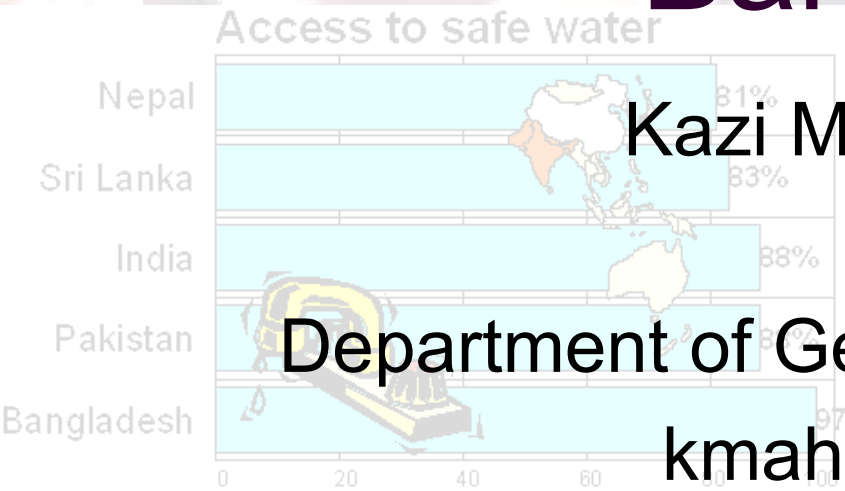
Groundwater Quality and Health Hazards in Bangladesh



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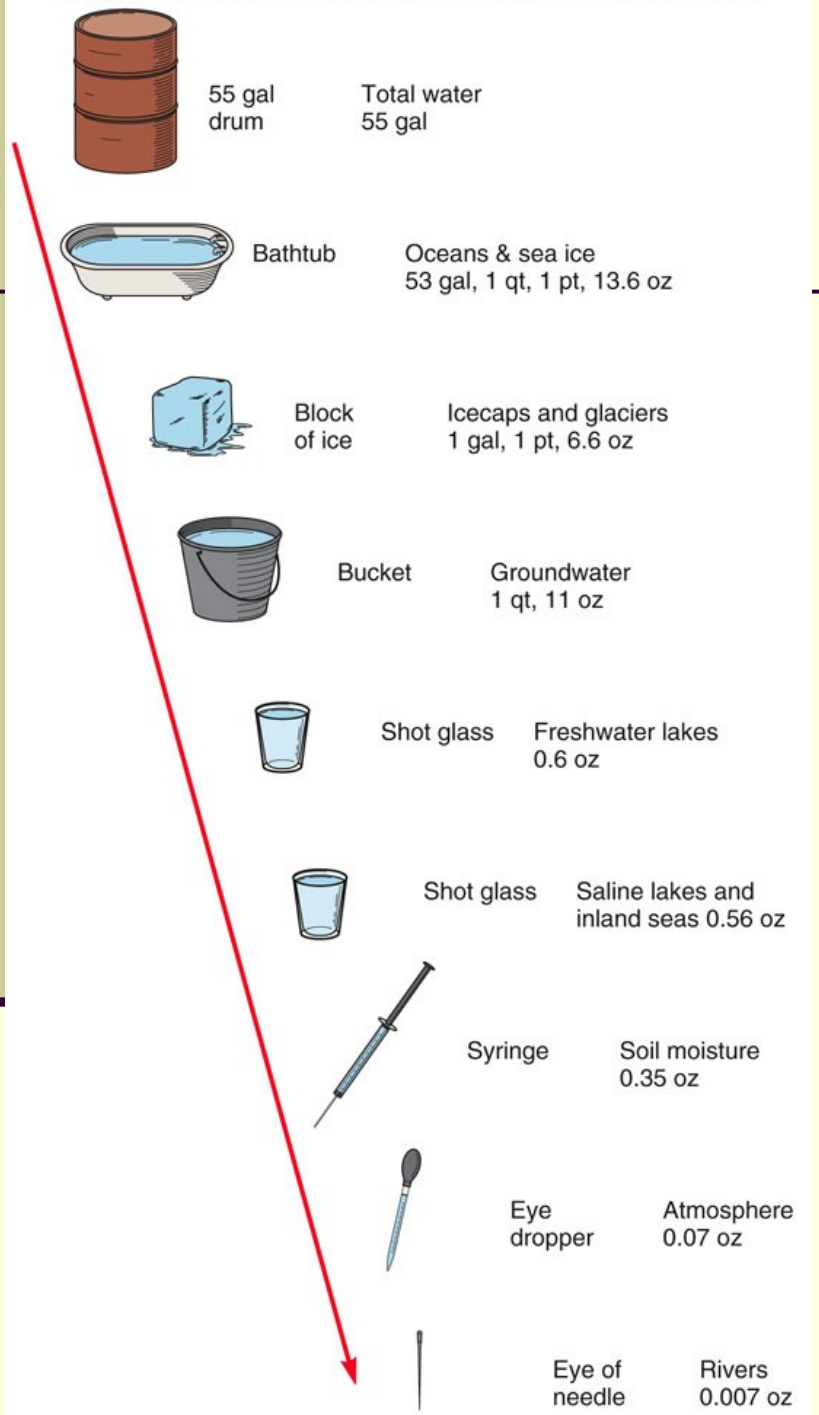
Contents

- Groundwater- the vital Resource
- Uses of Groundwater
- Dissolved Constituents in Groundwater
- Groundwater Contamination
- Water Quality Standards
- Water Quality and Public Health Hazards in Bangladesh
- Groundwater Protection



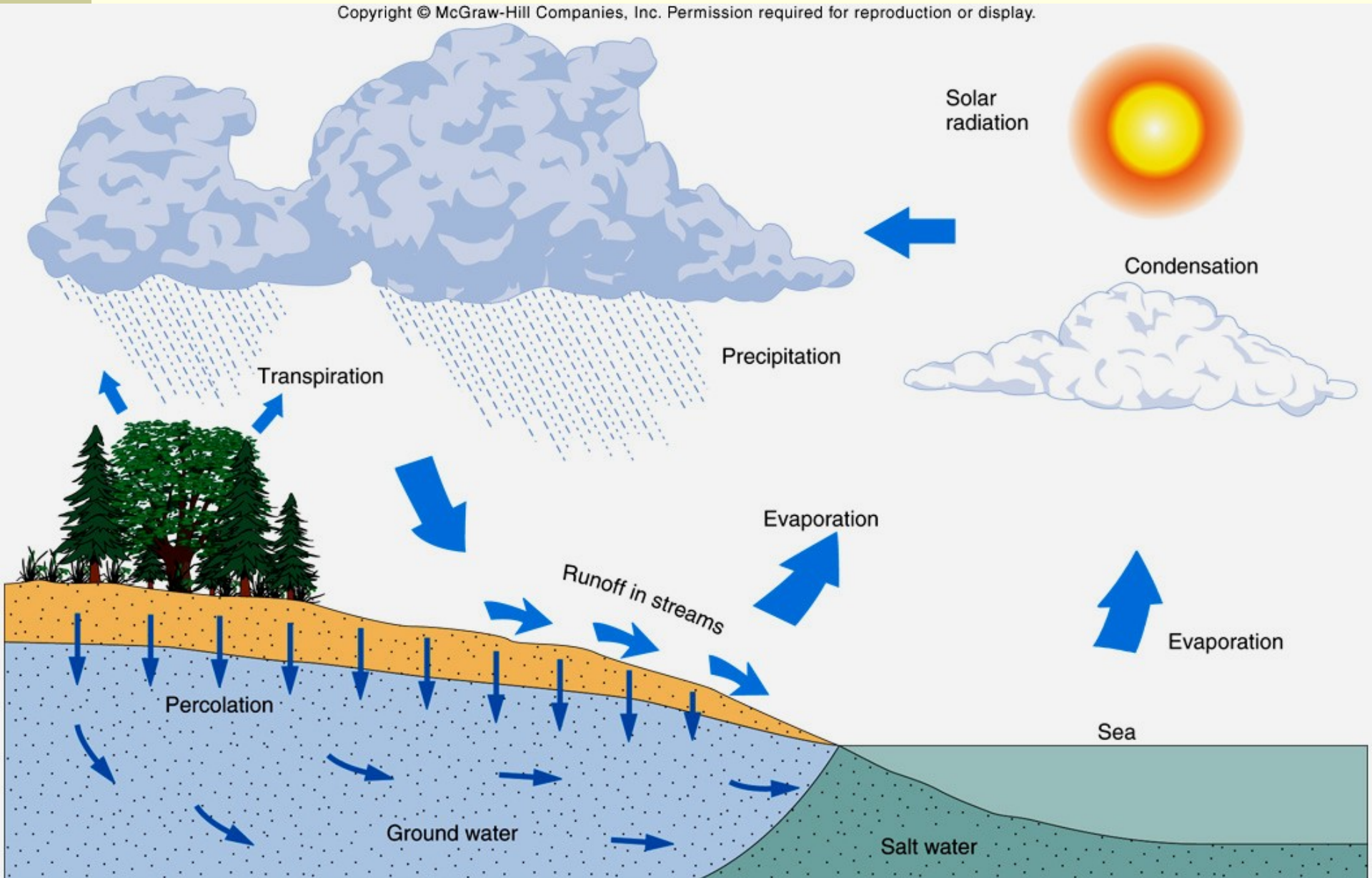
RESERVOIRS

Comparison of the amount of water supply held in each of the major reservoirs

If the total earth's water supply was a 55 gallon drum

Groundwater comprises 97.5% of all available fresh water on the Earth

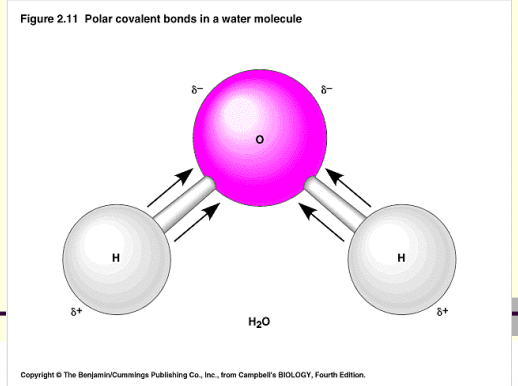
The Hydrologic Cycle

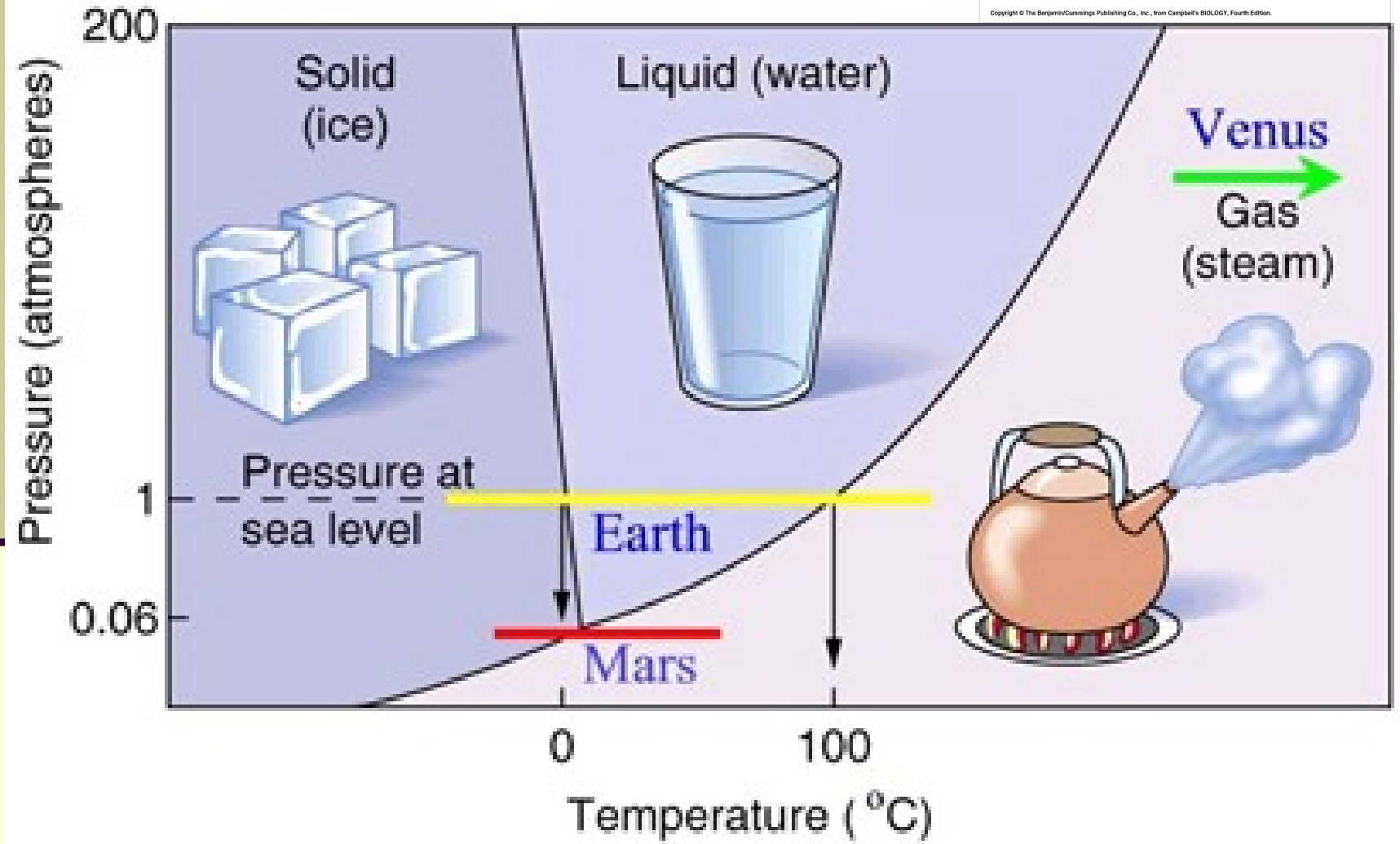


WATER

- **Water as a Chemical Compound**
  Water is a composed simply of two hydrogen atoms and one oxygen atom; placement of hydrogen atoms is not symmetric - creating a "polar" ionic structure
- **Three States of Water**
  - Gas (water vapor) - each molecule is energetic and separated ; T>100 degrees C
  - Liquid - some molecules link into loose groups; 100 degrees C>T< 0 degrees C
  - Solid (Ice)- all molecules linked in rigid open crystalline structure; T<0 degrees C

States of Water



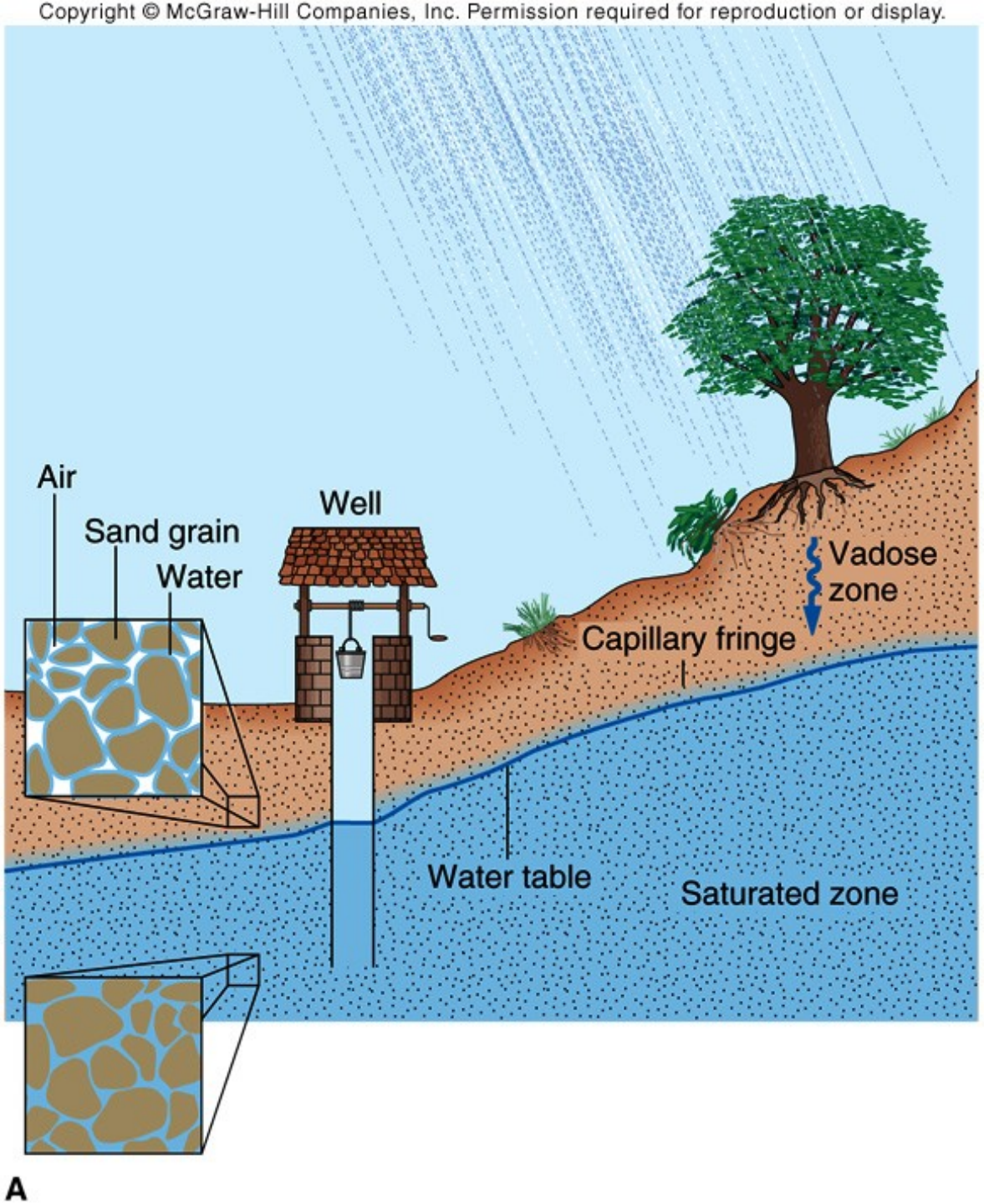


Water as a Basic Human Right

"All people, whatever their stage of development and social and economic condition, have the right to have access to drinking water in quantities and of a quality equal to their basic needs." (UN Conference at Mar del Plata, 1977)

"The human right to water entitles everyone to sufficient, safe, acceptable, physically accessible and affordable water for personal and domestic uses." (WHO, 2002)

Groundwater



Use of Groundwater

- Potable (drinking)
- Municipal water supply
- Irrigation
- Industrial
- Aesthetic
- Environmental

Sectoral Demand of Groundwater

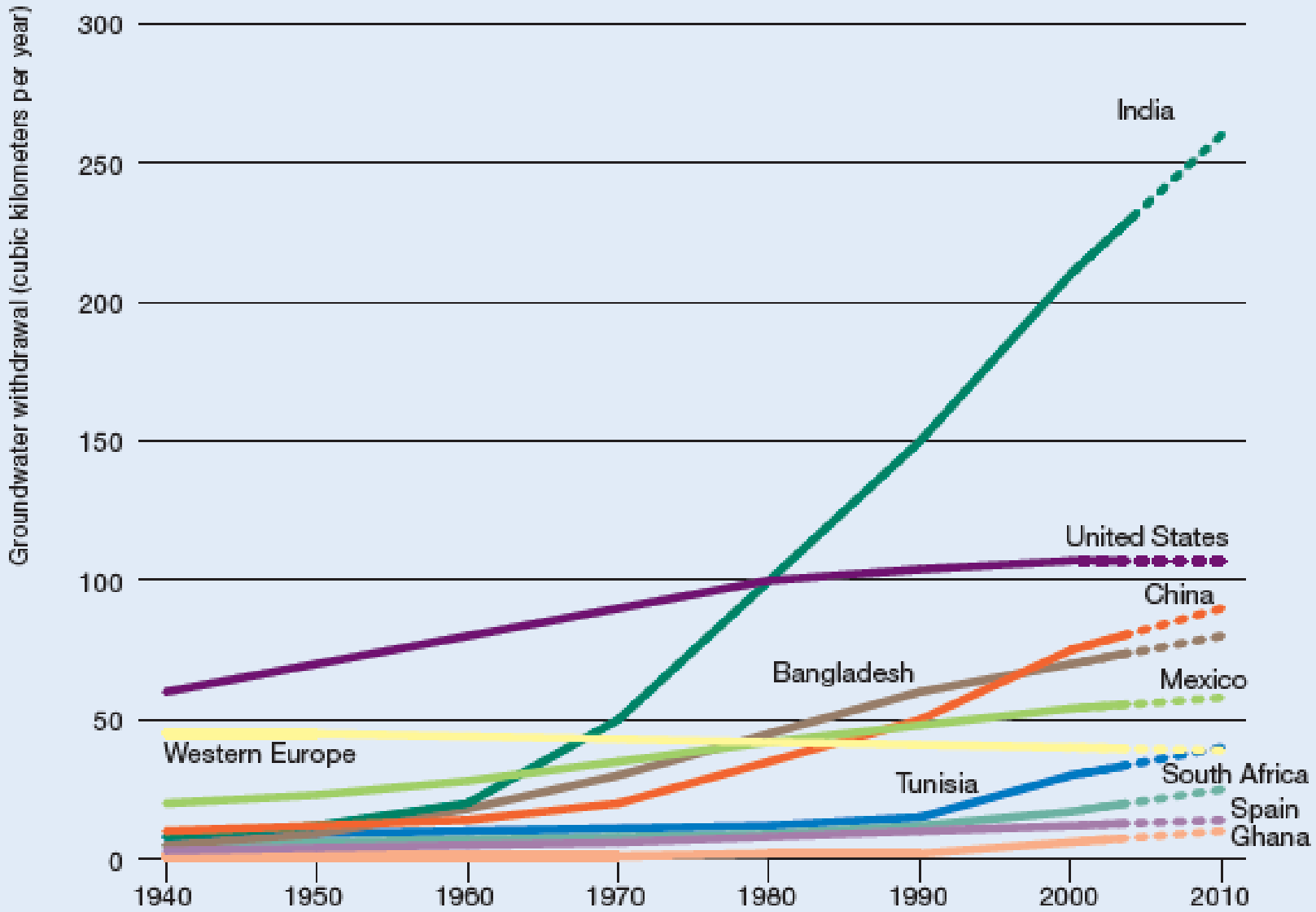
Region	Gross Area (Kha)	Usable (1) Recharge, UR, (Mm^3)	Groundwater Demands, GD, (Mm^3) (2)				Balance: UR – GD (mm^3, %)
			Water Supply	Environment	Agriculture	Total	
Northwest	3,016	12,100	539	1290	9548	11,377	+ 723 (6%)
Northeast	-	-	222	170	1357	1,749	17,066
North-central	3,569	23,100	566	637	3082	4,285	(74%)
Southeast	3,007	9,800	232	149	1158	1,584	8,216 (84%)
South-central	1,426	3,500	179	88	652	919	2,581 (74%)
Southwest	2562	5,600	289	620	4196	5,105	495 (9%)
Eastern Hills	-	-	181	-	-	181	-
Total (mm^3)	13,580	54,100	2,208	2,999	19,993	25,200	28,900
(%)			**(8.8%)**	**(11.9%)**	**(79.3%)**	**(100%)**	**(53%)**

Notes: (1) Resource Assessment by NWP-II; (2) Groundwater demand estimated by NWMP.

UR – Usable Recharge; GD – Groundwater Demand, Kha – Thousand hectares

Source: SDP, 2011

figure **10.1** | **Development in groundwater withdrawal in selected countries**



Source: Shah 2005.

Why Groundwater?

- Seven reasons for utilisation of groundwater more desirably over surface water:
  - Free from pathogenic organisms
  - Temperature is constant
  - Turbidity and colour are generally absent
  - Chemical composition is commonly constant
  - Groundwater storage is larger than surface water storage
  - Radiochemical and biological contamination of groundwater is difficult
  - Is available in areas which do not have dependable sources of surface water


Poor Sanitation

Water Scarcity!

Pure Water vs Natural Water

- Pure Water: H_2O, nothing else!
- Natural Water (Rainwater, surface water, groundwater, sea water, brines): H_2O plus many other suspended / amorphous / dissolved constituents
- To understand groundwater chemistry, we need to understand various processes those influences the chemical evolution of groundwater from rainwater.

“Universal” Solvent

- A liquid that is a completely homogeneous mixture of two or more substances is called a solution.
- The dissolving agent is the solvent and the substance that is dissolved is the solute.
- In an aqueous solution, water is the solvent.
- Water is not really a universal solvent, but it is very versatile because of the polarity of water molecules.

Water Quality Standards

- Designed to protect public health by requiring that contaminants or naturally occurring constituents in water be less than certain limits
- Primary drinking water standards
- Secondary drinking water standards
- MCL: *maximum contaminant level*: highest level of a contaminant that is allowed in drinking water (enforceable standards)
- MCLG: *maximum contaminant level goal*: the level of a contaminant in drinking water below which there is no known or expected health risk (Non-enforceable standard)

Public Health

- What is Public Health?
- The art and science of safeguarding and improving community health through organized community effort involving prevention of disease, control of communicable disease, application of sanitary measures, health education and monitoring of environmental hazards.

Water-related Disease Incidence

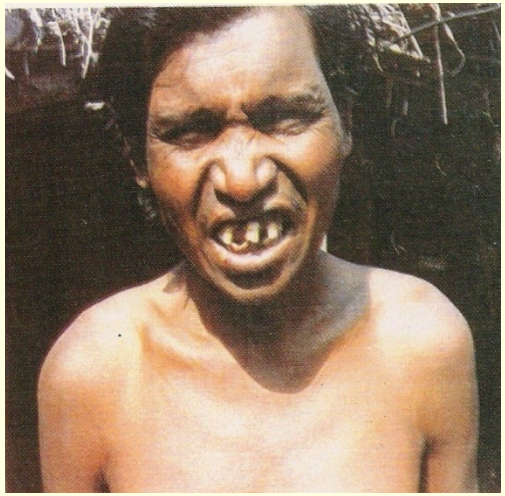
- Water-related diseases account for 80% of all deaths in developing countries
- Infectious and parasitic diseases are major cause of morbidity (illness)
- Many water-related diseases lead to epidemics with high death rates (e.g. cholera)

GROUNDWATER POLLUTANT & THEIR EFFECTS: WATER BORNE DISEASES

XERODERMA PIGMENTOSIS

SKELETAL FLUOROSISC

KNOCK – KNEED CHILD



MOTTLED TEETH

ADENOMA SEBACEUM

TYLOSIS-SOLE

NERVUS VASCULAR

SPOTTED KERATOSIS - SOLE

Microbiological Contaminants

- **Microbiological** contaminants are of most significance in both developing and developed countries and responsible for spread of infectious and parasitic diseases, such as cholera, typhoid, dysentery, hepatitis, giardiasis, schistosomiasis

Inorganic Contaminants

- **Inorganics** (heavy metals, nitrate)
  - Sources are industrial practices, runoff from fertilizer, mining wastes, septic tank failures)
  - Heavy metals may cause permanent brain damage, harm organs (kidneys, liver), and some are carcinogenic
    - mercury, arsenic, cadmium, lead
  - Nitrates above 10 mg/L may cause methemogobinemia (blue baby) in children younger than 2 yrs.

Organic Contaminants

- Synthetic Organics and Volatile Organics (VOCs) (TCE, lindane, dioxin, benzene, disinfectant by-products)
  - Sources are pesticide runoff, chemical solvents, household products, leaking underground gas tanks.
  - Increasing number of synthetic organic compounds being introduced into the environment

Radionuclide Contaminants

- Radionuclides (radon, uranium)
  - Sources are groundwater contamination, naturally occurring in bedrock (check to see if your country is a “hot spot” for radon)
  - Radionuclides undergo process of natural decay, emit radiation
  - Showering, laundering, dishwashing agitate water and release radon into air
  - Radiation is carcinogenic at certain exposure levels and concentrations

Important Groundwater Quality Parameters for Bangladesh

Categories of Water Quality Parameters	Parameters
Natural parameters of concern and cover wide areas	*Arsenic, iron, manganese and salinity*
Natural parameters that are more localized or low intensity problems	*Barium, boron, uranium, nitrate and ammonium*
Anthropogenic parameters: risk associated with these parameters can be minimized through monitoring and putting up barriers against hazards	*Microbiological, agrochemical and industrial pollutants*
Health-related parameters by WHO but are not expected to occur in Bangladesh (need to be confirmed by analyzing representative samples	*Mercury, tin, radioactivity, radon and silver*

Source: SDP, 2011

Parameter	Chem. symbol	WHO GV (mg/l)	Banglad. standard (mg/l)	% exceedance Shallow aquifer		% exceedance Deep aquifer		Comments
				WHO GUIDE LINE VALUE	Bangladesh standard	WHO GV	Bangladesh standard	
Chemicals of health significance								
Antimony	Sb	0.005 (P)	–	–	–	–	–	Not measured in NHS. SS data suggest not a problem
Arsenic	As	0.01 (P)	0.05	46	27	4.6	0.9	Serious problem
Barium	Ba	0.7	0.1?	0.2	28	1.2	26	Occasional problem
Beryllium	Be	NAD	–	–	–	–	–	Not measured in NHS. Rarely detected in SS (always <0.1 µg/l)
Boron	B	0.5 (P)	1.0	2.8	0.4	29	8	Occasional problem especially in more saline waters
Cadmium	Cd	0.003	0.005	–	–	–	–	NHS data not sensitive enough. SS found no exceedances
Chromium	Cr	0.05 (P)	0.05	0.2	0.2	<1	<1	SS data: essentially no problem
Copper	Cu	2 (P)	1	0	0	0	0	SS confirms no problem
Fluoride	F	1.5	1	–	–	–	–	SS and BWDB indicates if anything too low esp. in NW
Lead	Pb	0.01	0.05	–	–	–	–	NHS data not sensitive. Results from SS suggest not a problem
Manganese	Mn	0.5 (P)	0.1	39	79	2	22	Widespread exceedances, sometimes of large magnitude
Molybdenum	Mo	0.07	–	–	–	–	–	NHS data not sensitive enough. Results from SS suggest not a problem
Mercury	Hg	0.001	–	–	–	–	–	Not measured
Nickel	Ni	0.02 (P)	0.1	6	0.1	0.9	0.3	Rare problem. Not exceeded in SS
Nitrate	NO_3	50	10	–	–	–	–	Not measured in National Hydrochemical Survey. SS indicates very low in most groundwaters. Greatest problem likely in shallow, polluted wells
Selenium	Se	0.01	0.01	–	–	–	–	Not measured in NHS but 20 samples were all <0.0005 mg/l
Uranium	U	0.002 (P)	–	–	–	–	–	Not measured in National Hydrochemical Survey; SS results suggest a significant exceedance especially in more oxidising waters

Source: DHPE & BGS, 2001

Groundwater Quality in Bangladesh

Parameter	Chem. symbol	WHO GV (mg/l)	Banglad. standard (mg/l)	% exceedance Shallow aquifer		% exceedance Deep aquifer		Comments
				WHO GUIDE LINE VALUE	Bangladesh standard	WHO GV	Bangladesh standard	
Substances that may give rise to complaints from consumers								
Aluminium	Al	0.2	0.2	1.7	1.7	6	6	Normally below 0.1 mg/l
Ammonia	NH_3	1.5	–	–	–	–	–	Frequent exceedances
Iron	Fe	0.3	0.3–1.0	68	55	32	15	Frequent exceedances
Potassium	K	10	12	10	8	4	2	Occasional problem especially in southern Bangladesh
Sodium	Na	200	200	8.5	8.5	49	49	Serious problem in coastal areas
Zinc	Zn	3	5	0	0	0.3	0.3	Not a serious problem

– no reliable data.
(P) – Provisional WHO guideline maximum value.
NAD – No adequate data to permit recommendation of a health-based guideline value.
NHS – DPHE/BGS National Hydrochemical Survey.
BWDB – water-quality survey of tubewells in the Bangladesh Water Development Board monitoring network.
SS – Special Study Areas survey (Chapai Nawabganj, Faridpur, Lakshmipur upazilas).

Source: DHPE & BGS, 2001

As Hazards in West Bengal, India

- First detected in early eighties through epidemiological studies

Arsenic Contamination in Bangladesh

Modes of Water Supply	Population Coverage, Million	Percent Tubewel (≅Population.) Contaminated with As>50µg/L	Population Exposed to As>50µg/L, Million
Piped water supply	13.10	7.2	0.94
Manually operated Deep Tubewells	8.20	1	0.08
Manually Operated Shallow Tubewells	103.00	27.4	28.22
Dug well	1.30	0	0
PSF, VSST, SST, RWH, Etc.	1.50	0	0
Others	2.15	0	0
Total	**129.25**		**29.24**

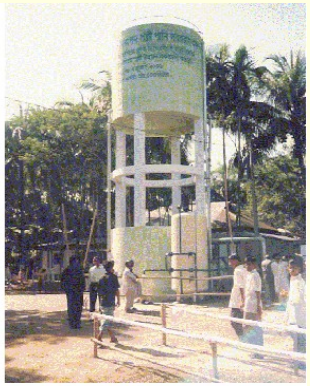
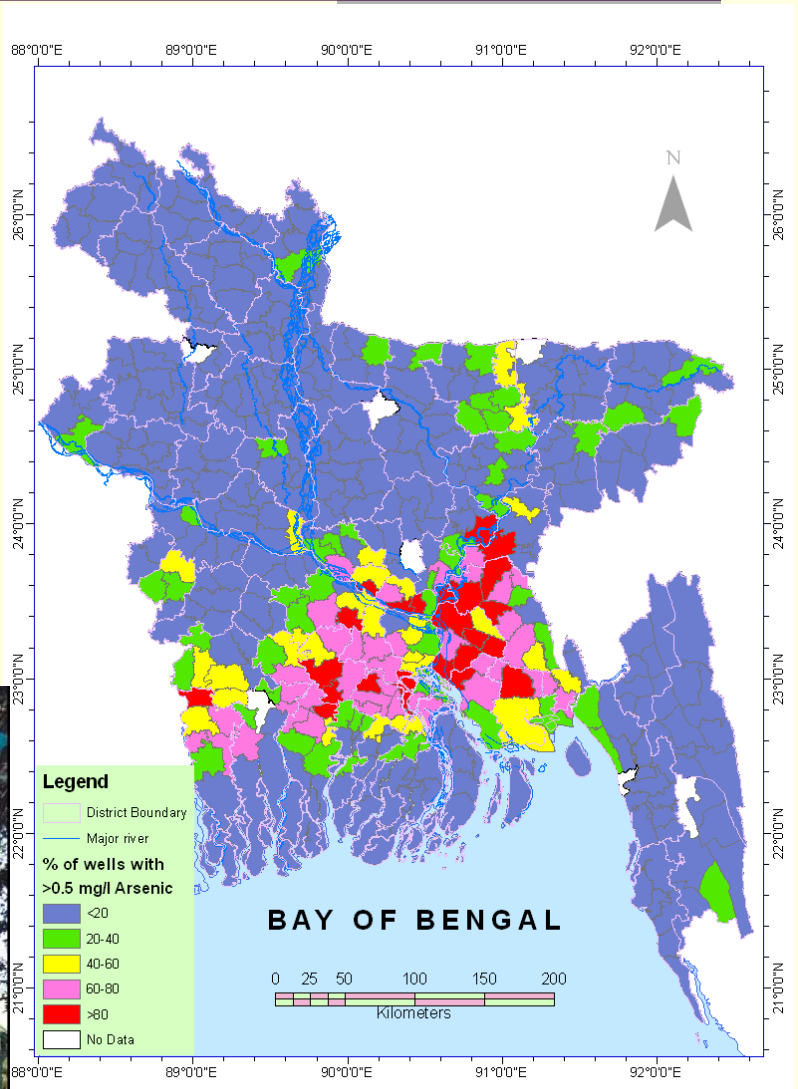
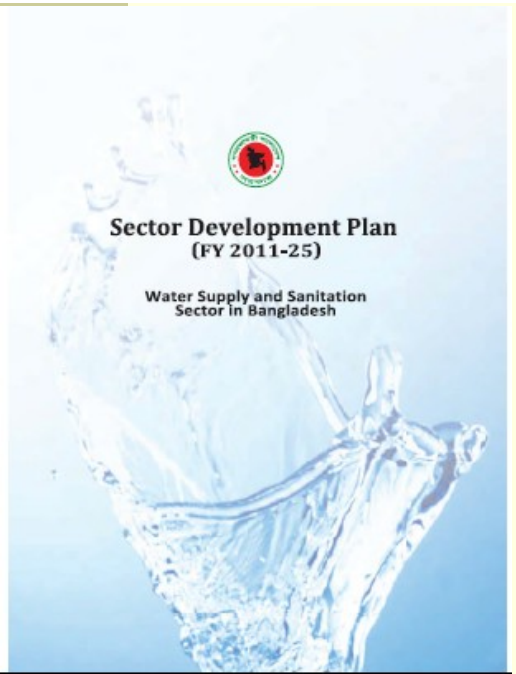


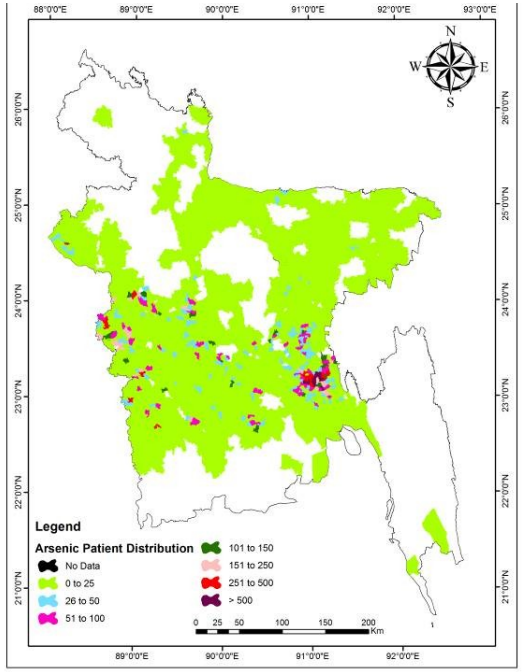
Fig. 3.18 A Piped Water Supply System in a Rural Arsenic Affected Area

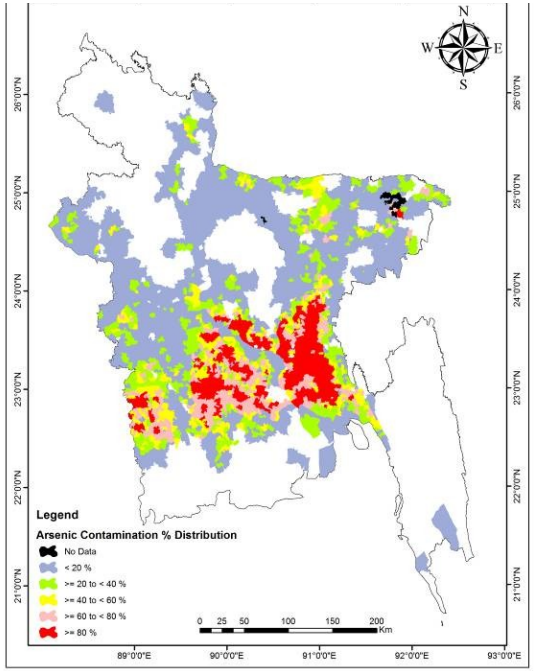


Arsenicosis Patients

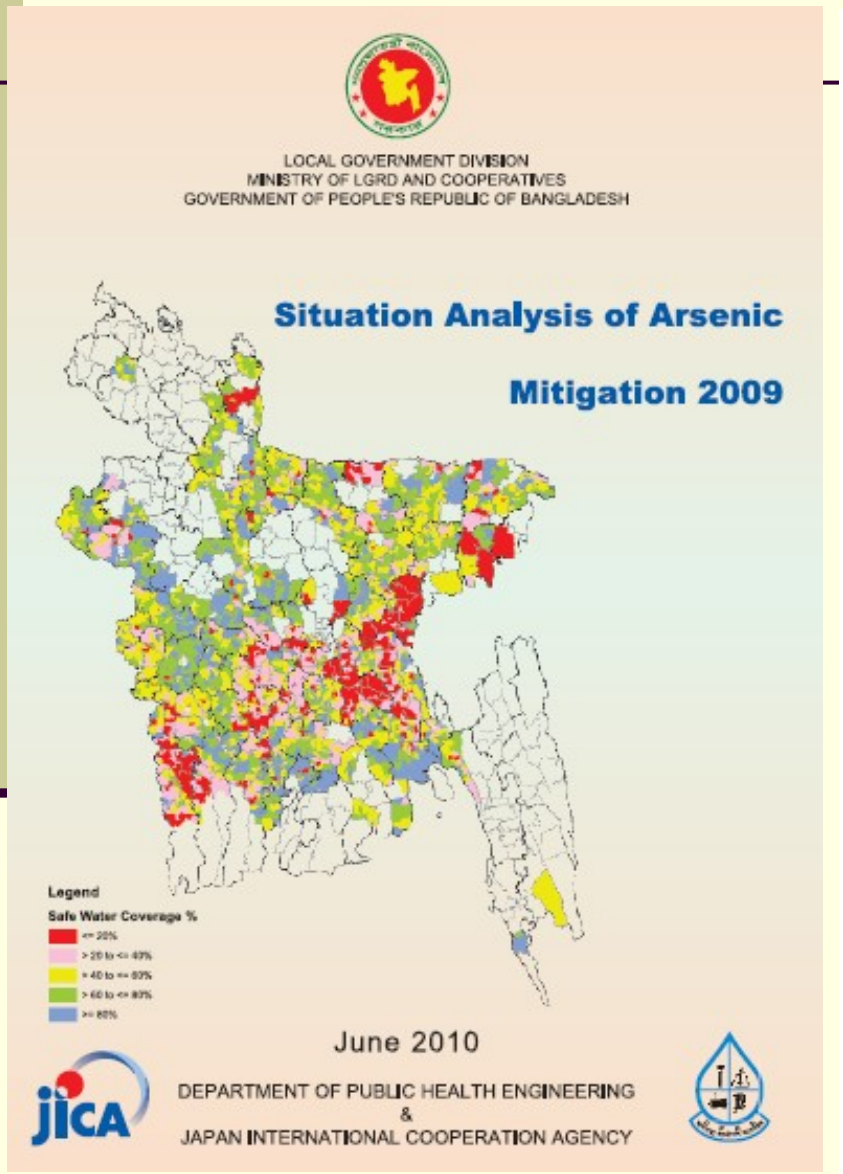
Public Safe Water Coverage	Percentage of Tubewells with Arsenic Contamination					
	<20%	20 - 40%	40 - 60%	60 - 80%	>80%	Total
<20%	189	223	370	535	7,204	8,521
20 - 40%	428	666	935	1,034	8,888	11,951
40 - 60%	1,885	1,890	1,213	792	1,708	7,488
60 - 80%	1,682	1,049	631	1,348	509	5,219
80 - 100%	770	490	148	214	245	1,867
>100%	418	674	483	274	118	1,967
No data	18	8	0	0	0	26
Total	**5,390**	**5,000**	**3,780**	**4,197**	**18,672**	**37,039**

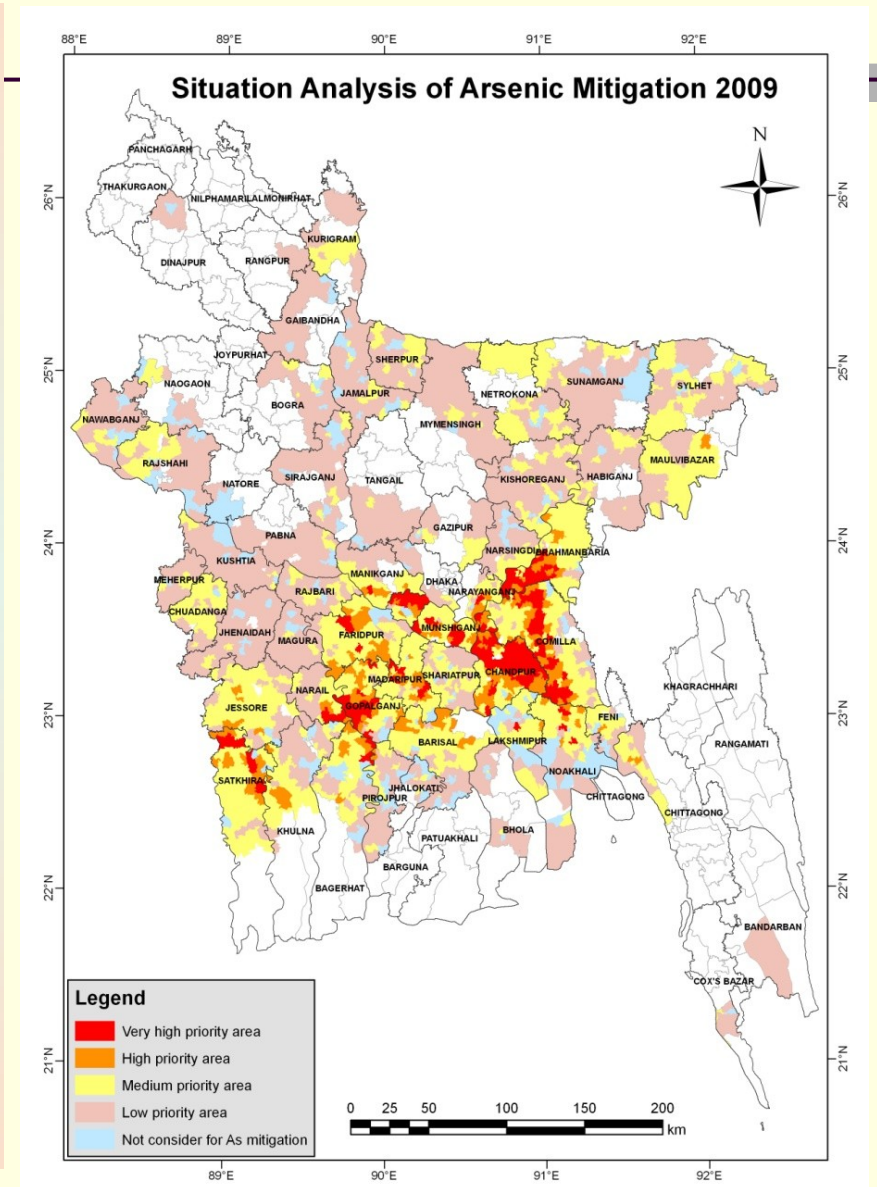




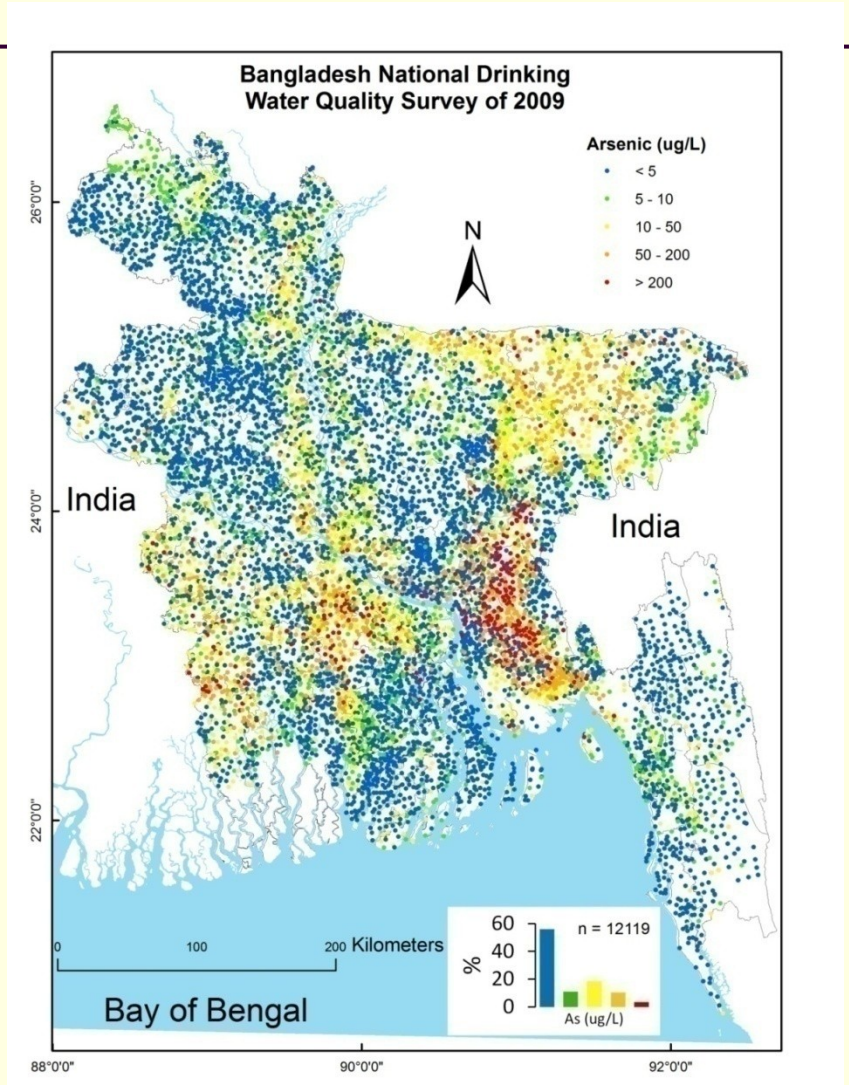


Arsenic Situation Analysis 2009





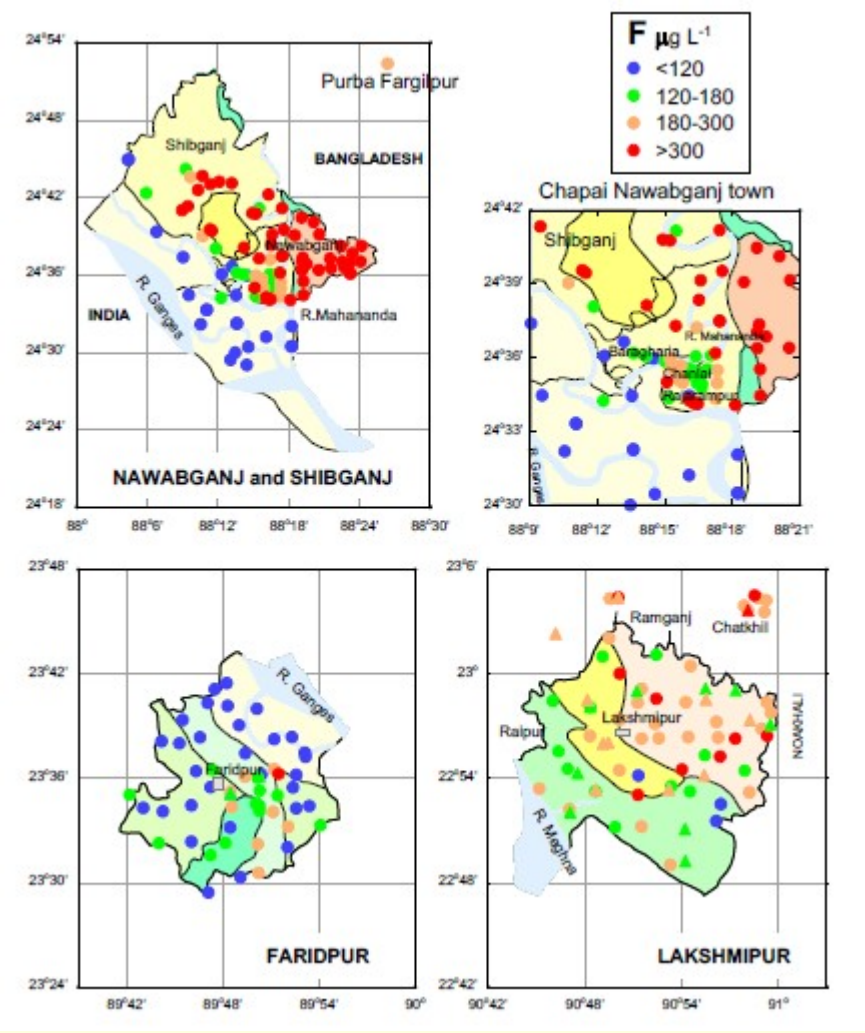
Arsenic Exposure Situation 2009

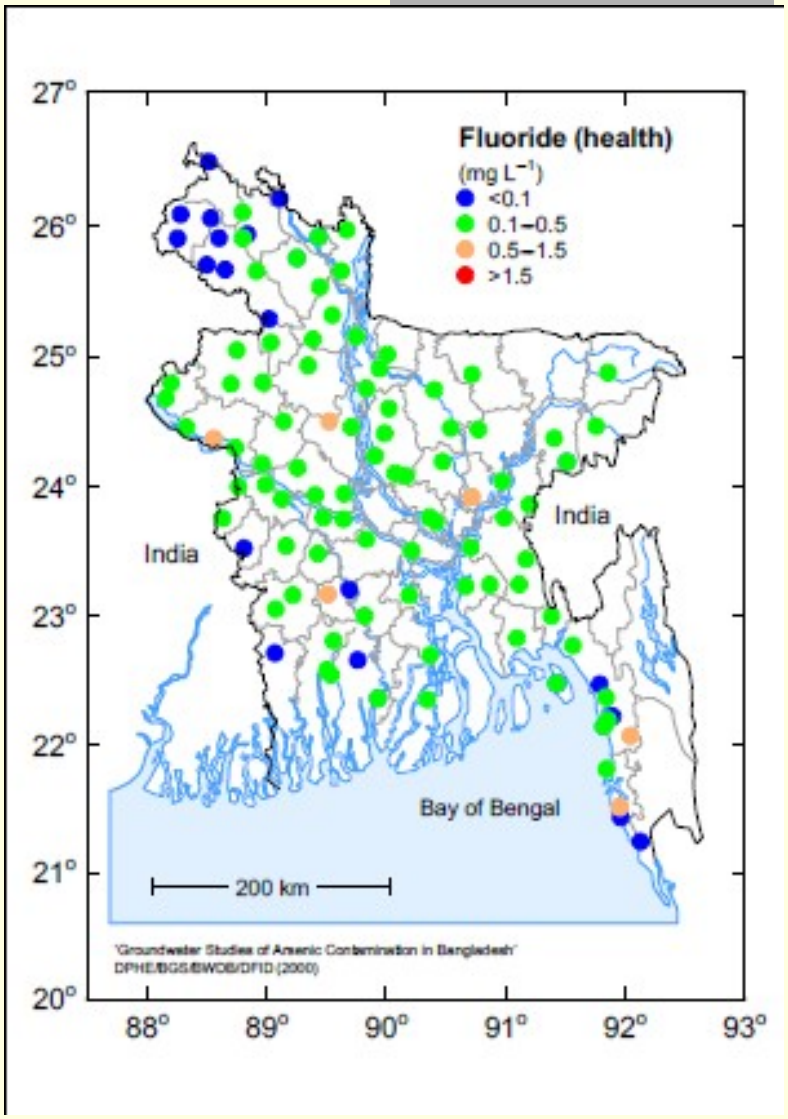


- In 2009, about 5.6, 22 and 35 million people are exposed to >200, >50, > 10 ug/L As in drinking water.
- Health implications: 1 in 14 adult deaths attributable to arsenic exposure, or about 43,000 to 56,000 deaths per year
- Economic implications: ~0.5% of annual GDP in lost income

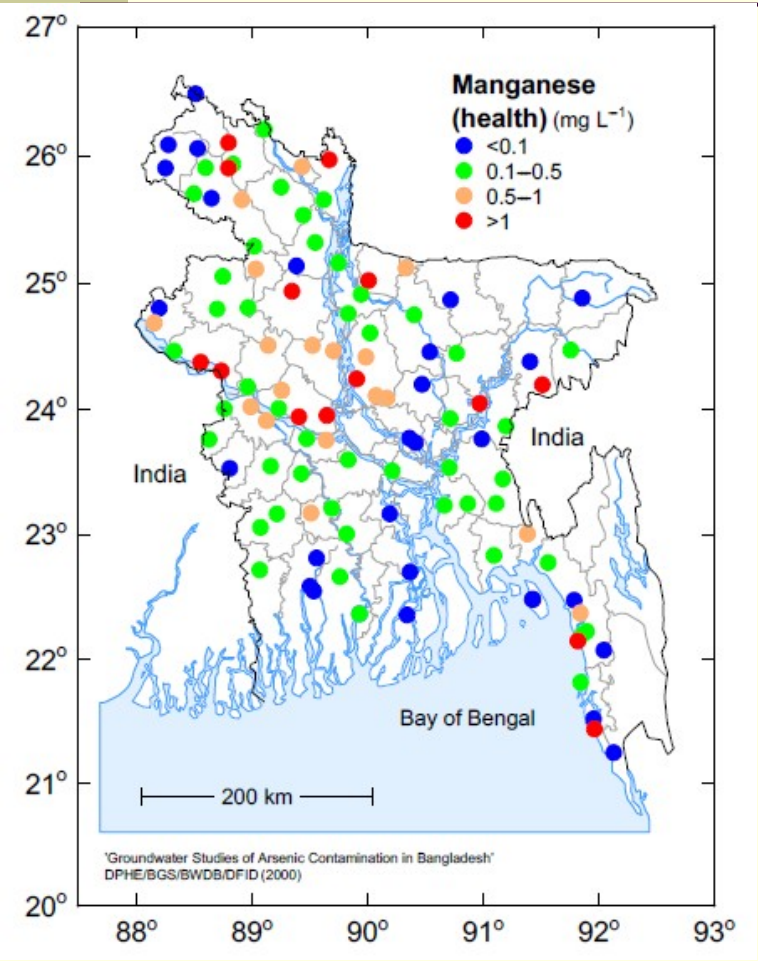
http://www.unicef.org/bangladesh/knowledgecentre_6868.htm

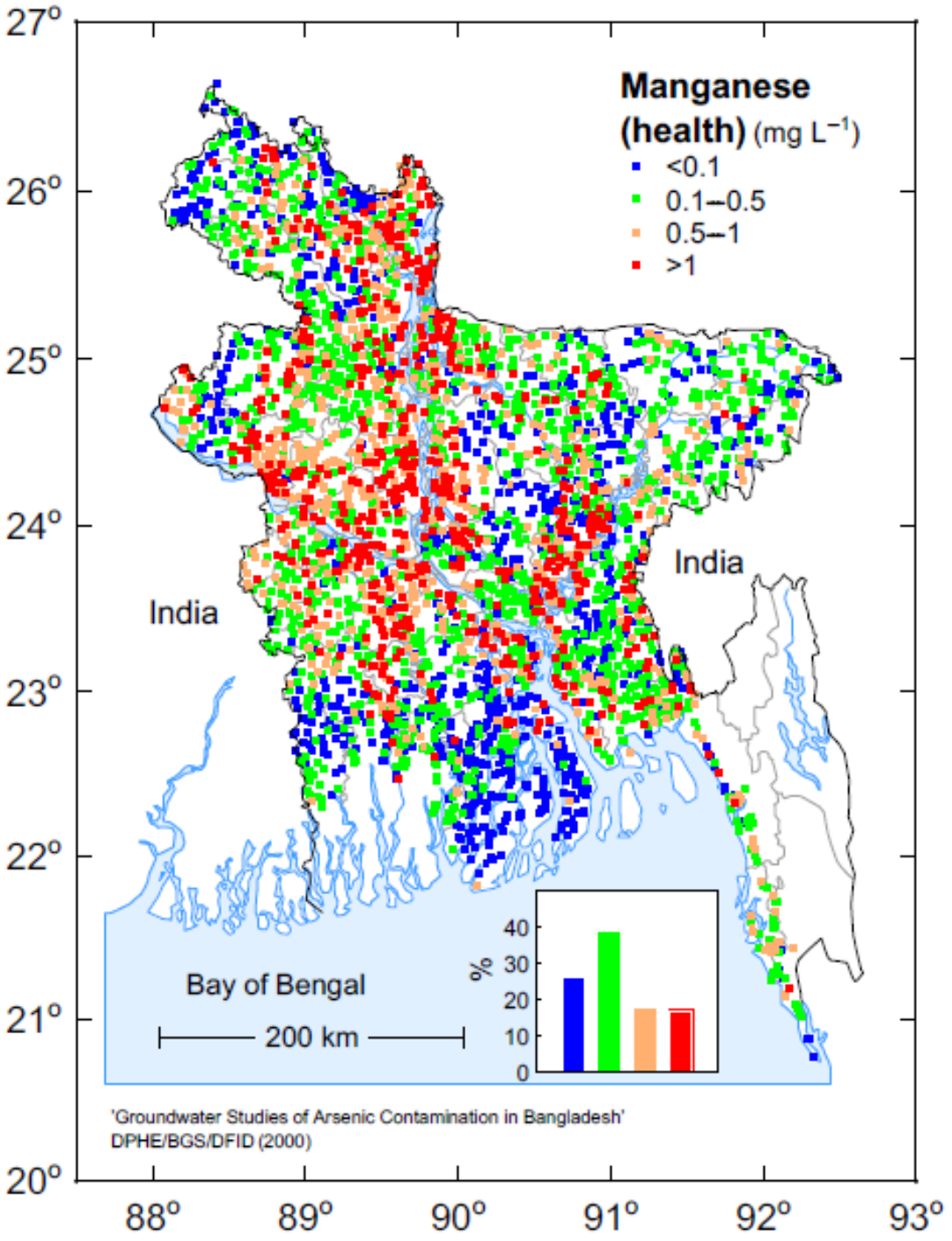
Fluoride in Bangladesh Groundwater



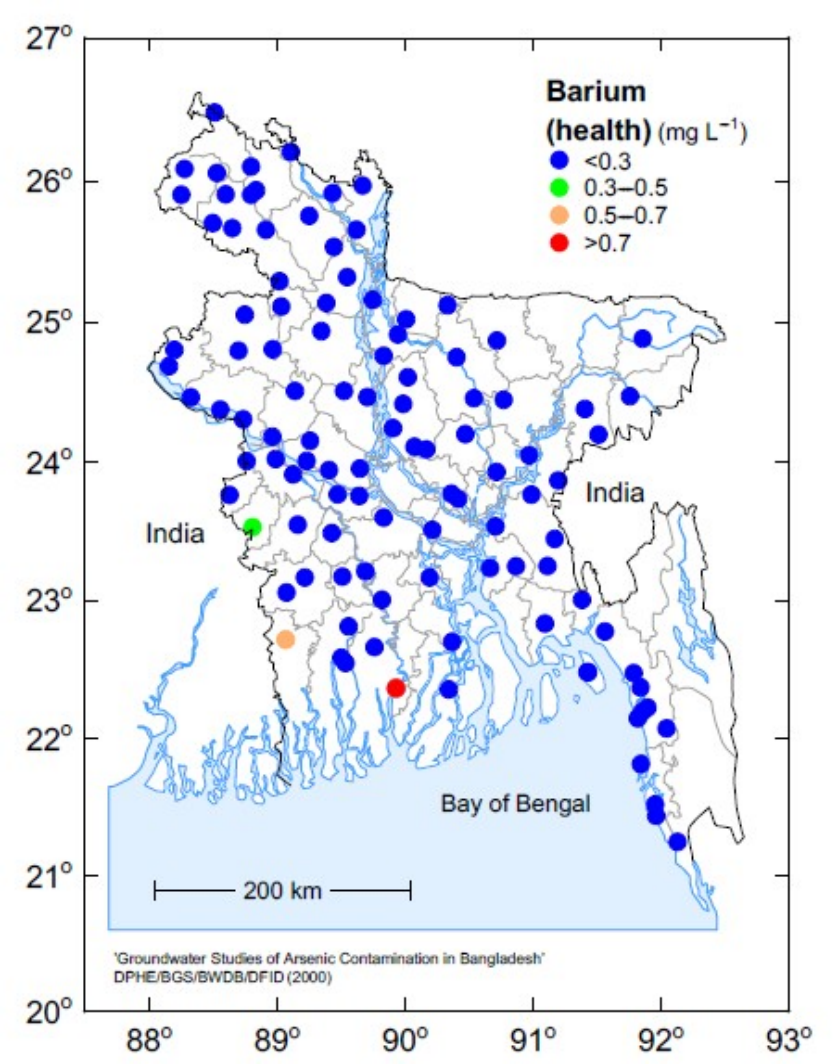


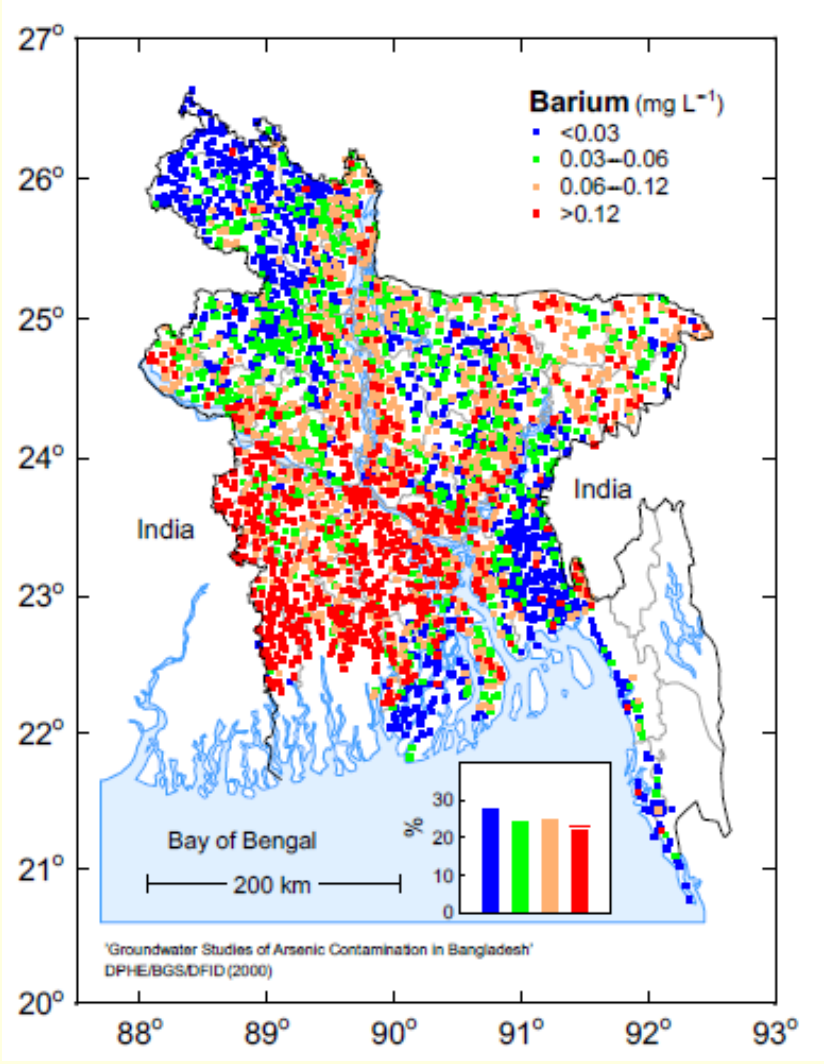
Manganese


Manganese
(health) (mg L⁻¹)
<0.1
0.1–0.5
0.5–1
>1
India
India
Bay of Bengal
200 km
'Groundwater Studies of Arsenic Contamination in Bangladesh'
DPHE/BGS/BWDB/DFID (2000)
27°
26°
25°
24°
23°
22°
21°
20°
88°
89°
90°
91°
92°
93°

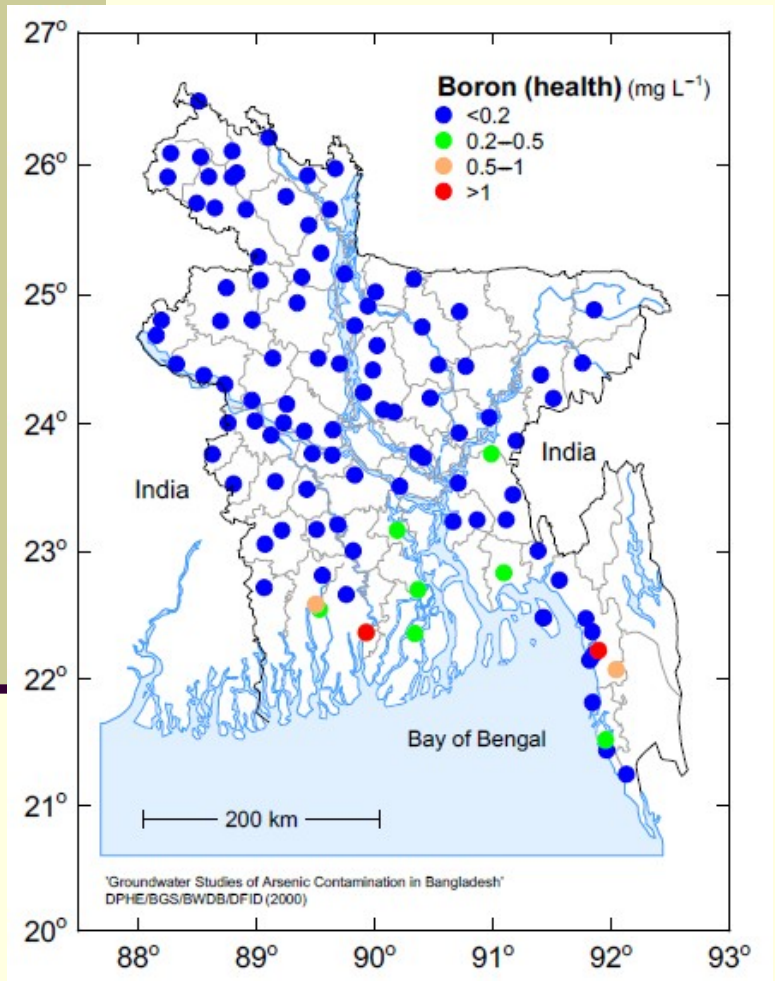

Manganese
(health) (mg L⁻¹)
<0.1
0.1–0.5
0.5–1
>1
India
India
Bay of Bengal
200 km
%
40
30
20
10
0
'Groundwater Studies of Arsenic Contamination in Bangladesh'
DPHE/BGS/DFID (2000)
27°
26°
25°
24°
23°
22°
21°
20°
88°
89°
90°
91°
92°
93°

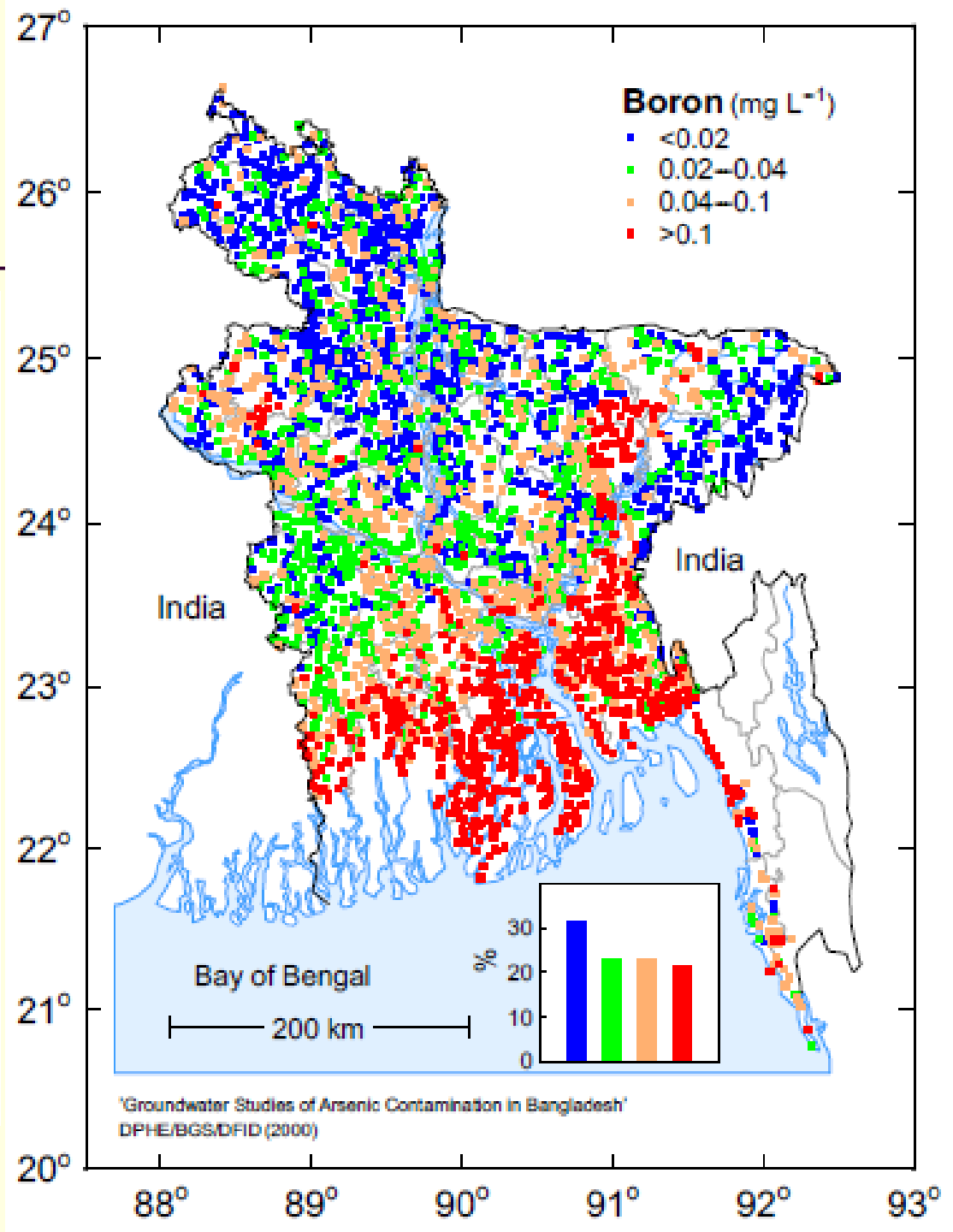
Barium


Barium (health) (mg L⁻¹)
<0.3
0.3–0.5
0.5–0.7
>0.7
India
India
Bay of Bengal
200 km
'Groundwater Studies of Arsenic Contamination in Bangladesh'
DPHE/BGS/BWDB/DFID (2000)
27°
26°
25°
24°
23°
22°
21°
20°
88°
89°
90°
91°
92°
93°

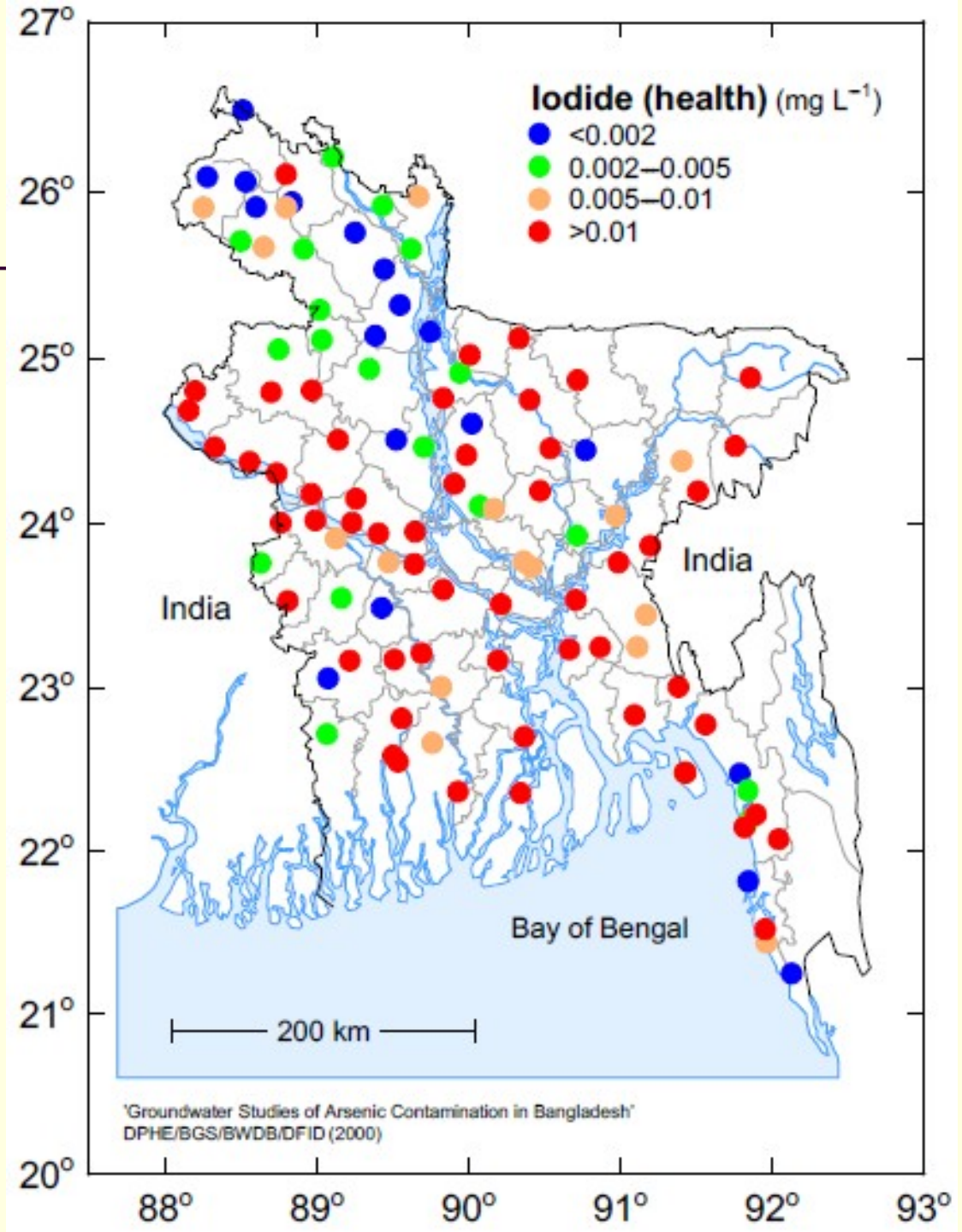

Barium (mg L⁻¹)
<0.03
0.03–0.06
0.06–0.12
>0.12
India
India
Bay of Bengal
200 km
%
30
20
10
0
'Groundwater Studies of Arsenic Contamination in Bangladesh'
DPHE/BGS/DFID (2000)
27°
26°
25°
24°
23°
22°
21°
20°
88°
89°
90°
91°
92°
93°

Boron

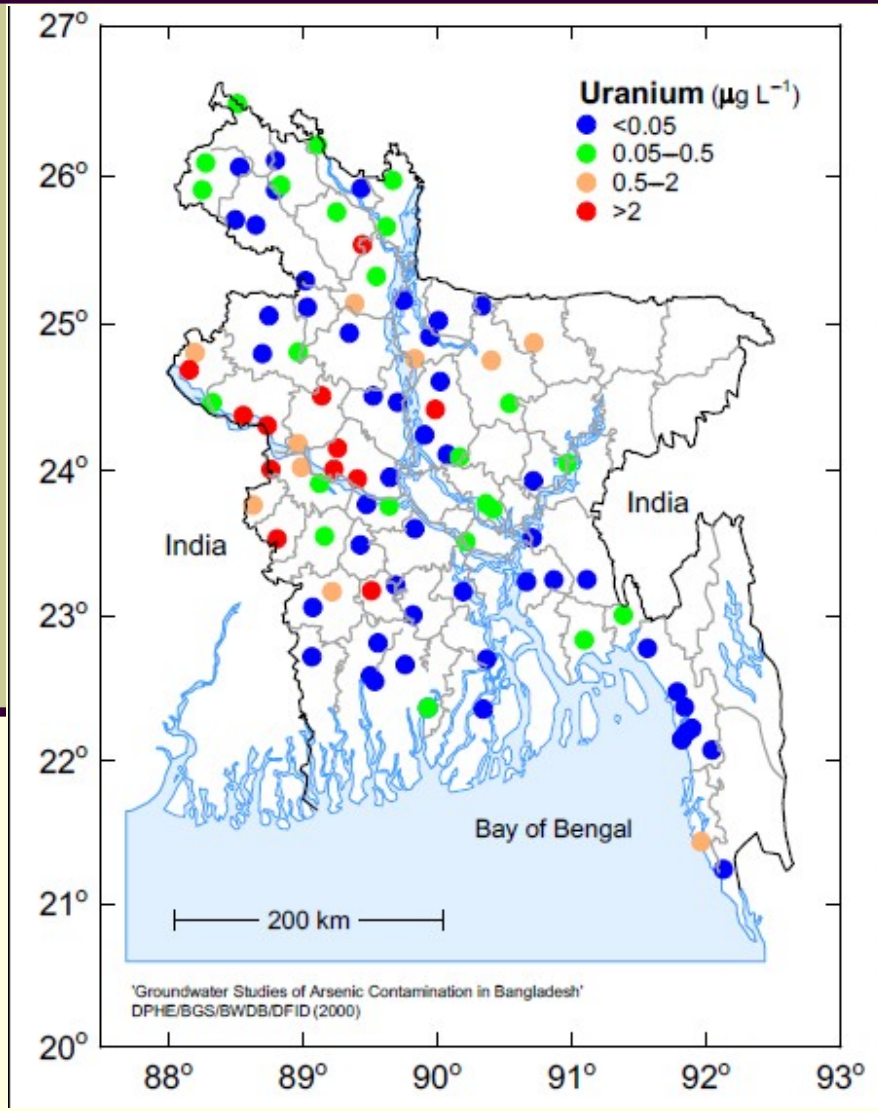

Boron (health) (mg L⁻¹)
<0.2
0.2–0.5
0.5–1
>1
India
India
Bay of Bengal
200 km
'Groundwater Studies of Arsenic Contamination in Bangladesh'
DPHE/BGS/BWDB/DFID (2000)
27°
26°
25°
24°
23°
22°
21°
20°
88°
89°
90°
91°
92°
93°

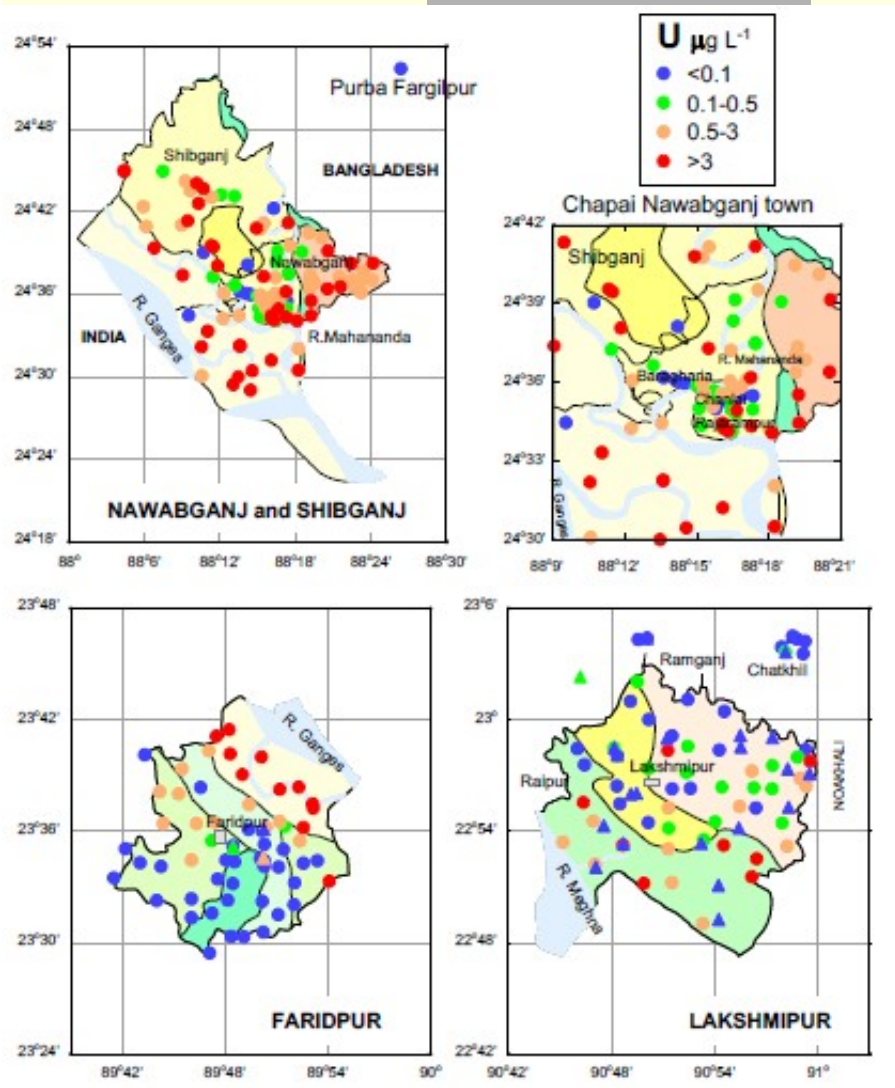

Boron (mg L⁻¹)
<0.02
0.02–0.04
0.04–0.1
>0.1
India
India
Bay of Bengal
200 km
%
30
20
10
0
'Groundwater Studies of Arsenic Contamination in Bangladesh'
DPHE/BGS/DFID (2000)
27°
26°
25°
24°
23°
22°
21°
20°
88°
89°
90°
91°
92°
93°

Iodine

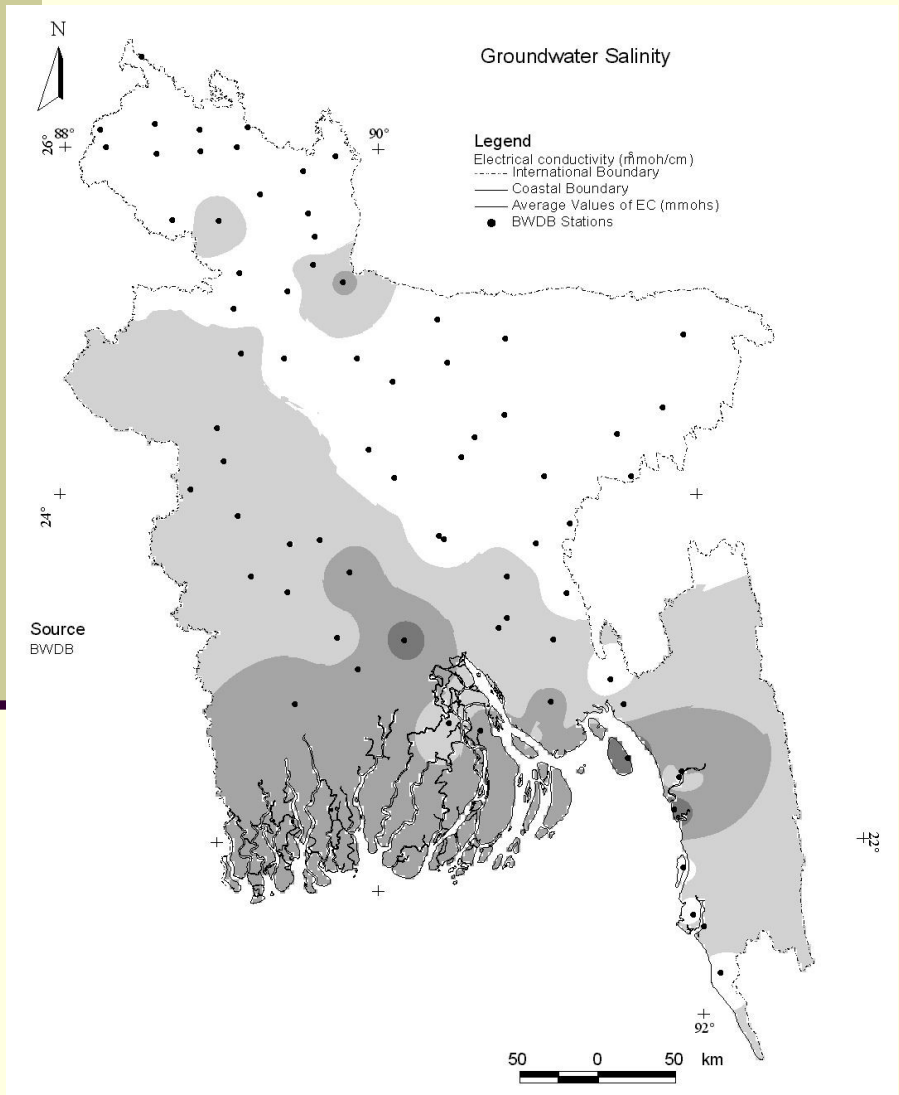

Iodide (health) (mg L⁻¹)
<0.002
0.002–0.005
0.005–0.01
>0.01
India
India
Bay of Bengal
200 km
'Groundwater Studies of Arsenic Contamination in Bangladesh'
DPHE/BGS/BWDB/DFID (2000)
27°
26°
25°
24°
23°
22°
21°
20°
88°
89°
90°
91°
92°
93°

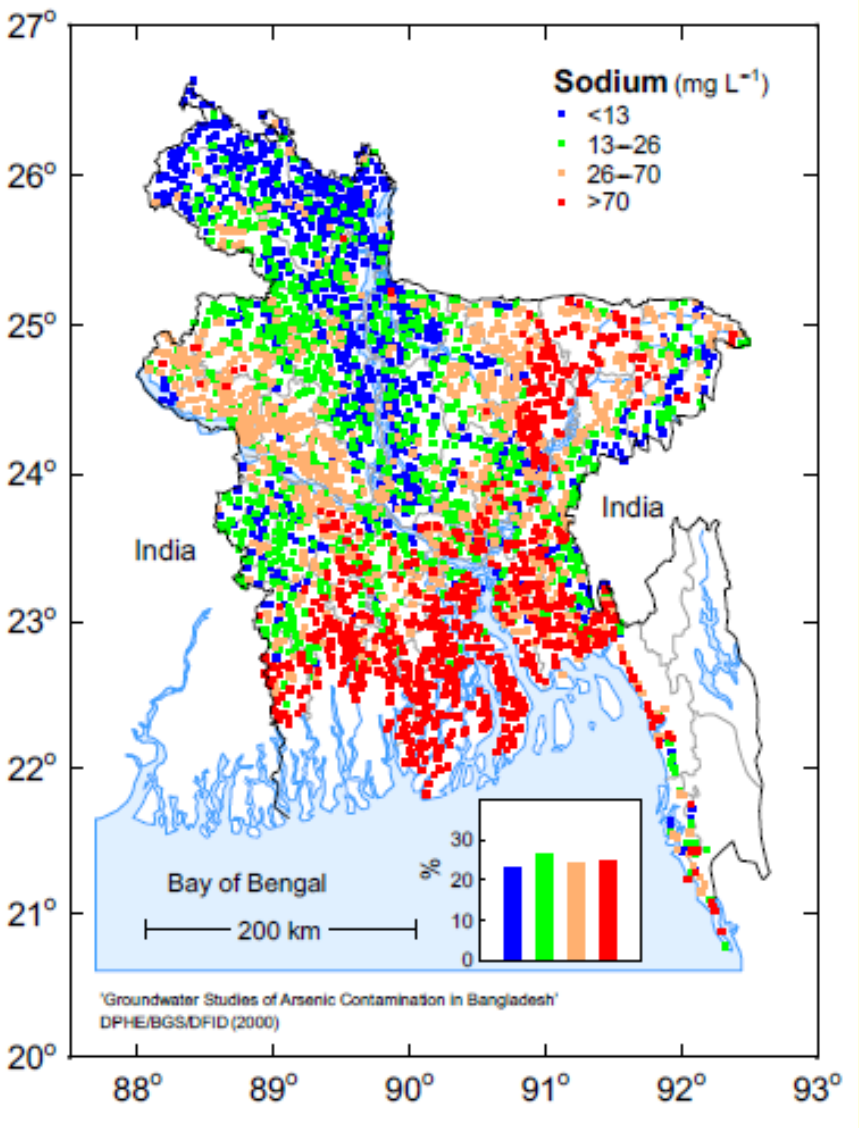
Uranium


Uranium (µg L⁻¹)
<0.05
0.05–0.5
0.5–2
>2
India
India
Bay of Bengal
200 km
'Groundwater Studies of Arsenic Contamination in Bangladesh'
DPHE/BGS/BWDB/DFID (2000)
27°
26°
25°
24°
23°
22°
21°
20°
88°
89°
90°
91°
92°
93°


U µg L⁻¹
<0.1
0.1-0.5
0.5-3
>3
Purba Fargilpur
Shibganj
BANGLADESH
Nawabganj
INDIA
R. Ganges
R.Mahananda
NAWABGANJ and SHIBGANJ
Chapai Nawabganj town
Shibganj
R. Mahananda
R. Ganges
Faridpur
R. Ganges
FARIDPUR
Ramganj
Chatkhil
Lakshmipur
Raipur
R. Meghna
NOAKHALI
LAKSHMIPUR

Salinity

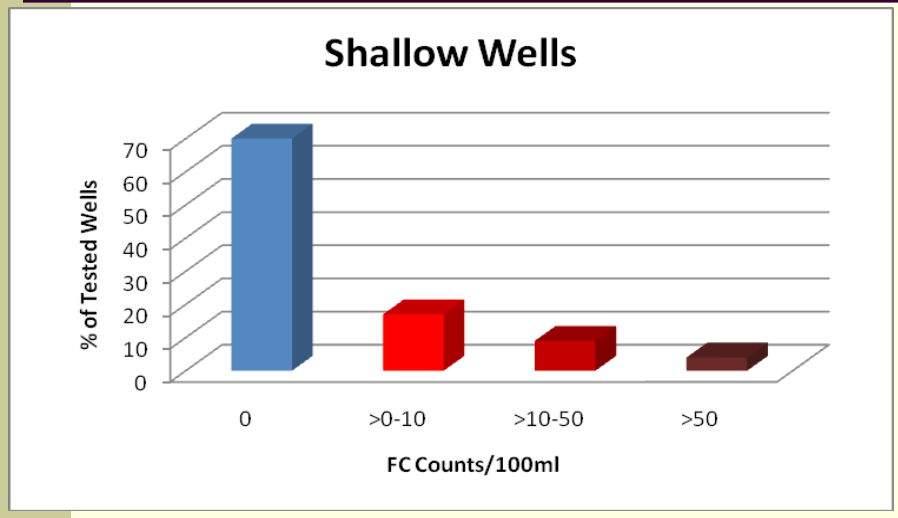

N
Groundwater Salinity
Legend
Electrical conductivity (mmoh/cm)
International Boundary
Coastal Boundary
Average Values of EC (mmohs)
BWDB Stations
Source
BWDB
26°
88°
90°
24°
22°
92°
50 0 50 km

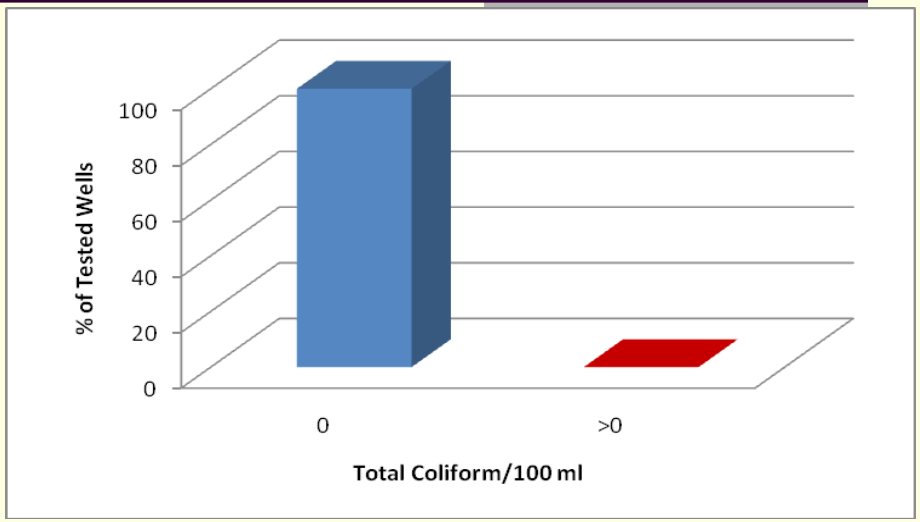

Sodium (mg L-1)
<13
13–26
26–70
>70
India
India
Bay of Bengal
200 km
%
30
20
10
0
'Groundwater Studies of Arsenic Contamination in Bangladesh'
DPHE/BGS/DFID (2000)
27°
26°
25°
24°
23°
22°
21°
20°
88°
89°
90°
91°
92°
93°

Scarcity of Fresh Water

Microbiological Contamination

Faecal Coliform





EC counts	Old Shallow Wells (25-50 ft)	New Deeper Wells (95-135 ft)
0	70	100
>0-10	17	0
>10-50	9	0
>50	4	0

Surveillance and Quality Control

- Separate roles for water supplier and authority responsible for independent oversight
- Surveillance: “the continuous and vigilant public health assessment and review of the safety and acceptability of drinking-water supplies”
- Surveillance requires a systematic program of surveys, audits, analysis, sanitary inspection, and community aspects
- National agencies provide a framework of targets, standards, and legislation
- Water suppliers are required to meet these standards
- Surveillance agency must be supported by strong and enforceable legislation

Groundwater Management and Protection

- Groundwater protection is a necessity if we want a development that meets the needs of the present without compromising the ability of future generations to meet their own needs
- Groundwater protection is crucial in achieving good safe drinking water without health hazards
- Establishment of groundwater management and regulatory regime with power to license abstractions;
- Capacity building in key sector agencies like WARPO, DPHE, WASAs and BWDB.

Concluding Remarks

- Groundwater is the most important natural resource on the Earth
- Groundwater is a resource out of site out of mind
- Poor groundwater quality can be associated with significant health hazards
- Lets take good care of our groundwater to reduce current public health hazards and to ensure availability of safe drinking water for future generations

Thank you all!