle to the implementation of such technologies. The Subterranean Arsenic Removal (SAR) technology which is free from chemical use and waste generation offers a viable alternative to aforesaid methods. The technology is scalable, and it offers an adaptable alternative to conventional treatment methods.

Keynote Training Lecture 6titled "The Contamination of Water and Soil from the Dissolution of As-bearing Mineral Waste in Matehuala, Mexico" was virtually given by **Ms. Nadia Martínez-Villegas**, Camino a la Presa San Jose **[Mexico]**.In her work, highly contaminated soil samples from the area were studied to determine total As concentrations in shallow and deep soils and to identify and characterize As-bearing minerals and their solubility behavior. Results showed that soil samples contained up to 4.2% As and the mineralogy consisted mainly of calcite, gypsum, and quartz. Additionally, As was adsorbed on ferrihydrite. Soil fractionation analysis showed that up to 74% of total As was present in the most mobile fractions, e.g., soluble, exchangeable, phosphate absorbable and slightly reducible.

Each of the Technical Sessions was followed by a Discussion and Q&A round.

Panel Discussion on Low Cost Technologies for Arsenic Removal from Groundwater

In order to facilitate an exchange of viewpoints and experience among the experts and in response to questions from the participants, a Panel Discussion on "Low-Cost Treatment Technologies for Arsenic Removal from Groundwater" was held amongst the panel members and with the participants.

The Panel Members included: (i) Prof. Dr. Enas Abou Taleb [Egypt]; (ii) Prof. Hanan Ibrahim Abdel Rahman [Egypt]; (iii) Dr. Farag Samah [Egypt]; (iv) Dr. Kishore Boodhoo [Mauritius]; (v) Dr. Shepherd Manhokwe [Zimbabwe] and (vi) Dr. Swachchha Majumdar [India].

It was discussed that presence of elevated levels of arsenic in groundwater has become a major concern for most of the countries globally.Although arsenic contamination of water sources

have been reported in a number of developing countries, the contamination scenario in some of the South East Asian and African Countries appears to be worse than others, both in terms of area and population affected.Arsenic pollution of groundwater is particularly challenging for these countries since tube well water extracted from shallow aquifers is the major source of drinking water for most of its population.There are many treatment technologies available for removal of arsenic from groundwater including membrane technology, co-precipitation, reverse osmosis, oxidation and ion exchange, adsorption, Subterranean Arsenic Removal (SAR) technology etc.However, further research is needed to improve real time field testing and monitoring of the drinking water sources, to develop new and cost effective arsenic remediation technologies along with finding new sources of safe drinking water.

The **Closing Session** was chaired by Prof. Dr. Gina Elfeky, ASRT, [Egypt] and Dr. Amitava Bandopadhyay, NAM S&T Centre, [New Delhi]. It was concluded that expanding international cooperation and extending capacity building support to developing countries in water related programmes such as desalination, water efficiency, wastewater treatment, recycling and reuse technologies will help the arsenic affected communities against its detrimental impacts on human health and environment as well as to achieve SDG-6 on access to safe and clean drinking water.

The Chairpersons thanked all the keynote speakers and other participants from various countries for their active engagements in the deliberations in various sessions and successful organization of the International Training Programme.

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INTERNATIONAL TRAINING PROGRAMME
ON
LOW COST TECHNOLOGIES FOR ARSENIC REMOVAL FROM GROUNDWATER

5-6 SEPTEMBER, 2023
CAIRO, EGYPT

PROGRAMME AGENDA

Day-0, Monday, 4 September 2023

Arrival of Delegates in Cairo, Egypt

Venue of Training Programme: Grand Nile Tower, Cairo, Egypt

Day-1, Tuesday, 5 September 2023

Egyptian Time (GMT+03 hrs.)	Programme Details
09:30 am – 10:00 am	**Registration and Technical Connectivity Check by the Egyptian Host (Testing Phase)**
Inaugural Session	
10:00 am – 10:10 am	**Welcome Remarks by Prof. Dr. Gina Elfeky,** Supervisor of Cultural and Scientific Sector, Academy of Scientific Research & Technology **[Egypt]**
10:10 am – 10:15 am	**About the Training Programme by Prof. Dr. Enas AbouTaleb,** Prof. of Wastewater Technologies, Water Research and Pollution Control Dept., Environmental Science Division, National Research Centre **[Egypt]**
10:15 am – 10:30 am	**Opening Remarks by Dr. Amitava Bandopadhyay,** Director General, Centre for Science & Technology of the Non-Aligned and Other Developing Countries (NAM S&T Centre), New Delhi **[India]**
10:30 am – 10:50 am	**Presidential Address by Prof. Dr. Mahmoud Sakr,** President, Academy of Scientific Research & Technology (ASRT) **[Egypt]**
10:50 am – 11:00 am	**Vote of Thanks by Mrs. Reham Sabry,** Master of Ceremony, Academy of Scientific Research & Technology **[Egypt]** **Group Photograph**
11:00 am – 11:30 am	**Tea Break**

Technical Session I - Country Status Reports on Arsenic Contamination of Groundwater	
11:30 am – 12:00 pm	**Keynote Training Lecture 1 – Arsenic Contamination of Water Sources in Southern Africa : A Review** by Prof. Xavier Poshiwa, Great Zimbabwe University, Masvingo **[Zimbabwe]**
12:00 pm – 12:15 pm	**Country Status Report 1** by Dr. Bayan Khalaf, Assistant Professor of Chemistry, Arab American University, Jenin **[Palestine]**
12:15 pm – 12:30 pm	**Country Status Report 2** by Dr. Shivaraju H.P, Associate Professor and Coordinator, Department of Environmental Sciences, JSS Academy of Higher Education & Research, Mysuru, Karnataka **[India]**
12:30 pm – 12:45 pm	**Country Status Report 3** by Prof. Kishore Boodhoo, Associate Professor, Department of Chemistry, Faculty of Science, University of Mauritius, Réduit **[Mauritius]**
12:45 pm – 01:00 pm	**Discussion and Q&A**
01:00 pm – 02:00 pm	**Lunch Break**
Technical Session II- Desalination and Water Treatment Technologies	
02:00 pm – 02:30 pm	**Keynote Training Lecture 2 – New Technologies for Water Desalination** by Prof. Dr. Abdel-Hammed M. El-Asar, Prof. of Water Chemistry and Water Desalination, Hydrochemistry Dept. & Central Lab, Egypt Desalination Research Center of Excellence (EDRC), Desert Research Centre **[Egypt]**
02:30 pm – 02:45 pm	**Paper Presentation 1 –Fabrication of Low Cost Antibacterial Hybrids Based on Local Resources for Water Treatment** by Prof. Dr. Hossam Eldin Abdel Fattah Elnazer, Professor of Water Technology & Renewable Energy, Chemical Industries Research Institute, National Research Centre **[Egypt]**
02:45 pm – 03:00 pm	**Paper Presentation 2 – Cost Effective Coagulation Clarification Using Iron-Based Polymeric Coagulant for Arsenic Removal from Water Resources** by Prof. Dr. Hanan Ibrahim Abdel Rahman, National Research Centre **[Egypt]**
03:00 pm – 03:15 pm	**Paper Presentation 3 – Innovative Water Solutions: Advanced Treatment Systems Shaping the UAE's Water Future** by Dr. Badr Mohamed, Senior Researcher, Technology Innovation Institute (TII), Abu Dhabi **[UAE]**
03:15 pm – 03:30 pm	**Paper Presentation 4 – Desalination Technology to Solve Africa's Water Crisis** by Dr. Sumaya Clarke, Senior Lecturer, Environmental and Water Science, Earth Science Department, Faculty of Natural Science, The University of the Western Cape, Bellville Cape Town **[South Africa]**
03:30 pm – 03:45 pm	**Discussion and Q&A**
End of Day 1	

Day-2, Wednesday, 6 September 2023

Technical Session III - Arsenic Contamination of Food and Water : A Serious Global Public Health Risk	
10:00 am – 10:30 am	**Keynote Training Lecture 3 – Arsenic in the Food Chain : Causes and Health Risks** by Prof. Bhaskar Sen Gupta, OBE, Professor in Water Technology, Heriot-Watt University, Edinburgh, Scotland **[United Kingdom] – Online**
10:30 am – 10:45 am	**Paper Presentation 5 – Health Issues due to Arsenic Contamination** by Prof. Dr. Aly Mohamed Ezz El-Arab Aly, Nutrition & Food Science Department, National Research Centre **[Egypt]**
10:45 am – 11:00 am	**Discussion and Q&A**
11:00 am – 11:30 am	**Tea Break**
Technical Session IV – Low-Cost Treatment Technologies for Removal of Arsenic, Iron, Fluoride and Other Toxic Heavy Metals from Groundwater	
11:30 am – 12:00 pm	**Keynote Training Lecture 4 – Water Purification Technologies for Arsenic Remediation of Groundwater : Perspectives from Developing World** by Dr. Swachchha Majumdar, Chief Scientist, CSIR – Central Glass and Ceramic Research Institute, Kolkata **[India] – Online**
12:00 pm – 12:15 pm	**Paper Presentation 6 – Remediation of Arsenic in Polluted Water Using Microalgae: Current Applications and Future Perspectives** by Prof. Dr. Sayeda Mohamed Abdo, Associate Professor, Water Pollution Research Group and Dr. Reda Mohamed Moghazy, Associate Professor, Applied Phycology, National Research Centre **[Egypt]**
12:15 pm – 12:30 pm	**Paper Presentation 7 – The Potential of Vacuum Membrane Distillation Technology for the Removal of Arsenic from Water** by Prof. Dr. Elham El Zanati, National Research Centre **[Egypt]**
12:30 pm – 12:45 pm	**Paper Presentation 8 – Development of Low Cost Ceramic Membrane for Arsenic Removal from Water** by **Dr. Mohd Riduan Bin Jamalludin,** Senior Lecturer, Universiti Malaysia Perlis, Arau, Perlis **[Malaysia]**
12:45 pm – 01:00 pm	**Paper Presentation 9 – Food Toxicity Caused by Transfer of Arsenic through Groundwater Irrigation : A Review** by **Dr. Shepherd Manhokwe,** Senior Lecturer, Food Science and Nutrition Department, Midlands State University, Gweru **[Zimbabwe]**
01:00 pm – 02:00 pm	**Lunch Break**
02:00 pm – 02:30 pm	**Keynote Training Lecture 5 – Arsenic Remediation Technologies for Community-Level Water Supply** by Prof. Bhaskar Sen Gupta, OBE, Professor in Water Technology, Heriot-Watt University, Edinburgh, Scotland **[United Kingdom] - Online**

02:30 pm – 03:00 pm	**Keynote Training Lecture 6 –The Contamination of Water and Soil from the Dissolution of As-bearing Mineral Waste in Matehuala, Mexico** by Ms. Nadia Martínez-Villegas, IPICYT, Instituto Potosino de Investigacion Cientificay Tecnologica, Division de Geociencias Aplicadas, Camino a la Presa San Jose **[Mexico] - Online**
03:00 pm – 03:15 pm	**Discussion and Q&A**
03:15 pm – 04:15 pm	**Panel Discussion on Low-Cost Treatment Technologies for Arsenic Removal from Groundwater** **Panel Members –** (i) Prof. Dr. Hanan Ibrahim Abdel Rahman [Egypt] (ii) Prof. Dr. Enas Abou Taleb [Egypt] (iii) Prof. Dr. Farag Samah [Egypt] (iv) Prof. Kishore Boodhoo [Mauritius] (v) Dr. Shepherd Manhokwe [Zimbabwe] (vi) Dr. Swachchha Majumdar [India]
Closing Session	
04:15 am – 04:30 pm	**Closing Remarks** by Prof. Dr. Gina Elfeky, ASRT [Egypt] and Dr. Amitava Bandopadhyay, NAM S&T Centre, New Delhi [India] **Vote of Thanks** by Mrs. Reham Sabry, ASRT [Egypt]
End of Day 2	

Day-3, Thursday, 7 September 2023

Departure of Delegates from Cairo, Egypt

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ON
LOW COST TECHNOLOGIES FOR ARSENIC REMOVAL FROM GROUNDWATER

5-6 SEPTEMBER, 2023
CAIRO, EGYPT

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