Climate Change, Human and Planetary Health through the Lens of Water

Susan Murcott
D-Lab: Water, Climate Change and Health

Development through Discovery, Design and Dissemination

16 year-old Greta Thunberg at the Davos World Economic Forum Jan. 25, 2019

https://www.weforum.org/agenda/2019/01/our-house-is-on-fire-16-year-old-greta-thunberg-speaks-truth-to-power/

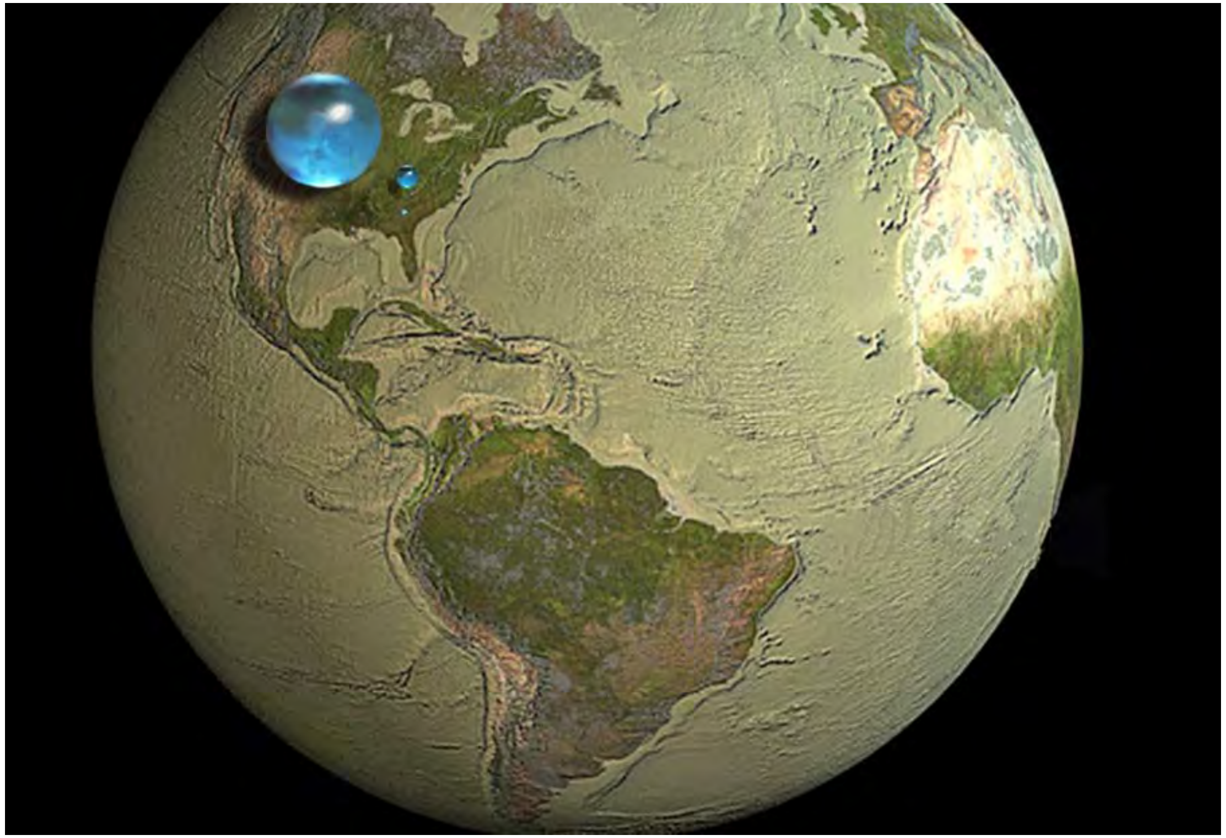
Greta Thunberg, Stockholm
School strike for climate - save the world by changing the rules

https://www.youtube.com/watch?v=EAmmUIEsN9A

Lecture Outline

- How much water on Earth?
- A Living Planet? What is Life?
- Some Conditions for Life on Earth
- Climate Change Impacts, esp. the Role of Water
- Human Health, Planetary Health
- Solutions
- Water, Climate Change & Health Actions
    - Puerto Rico
    - Nepal

How much Water on Earth?

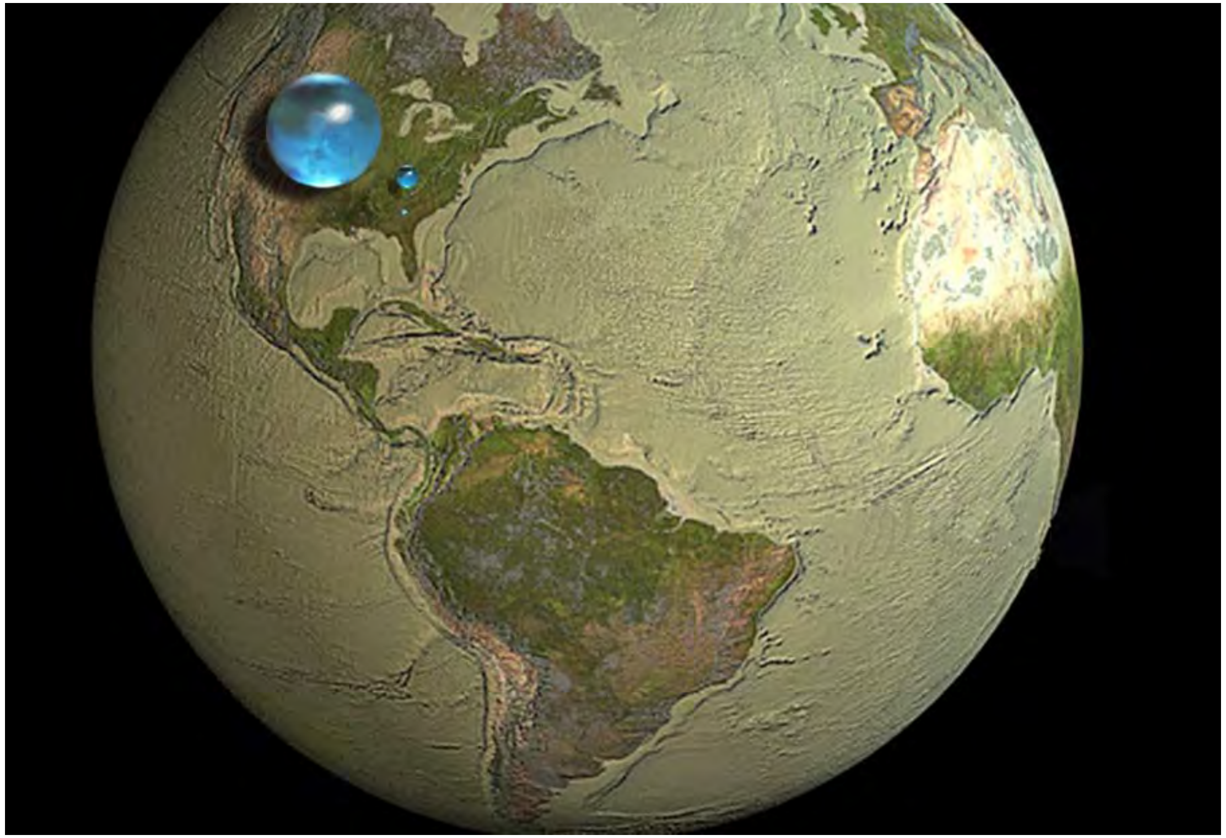


- Large sphere= all water on earth; 860-miles in diameter sphere (1.4 Billion km^3).
- Medium sphere = freshwater on earth = groundwater & surface water; 170 miles in diameter (11 Million km^3) .
- Small sphere = surface fresh water on earth; 34.9 miles in diameter (93,000 km^3).
- Ave. depth of ocean ≈ 1.7 mi. (2.7 km)

https://www.usgs.gov/media/images/all-earths-water-a-single-sphere

How much Water on Earth? (MORE DETAIL)

Large sphere= all water on earth (1.4 Billion km^3). Medium sphere = freshwater on earth (11 Million km^3) . Small sphere = surface fresh water on earth (93,000 km^3).



- Large sphere: represents all the water on earth – in oceans, ice caps, lakes, rivers, groundwater, the atmosphere, and living things. It has a diameter of about 860 miles. That 860-mile-high sphere is the largest bubble in the picture, which stretches from Salt Lake City, Utah to Topeka, Kan. It has a volume of over 332 million cubic miles.

- The 2nd, smaller blue sphere, over Kentucky – is about 170 miles in diameter. It represents the world's liquid freshwater, including groundwater, lakes, swamp water, and rivers. However, 99 percent of that sphere is groundwater, much of which is not accessible to humans.

- The smallest sphere, represents the freshwater, all the lakes and rivers on the planet. Most of the water that people and ecosystems use every day comes from these surface-water sources. The diameter of this sphere is a mere 34.9 miles, with a volume of a little over 22,000 cubic miles.

Blue Marble – A Living Planet?

Earth seen from Apollo 17 on Dec. 7, 1972

What is life?

- <u>Physicist's view</u>: a reduction in entropy
- <u>Neo-Darwinist's view</u>: organic growth and reproduction, with errors corrected through natural selection
- <u>Biochemist's view</u>: able to utilize energy, either from sunlight or food and to grow according to genetic instructions
- <u>Geophysiologist's view</u>: a bounded homeostatic system, keeping its internal conditions constant, despite changing external conditions.

J. Lovelock, Healing Gaia, 1991

Characteristics of Life Forms

Characteristic	Bacteria	Mammal	Tree	Beehive	Living Planet Earth
Reproduction	+	+	+	-	-
Metabolism	+	+	+	+	+
Evolution	+	+	+	+	+
Thermostasis	-	+	-	+	+
Chemostatis	+	+	+	-	+
Self-healing	+	+	+	+	+

J. Lovelock, Healing Gaia, 1991

Some Conditions for Life on Earth

- Earth must be a certain distance from the sun for sufficient sunlight and heat
- Relatively narrow temperature range
- A supply of needed elements
- Living creatures primarily composed of 4 elements: carbon, nitrogen, oxygen and hydrogen.
- Life requires materials that move about, permitting cycles.
- Continual access to new sources of materials and the movement of used materials we call "wastes" to species that can use them for their own purposes
- 4 great cycles

Liebes Sidney et al., A Walk Through Time, 1998.

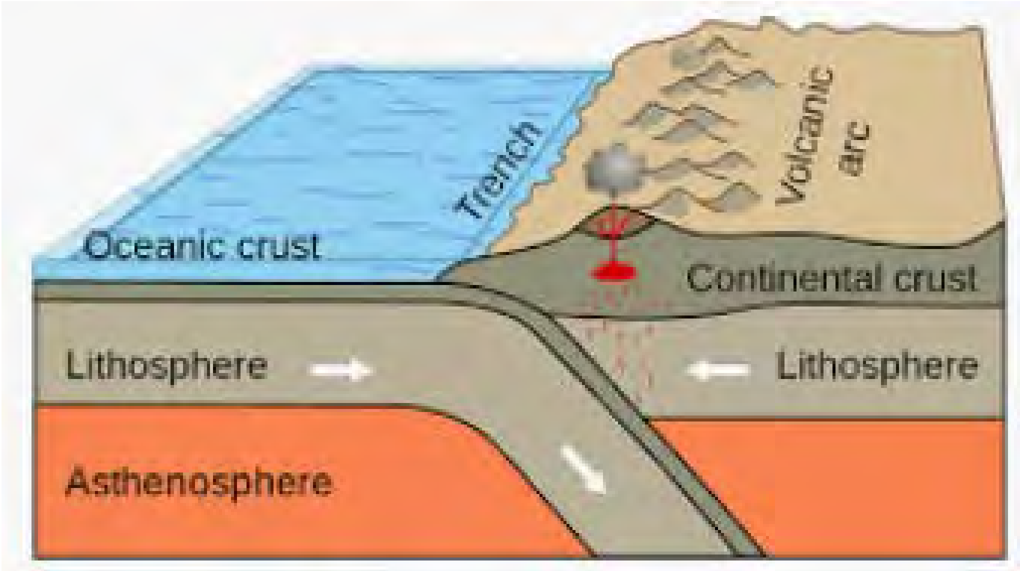
4 Great Cycles on Earth

- Lithosphere,
- Hydrosphere
- Atmosphere
- Biosphere

Lithosphere, rock cycle

- The lithosphere lies below the crust.
- Magma erupts from the lithosphere. Crust thickens and forms tectonic plates. Plates edges pushed up or under other plates, melting magma, which again erupts.

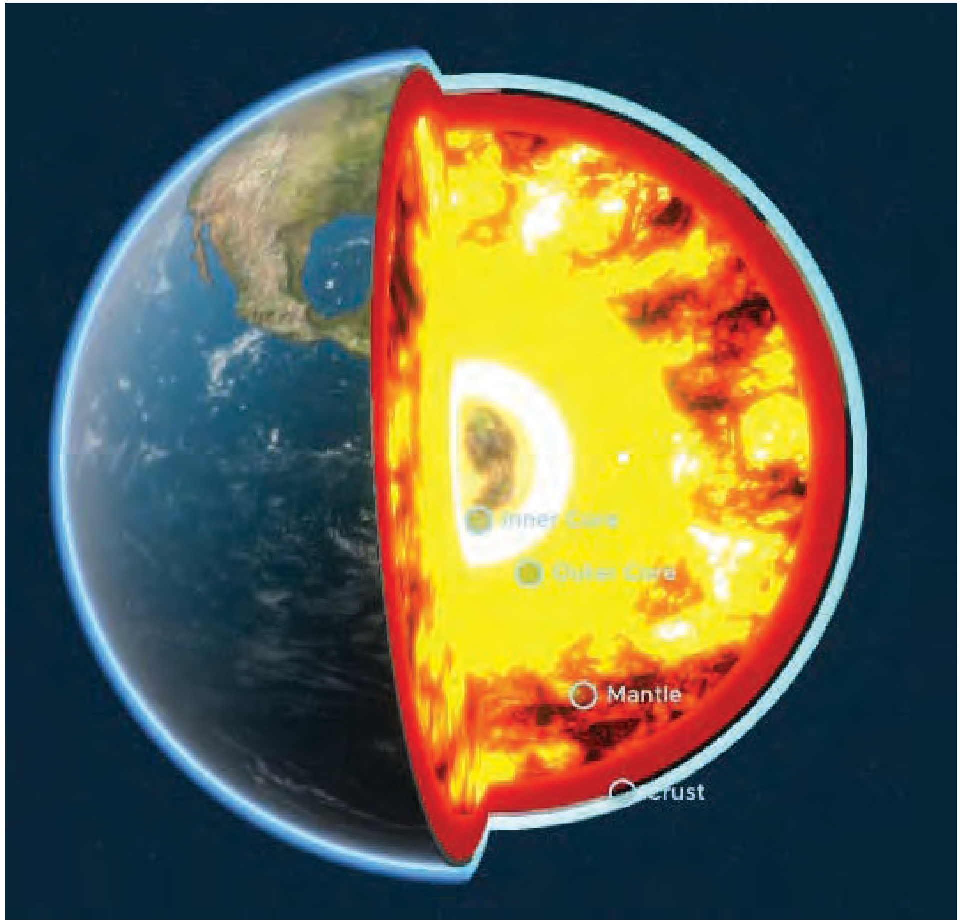
Liebes Sidney et al., A Walk Through Time, 1998.



http://www.differencebetween.net/science/differences-between-the-earths-lithosphere-and-asthenosphere/

Crust

- The Earth's crust ranges from 5–70 kilometres (3.1–43.5 mi) in depth and is the outermost layer. The thin parts are the oceanic crust, which underlie the ocean basins (5–10 km) and are composed of dense (mafic) iron magnesium silicate igneous rocks, like basalt.



Courtesy of NASA. Image is in the public domain.

Differences between the Earth's Lithosphere and Asthenosphere:

Lithosphere	**Asthenosphere**
The lithosphere concept was proposed in 1911	The asthenosphere concept was proposed in 1926
Lithosphere is composed of the crust and upper most solid mantle	Asthenosphere is composed of the upper most weaker part of the mantle
Lies beneath the atmosphere and above the asthenosphere	Lies beneath the lithosphere and above the mesosphere
The physical structure consists of a rigid outer layer that is divided by tectonic plates. It is regarded as rigid, brittle, and elastic.	The physical structure is mostly solid with some regions containing partially molten rock, which exhibits plastic properties
Characterized as elastic and less ductile	Has a higher degree of ductility than the lithosphere
Ranges from a depth of 80km and 200 km below the earths surface	Extends to a depth of 700km below the earths' surface
Approximate temperature of 400 degrees Celsius	Approximate temperature ranging from 300 to 500 degrees Celsius
Has a lower density than the asthenosphere	Asthenosphere is denser than the lithosphere
Allows for conductive heat transfer	Allows for advective heat transfer
Seismic waves travel at faster speeds across lithosphere	Seismic waves travel 5 to 10% slower in asthenosphere than in lithosphere
Rocks are under much less pressure forces	Rocks are under immense pressure forces
Chemical composition consists of 80 elements and approximately 2000 minerals	Asthenosphere is mainly composed of iron-magnesium silicates

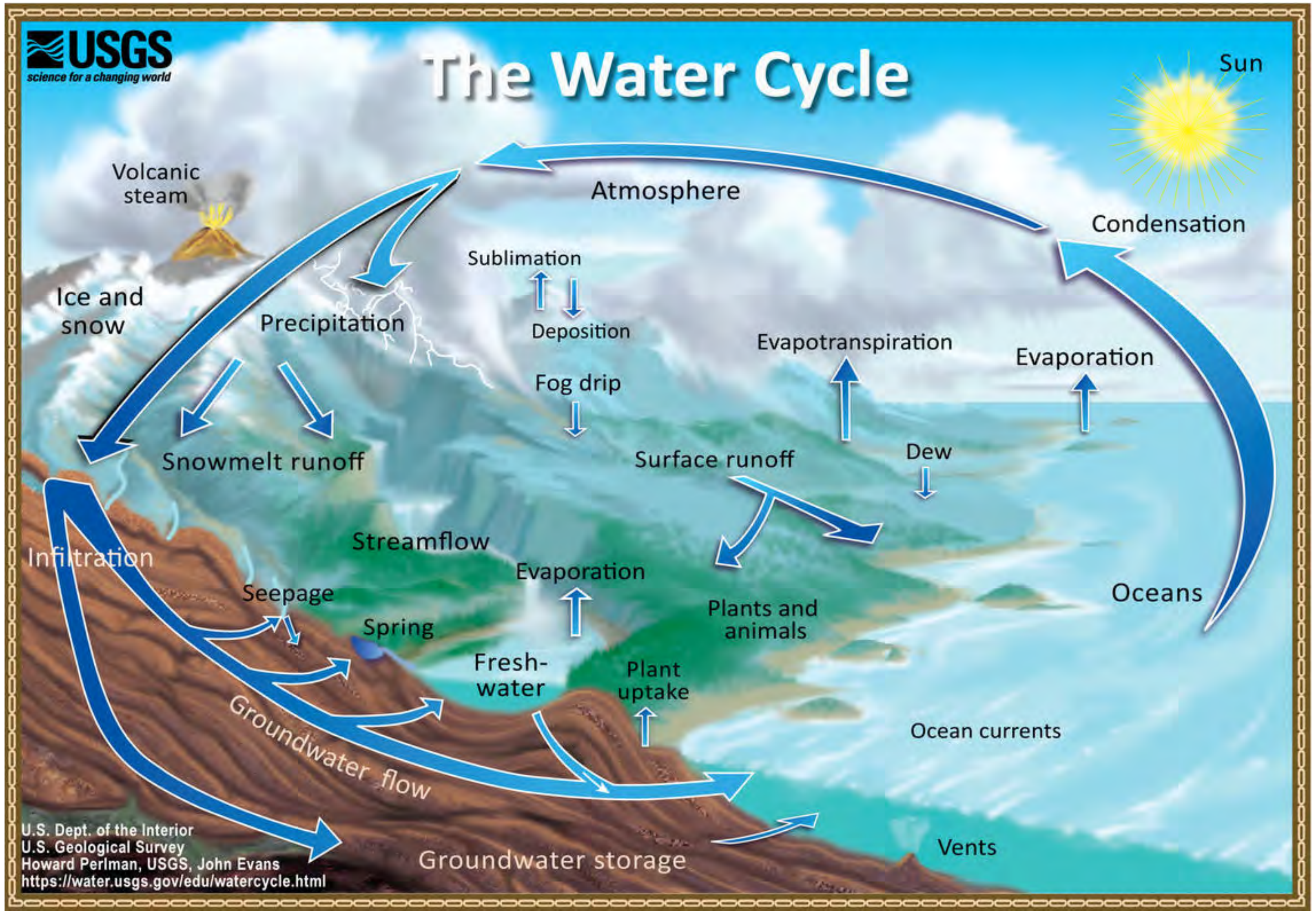
http://www.differencebetween.net/science/differences-between-the-earths-lithosphere-and-asthenosphere/

Hydrosphere – Water Cycle

- Begins with steam released from magma. As the earth cools the steam condenses into rain. Rain forms rivers and pours into seas. As the seas form, the surface water evaporates into clouds under the Sun's heat, creating a cycle of weather driven by solar energy.
- Later, living systems take an active role in the weather cycle. H2S gas, produced by plankton, rises into the atmosphere. The molecules of this gas form nuclei that attract water molecules and form raindrops. Thus plankton seed the clouds.
- Humans, huge consumers of plankton, keep it in check. But humans kill whales, while at the same time chemical runoff into the sea feed huge blooms of new ocean plankton.

Liebes Sidney et al., A Walk Through Time, 1998.

Water is a Vital Component of the Climate Cycle

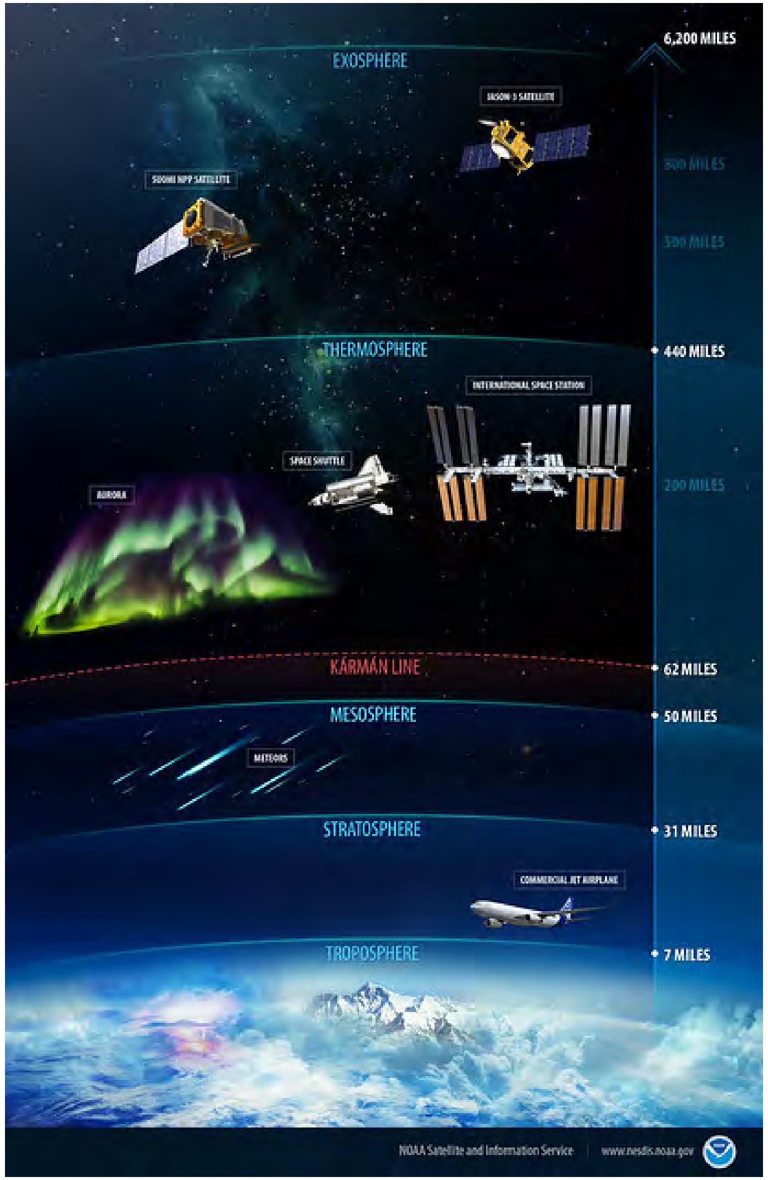


Courtesy of USGS. Image is in the public domain.

Oceans contain over 97% of Earth's water, 2% is in glacial ice, less than 1% in all the rest of Earth's reservoirs.
The hydrologic cycle, the continual recycling of water among all these reservoirs, including much smaller amounts cycling in the atmosphere, in plants, in lakes, in rivers, and in soil, is vital to the operation of the climate system.

Atmosphere

- Early Earth atmosphere may have been hot and loaded with methane, ammonia, nitrogen, carbon dioxide and water (scientists differ on its composition).
- Large organic molecules formed from the early compounds.
- Today's atmospheric composition is dramatically different, as it is breathed in and out by living systems

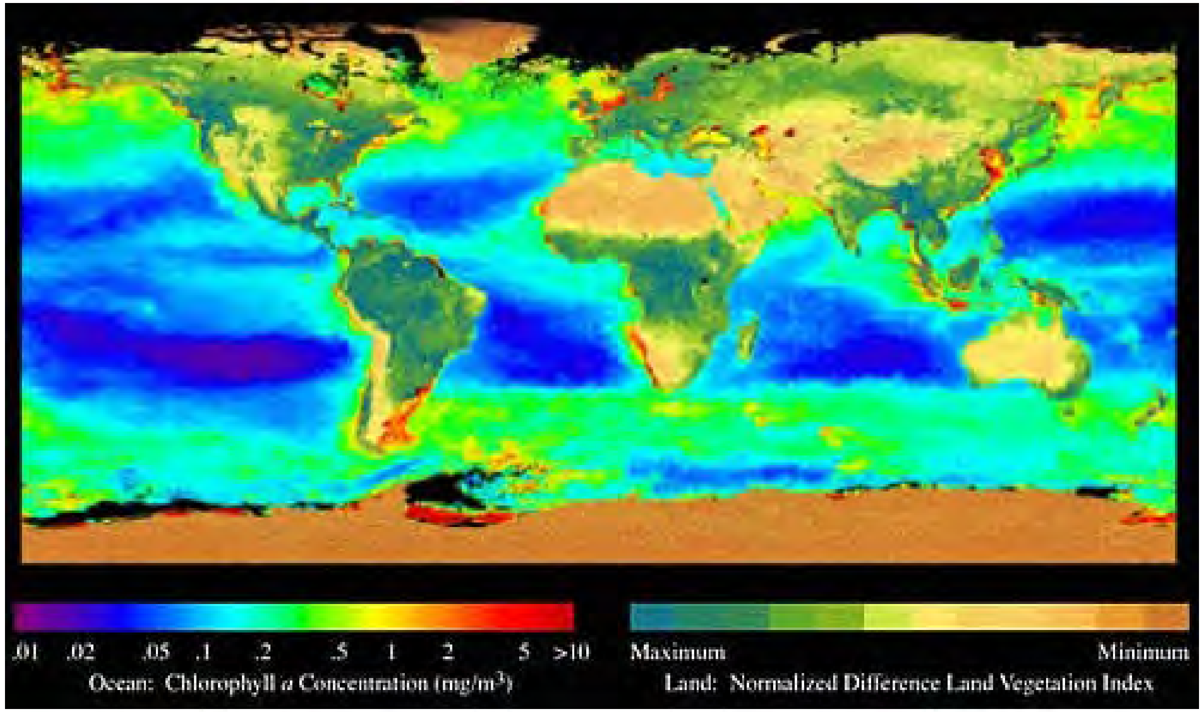


Liebes Sidney et al., A Walk Through Time, 1998.

https://scied.ucar.edu/atmosphere-layers

Biosphere

- Science has been largely reductionist, focusing on individual units, on parts of system.
- James Hutton, in 1785 called the Earth a living superorganism.
- Another exception is the Russian geologist Vladimir Vernadsky, who defined life as a geochemical process, Earth's crustal rock in solid form or as sand and dust transforming into living matter, then back into rock, a kind of planetary metabolism or biochemical process.
- James Lovelock updated these ideas with his controversial "Gaia hypothesis," stating that living and non-living systems of Earth are tightly coupled and that life creates its optimal conditions by regulating surface temperatures and chemical balance in soils, seas and atmosphere.



This view of Earth highlights biological activity - specifically, the amount of photosynthesis happening. Higher chlorophyll concentrations in the ocean are indicated with green, yellow, and red colors. The amount of vegitation on land is indicated with incresingly deep shades of green. (*SeaWiFS Project, NASA/Goddard)*

Liebes Sidney et al., A Walk Through Time, 1998.

Climate Change Impacts, especially the Role of Water

Climate Change Impacts
M. Maslin, Ch. 5.

- Coastal flooding
- Storms and floods
- Heat waves and drought
- Human health
- Biodiversity
- Agriculture
- Ocean acidification

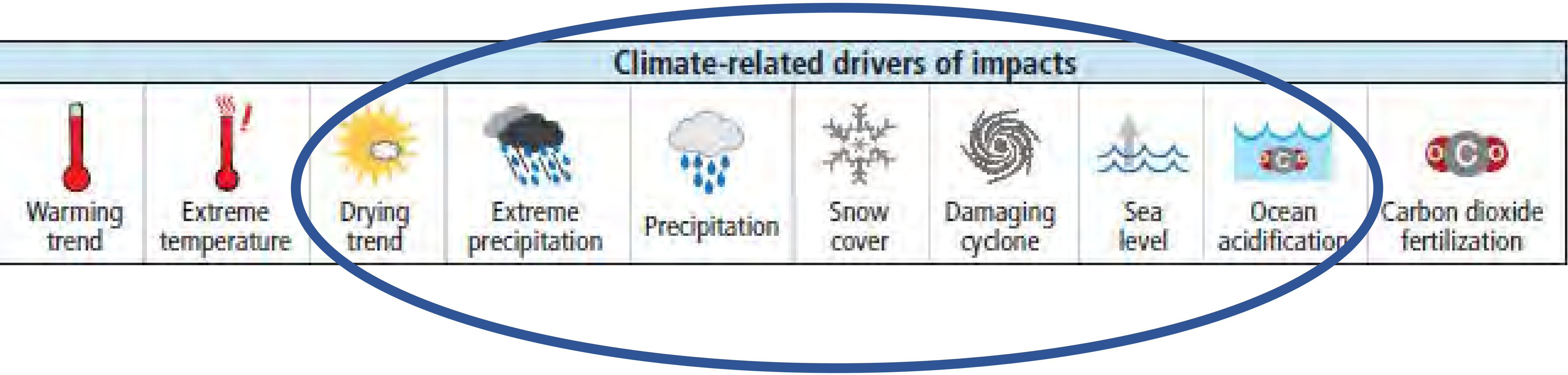
[Graph of hunger, malaria, and flooding risk vs. global temperature increase removed due to copyright restrictions. Maslin, Mark. *Climate Change: A Very Short Introduction.* 3rd Edition. Oxford University Press, Oxford, UK, 2014. Ch. 5.]

Climate Change Impacts
Risk of Water Shortage
M. Maslin, Ch. 5. p. 70

This figure shows that the risk of water shortage changes dramatically at a global temperature increase above pre-industrial levels over 2 degrees C.

[Graph of water shortage risk vs. global temperature increase removed due to copyright restrictions. Maslin, Mark. *Climate Change: A Very Short Introduction*. 3rd Edition. Oxford University Press, Oxford, UK, 2014. Ch. 5.]

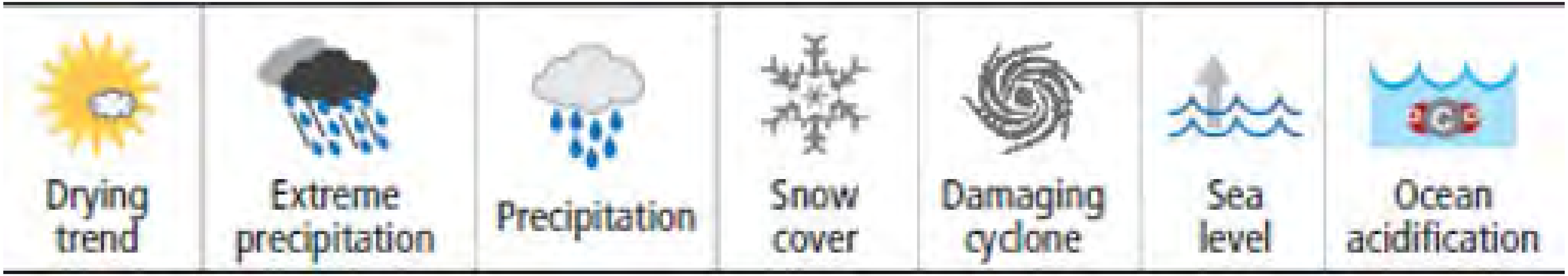
IPCC 2014 Climate-Related Drivers of Impacts



- 7 of 10 climate-related drivers of impacts pertain directly to water.
- This suggests that it is vitally important to understand the role of water in climate change.

Climate Change – 2014. IPCC AR5, WGII "Impacts, Adaptation & Vulnerability" p.21

Water-Related Drivers of Impacts (subset from previous slide)



- Drying trends
- Precipitation / Extreme precipitation
- Snow cover
- Damaging cyclones
- Sea level rise
- Ocean acidification

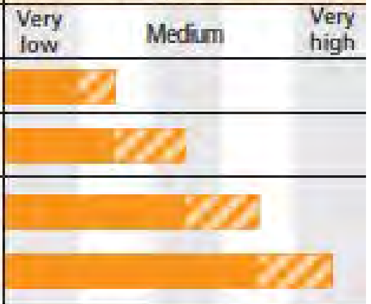
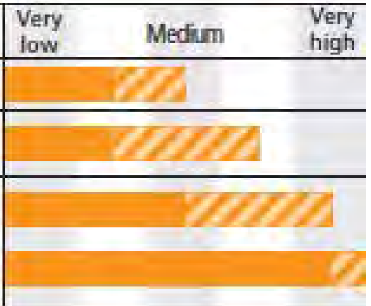
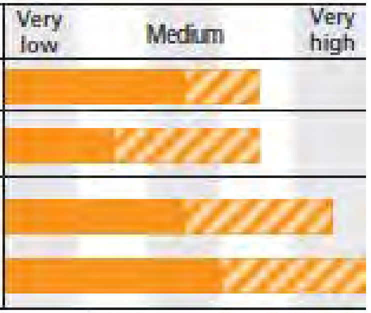
Climate Change – 2014. IPCC AR5, WGII "Impacts, Adaptation & Vulnerability" p.21

Assessment Box SPM.2 Table 1, IPCC_AR5_WG2_pp.21-25

- Stress on water resources
- Stress on freshwater and terrestrial ecosystems
- Food production
- Vector and water borne diseases
- Flooding
- Water availability in arid and glacial meltwater areas

Assessment Box SPM.2 Table 1 | Key regional risks from climate change and the potential for reducing risks through adaptation and mitigation. Each key risk is characterized as very low to very high for three timeframes: the present, near term (here, assessed over 2030–2040), and longer term (here, assessed over 2080–2100). In the near term, projected levels of global mean temperature increase do not diverge substantially for different emission scenarios. For the longer term, risk levels are presented for two scenarios of global mean temperature increase (2°C and 4°C above preindustrial levels). These scenarios illustrate the potential for mitigation and adaptation to reduce the risks related to climate change. Climate-related drivers of impacts are indicated by icons.

Africa

Key risk	Adaptation issues & prospects	Climatic drivers	Timeframe	Risk & potential for adaptation
Compounded stress on water resources facing significant strain from overexploitation and degradation at present and increased demand in the future, with drought stress exacerbated in drought-prone regions of Africa (*high confidence*) [22.3-4]	• Reducing non-climate stressors on water resources • Strengthening institutional capacities for demand management, groundwater assessment, integrated water-wastewater planning, and integrated land and water governance • Sustainable urban development		Present Near term (2030–2040) Long term (2080–2100) 2°C 4°C	
Reduced crop productivity associated with heat and drought stress, with strong adverse effects on regional, national, and household livelihood and food security, also given increased pest and disease damage and flood impacts on food system infrastructure (*high confidence*) [22.3-4]	• Technological adaptation responses (e.g., stress-tolerant crop varieties, irrigation, enhanced observation systems) • Enhancing smallholder access to credit and other critical production resources; Diversifying livelihoods • Strengthening institutions at local, national, and regional levels to support agriculture (including early warning systems) and gender-oriented policy • Agronomic adaptation responses (e.g., agroforestry, conservation agriculture)		Present Near term (2030–2040) Long term (2080–2100) 2°C 4°C	
Changes in the incidence and geographic range of vector- and water-borne diseases due to changes in the mean and variability of temperature and precipitation, particularly along the edges of their distribution (*medium confidence*) [22.3]	• Achieving development goals, particularly improved access to safe water and improved sanitation, and enhancement of public health functions such as surveillance • Vulnerability mapping and early warning systems • Coordination across sectors • Sustainable urban development		Present Near term (2030–2040) Long term (2080–2100) 2°C 4°C	

Assessment Box SPM.2 Table 1, IPCC_AR5_WG2_pp.21-25

North America

Key risk	Adaptation issues & prospects	Climatic drivers	Timeframe	Risk & potential for adaptation
Wildfire-induced loss of ecosystem integrity, property loss, human morbidity, and mortality as a result of increased drying trend and temperature trend (*high confidence*) [26.4, 26.8, Box 26-2]	• Some ecosystems are more fire-adapted than others. Forest managers and municipal planners are increasingly incorporating fire protection measures (e.g., prescribed burning, introduction of resilient vegetation). Institutional capacity to support ecosystem adaptation is limited. • Adaptation of human settlements is constrained by rapid private property development in high-risk areas and by limited household-level adaptive capacity. • Agroforestry can be an effective strategy for reduction of slash and burn practices in Mexico.		Present Near term (2030–2040) Long term (2080–2100) 2°C / 4°C	Very low – Medium – Very high
Heat-related human mortality (*high confidence*) [26.6, 26.8]	• Residential air conditioning (A/C) can effectively reduce risk. However, availability and usage of A/C is highly variable and is subject to complete loss during power failures. Vulnerable populations include athletes and outdoor workers for whom A/C is not available. • Community- and household-scale adaptations have the potential to reduce exposure to heat extremes via family support, early heat warning systems, cooling centers, greening, and high-albedo surfaces.		Present Near term (2030–2040) Long term (2080–2100) 2°C / 4°C	Very low – Medium – Very high
Urban floods in riverine and coastal areas, inducing property and infrastructure damage; supply chain, ecosystem, and social system disruption; public health impacts; and water quality impairment, due to sea level rise, extreme precipitation, and cyclones (*high confidence*) [26.2-4, 26.8]	• Implementing management of urban drainage is expensive and disruptive to urban areas. • Low-regret strategies with co-benefits include less impervious surfaces leading to more groundwater recharge, green infrastructure, and rooftop gardens. • Sea level rise increases water elevations in coastal outfalls, which impedes drainage. In many cases, older rainfall design standards are being used that need to be updated to reflect current climate conditions. • Conservation of wetlands, including mangroves, and land-use planning strategies can reduce the intensity of flood events.		Present Near term (2030–2040) Long term (2080–2100) 2°C / 4°C	Very low – Medium – Very high

Assessment Box SPM.2 Table 1 | Key regional risks from climate change and the potential for reducing risks through adaptation and mitigation. Each key risk is characterized as very low to very high for three timeframes: the present, near term (here, assessed over 2030–2040), and longer term (here, assessed over 2080–2100). In the near term, projected levels of global mean temperature increase do not diverge substantially for different emission scenarios. For the longer term, risk levels are presented for two scenarios of global mean temperature increase (2°C and 4°C above preindustrial levels). These scenarios illustrate the potential for mitigation and adaptation to reduce the risks related to climate change. Climate-related drivers of impacts are indicated by icons.

Central and South America

Key risk	Adaptation issues & prospects	Climatic drivers	Timeframe	Risk & potential for adaptation
Water availability in semi-arid and glacier-melt-dependent regions and Central America; flooding and landslides in urban and rural areas due to extreme precipitation (*high confidence*) [27.3]	• Integrated water resource management • Urban and rural flood management (including infrastructure), early warning systems, better weather and runoff forecasts, and infectious disease control			Very low — Medium — Very high
			Present	
			Near term (2030–2040)	
			Long term (2080–2100) 2°C	
			Long term (2080–2100) 4°C	
Decreased food production and food quality (*medium confidence*) [27.3]	• Development of new crop varieties more adapted to climate change (temperature and drought) • Offsetting of human and animal health impacts of reduced food quality • Offsetting of economic impacts of land-use change • Strengthening traditional indigenous knowledge systems and practices			Very low — Medium — Very high
			Present	
			Near term (2030–2040)	
			Long term (2080–2100) 2°C	
			Long term (2080–2100) 4°C	
Spread of vector-borne diseases in altitude and latitude (*high confidence*) [27.3]	• Development of early warning systems for disease control and mitigation based on climatic and other relevant inputs. Many factors augment vulnerability. • Establishing programs to extend basic public health services			Very low — Medium — Very high
			Present	
			Near term (2030–2040)	
			Long term (2080–2100) 2°C	not available
			Long term (2080–2100) 4°C	not available

Assessment Box SPM.2 Table 1, IPCC_AR5_WG2_pp.21-25

Small Islands

Key risk	Adaptation issues & prospects	Climatic drivers	Timeframe	Risk & potential for adaptation
Loss of livelihoods, coastal settlements, infrastructure, ecosystem services, and economic stability (*high confidence*) [29.6, 29.8, Figure 29-4]	• Significant potential exists for adaptation in islands, but additional external resources and technologies will enhance response. • Maintenance and enhancement of ecosystem functions and services and of water and food security • Efficacy of traditional community coping strategies is expected to be substantially reduced in the future.			Very low / Medium / Very high
			Present	
			Near term (2030–2040)	
			Long term (2080–2100) 2°C	
			Long term (2080–2100) 4°C	
The interaction of rising global mean sea level in the 21st century with high-water-level events will threaten low-lying coastal areas (*high confidence*) [29.4, Table 29-1; WGI AR5 13.5, Table 13.5]	• High ratio of coastal area to land mass will make adaptation a significant financial and resource challenge for islands. • Adaptation options include maintenance and restoration of coastal landforms and ecosystems, improved management of soils and freshwater resources, and appropriate building codes and settlement patterns.			Very low / Medium / Very high
			Present	
			Near term (2030–2040)	
			Long term (2080–2100) 2°C	
			Long term (2080–2100) 4°C	

Assessment Box SPM.2 Table 1, IPCC_AR5_WG2_pp.21-25

Polar Regions

Key risk	Adaptation issues & prospects	Climatic drivers	Timeframe	Risk & potential for adaptation
Risks for freshwater and terrestrial ecosystems (*high confidence*) and marine ecosystems (*medium confidence*), due to changes in ice, snow cover, permafrost, and freshwater/ocean conditions, affecting species' habitat quality, ranges, phenology, and productivity, as well as dependent economies [28.2-4]	• Improved understanding through scientific and indigenous knowledge, producing more effective solutions and/or technological innovations • Enhanced monitoring, regulation, and warning systems that achieve safe and sustainable use of ecosystem resources • Hunting or fishing for different species, if possible, and diversifying income sources		Present Near term (2030–2040) Long term (2080–2100) 2°C 4°C	Very low – Medium – Very high
Risks for the health and well-being of Arctic residents, resulting from injuries and illness from the changing physical environment, food insecurity, lack of reliable and safe drinking water, and damage to infrastructure, including infrastructure in permafrost regions (*high confidence*) [28.2-4]	• Co-production of more robust solutions that combine science and technology with indigenous knowledge • Enhanced observation, monitoring, and warning systems • Improved communications, education, and training • Shifting resource bases, land use, and/or settlement areas		Present Near term (2030–2040) Long term (2080–2100) 2°C 4°C	Very low – Medium – Very high
Unprecedented challenges for northern communities due to complex inter-linkages between climate-related hazards and societal factors, particularly if rate of change is faster than social systems can adapt (*high confidence*) [28.2-4]	• Co-production of more robust solutions that combine science and technology with indigenous knowledge • Enhanced observation, monitoring, and warning systems • Improved communications, education, and training • Adaptive co-management responses developed through the settlement of land claims		Present Near term (2030–2040) Long term (2080–2100) 2°C 4°C	Very low – Medium – Very high

Climate Change, Water & Sanitation (2016)

"Climate change represents the most significant challenge of the 21st c and poses a risk to water and sanitation" p. 253

"Relatively little attention has been paid to how these threats will impact drinking water and sanitation, despite their importance to human health." p. 255

Water Risks	Sanitation Risks
Flooding damage to water supply infrastructure	Flooding damage to sanitation infrastructure
Water scarcity (due to changing patterns of precipitation and increased demand pressure)	Reduced carrying capacity of bodies of water receiving wastewater
Water quality change	

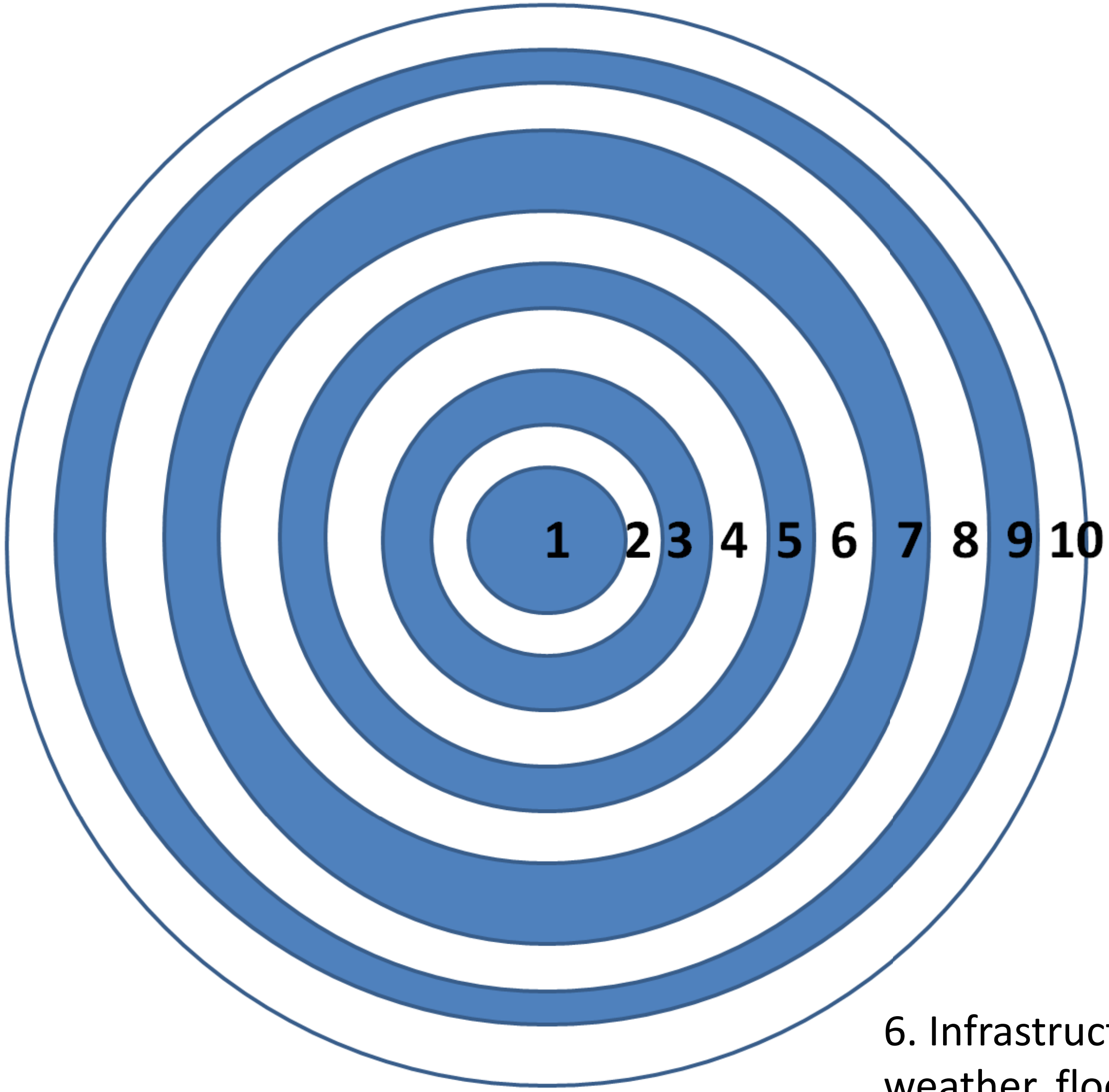
Ref: Howard, G. et al. Climate Change and Water & Sanitation (2016)

Climate Change and Human Health

- Increased temperature -> increased diarrheal disease
- Extreme weather -> outbreaks due to drinking water contamination
- Climate change will likely increase cholera outbreaks in Bengal Delta
- Climate change may affect non-communicable diseases, such as hypertension (p 257)
- Significant association was found between patients with gastrointestinal disease and floods in Mass.

Ref: Howard, G. et al. Climate Change and Water & Sanitation (2016)

Some water-related & health-related risks from climate change, arranged on a scale, from human-scale to planetary- scale



1. Water-related diseases
2. Water & food shortages
3. Impact on water for multiple (productive) uses
4. Impact on surface and ground waters
5. Impacts on oceans & fisheries

6. Infrastructure damage from extreme weather, floods, sea level rise
7. Impact on watersheds, ecosystem services
8. Biodiversity
9. Impact on atmosphere
10. Impact on planetary health

Some Frameworks for Action on Climate Change Solutions

(1)

Drawdown: The Most Comprehensive Plan Ever Proposed to Reverse Global Warming

(2)

IPCC AR5,

WG2 & WG3

(3)

Stabilization Wedges: Solving the Climate Problem for the Next 50 Years with Current Technologies

(4) SUSTAINABLE DEVELOPMENT GOALS

- On September 25th 2015, 193 member countries adopted a set of goals to **end poverty**, **protect the planet**, and **ensure prosperity for all** as part of a new sustainable development agenda.
- Each goal has specific targets to be achieved over the next 15 years.

SDG Goal 6 – Clean Water and Sanitation

SUSTAINABLE DEVELOPMENT GOALS

SDG 6 defines "safely managed drinking water" as:

- Located on premises
- Available when needed
- Free from fecal contamination and priority chemical contamination (e.g. arsenic and fluoride)

(5) Lancet Commission on Planetary Health Framework

Human Health is Dependent on Enabling Infrastructure and the Natural Environment (Planetary Health)

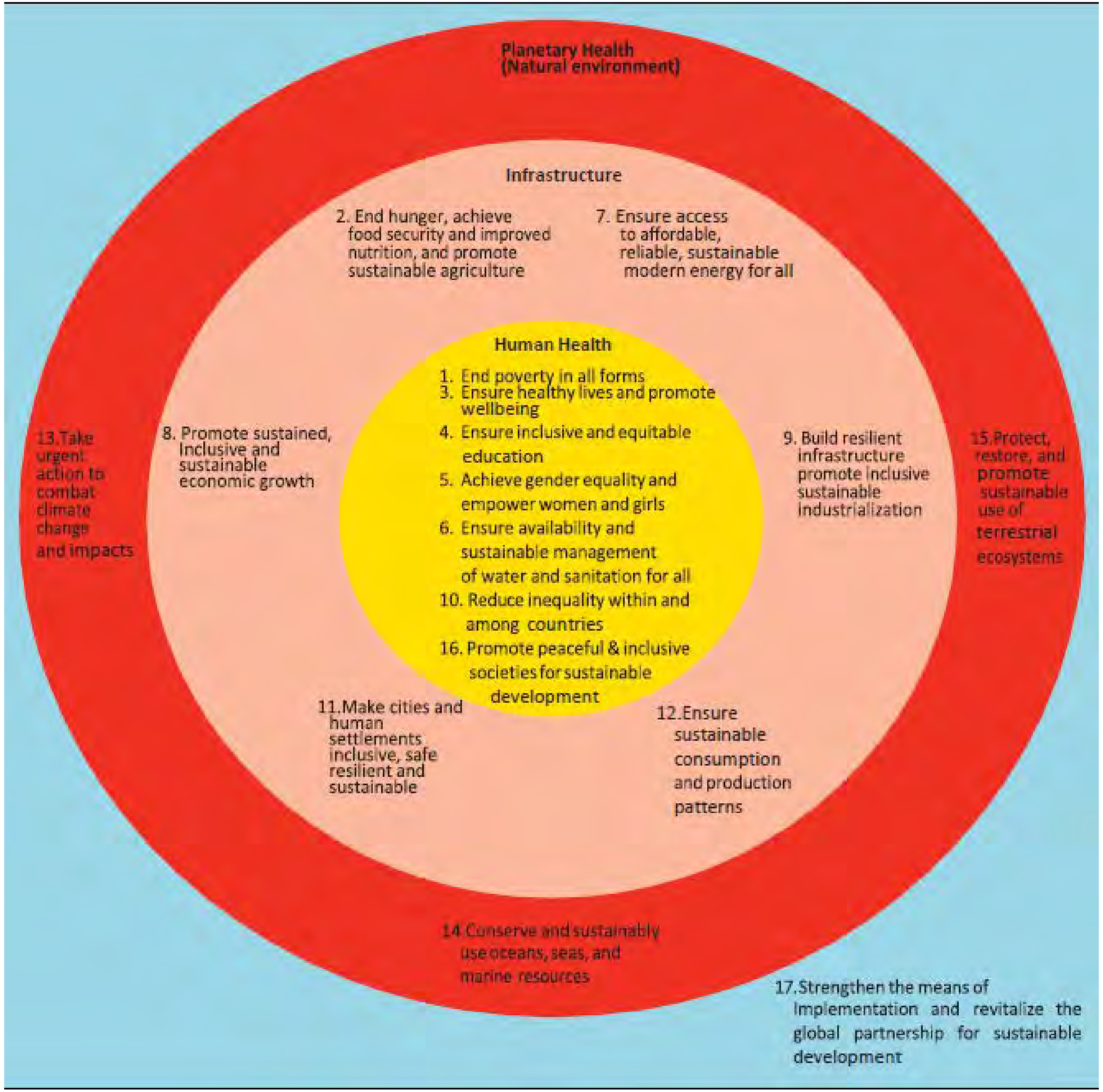


Fig. 20. Sustainable Development Goals Arranged by Themes --Human Health, Infrastructure and Natural Environment (Planetary Health)

Note: Goal 17 is outside the framework as it is an enabling goal. Adapted from Waage & colleagues.

(6) ONE HEALTH

Collaborative effort of multiple disciplines working locally, nationally and globally to attain optimal health for humans, animals and the environment

AVMA One Health Initiative Task Force
2008

Hellen Amuguni
Asst Prof. Infectious Diseases and Global Health
Cummings School of Veterinary Medicine, Tufts

Discussion Questions: Planetary Paradigms

- Copernicus and Galileo: Scientific evidence for a heliocentric solar system vs. Christian Biblical faith paradigm

- Scientific evidence for climate change vs. Political and financial and consumer material well-being dependent on fossil fuels.

- Why is “Gaia Hypothesis” controversial?

Two Water Case Studies (Susan’s work)

- Puerto Rico – 2017-2018
- Nepal 2000-2005 & Jan. 2019

Case Study - Impacts of Hurricane Maria in Puerto Rico

Immediate/Short-term impacts:

- physical injury or death
- drowning

Medium- and long-term impacts:

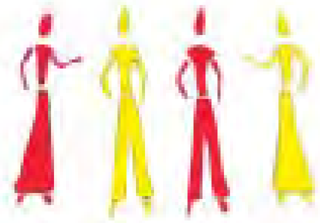
- limited access to food and safe water
- contamination of water and food sources from waste, debris, and other pollution
- disruption of services at hospitals, clinics, and other care facilities
- reduced ability to access health care, medicines or other essential health items
- increased risk from infectious diseases due to lack of safe water, adequate hygiene, and sanitation
- growing burden from unaddressed chronic disease care needs, such as cancer and diabetes
- mental health issues including stress, depression and suicide

Ref: Website of the Kaiser Family Foundation: https://www.kff.org/other/issue-brief/public-health-in-puerto-rico-after-hurricane-maria/

Some Design & Development Definitions

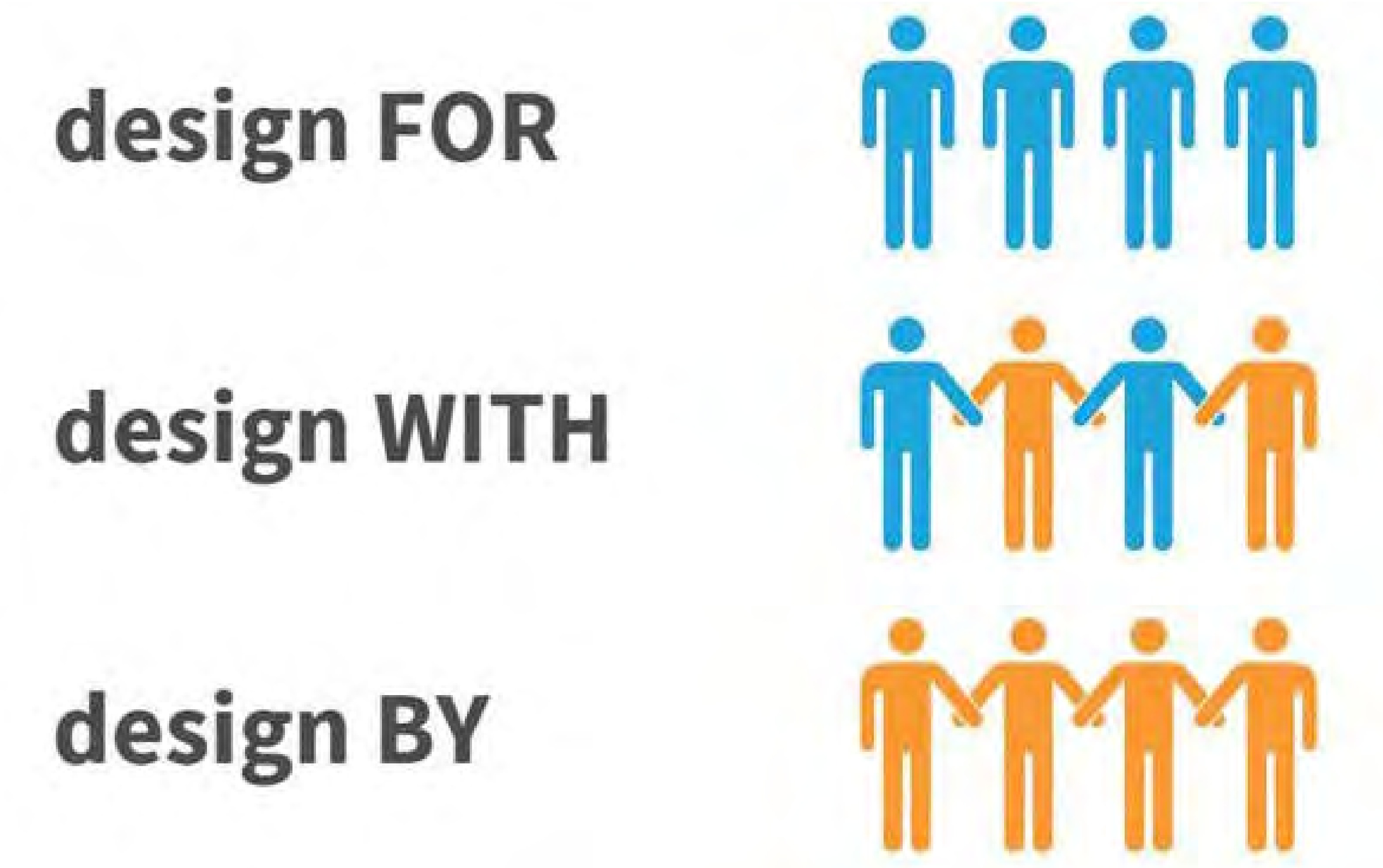
Human-Centered Design/
User-Centered Design

Co-Creation/Participation



Creative Capacity Building

Philosophy – Creative Capacity Building



Pertains to 2nd case study on the arsenic remediation done by Susan's MIT team, and especially by Lumbini Filter Industries

Arsenic Biosand Filter and the Kanchan Filter in Nepal

This picture shows a Terai-region school-girl drinking safe water from the Kanchan Arsenic Filter.

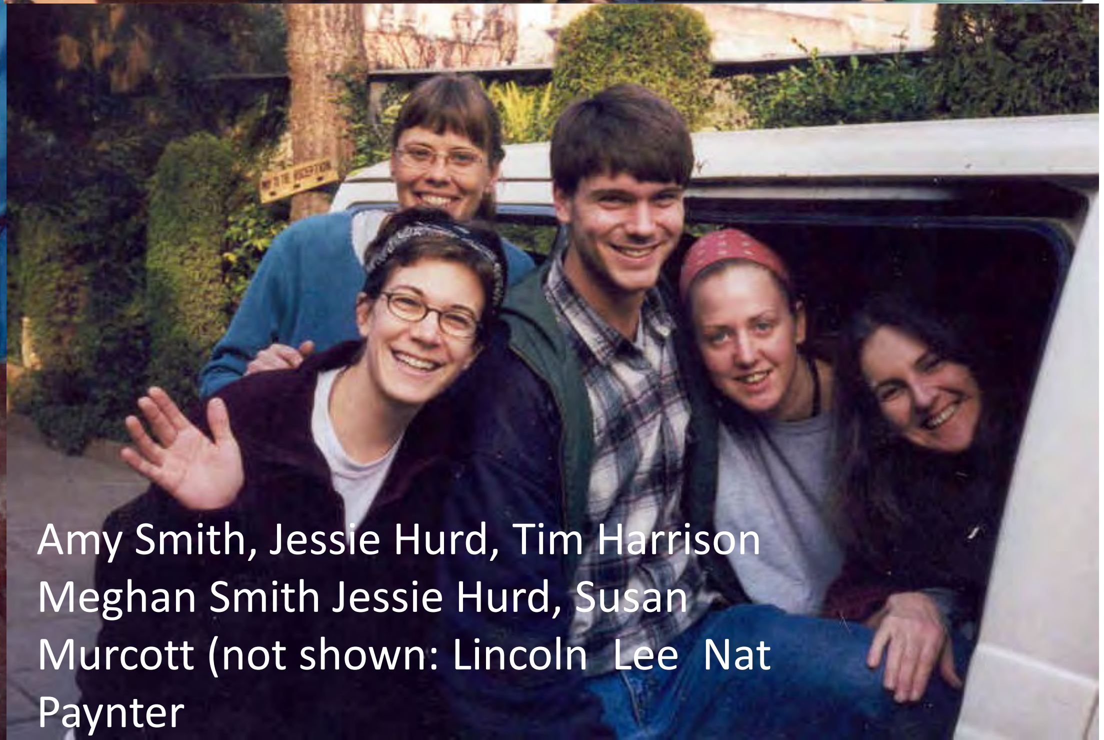
Having “discovered” arsenic in drinking water in the Terai region of Nepal, the arsenic biosand filter and the Kanchan filter was invented by my team to address it.

I learned about the need for safe and accessible water from these women and others like them

2nd Intern’l Women & Water Conference - Kathmandu, Nepal

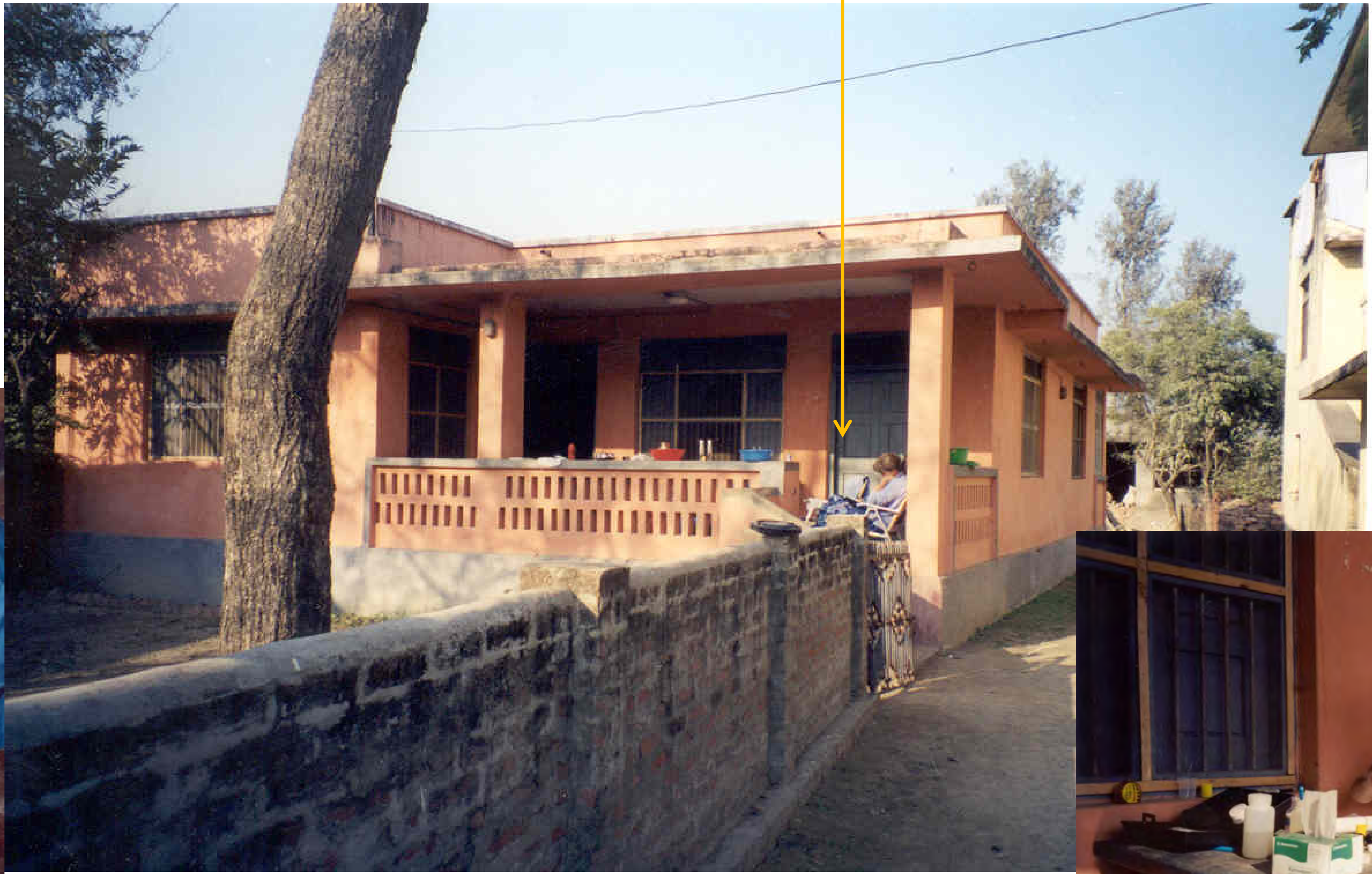
September 1998

Parasi, Nepal, IAP, 2001



Amy Smith, Jessie Hurd, Tim Harrison Meghan Smith Jessie Hurd, Susan Murcott (not shown: Lincoln Lee Nat Paynter

Jan. 2001: Amy & Jessie lived here in Parasi, Lumbini Zone, Nawalparasi District during, mostly on the porch



By coincidence, the well in the back yard of this house in Parasi, Nepal, had the highest arsenic found to date at that time in Nepal.

Jessie Hurd applied irons filings (from PA) in her arsenic treatment pilot study, the first arsenic remediation studies in Nepal, and Susan & Jessie searched for local iron products to substitute for the “imported” arsenic adsorption media

Local market street where Susan and Jessie shopped for appropriate for iron products

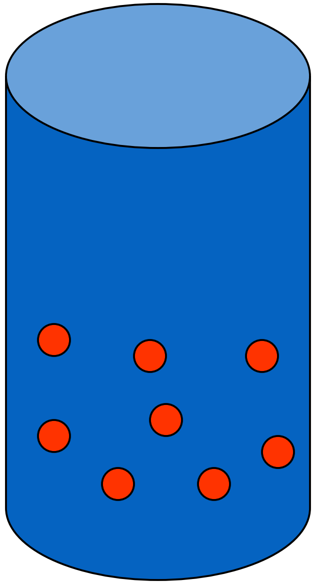
Jessie's Three-Kolshi (Gagri) System

From 2001-2005, we researched and tested 8 different arsenic removal technologies

- (1) 3 *Kolshi* (in Nepali = 3 *Gagri* with zero valent iron filings);
- (2) Iron filings in jerry can;
- (3) Coagulation/Filtration (2-*Kolshi* based on Chakraborti's arsenic removal system);
- (4) Iron oxide coated sand;
- (5) Activated alumina metal oxide #1 (Apyron Inc.);
- (6) Activated alumina metal oxide #2 (Aquatic Treatment Systems Inc.);
- (7) Arsenic treatment plant;
- (8) *Kanchan*™ Arsenic Filter

Jerry Can

1. Fill 10 L plastic jug with raw water.

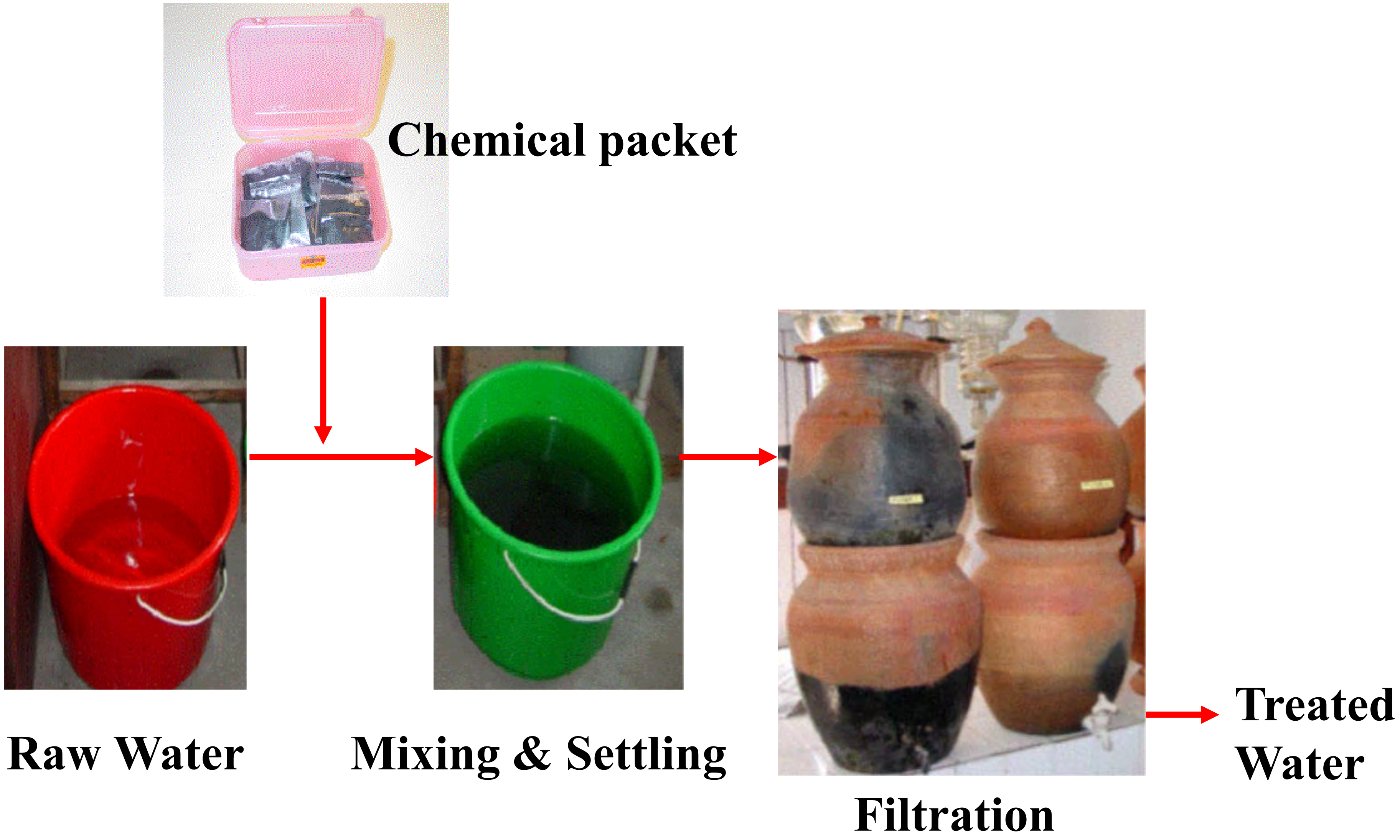


2. Add iron filings

3. Wait 3 hours

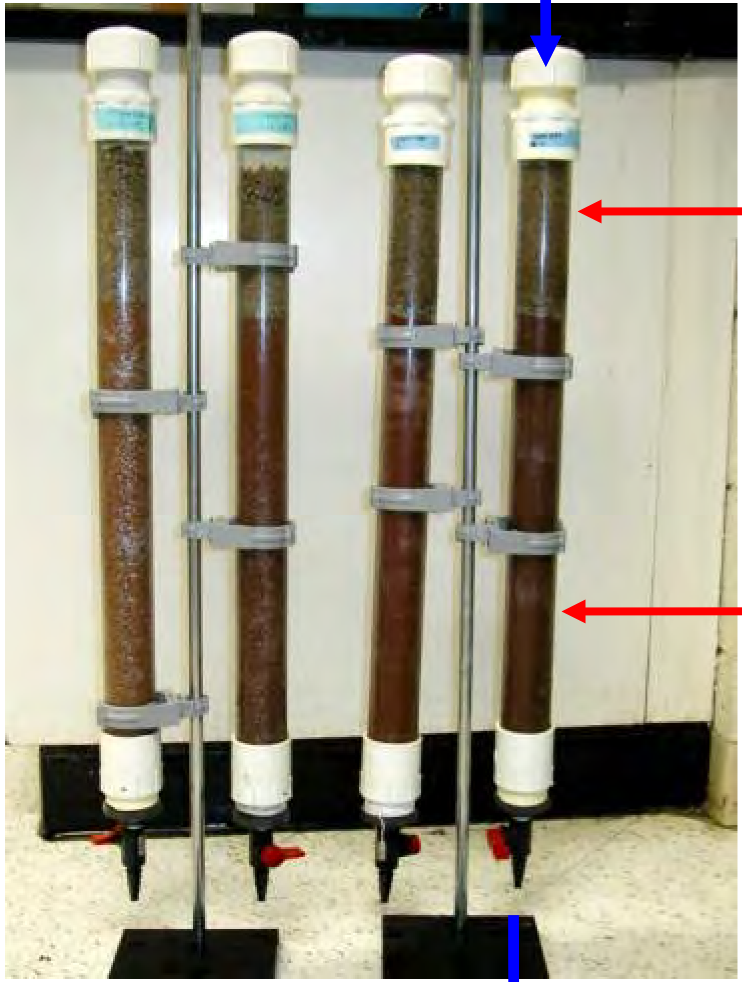
4. Decant treated water

Coagulation/Filtration (2-Kolshi)



Iron Oxide Coated Sand (IOCS)

Raw Water

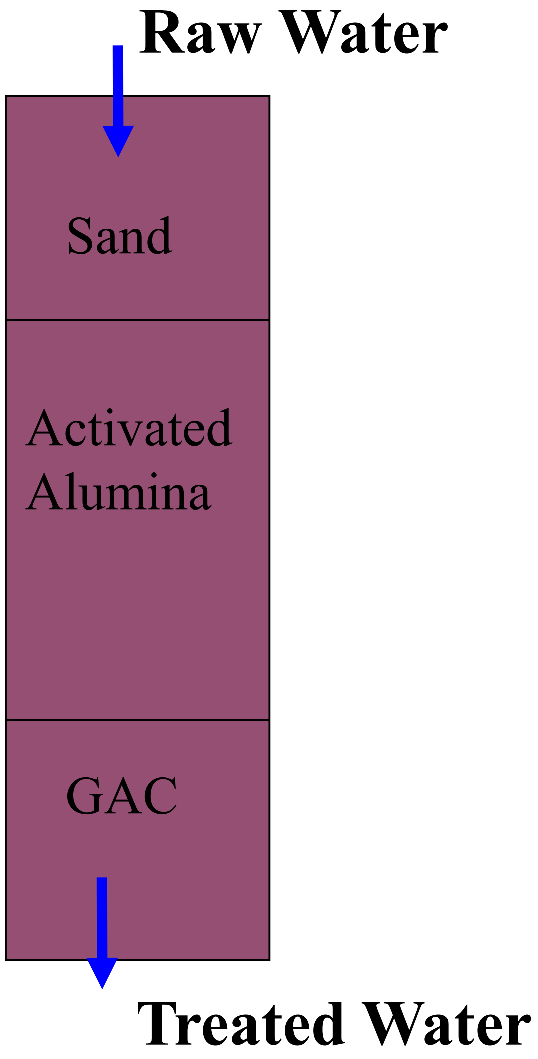


Sand and gravel

Iron Oxide Coated Sand (IOCS)

Treated Water

Activated Alumina Metal Oxide #1
(Apyron Aqua-Bind Media)



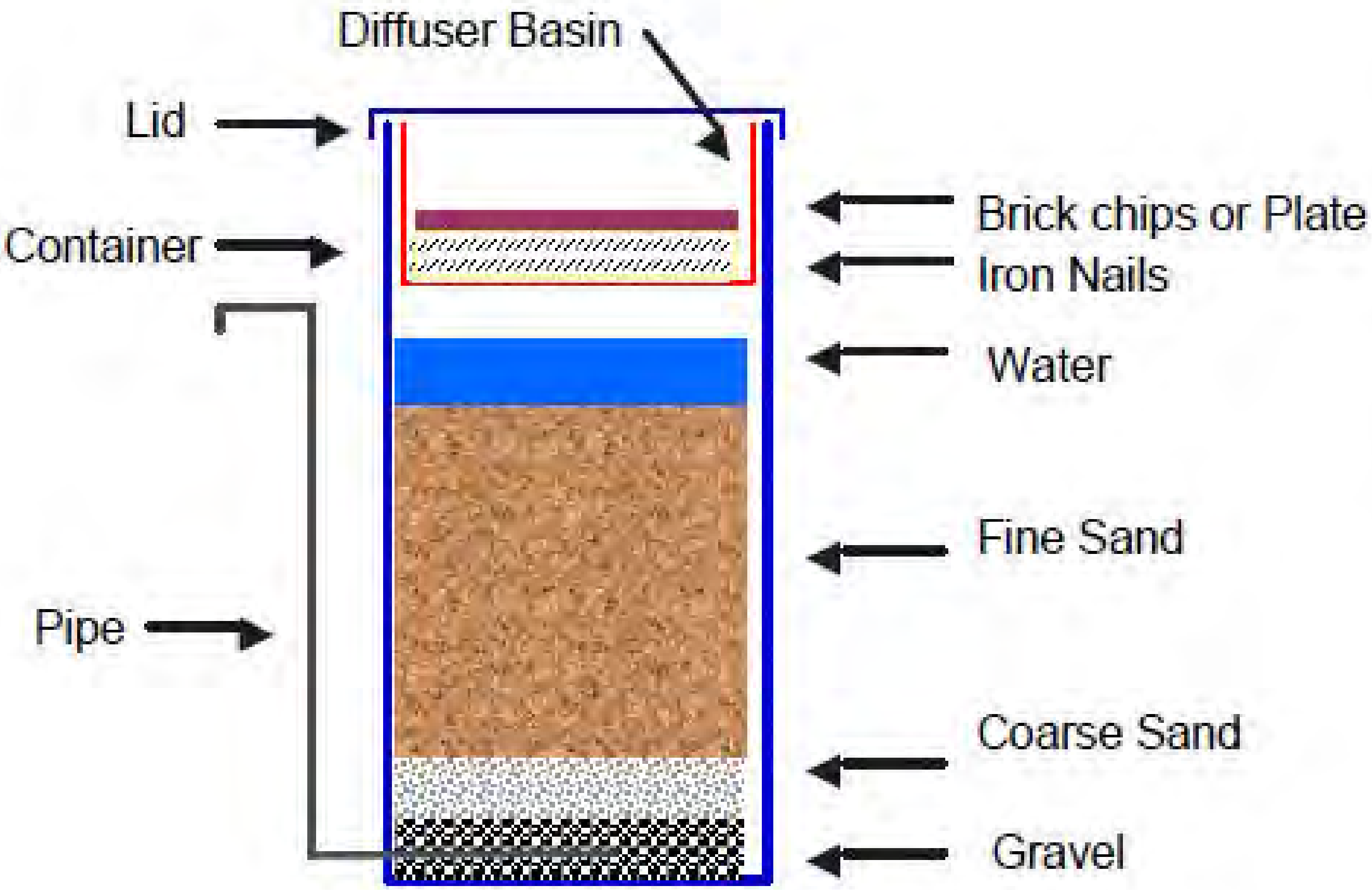
Activated Alumina Metal Oxide #2

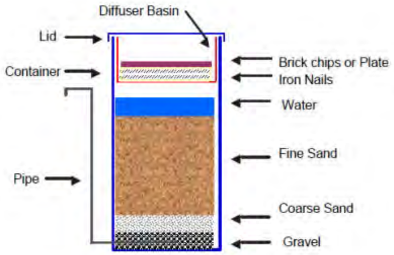
(Aquatic Treatment Systems, Inc.)

Arsenic Treatment Plants (ATPs)

Kanchan™ Arsenic Filter (KAF) – invented by Tommy Ngai & team in 2002

Arsenic Biosand Filter Components





Plastic Version of the Arsenic Biosand Filter (branded “Kanchan”)

12 Month Pilot Study of 3 Arsenic Removal Technologies

3 Kolshi

Coagulation/
filtration
System
(2-Kolshi)

Arsenic
Biosand
Filter

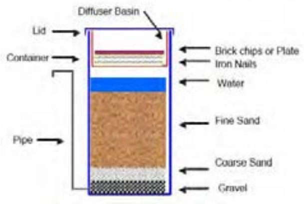
Phase II Evaluation Summary

	3-Kolshi	2-Kolshi	As Biosand
Arsenic removal	95-99%	80-90%	90-95%
Iron removal	Not tested	Not tested	93-99%
Flow rate	3-5L/hr	1-5L/hr	10-15L/hr
Materials availability	✹✹✹	✹	✹✹✹
Easy construction	✹✹✹	✹✹✹	✹✹✹
Simple O&M	✹✹	✹✹	✹✹✹
Long-term sustainability	✹✹	✹	✹✹✹
User acceptance	✹✹	✹	✹✹✹
Low initial cost	✹✹✹	✹✹✹	✹✹
Low running cost	✹✹	✹✹	✹✹✹
Overall Ranking	**2nd**	**3rd**	**Best**

✹ = poor ✹✹ = moderate ✹✹✹ = good

Arsenic Biosand Filter 12 Mo. Pilot Study Results (n=16)

Technical Indicators	Average Results
Arsenic Removal	93 %
Total Coliform Removal	58 %
E. Coli Removal	64 %
Iron Removal	93 %
Flow Rate	14 L/hr



Entrepreneur factory yard – Nawalparasi, Nepal

The Arsenic Biosand Filter was recognized by various awards …

•*MIT IDEAS Competitions – (2002, 2003, 2005)*

•*World Bank Development Marketplace Competition*

** Wall Street Journal
Technology Innovation Award –
Environment Category (2005)*

** St. Andrews Prize for the
Environment – 2nd Prize (2006)*

** Kyoto Water Prize - Top Ten
Finalists (2006)*

Tommy Ngai, Susan's former MIT MEng student, and Narayan Panday, one of the filter entrepreneurs Tommy trained in 2003-2007

Tommy Ngai and I visited Narayan Pandy & family on Jan. 29, 2019. Narayan’s highly success social business is called “Lumbini Filter Industries.”

2005 original home and business site of Narayan Pandey and Lumbini Filter Industries (left photo)

2019 mansion (same site – right photo)

2005 conveyance, by bike.
2019 conveyance, by truck

2005 filters painted blue
2019 filters with ceramic tiles & safe storage container

Conveyor System for Arsenic Biosand Filter Transport – another indigenous innovation of Lumbini Filter Industries

Lumbini Filter Industries Phone Number on each unit. 10 Year Warrantee/Follow-up

Lumbini Filter Industries' Educational Posters on How the Filter Works and How to Operate It.

Local prosperous homes of Lumbini Filter Industries customers, each with their own private well in front year. Location: Rupendehi, Nepal.

Many impressive homes in this upwardly mobile neighborhood in Rupendehi, Nepal have Arsenic Biosand Filters from Lumbini Filter Industries

A filter producers association has standardized on a common diffuser basin of their own design, improving on the earlier the original MIT-ENPHO team recommended.

Rupendehi resident and customer of Lumbini Filter Industries

Local Shop in Parasi, Nepal selling Arsenic Biosand Filters, among other housewares

Gyanshampur Village, Nawalparasi District. The man on crutches has had his leg amputated due to the mistaken idea that it can cure him of his arsenicosis. Five family members suffer the same.

1st School with Arsenic Biosand scaled up system we visited. This one was working well.

Courtesy of Tommy Ngai. Used with permission.

Arsenic Treatment System -- 1st School We Visited

ENPHO
Creating Eco Societies

CAWST

EXPO 2020
DUBAI, UAE
CANDIDATE CITY

Pictures showing well and public sink at 1st school with arsenic biosand filter we visited in Nawalparasi District

Arsenic Contamination in the World

- Worldwide estimated 226+ million people are exposed to arsenic contamination from drinking water or food. (Murcott, 2012)
- At least 105 countries in the world where people are potentially exposed to arsenic in drinking water or food.

http://www.iwapublishing.com/books/9781780400389/arsenic-contamination-world

International Water Assn. Publishers, 2012

Take-aways from Arsenic in Nepal Case Study

- Narayan Pandey has made “a biosand filter for every family in Nepal” his life work.
- Lumbini Filter Industries is an outstanding example of “design for/design with/design by,” having taken an original idea, innovated on it, and built his life around this innovation.
- There is still work to do in the region, people are still getting arsenicosis (arsenic poisoning).*
- Scale up is happening to address arsenic in drinking water in schools. Some successful, some less successful. More work is needed.
- Worldwide the arsenic contamination problem is largely invisible.

* Cutaneous manifestations (melanosis, keratosis, and cutaneous cancers) are essential clues in the diagnosis

Infiltration vs. Runoff & Erosion in a Rain Simulator

Notice 10 glass jars:

5 back jars receive infiltration water

5 front jars receive surface runoff

5 trays have varying degrees of tilled soil on right all the way to deeply rooted soil microbiology and plant life

Photo Credit: Benton James, Madison County Soil Conservation District, Tennessee

Ray Archuleta, USDA scientist demonstrating the Soil Stability Test of two exact same soils, except…

On the left is 35 yr old conventionally farmed soil, with chemicals and fertilizer

On the right is 40 year old healthy soil with diverse biota.
See the difference when added to water columns

- https://www.facebook.com/drbuzkloot/videos/vb.197148037353808/707664362917959/?type=2&theater (1 minute)