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Survival of mankind requires Water Applied Testing and Environmental Research (WATER) Centers in each country.

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Survival of mankind requires Water Applied Testing and Environmental Research (WATER) Centers in each country.

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Abstract

Climate change, increasing water scarcity, population growth, demographic changes and urbanization already pose challenges for water supply systems. By 2025, half of the world's population will be living in water-stressed areas (WHO, 2016).

Contaminated water and poor sanitation are linked to transmission of diseases such as cholera, diarrhea, dysentery, hepatitis A, typhoid and polio. Absent, inadequate, or inappropriately managed water and sanitation services expose individuals to preventable health risks. This is particularly the case in health care facilities where both patients and staff are placed at additional risk of infection and disease when water, sanitation and hygiene services are lacking.

Each country should now consider operating a Water Applied Testing and Environmental Research (WATER) Center to support public health surveillance of drinking water. The WATER Center should be independent of Government control and provide unbiased results. Each Water Applied Testing and Environmental Research (WATER) Center would enable public health surveillance of drinking water.

With the growing scarcity of drinking water worldwide proactive strategic thinking and planning is necessary. Investing in water quality and water quantity management ensures that the public health and economic benefits for all things related to water is maximized. "While the private sector has a key role to play in making innovation happen, government must provide three key public-good inputs that allow innovation to blossom: investments in human capital, infrastructure, and research"(Pool & Erickson, 2012).

Introduction

One of the most important policy decisions regarding water occurred in July, 2010 when the United Nations General Assembly recognized the human right to water and sanitation. The Assembly recognized the right of every human being to have access to sufficient water for personal and domestic uses (between 50 and 100 litres of water per person per day), which must be safe, acceptable and affordable (water costs should not exceed 3 per cent of household income), and physically accessible (the water source has to be within 1,000 metres of the home and collection time should not exceed 30 minutes) (United Nations, 2017).

> *Fresh water sustains human life and is vital for human health. There is enough fresh water for everyone on Earth. However, due to bad economics or poor infrastructure,*

> *millions of people (most of them children) die from diseases associated with inadequate water supply, sanitation and hygiene. Water scarcity affects more than 40 per cent of the global population and is projected to rise. It is estimated that 783 million people do not have access to clean water and over 1.7 billion people are currently living in river basins where water use exceeds recharge.*
>
> *Access to safe drinking water and adequate sanitation services is vital to human health, but also has other important benefits ranging from the easily identifiable and quantifiable (costs avoided, time saved) to the more intangible (convenience, well-being, dignity, privacy and safety)* (United Nations 2017).

It is estimated that human adults need to consume 3 L of water at least every few days. Her body consists of about two thirds water. We use water for internal digestion, for circulation of bodily fluids, and for elimination of waste products. We also use water for bathing, cooking, cleaning and sanitation, cooling, food production, power generation, and manufacturing. Humans derive almost all our fresh water supply from surface water impoundments (4%) and from groundwater aquifers (96%). Water sources can be put at risk because of evaporation, especially in arid regions. In addition over-pumping of fresh water aquifers near seacoast can cause salt water and intrusion of inland aquifers. Surface impoundments or reservoirs can lose volume when they become silted. The presence of freshwater lakes or streams can be damned allowing nearby communities to rely on surface water supplies (Schuchfield & Keck, 2009).

Data and Results

World Wide Water Threats

Of the entire water supply of the earth it is estimated that only 2.5% is fresh and not salty or brackish. Freshwater access is further limited by its availability. About 2% of the entire supply of fresh water are in glaciers. The remaining ½% of available freshwater can become contaminated, rendering it unfit for human use. Consequently, governments and public health agencies must be concerned about water supply and water quality. The hydrologic cycle is a closed system and the amount of water on earth is fixed, except for slight editions of ice from impacting comets. Within this system, we find water and oceans, the atmosphere/clouds, rivers, lakes, glaciers, snowfields, water bearing strata or aquifers in the ground, artificial ponds, soil and moisture, wetlands, humid air, water vapor spewed by volcanoes, living creatures, water in food and plant life, hydrous minerals and other natural compounds, and manufactured items that combine water in their chemical makeup during processing (Schuchfield & Keck, 2009).

Globally, large uncertainty in global groundwater storage exists (Alley, 2006). “The insufficient knowledge of total groundwater supplies will continue to limit effective governance of groundwater systems until a significant effort is made to improve groundwater storage estimates… It is no longer adequate to continue citing decades-old, heuristically derived, highly uncertain estimates of total groundwater storage. The lack of ground-based measures of total storage will continue to prevent a full characterization of aquifer stress and resilience until large scale efforts are implemented to improve the state-of-knowledge on groundwater stocks." To improve current storage estimates, a significant investment in regional monitoring and measuring systems to better characterize saturated thickness and soil properties within an aquifer is required (Richey, 2015).

Risks to Human Health

In most countries, the principal risks to human health associated with consumption of polluted water are microbiological in nature (although the importance of chemical contamination should not be underestimated) (WHO, 1997). Climate change, increasing water scarcity, population growth, demographic changes and urbanization already pose challenges for water supply systems. By 2025, half of the world's population will be living in water-stressed areas (WHO, 2016).

The uncertainty in the assessment of waterborne risks worldwide creates an additional threat to adequate water quality management. Limitations in science generate uncertainty in estimates of waterborne risk. Unsafe water, sanitation and lack of hygiene were responsible for an estimated 871 000 deaths in 2012. Most of these deaths were in the African region and the South-East Asia region. The number of deaths related to unsafe water are probably much higher because only half of WHO Member States register at least 80% of deaths with information on the cause of death. (WHO, 2017).

Globally, 15% of patients develop an infection during a hospital stay, with the proportion much greater in low-income countries. Many of these infections are waterborne. In low- and middle-income countries, 38% of health care facilities lack improved water source, 19% do not have improved sanitation and 35% lack water and soap for handwashing. Globally, at least 1.8 billion people use a drinking-water source contaminated with feces. Contaminated water can transmit diseases such diarrhea, cholera, dysentery, typhoid and polio. Contaminated drinking-water is estimated to cause 502 000 diarrheal deaths each year (WHO, 2016).

Drought, bad management of pumping, leaky pipes in big-city municipal water systems, aging infrastructure, inadequate technology, population growth, and the demand for more food production are all putting increasing demand on pumping more groundwater. In farming flood irrigation, which is inefficient, remains the dominant irrigation method worldwide. As regions and nations run short of water, economic growth will decline and food prices will spike, raising the risk of violent conflict and waves of large migrations. Consider that in the world's 37 largest aquifers, the ones under the greatest threat are in the most heavily populated areas. The most over-stressed is the Arabian Aquifer System, which supplies water to 60 million people in Saudi Arabia and Yemen. The Indus Basin aquifer in northwest India and Pakistan is the second-most threatened, and the Murzuk-Djado Basin in northern Africa, the third. Sadly more is known about oil reserves than water. (Parker, 2017).

Numerous groundwater studies have shown that groundwater is being used at rates that exceed natural rates of recharge globally (Döll, 2009; Wada et al., 2010; Gleeson et al., 2012;

Richey et al., 2015). The importance of groundwater resilience lies in the fact that groundwater is a coupled human-natural system (Steward et al., 2009) providing critical services to human and natural ecosystems. Its ability to do so indefinitely relies on the balance between the volume of water that enters a groundwater system and the volume that leaves the system. In a natural system and over long time periods, the average input (i.e., recharge) is balanced by average output (i.e., base flow and evapotranspiration) (Richey et al., 2015).

Discussion

Water Policy

The development of any policy that involves life on the planet Earth should have accurate information about the current and expected availability of drinking water. Creating an index of water quality and quantity in communities and throughout countries in the world would serve to improve water use, economic and population health planning. Because water is a finite resource monitoring this resource should be given high priority. Government and corporate organizations should work together to manage drinking water.

What is required is a ‘charter’ between government and the people regarding the oversight of drinking water (Macgill, Fawtrell, Chudley & Kay, 2001). As human population increases in size, water quality and conservation grows in importance. In addition eliminating actions that waste water also become more important to maintain water supplies (Schuchfield & Keck, 2009).

Each country should now consider operating a Water Applied Testing and Environmental Research (WATER) Center to support public health surveillance of drinking water. The WATER Center should be independent of Government control and provide unbiased results. Each Water Applied Testing and Environmental Research (WATER) Center would enable public health surveillance of drinking water. Each WATER center should contribute information about water quality and quantity in their world region to the broader understanding of how to best manage this human resource.

Evidence-Based Water Management

Water can cause health problems if it contains pathogens (e.g., bacteria, viruses, and parasites. Water contaminants can cause adverse health effects in part because are usually invisible to the naked eye and lack sense or taste. Water pollution can be from point sources (identifiable waste stream outlets) or from nonpoint sources (runoff from agricultural fields or pavements) (Schuchfield & Keck, 2009).

The oversight of drinking water must be evidence-based. The policy standard throughout the world must include surveillance, (case finding) and risk stratification, based on historical utilization or predictive analytics, across a broad population (Cuddeback & Fisher, 2016). This evidenced based system should include regular and ongoing community water testing. The community water testing results should be cross indexed with public health surveillance data, patient data from community health care providers and patient registry information. This would enable consistent epidemiological studies that would provide proof that contaminants or pathogens are involved in an outbreak of health problems in a population.

People in a defined population, such as children and the elderly and those with particular vulnerable or chronic condition should be cross indexed with known pathogens in a community including those in the drinking water system. Algorithms could help identify episodes of illness, using longitudinal claims data to distinguish morbidity and mortality that can be connected to known waterborne pathogens. In particular, any complications in treatment by a health care provider that also have evidence of exposure to a known environmental pathogen and/or contaminant should be given epidemiological scrutiny. It could be used to determine, for example, which health care acquired infections (HAIs) have a waterborne origin.

This evidence-based approach should be used to manage the coordination of preventive strategies to minimize exposure to opportunistic pathogens and contaminants. Potential waterborne outbreaks could be identified through predictive models which use large databases to determine factors that identify people at risk for future illness.

The Water Quality Standard and Risk Assessment

The USA National Academy of Sciences has defined risk characterizations for the core scientific process of estimating risk in drinking water. This risk is integrated into three distinct stages. The stages are hazard assessment, dose-response assessment and exposure assessment (NAS, 1983). . See Table 1. The overall risk characterization, as the integration of these three stages, produce an estimate of the severity and likelihood of a defined impact resulting from exposure to a specified hazard. It is sometimes expressed as a number or range. In more sophisticated studies, Monte Carlo analysis might be included as part of the approach. (Macgill, Fawtrell, Chudley & Kay, 2001).

Table 1 General paradigm for risk assessment of drinking water

Risk Assessment Stages	Core Scientific Process & Issues
Hazard assessment	Looks at the nature and strength of evidence that an environmental agent can potentially cause harm. The evidence may come from tests on animals, coupled with inferences about possible human effects; or from case studies of people known to have been exposed to the agent of interest; or from human volunteer experiments. There are widely recognized limitations in extrapolating animal findings to human populations. There are difficulties in being absolutely sure that the observed responses are indeed caused by the suspected substance, and not by some other cause. There are doubts about how representative and experimental group is of a population more generally, or of sub- groups that may be

	particularly susceptible. There are differences in treatment efficacies.
Dose-response assessment	Aims to specify the relationship between the dose of a substance and the extent of any resulting health effects. Calibration of dose-response models may lead to the identification of critical threshold levels below which there are no observed adverse effects, or alternatively to representation of the classic U-shaped of dose-response relationship for chemical essential elements (moderate dose beneficial to health; low and high dose both harmful to health). The conclusion from dose-response assessments are often controversial, as there can be large measurement errors, misinterpretation of symptoms and often conclusions rely on statistical analysis which is vulnerable to misuse. It is particularly difficult, perhaps impossible, to specify a dose-response model for low levels of concentration. The translation of findings from one species to another as well as from one population to another is problematic.
Exposure assessment	Seeks to establish the intensity, duration and frequency of the exposure experienced by human population. There is a great deal of uncertainty here, owing to difficulties in measuring diluted concentrations of substances far from their originating source, limits of detection of some substances, and lack of specific knowledge about species recovery in viability. There are also problems in predicting population distribution patterns relative to those concentrations, in knowing water consumption rates, and lack of awareness of specific local conditions (such as plumbing or hygiene conditions).

Source: National Academy of Sciences (1983)

Risk Assessment Check List

Waterborne risk assessment can be based on a checklist of criteria against which the strength of scientific inputs to risk characterization can be systematically evaluated. The checklist approach is preferred because it is conceptually simpler while at the same time being systematic and offering flexibility. As with all scientific endeavor, this process has an empirical or observational aspect (data), and a theoretically informed methodological aspect. These two inputs combined to produce an estimate of risk probability, risk magnitude or dose-response affects according to context. The authority or standing of such outputs should be subject to peer review. Consensus on the basis of peer review must be a necessary condition for producing definitive quantification. The relevance (validity) of the quantified outputs to a particular context of interest must be accounted for to determine the quality of drinking water. See Figure 1 Quality Audit Framework (Macgill, Fawtrell, Chudley & Kay, 2001).

Figure 1. Quality Audit Framework

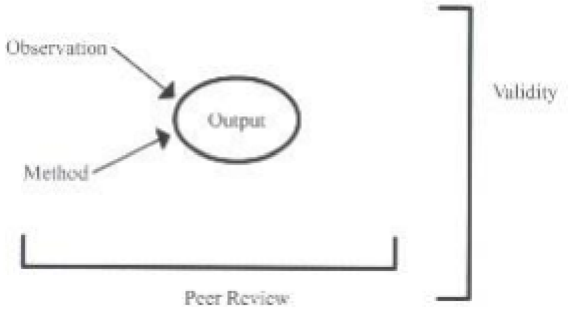

Figure 1. Conceptual representation of quality audit framework components. Reprinted from Macgill et al., 2000, published in Fewtrell, L. & Bartram, J. (2001). *Water quality: Guidelines standards and standards of health*.

Water Testing

The USA-Center for Disease Control and Prevention (CDC) standard of meeting a Class I or II strength of evidence classification can be used as a model/best practice benchmark, although it is seldom reached in epidemiological studies. This standard would require epidemiologic data to be provided about exposed and unexposed persons, with a relative risk or odds ratio ≥2 or p-value ≤0.05 or a molecular characterization of the pathogens that linked multiple persons who had a single identical exposure.

At best, typically the water testing standard in the United States is at Class III where the epidemiologic data provided did not meet the criteria for Class I or II (CDC, 2015, August). See Table 2 Strength-of –Evidence Classification of Investigations of Waterborne Disease Outbreaks-United States.

Table 2

Strength-of-Evidence Classification of Investigations of Waterborne Disease Outbreaks		
Class	**Epidemiologic and clinical laboratory data**	**Environmental health data**
I	**Provided and adequate**	**Provided and adequate**
	Epidemiologic data provided about exposed and unexposed persons, with relative risk or odds ratio ≥2 or p-value ≤0.05; OR	Laboratory data or historic information (e.g., history of a chlorinator or acid feed pump malfunction, no detectable free-chlorine residual, or a breakdown in circulation system);

	Molecular characterization of pathogens linked multiple persons who had a single identical exposure	OR Molecular characteristics of pathogens isolated from water and at least one clinical specimen were identical
II	**Provided and adequate**	**Not provided or inadequate**
	Epidemiologic data provided about exposed and unexposed persons, with relative risk or odds ratio ≥2 or p-value ≤0.05; OR Molecular characterization of pathogens linked multiple persons who had a single identical exposure	E.g., laboratory testing of water not conducted and no historic information available
III	**Provided but limited**	**Provided and adequate**
	Epidemiologic data provided that did not meet the criteria for Class I or II or claim made that ill persons had no exposures in common, besides water, but no data provided	Laboratory data or historic information(e.g., history of a chlorinator or acid feed pump malfunction, no detectable free-chlorine residual, or a breakdown in circulation system); OR Molecular characteristics of pathogens isolated from water and at least one clinical specimen were identical
IV	**Provided but limited**	**Not provided or inadequate**
	Epidemiologic data provided that did not meet the criteria for Class I or II or claim made that ill persons had no exposures in common, besides water, but no data provided	E.g., laboratory testing of water not conducted and no historic information available

Source: CDC (2015, June 2)

Water is finite and necessary to support life. Available freshwater can become contaminated, rendering it unfit for human use. It is because the current water quality and testing standards lack consistency that it is becoming necessary that every country establish a **W**ater **A**pplied **T**esting and **E**nvironmental **R**esearch (**WATER**) Center to conduct Level I and level II evidence-based water testing. The expected outputs of a **WATER** Center using Level I and II evidence-based testing are identified in Table 3.

Table 3 WATER Center Testing Facility Outcomes, Outputs and Expected Results

Process	Outcomes	Outputs	Expected Results
(1) Identify threats to community drinking water.	Measure water quality in the public facilities.	A published water content index by community for contaminants and pathogens.	Provide information to public health officials to use to maintain and as necessary to improve community drinking water.
(2) Identify and quantify waterborne pathogens and other waterborne contaminants in potable water.	Develop comparable measures of water quality.	Identify presence and measure contaminant and pathogen in drinking water.	Contribute data toward a comprehensive assessment of the State's drinking water.
(3) Create an index of drinking water quality by community.	Test water quality in communities.	Community water quality list.	Provide information for community leaders to use to for safe water management.
(4) Establish a time line for future research.	Develop a reliable and efficient method to measure water quality.	Monitor for persistent pathogens and other toxic substances and chemicals of emerging concern in water.	Provide information to strengthen decision making and environmental management of the State's drinking water supply.
(5) Develop a prototype for community water testing.	Initial focus would be on the most heavily populated watersheds.	Provide water testing at healthcare facilities, schools and other government facilities.	The laboratory is expected to provide a site for sustained analytical services to business, industry and government.
(6) Create the foundation for the development of a level 1 testing lab.	Develop cooperative working arrangements with the government and non-governmental water users.	Provide training opportunities for students, government water professionals, public health employees, university and college faculty in water testing and monitoring techniques and strategies.	Establish a contractual arrangement with the WHO and other appropriate health agencies like the US CDC. Create partnerships with the business, medical and educational

			community. Encourage shared research regarding water testing and treatment.
(7) Establish a baseline from which to make future comparisons of water quality.	Develop information for policy making.	Verified data regarding content of potable water.	Help reduce the human cost in morbidity and mortality and the economic loss brought on by waterborne pathogens and contaminants.
(8) Bring together University, Government and business interests in development of water quality research.	The laboratory will provide the opportunity space to share equipment, expertise and common interest in water quality testing while supporting the academic research and business development.	Published work by subject matter experts.	Increase the resources on the ground to continue the study of water. Develop sustainable water management.
(9) Provide public health agencies with useful information about water quality.	Shared effort in implementing the law of the land with regards to water quality.	Improved effort and methods in testing water quality.	Support the Public Health Security and Bioterrorism Preparedness.
(10) Establish testing systems that will support improvement in the quality of water supplies.	Detect and monitor adverse events and assess risk. Develop protective procedures as it relates to drinking water.	Evaluate the testing and reporting practices for drinking water. Measure the value of preventive efforts. Provide a warning and advising service to water users.	Provide information to event reporters and stakeholders and partner with them to implement effective prevention strategies and create an actionable water safety plan.

Source: Kozicki & Baiyasi-Kozicki (2015)

Conclusion

Worldwide Water Policy

Worldwide, there should be a change in focus about water policy. It should be considered one of the most important policies the government develops. The water policies should:

- Raise the priority of the nation’s drinking water to the highest level of funding.
- Provide a local, regional and national Water Quality Index (WQI).
- Update the data annually about the nation’s water supply and uses.
- Create independent WATER centers. These WATER centers should become the responsible entity to work with each community public health agency to certify water quality at the point of use. These state WATER Centers would become the location where all relevant information about water quality and quantity would be analyzed. These WATER centers should serve to provide education and as a research incubator for best practices related to water management. They would operate in conjunction with universities and colleges.
- Develop big data from constant water testing and compare it to big data being generated from health records of millions of people to eventually lead to epidemiological insights into how know waterborne contaminants and pathogens effects public health. The time has come for all countries to reach Class I or II strength of evidence classification in epidemiological studies.
- Utilize existing government supported assets which include government buildings, public schools, hospitals and healthcare facilities, military installations and government installations located in national parks, publicly held land, lakes, rivers and wetlands to become water testing sites to create thousands of data points which can be used to provide the most accurate daily water quality index of the nation’s water supply.
- Members of the nation’s water research community need to meet annually to share information and promote the best practices in managing water. This annual meeting is to promote a national conversation about water. The result of this annual meeting should also provide advisement about the current and future and state of the nation’s water supply.
- Private industry should be given incentives by the government to develop the most efficient and effective methods for producing safe and reliable drinking water for both humans and animals.
- A national infrastructure water system plan needs to be developed and appropriations by the government should be provided to build and maintain infrastructure. Public health agencies also need to begin making changes in how they interpret their role in managing waterborne threats to population health.
- Community public health agencies need to be involved in certifying the safety of drinking water. This includes routine sampling for testing of drinking water in health care facilities, schools, government buildings, restaurants, public housing, apartment buildings, local businesses and residences.
- Community water emergency information must be shared sooner to protect the public health. All entities using water must provide to their local health department and the

state public health agency (a) proof of a rigorous water testing protocol, (b) an operational plan to warn the public if water quality is threatened, (c) an operational plan to provide drinking water to the community if the community drinking water is compromised, (d) proof that the community drinking water warning and response plan is tested at least annually, and (e) compliance with rules for maintaining safe drinking water.

Closing Summary

Globally, large uncertainty in global groundwater storage exists (Alley, 2006). To improve current storage estimates require a significant investment in regional monitoring and measuring systems…" (Richey, 2015). What is required is a 'charter' between government and the people regarding the oversight of drinking water (Macgill, Fawtrell, Chudley & Kay, 2001).Water testing should be ongoing process and the information should be shared to create a Worldwide Water Quality Index. Water research must be given sustained support and be unimpeded by biased interests. Each Government must provide meaningful oversight and develop evidence and health-based drinking water standards. Decades of insufficient research about the quality of world water and the effect on the health of the population has placed millions of people at risk. Public health agencies need to be more involved in water testing and epidemiological research. Each country should utilize a WATER center to monitor and assist in the management of drinking water. "While the private sector has a key role to play in making innovation happen, government must provide three key public-good inputs that allow innovation to blossom: investments in human capital, infrastructure, and research" (Pool & Erickson, 2012).

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