Chemical Contamination of Surface and Groundwater

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Water and Health

- Access to clean water has been designated a human right by UN

- “Safe” or “clean” drinking water generally refers to water that is free of disease-causing microbes.

Annex Table 9 Attributable mortality by risk factor, level of development and sex, 2000[a]

	High mortality developing countries AFR-D, AFR-E, AMR-D, EMR-D, SEAR-D		Low mortality developing countries AMR-B, EMR-B, SEAR-B, WPR-B		Developed countries AMR-A, EUR-A, EUR-B, EUR-C, WPR-A	
	Males	Females	Males	Females	Males	Females
Environmental risks						
Unsafe water, sanitation and hygiene	792	746	92	80	10	10
Urban air pollution	119	101	215	211	78	76
Indoor smoke from solid fuels	490	549	159	399	9	13
Lead exposure	60	33	46	23	49	23
Climate change	73	75	3	2	0	0

Annex Table 10 Attributable DALYs by risk factor, level of development and sex, 2000[a]

	High mortality developing countries AFR-D, AFR-E, AMR-D, EMR-D, SEAR-D		Low mortality developing countries AMR-B, EMR-B, SEAR-B, WPR-B		Developed countries AMR-A, EUR-A, EUR-B, EUR-C, WPR-A	
	Males	Females	Males	Females	Males	Females
Environmental risks						
Unsafe water, sanitation and hygiene	23 157	23 026	3 846	3 304	429	396
Urban air pollution	1 454	1 231	2 272	1 736	687	484
Indoor smoke from solid fuels	15 534	14 859	3 252	4 343	253	297
Lead exposure	3 206	2 747	3 020	2 564	886	502
Climate change	2 535	2 667	156	138	10	12

Units: 1000s

From: WHO. 2002. Reducing Risks, Promoting Healthy Life. Annual Report. Geneva, World Health Organization

Safe Drinking Water

- More than just microbe-free
- The definition of “safe” is expanding to include natural elements and industrial contaminants.

Triple Threat in Water of Developing Countries

- Microbial Contaminants {Traditional}
  - Bacteria, viruses, protozoa, and small animals such as worms
- Anthropogenic Contaminants {Modern}
  - Disinfection by-products, pesticides, industrial chemicals, pharmaceuticals (endocrine disrupters)
- Natural Elements
  - Arsenic, fluoride, manganese

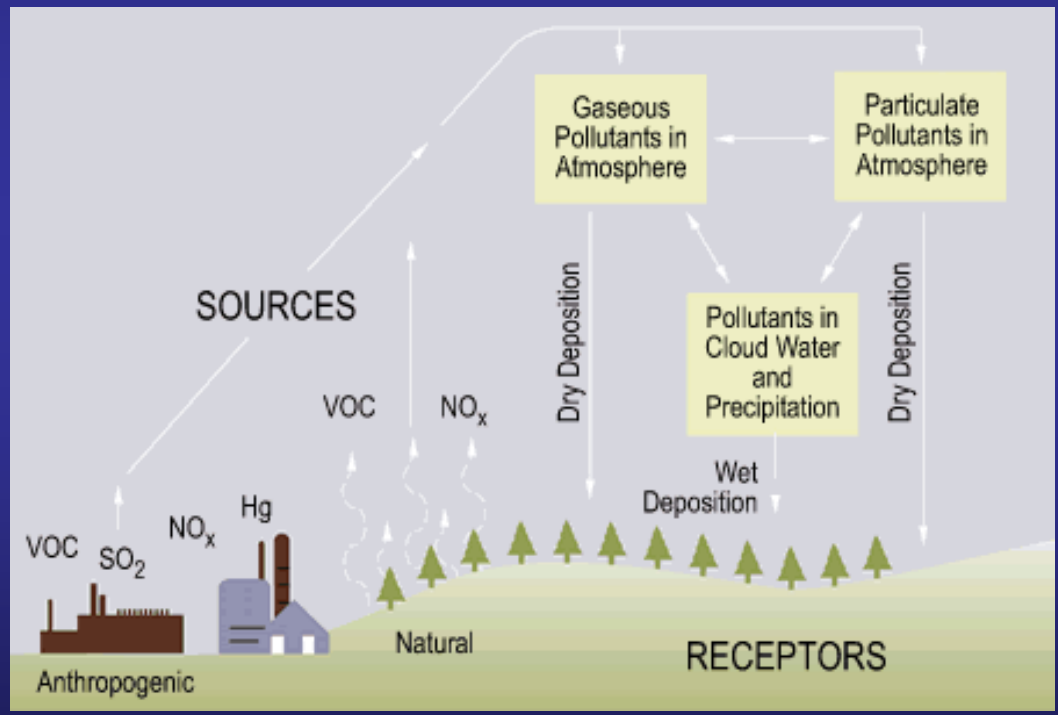
Industrial Contaminants

- Disinfection-byproducts
  - Heavy doses of chlorine are reportedly used in urban water supplies of developing countries
    - Health effects only beginning to be uncovered

- Industrial discharges of toxic chemicals taint ground-water and surface water supplies.
  - Approximately 60% of smelting and 50% of lead mining operations are located in developing countries causing trace metal pollution (e.g., cadmium, nickel, and lead) in aquatic systems
    - Coupled with drinking untreated surface water, this may be a concern.

Industrial Contaminants cont'd

- Rainwater
  - Millions of people in developing countries drink rainwater collected from roof tops, stem flows or other systems.
  - In many urban areas, this source of drinking water has become contaminated through scavenging of airborne pollutants and leaching of air toxics deposited on the roof surfaces



Industrial Contaminants cont'd

- Pesticides
  - Less expensive, more acutely toxic pesticides are more readily available
    - Even if their use has been banned or curtailed in more developed countries
    - Estimated 25 million workers poisoned each year
      - Largely a result of limited worker training and inadequate clothing protections
  - Also, > 500,000 pounds of obsolete pesticides are stockpiled
    - Stockpiles accumulated after gov't's banned pesticides after they were imported

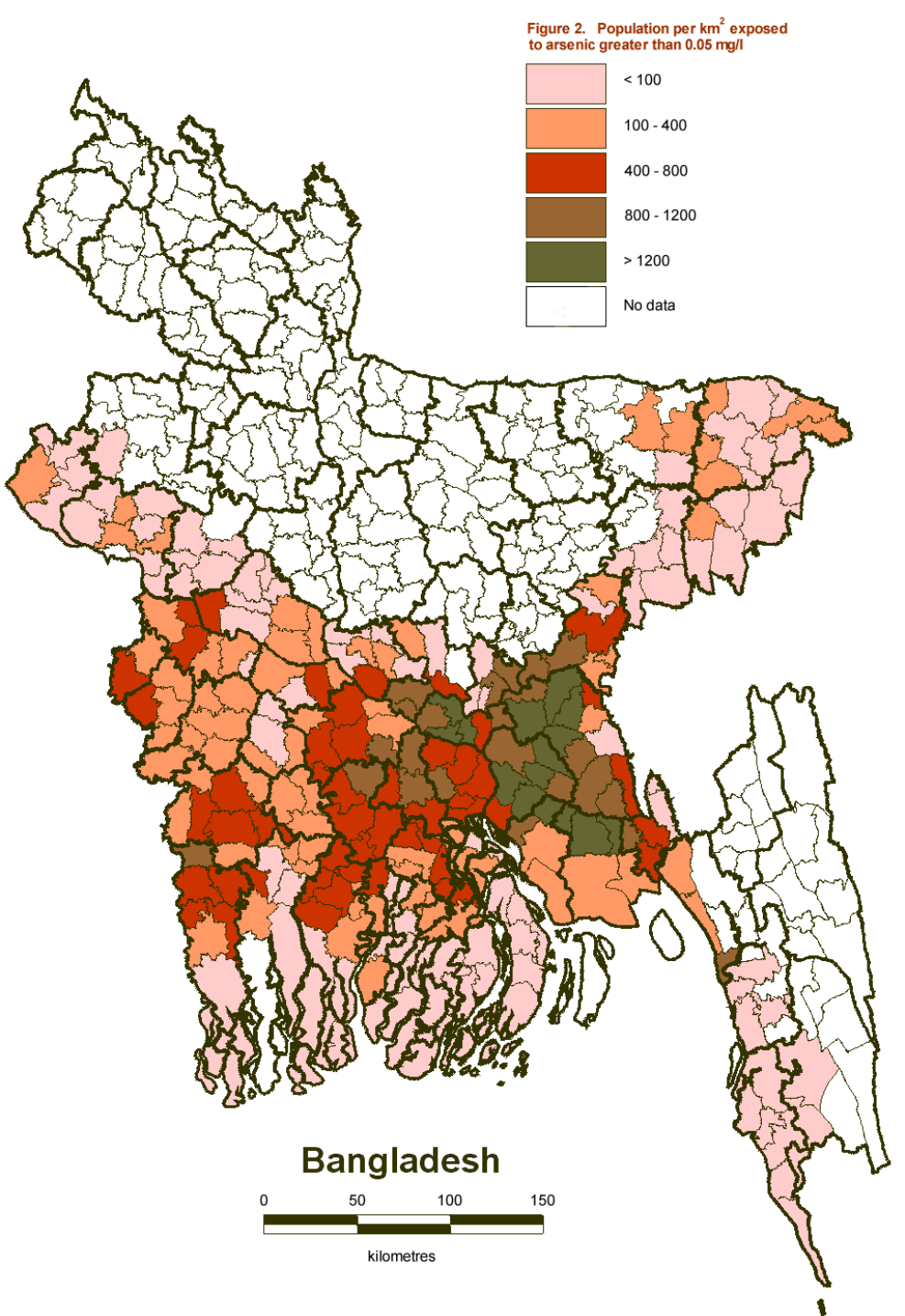
Pesticide waste in rusted and corroded containers (Photo by Alemayehu Wodageneh courtesy FAO)

Arsenic in Bangladesh

- In 1970s and 1980s, to lessen the toll from microbial disease in surface water
  - Shallow tube wells were dug in Bangladesh to provide groundwater for drinking
  - ~11 million tube wells dug
  - Tested safe for microbes; never tested for As (neither are most private wells in USA)
  - In early 1990s, arsenic problem discovered
- Similar story occurred in Vietnam, only a few years later
- Well water still not regularly tested for arsenic in many parts of the world

Arsenic-Health Effects

- Epidemiologic studies indicate that arsenic in drinking water is associated with
  - Vascular diseases (blackfoot disease, hypertension, stroke)
  - Skin ailments (lesions, hypo- and hyper-pigmentation)
  - Diabetes
  - Birthing outcomes (low birth weight)
  - Intellectual function (IQ)
  - Cancers
    - International Agency for Research on Cancer (IARC) concludes *sufficient evidence* for an increased risk of cancers of the bladder, lung, and skin in humans



As in Bangladesh

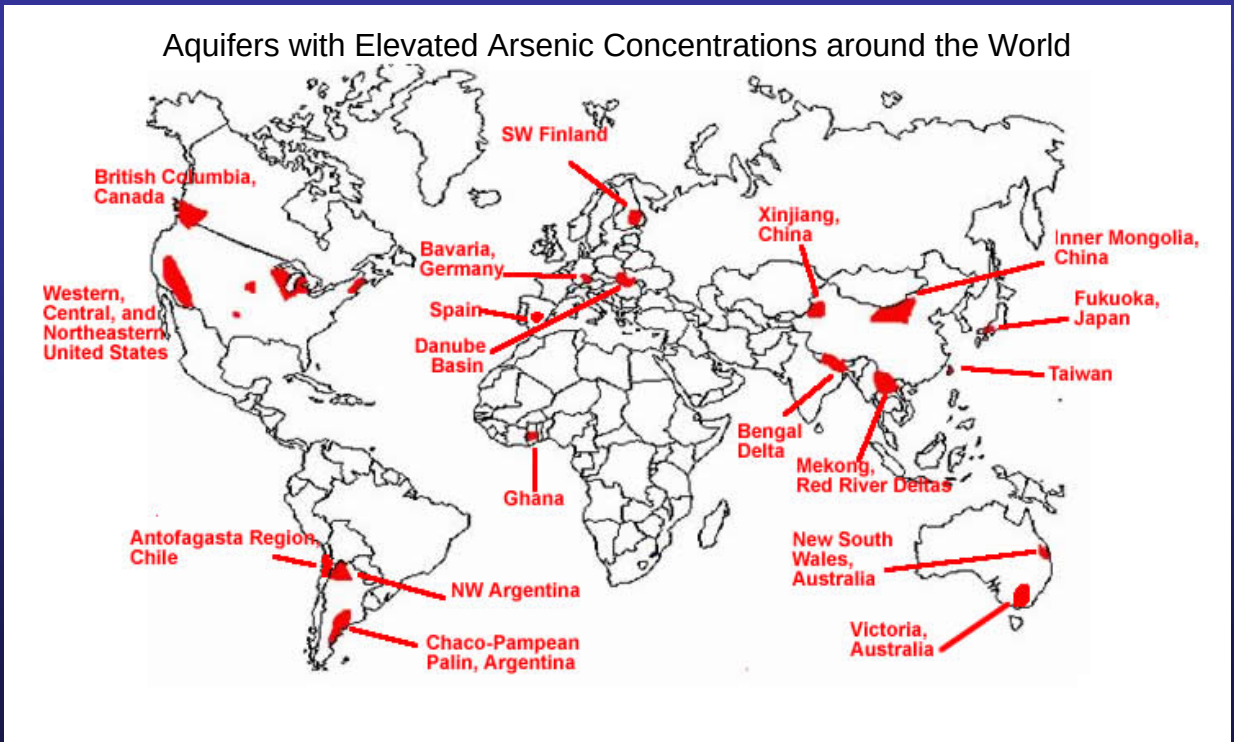
- Worldwide concern over possible health problems in the area
- Already seeing skin problems, diabetes, and vascular problems

Bangladesh cont'd

- Shallow wells have higher As
- Great deal of spatial variability
  - Short-range variability within a village
    - High-As well adjacent to low-As well
  - Regional patterns are apparent
- Very difficult to predict

Arsenic in Underground Aquifers

- The more places we look for arsenic, the more we discover it in potentially harmful concentrations



Other Regions

- Taiwan
  - High As well water in south-west coast
- Antofagasta, Chile
  - High As levels in Tocance river
    - Water source comes from Andes mountains
      - Volcanic sediments high in arsenic are believed to be ultimate source
- Mexico, Argentina, Western US
  - High arsenic in groundwater and shallow well water also associated with volcanic sediments in parts of these regions
- Hungary/Romania
  - High arsenic in well water of Danube River Basin
- Ghana
  - High arsenic in mine waste gets into water supply

- Mechanisms that explain short-range and long-range spatial variability in arsenic concentrations are a topic of considerable research

Estimates of Worldwide Population Exposed to Arsenic in Drinking Water

Country	Population Exposed to As ≥ 300 µg/L	Population Exposed to As ≥ 50 µg/L	Population Exposed to As ≥ 10 µg/L
Bangladesh	5 000 000	25 000 000	38 000 000
West Bengal, India	1 000 000	6 000 000	12 000 000
Nepal	?	?	2 500 000
Taiwan	150 000	900 000	1 800 000
Mainland China	1 000 000	5 600 000	14 600 000
Vietnam	600 000	3 000 000	6 000 000
Argentina	?	270 000	?
Chile	?	500 000	?
Mexico	?	400 000	?
USA	?	350 000	13 000 000
Hungary	?	29 000	?
Total	~10 000 000	~50 000 000	~100 000 000

Meliker, Lifetime Exposure to Arsenic in Drinking Water, VDM Dr Muller Publishers, 2007.

Unknowns

- Can only identify what we look for
  - There are still contaminants that we are not looking for
    - Unknown unknowns
  - And contaminants we know about but do not measure for
    - Known unknowns: Arsenic, manganese (perhaps the next arsenic?)
- Future research will likely uncover different classes of contaminants that we are not concerned about today

Contaminants to Think about...

- If turning to groundwater
  - Other natural elements (As, Mn, Fl, U)
  - Intrusion of anthropogenic contaminants
- If relying on surface water
  - DBPs
  - Pharmaceuticals (from fish farms, human waste)
  - Direct discharge of industrial effluent
  - Hg (mainly in fish) from Lake Victoria gold mining operations
  - Pesticides, fertilizer (nutrients)
- If harvesting rainwater
  - Atmospheric pollutants returning to earth via rainfall
    - Industries
    - Informal economy (electronic-waste recycling)

Thank you

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