

Mitigation and Remedy of Groundwater Arsenic Menace in India: A Vision Document



By:

**National Institute of Hydrology, Roorkee
Central Ground Water Board, New Delhi**



Under the aegis of:

**Ministry of Water Resources
Government of India
New Delhi
June, 2010**

Contents

	<i>Page No.</i>
Disclaimer	i
Foreword	ii
Acknowledgement	iv
Abstract	vi
Contents	x
List of Figures	xv
List of Tables	xvii
Elaboration of Abbreviations	xviii

Chapter-1: Arsenic -Source, Occurrence and Geochemistry 1-8

1.1 Occurrences in Groundwater	4
1.2 Geochemistry of Arsenic	4
1.2.1 <i>Red-ox potential</i>	4
1.2.2 <i>Adsorption/ Desorption</i>	5
1.2.3 <i>Precipitation and Dissolution</i>	5
1.2.4 <i>Arsenic Speciation</i>	6
1.2.5 <i>Influence by pH</i>	6
1.2.6 <i>Influence by competing ions</i>	6
1.2.7 <i>Biological transformation</i>	6
1.3 Hypotheses on Mechanism of Arsenic Mobilization.....	7
1.4 Summary	8

Chapter-2: Arsenic Menace in India- An Appraisal 9-40

2.1 Global Arsenic Scenario.....	10
2.2 Background of Groundwater Arsenic Contamination in India (1976-2008).....	12
2.3 Magnitude of Groundwater Arsenic Contamination and its Effects on Health in Arsenic Affected States of India	17
2.3.1 <i>Impacts of arsenic on human health in chronically exposed population</i>	17
2.3.2 <i>Arsenical health effects in India</i>	18
2.3.3 <i>Other multi-systemic common features in arsenic affected areas.</i>	18
2.3.3.1 <i>State West Bengal</i>	19
2.3.3.1.1 <i>A detailed study on groundwater arsenic contamination and health..... effects situation in Murshidabad, one of the nine arsenic affected districts in West Bengal</i>	20
2.3.3.2 <i>Bihar</i>	22
2.3.3.3. <i>Uttar Pradesh (UP)</i>	24
2.3.3.4. <i>Jharkhand</i>	25
2.3.3.5. <i>Assam & Manipur in North Eastern Hill states.....</i>	27
2.3.3.6. <i>Chhattisgarh</i>	28

2.4	Effect of Arsenic Poisoning in Children	28
2.5	Arsenic in Food Chain	29
2.6	Socio-economic Effects of Arsenic Contamination	31
2.7	Summary	31

Chapter-3: Sources and Causes of Groundwater Arsenic Contamination in Ganga-Brahmaputra Plains 41-56

3.1	Probable Natural Sources.....	41
3.2	Anthropogenic Sources	42
3.3	Occurrences of Arsenic in Groundwater.....	43
3.4	Mechanisms of As Mobilization.....	44
3.5	Transport modeling to understand arsenic movement	48
3.6	Chemical processes of arsenic contamination.....	49
3.7	Observations, Analysis and Appraisal.....	52
3.8	Summary	54

Chapter-4: Mitigation and Remediation Update from West Bengal and Bihar - Studies and Projects Initiated 57-76

4.1	West Benga.....	7
4.1.1	<i>Steps and measures taken by the Government.</i>	58
4.1.2	<i>Findings of initiated R & D studies</i>	60
4.1.3	<i>Projects Initiated/Implemented as Remedial Measures.....</i>	62
4.1.4	<i>Uses of surface water sources.....</i>	62
4.1.5	<i>Uses of arsenic free groundwater by tapping deep aquifers</i>	64
4.1.6	<i>Use of arsenic removal filters for supply of arsenic free groundwater.....</i>	67
4.1.7	<i>Rain Water Harvesting/Watershed Management</i>	69
4.1.8	<i>Social Responses and Impacts</i>	69
4.2	Bihar	70
4.2.1	<i>Schemes Initiated on Remedial measures</i>	73
4.2.2	<i>Social Responses and Impacts</i>	74
4.3	Summary.....	75

Chapter-5: Technological Options and Arsenic Removal Technologies 77-108

5.1	Scientific standing of Arsenic Treatment Technologies	78
5.2	Conventional Technologies.....	79
5.2.1	<i>Oxidation and Filtration.....</i>	81

5.2.2	<i>Co-precipitation</i>	83
5.2.2.1	<i>Enhanced Lime Softening</i>	83
5.2.2.2	<i>Conventional Gravity Coagulation/Filtration</i>	84
5.2.2.3	<i>Coagulation Assisted Micro-filtration</i>	85
5.2.3	<i>Adsorption</i>	85
5.2.3.1	<i>Activated Alumina (AA)</i>	86
5.2.3.2	<i>Activated Carbon (AC)</i>	88
5.2.3.3	<i>Iron Based Sorbents (IBS)</i>	88
5.2.3.4	<i>Indigenous Filters</i>	89
5.2.3.5	<i>Cartridge Filters</i>	90
5.2.4	<i>Ion Exchange</i>	90
5.2.5	<i>Membrane Technology</i>	91
5.3	Innovative Technologies	94
5.3.1	<i>Permeable Reactive Barriers (PRBs)</i>	94
5.3.2	<i>Phytoremediation</i>	95
5.3.3	<i>Biological Treatment</i>	96
5.3.4	<i>Electrokinetic Treatment</i>	97
5.4	Waste Disposal / Sludge Management	98
5.4.1	<i>Landfill Disposal</i>	99
5.4.2	<i>Direct Discharge to Surface Waters</i>	99
5.4.3	<i>Indirect Discharge</i>	99
5.4.4	<i>Land Application</i>	100
5.4.5	<i>On-site Sewerage</i>	100
5.5	Alternative Options	100
5.6	Performance Audit, Evaluation and People's Participation	100
5.7	Observations, Analysis and Appraisal	102
5.8	Summary	105

**Chapter- 6: A Critical Appraisal- Future Risk, Scope
to Remediate, Technological Competence, etc. 109-124**

6.1	Appraisal on Source and Mobilization in the Bengal Basin	109
6.2	Appraisal on Arsenic Removal Technologies	112
6.2.1	<i>Arsenic Removal Technologies</i>	112
6.3	Future of Remediation Approaches	115
6.3.1	<i>In-situ Treatment of Arsenic in Aquifer by Removing Dissolved Iron</i>	115
6.3.2	<i>Limestone-based Arsenic Removal Methods</i>	116
6.3.3	<i>Remediation of Arsenic contaminated Soils by in situ Chemical Fixation</i>	117

6.4	Experiences during Arsenic Removal Technology.....	118
	Evaluation in Technology Park	
6.5	Alternate approach for ensuring supply of arsenic-free water	120
6.6	Summary.....	122

Chapter-7: Work Ahead: Critical Concerns and Key Challenges125-138

7.1	Unfinished Agenda	125
7.2	Critical Concerns	126
7.2.1	<i>National Standard for Arsenic in Drinking Water</i>	126
7.2.2	<i>Identification of Contaminated Sources and Creation of District, Block and Village Level Database: Key Challenges.....</i>	128
7.2.2.1	<i>Field Testing Kit vis-à-vis Network of Laboratory</i>	128
7.2.3	<i>Provision of Arsenic Safe Water to the Community: The Key Challenge of Sustainability.....</i>	129
7.3	Existing Knowledge Gaps	130
7.3.1	<i>Health Impact: Scientific Health Risk Assessment and Rational Estimation of Disease Burden.....</i>	130
7.3.2	<i>Arsenic Contamination in Agriculture: A Threat to Water - Soil- Crop - Animal - Human Continuum.....</i>	132
7.4	Critical Needs for Research and Capacity Building.....	135
7.5	Technology Options: Critical Constraints and limiting factors	135
7.6	Key Factors Impeding the Progress of Mitigatory Programmes in the Arsenic Affected States.....	136
7.7	Establishing a Transparent System of Information sharing by all Stakeholders.....	137

Chapter- 8: Roadmap for Achieving Envisaged Targets139-156

8.1	Important Milestones	139
8.1.1	<i>Emerging R & D Activities</i>	140
8.1.2	<i>Ensuring Arsenic Free Water</i>	144
8.1.3	<i>Capacity Building and Social Empowerment</i>	145
8.1.4	<i>Revision of the National Standard for Arsenic in drinking water.....</i>	147
8.2	Approaches for Achieving Milestones	147
8.2.1	<i>Bharat Nirman (2005-2009)</i>	148
8.2.2	<i>Accelerated Rural Water Supply Programme (ARWSP) & Prime Minister's Gramodaya Yojana (PMGY) - Rural Drinking Water.....</i>	148
8.2.3	<i>National Rural Employment Guarantee Act-2005 (NREGA).....</i>	149
8.3	Operational Framework	150
8.4	Mechanisms for Implementation of Envisaged Activities	152

Chapter - 9 : Financial Requirement.....	157-162
9.1 General	157
9.2 Distribution of Financial Allocations under Different Schemes.....	161
9.2.1 <i>Distribution of Financial allocation between the Central Government and the respective State Governments.....</i>	161
Chapter-10 : Mission Management and Time Frame	163-166
10.1 Mission Management	163
10.2 Time Frame	164
REFERENCES	167
CONTRIBUTORS	180
ANNEXURE	180-184