Groundwater Quality and Health Hazards in Bangladesh

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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

- Solar radiation
- Condensation
- Transpiration
- Precipitation
- Evaporation
- Runoff in streams
- Percolation
- Ground water
- Sea
- Salt 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

The diagram illustrates the phases of water (solid, liquid, and gas) under different conditions of pressure and temperature. At normal atmospheric pressure (1 atmosphere at sea level), water exists in its liquid state (water). As pressure increases, water can exist as solid ice. At higher pressures and temperatures (such as on Venus), water is in its gaseous state (steam). The diagram also compares Earth and Mars, showing that Mars experiences conditions where water can exist in all three states at certain pressures and temperatures.
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

<table>
<thead>
<tr>
<th>Region</th>
<th>Gross Area (Kha)</th>
<th>Usable (1) Recharge, UR, (Mm³)</th>
<th>Groundwater Demands, GD, (Mm³) (2)</th>
<th>Balance: UR – GD (mm³, %)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Water Supply</td>
<td>Environment</td>
</tr>
<tr>
<td>Northwest</td>
<td>3,016</td>
<td>12,100</td>
<td>539</td>
<td>1290</td>
</tr>
<tr>
<td>Northeast</td>
<td></td>
<td></td>
<td>222</td>
<td>170</td>
</tr>
<tr>
<td>North-central</td>
<td>3,569</td>
<td>23,100</td>
<td>566</td>
<td>637</td>
</tr>
<tr>
<td>Southeast</td>
<td>3,007</td>
<td>9,800</td>
<td>232</td>
<td>149</td>
</tr>
<tr>
<td>South-central</td>
<td>1,426</td>
<td>3,500</td>
<td>179</td>
<td>88</td>
</tr>
<tr>
<td>Southwest</td>
<td>2,562</td>
<td>5,600</td>
<td>289</td>
<td>620</td>
</tr>
<tr>
<td>Eastern Hills</td>
<td></td>
<td></td>
<td>181</td>
<td>-</td>
</tr>
<tr>
<td>Total (mm³)</td>
<td>13,580</td>
<td>54,100</td>
<td>2,208</td>
<td>2,999</td>
</tr>
<tr>
<td>(%)</td>
<td></td>
<td></td>
<td>(8.8%)</td>
<td>(11.9%)</td>
</tr>
</tbody>
</table>

**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
Development in groundwater withdrawal in selected countries

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: $\text{H}_2\text{O}$, nothing else!
- Natural Water (Rainwater, surface water, groundwater, sea water, brines): $\text{H}_2\text{O}$ 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 FLUOROSIS
- KNOCK – KNEED CHILD
- MOTTLED TEETH
- ADENOMA SEBACEUM
- TYLOSIS-SOLE
- NERVUS VASCULAR
- SPOTTED KERATOSIS - SOLE
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 methemoglobinemia (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

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

Source: SDP, 2011
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Chem. symbol</th>
<th>WHO GV (mg/l)</th>
<th>Bangladesh standard (mg/l)</th>
<th>% exceedance Shallow aquifer</th>
<th>% exceedance Deep aquifer</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Antimony</td>
<td>Sb</td>
<td>0.005 (P)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Arsenic</td>
<td>As</td>
<td>0.01 (P)</td>
<td>0.05</td>
<td>46</td>
<td>27</td>
<td>4.6 0.9</td>
</tr>
<tr>
<td>Barium</td>
<td>Ba</td>
<td>0.7</td>
<td>0.1?</td>
<td>0.2</td>
<td>28</td>
<td>1.2 26</td>
</tr>
<tr>
<td>Beryllium</td>
<td>Be</td>
<td>NAD</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Boron</td>
<td>B</td>
<td>0.5 (P)</td>
<td>1.0</td>
<td>2.8</td>
<td>0.4</td>
<td>29 8</td>
</tr>
<tr>
<td>Cadmium</td>
<td>Cd</td>
<td>0.003</td>
<td>0.005</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Chromium</td>
<td>Cr</td>
<td>0.05 (P)</td>
<td>0.05</td>
<td>0.2</td>
<td>0.2</td>
<td>1&lt;1 1&lt;1</td>
</tr>
<tr>
<td>Copper</td>
<td>Cu</td>
<td>2 (P)</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0 0</td>
</tr>
<tr>
<td>Fluoride</td>
<td>F</td>
<td>1.5</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Lead</td>
<td>Pb</td>
<td>0.01</td>
<td>0.05</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Manganese</td>
<td>Mn</td>
<td>0.5 (P)</td>
<td>0.1</td>
<td>39</td>
<td>79</td>
<td>2 22</td>
</tr>
<tr>
<td>Molybdenum</td>
<td>Mo</td>
<td>0.07</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Mercury</td>
<td>Hg</td>
<td>0.001</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Nickel</td>
<td>Ni</td>
<td>0.02 (P)</td>
<td>0.1</td>
<td>6</td>
<td>0.1</td>
<td>0.9 0.3</td>
</tr>
<tr>
<td>Nitrate</td>
<td>NO₃</td>
<td>50</td>
<td>10</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Selenium</td>
<td>Se</td>
<td>0.01</td>
<td>0.01</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Uranium</td>
<td>U</td>
<td>0.002 (P)</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

*Chemicals of health significance*

Not measured in NHS. SS data suggest not a problem

Serious problem

Occasional problem

Not measured in NHS. Rarely detected in SS (always <0.1 µg/l)

Occasional problem especially in more saline waters

SS data not sensitive enough. SS found no exceedances

SS confirms no problem

SS and BWDB indicates if anything too low esp. in NW

NHS data not sensitive. Results from SS suggest not a problem

Widespread exceedances, sometimes of large magnitude

NHS data not sensitive enough. Results from SS suggest not a problem

Not measured

Rare problem. Not exceeded in SS

Not measured in National Hydrochemical Survey. SS indicates very low in most groundwaters. Greatest problem likely in shallow, polluted wells

Not measured in NHS but 20 samples were all <0.0005 mg/l

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

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Chem. symbol</th>
<th>WHO GV (mg/l)</th>
<th>Bangladesh standard (mg/l)</th>
<th>% exceedance Shallow aquifer</th>
<th>% exceedance Deep aquifer</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminium</td>
<td>Al</td>
<td>0.2</td>
<td>0.2</td>
<td>1.7</td>
<td>1.7</td>
<td>6</td>
</tr>
<tr>
<td>Ammonia</td>
<td>NH₃</td>
<td>1.5</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Iron</td>
<td>Fe</td>
<td>0.3</td>
<td>0.3–1.0</td>
<td>68</td>
<td>55</td>
<td>32</td>
</tr>
<tr>
<td>Potassium</td>
<td>K</td>
<td>10</td>
<td>12</td>
<td>10</td>
<td>8</td>
<td>4</td>
</tr>
<tr>
<td>Sodium</td>
<td>Na</td>
<td>200</td>
<td>200</td>
<td>8.5</td>
<td>8.5</td>
<td>49</td>
</tr>
<tr>
<td>Zinc</td>
<td>Zn</td>
<td>3</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>0.3</td>
</tr>
</tbody>
</table>

Substances that may give rise to complaints from consumers:
- Aluminium: Normally below 0.1 mg/l
- Ammonia: Frequent exceedances
- Iron: Frequent exceedances
- Potassium: Occasional problem especially in southern Bangladesh
- Sodium: Serious problem in coastal areas
- Zinc: Not a serious problem

Source: DHPE & BGS, 2001

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(P) – Provisional WHO guideline maximum value.
NAD – No adequate data to permit recommendation of a health-based guideline value.
SS – Special Study Areas survey (Chapai Nawabganj, Faridpur, Lakshmipur upazilas).
As Hazards in West Bengal, India

- First detected in early eighties through epidemiological studies
## Arsenic Contamination in Bangladesh

<table>
<thead>
<tr>
<th>Modes of Water Supply</th>
<th>Population Coverage, Million</th>
<th>Percent Tubewell Contaminated with As&gt;50μg/L</th>
<th>Population Exposed to As&gt;50μg/L, Million</th>
</tr>
</thead>
<tbody>
<tr>
<td>Piped water supply</td>
<td>13.10</td>
<td>7.2</td>
<td>0.94</td>
</tr>
<tr>
<td>Manually operated Deep Tubewells</td>
<td>8.20</td>
<td>1</td>
<td>0.08</td>
</tr>
<tr>
<td>Manually Operated Shallow Tubewells</td>
<td>103.00</td>
<td>27.4</td>
<td>28.22</td>
</tr>
<tr>
<td>Dug well</td>
<td>1.30</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>PSF, VSST, SST, RWH, Etc.</td>
<td>1.50</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Others</td>
<td>2.15</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>129.25</strong></td>
<td><strong>29.24</strong></td>
<td><strong>29.24</strong></td>
</tr>
</tbody>
</table>

*Fig. 31.1: A Piped Water Supply System in a Rural Arsenic Affected Area*
## Arsenicosis Patients

<table>
<thead>
<tr>
<th>Public Safe Water Coverage</th>
<th>Percentage of Tubewells with Arsenic Contamination</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt;20%</td>
<td>20 - 40%</td>
</tr>
<tr>
<td>&lt;20%</td>
<td>189</td>
<td>223</td>
</tr>
<tr>
<td>20 - 40%</td>
<td>428</td>
<td>666</td>
</tr>
<tr>
<td>40 - 60%</td>
<td>1,885</td>
<td>1,890</td>
</tr>
<tr>
<td>60 - 80%</td>
<td>1,682</td>
<td>1,049</td>
</tr>
<tr>
<td>80 - 100%</td>
<td>770</td>
<td>490</td>
</tr>
<tr>
<td>&gt;100%</td>
<td>418</td>
<td>674</td>
</tr>
<tr>
<td>No data</td>
<td>18</td>
<td>8</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>5,390</strong></td>
<td><strong>5,000</strong></td>
</tr>
</tbody>
</table>

**Legend**

- **Arsenic Patient Distribution**
  - No Data
  - < 25
  - 25 to < 50
  - 50 to < 100
  - 100 to < 150
  - ≥ 150

- **Arsenic Contamination % Distribution**
  - No Data
  - < 10%
  - 10% to < 20%
  - 20% to < 40%
  - 40% to < 60%
  - ≥ 60%
Arsenic Situation Analysis 2009

 Situation Analysis of Arsenic Mitigation 2009

Legend
Safe Water Coverage %

June 2010
DEPARTMENT OF PUBLIC HEALTH ENGINEERING
& JAPAN INTERNATIONAL COOPERATION AGENCY

Legend
Very high priority area
High priority area
Medium priority area
Low priority area
Not considered for As mitigation

0 25 50 100 150 200 km
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
Barium
Iodine

Map showing the distribution of iodide levels in Bangladesh, with different colors indicating varying concentrations.
Uranium

[Map showing distribution of uranium levels in Bangladesh]
Salinity
Scarcity of Fresh Water
Microbiological Contamination
## Faecal Coliform

<table>
<thead>
<tr>
<th>FC counts</th>
<th>Old Shallow Wells (25-50 ft)</th>
<th>New Deeper Wells (95-135 ft)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>70</td>
<td>100</td>
</tr>
<tr>
<td>&gt;0-10</td>
<td>17</td>
<td>0</td>
</tr>
<tr>
<td>&gt;10-50</td>
<td>9</td>
<td>0</td>
</tr>
<tr>
<td>&gt;50</td>
<td>4</td>
<td>0</td>
</tr>
</tbody>
</table>
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
- Let's 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!