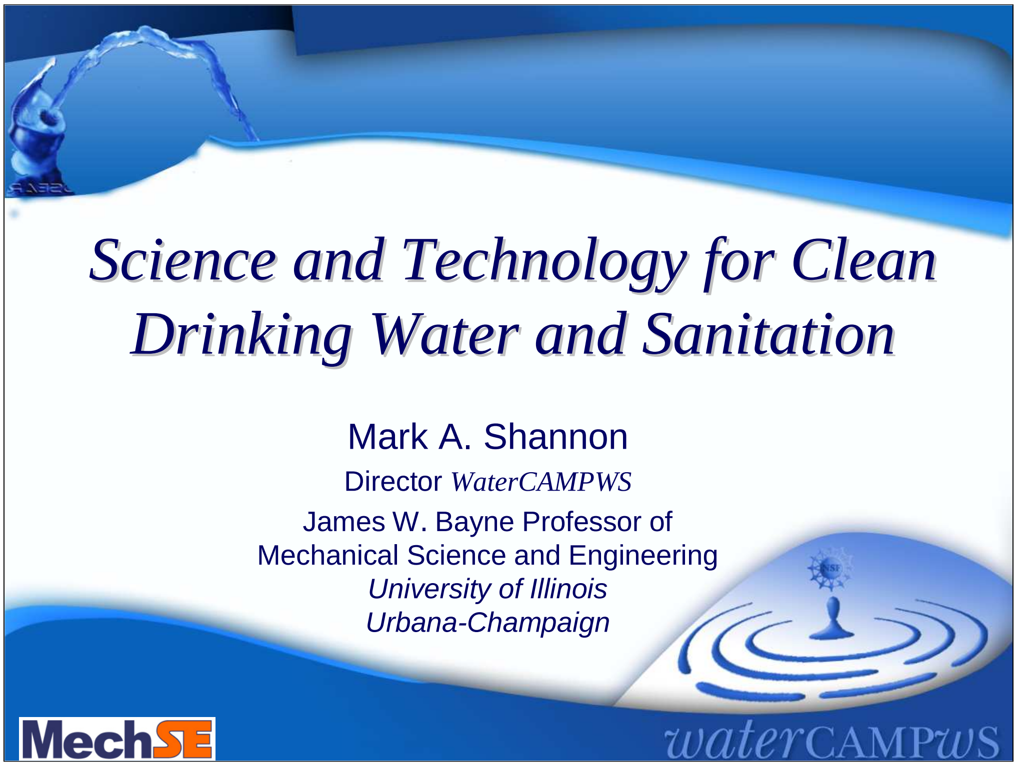
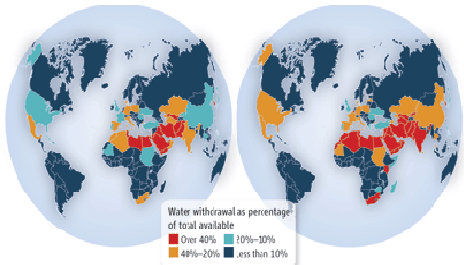


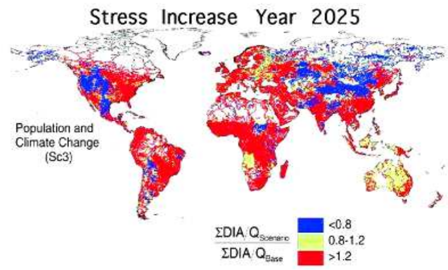
The WaterCAMPWS is the Center of Advanced Materials for the Purification of Water with Systems, a National Science Foundation (NSF) Science and Technology Center that was awarded late 2002, with an annual budget of $4 million a year from NSF and $400 thousand from Illinois. The goals of the WaterCAMPWS are to DEVELOP REVOLUTIONARY NEW MATERIALS & SYSTEMS FOR WATER PURIFICATION, and to build the knowledge capacity in water purification, educating students and the public-at-large in issues related to cleaning water for human use. The WaterCAMPWS consists of 10 universities over the United States, with the University of Illinois as the lead, with 7 government partners, 14 industrial affiliates, ~183 students, ~41 faculty.

Major Problems Facing World

- 1.2 Billion people at risk from lack of clean water
- 2.6 Billion people lack adequate sanitation



World Map showing water consumption world-wide as percentage of total available water.



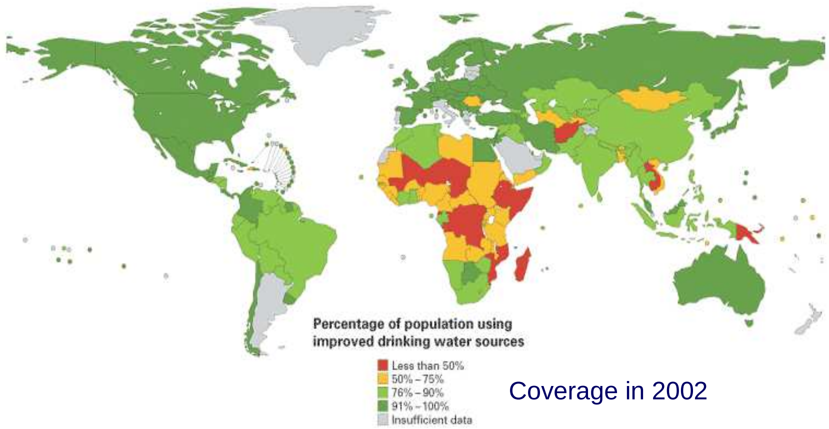
World Map showing affect of population and climate change on water stress.

Consumption, withdrawal, and discharge: Population growth pushes consumption higher, water supplies will become more stressed, and withdrawals and discharges will affect life of rivers and lakes, and overall environment ever more so.

waterCAMPws

Problems for the most part are well-known. However, changes are coming in global water supply and consumption that will affect waters everywhere. As consumption goes up, less water is returned to the environment after withdrawal. Moreover, the discharged water is of lower quality. Less and lower quality water discharged will make environmental problems worse, and will also cause water needed for human use to need more treatment, raising the costs and environmental impact further.

Areas with Developed Drinking Water



Coverage in 2002

- Storage in reservoirs increases consumption via evaporation. Silting of reservoirs behind dams increases consumption per volume stored. Very high total system cost. Developed does not always mean SAFE!

waterCAMPwS

Currently there are 1.2 billion people at risk from lack of clean water and 2.6 billion people who lack adequate sanitation in the world. The Millennium Development Goals are to cut these numbers by half by 2015, but at best the rate of increase has slowed down. New approaches are needed to help reach the goals.

Africa has the least amount of coverage in developed drinking water. Access to improved drinking water is estimated by the percentage of the population using the following drinking water sources: household connections, public standpipe, borehole, protected dug well, protected spring, or rainwater collection. It does NOT include unprotected wells, unprotected springs, vendor provided water, tanker truck-provided water and bottled water (if secondary source is not an improved source).

Traditional methods to increase water supplies include developing reservoirs, cannels, and central distribution systems. These systems have very high costs to construct, maintain, and operate. Moreover, they have a relatively short life span of less than 50 years in many parts of the world. Significantly, reservoirs increase the evaporation of water, which is then lost to the supply system the reservoir was constructed for, reducing the total water supply.

Perhaps most importantly, developed water is not necessarily safe. Contaminants and pathogens can be widely distributed in developed water systems.

Currently there are 2.6 billion people who lack adequate sanitation in the world. There is a strong correlation between lack of sanitation and unsafe water. Proportion of population without developed sanitation coverage in 2002 is a much larger area than those without developed drinking water across the world. Access to improved sanitation is estimated by the percentage of the population using the following sanitation facilities: connection to a public sewer, connection to a septic system, pour-flush latrine, simple pit latrine (a portion of pit latrines are also considered unimproved sanitation), and ventilated improved pit latrine.

New technologies that can affordably treat wastewater from small households to larger communities of people, without requiring large tracts of land or ownership, that does not contaminate drinking water supplies is desired to meet the Millennium Development Goals. Sustaining the operation of these systems in connection with supplying clean water is desired. Separating the consideration of sanitation and drinking water systems, as often done in the U.S., can lead to negative consequences: Cross contamination without knowing it is happening.

Gender specific sanitation facilities for children can help facilitate an increase in supplying hygienic facilities to meet the World Fit for Children Goals. Water Advocates is working on plans to do this.

Freshwater Stress and Scarcity Projections in Africa by 2025

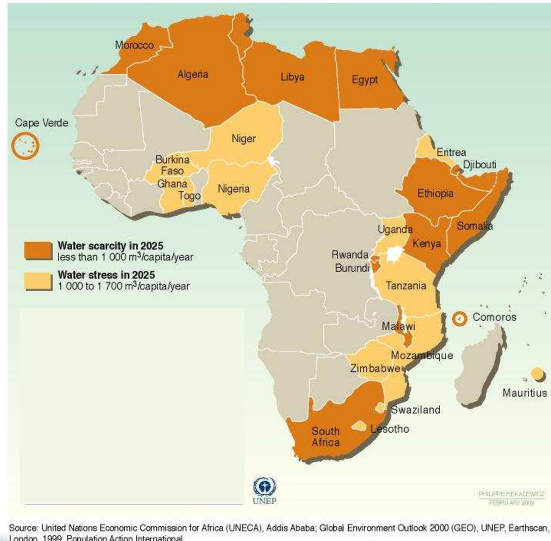
Average Sector Use

Domestic	10%
Industry	21%
Agriculture	69%

Sources: Gleick (1999) and WRI (2000)

~80% of industrial & domestic use can be reclaimed.

~20% from irrigation and livestock can be reclaimed, which is more water.



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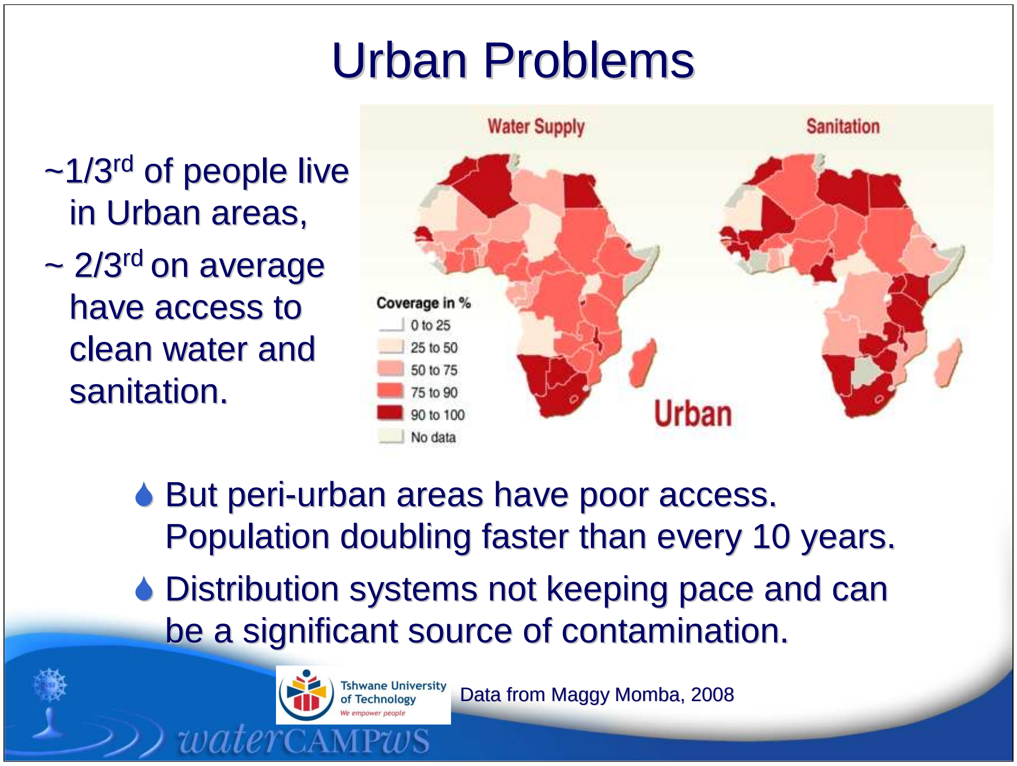
The amount of waters available for human use in Africa is expected to decrease in many areas of Africa, in particular the north, east, and south. Many areas that now experience periodic stress to the supply for all uses (domestic, industrial, and agriculture) will experience water scarcity, where there will not be enough water in total to meet the needs of the people. This freshwater scarcity and stress will make water treatment even more important, as there will be much less CLEAN freshwater available. The lack of clean freshwater is already a crisis in many areas of Africa (and world).

A key objective is to seek non-traditional sources of water, such as reclaimed and reused waters, so that more water can be treated to provide clean fresh water. Sources of reclaimed water can be from domestic use, industrial, and agricultural (including livestock). Properly treated reclaimed waters can extend the supply available by a factor of 4 or more (greater than 400%), making it a potentially valuable resource. Note that although a much higher percent of water from industrial and domestic uses can potentially be reclaimed or reused (~80%) , with proper water treatment, than agricultural waters (~20%), in many areas (in particular rural) the amount of water used by agriculture and livestock is much larger. Thus, reclaiming agricultural runoff can be a great source of water, if properly treated. Domestic, industrial, and agricultural waters have different types of contaminants. Thus, treatment methods are different from each.

How much water can be supplied by reclamation depends on how much water is consumed (via evaporation) and how much is discharged from the total amount withdrawn from a watershed. Population growth pushes consumption higher, stressing water supplies more, affecting life of rivers and lakes, and overall environment. Hence efforts need to be made to reduce consumption via conservation. Conservation of water acts the same as doubling the water supplies, if water is reclaimed and reused.



Urban and rural areas have different problems, but can use many of the same solutions. In urban areas, on average most people have access to clean drinking water and sanitation (68% of these have access to safe drinking water and 64% have access to sanitation), though with significant disparities between countries and even within the same city. Outlying areas, slums, and dry season camps have virtually no access to clean water and sanitation. In many urban areas, even with access to water, the distribution systems themselves can be contaminated with pathogens and toxic compounds.

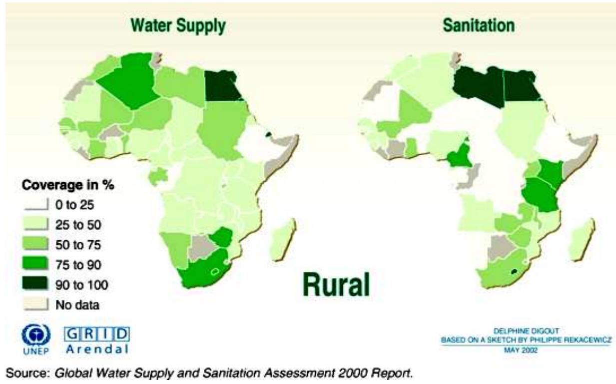
About twice as many people live in rural areas as urban, but only 43% of these have access to safe drinking water, and only 32% have access to sanitation. Because of this difference, more die in rural areas than urban. But the problem of access to clean water in rural areas is similar to those in the outlying urban areas: Neither are typically served by a fixed distribution system. They need point-of-source, point-of-discharge, and point-of-use systems to treat water where they are.

Even for urban areas with contaminated distribution systems, small, affordable, and robust point-of-use systems can increase water quality and safety.

Rural Problems

~2/3rd of people live in Rural areas,

~Only about 1/3rd have access to safe drinking water & sanitation.



- Groundwater contamination a major factor for disease.
- More sicken and die in rural areas.
- Less health care for diarrheal diseases than in urban areas.

Tshwane University of Technology
We empower people

Data from Maggy Momba, 2008

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Urban and rural areas have different problems, but can use many of the same solutions. In urban areas, on average most people have access to clean drinking water and sanitation (68% of these have access to safe drinking water and 64% have access to sanitation), though with significant disparities between countries and even within the same city. Outlying areas, slums, and dry season camps have virtually no access to clean water and sanitation. In many urban areas, even with access to water, the distribution systems themselves can be contaminated with pathogens and toxic compounds.

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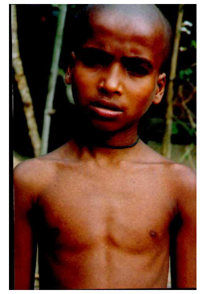
Health Effects from Contamination

- Over 2.4 million people a year in developing world die from contaminated water
- A child under 5 dies every 17.5 seconds from water problems.
- Over 2.85 billion sickened
- Over 186 million lost years of life from disability and disease (Disability Adjusted Life Year) in Africa
- Diarrheal diseases from bad water a leading cause of malnutrition and pressure on food supply
- Contaminated water from heavy metals, petroleum byproducts, and toxins sicken large numbers of people



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Sources: World Health Organization (2001); Gleick (2002), (2005); Water Can-EauVive –www.watercan.com

The major water related problems that cause so many people to die are primarily from pathogens, including bacteria, protozoa, parasites, and viruses. Some directly sicken and weaken the afflicted, but 2.2 million of the 2.4 million who die succumb to complications from dehydration and malnutrition caused by diarrheal diseases. The massive majority of these deaths come to children under 5 years of age, due to the smaller bodies inability to withstand large changes in hydration.

Of the 2.85 billion sickened from water, the massive majority of these (2 billion) are sickened by parasites, many of which can be easily filtered out of drinking water. However, many are exposed via contact during cleaning and hygiene. Parasites afflict Africa as much or greater than Asia.

Perhaps as significant as those who are sickened, is those who become disabled due to the illness, which prevents people from working to sustain their lives and those of their family. The majority of the 186 million lost years of life that occur every year in Africa are from traditional diseases such as dysentery, cholera, typhoid, norwalk virus, adenoid virus, hepatitis, polio, … The illness and loss of economic output decreases quality of life for everyone.

The large number of people afflicted by toxic compounds in water, such as heavy metals, while small in comparison to disease vectors, is still very high by developed world standards, causing a tremendous health problems. An opportunity exists to address these problems while disinfecting water from pathogens.

Change in demographics is driving major changes in water needs. High birth rates coupled with high death rates and migration from rural to urban areas is shifting populations of people. Water demands are shifting, changing the amount available to people in specific areas.

At same time, climate change is causing growth in deserts, taking out productive land for supplying food and water. More people need to live on less productive land and water.

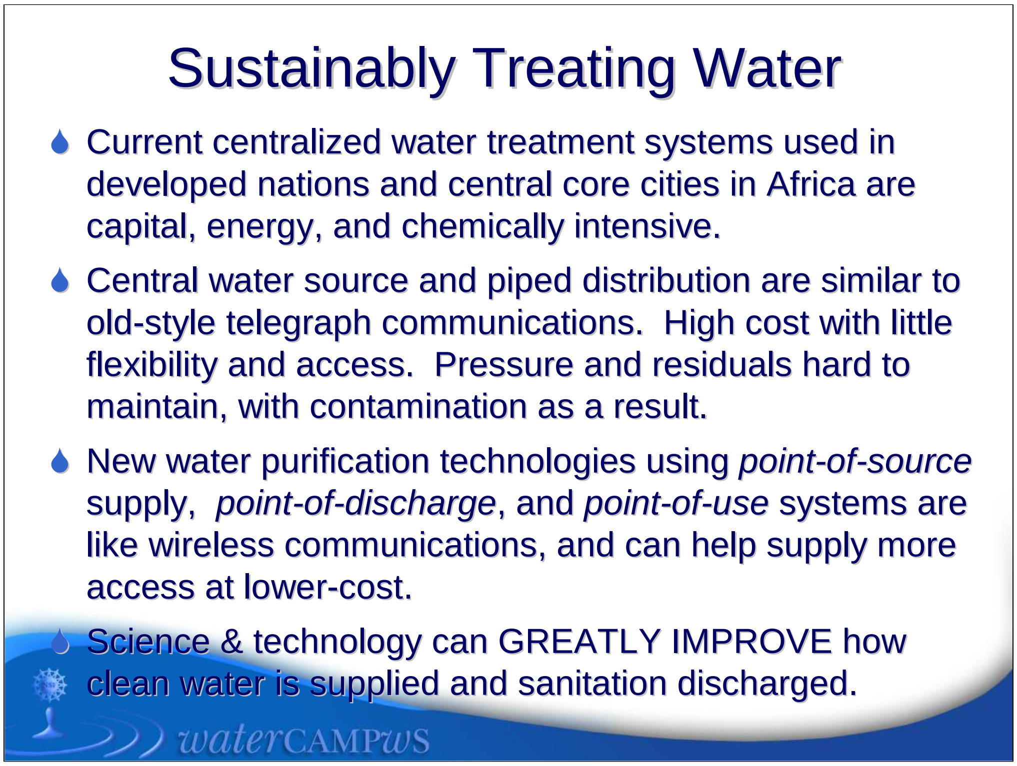
Pumping out ground water to make up for loss of surface water is not sustainable.

More migration from rural areas without food and water to cities makes supplying water to the outskirts of urban areas more pressing and difficult.

Large amounts of energy is needed to move water from one region to another to supply water to cities, and to purify water with conventional treatment. With rising energy prices, getting that energy is going to be difficult. Without water for processing fuels and cooling water for generation, energy cannot be supplied either.

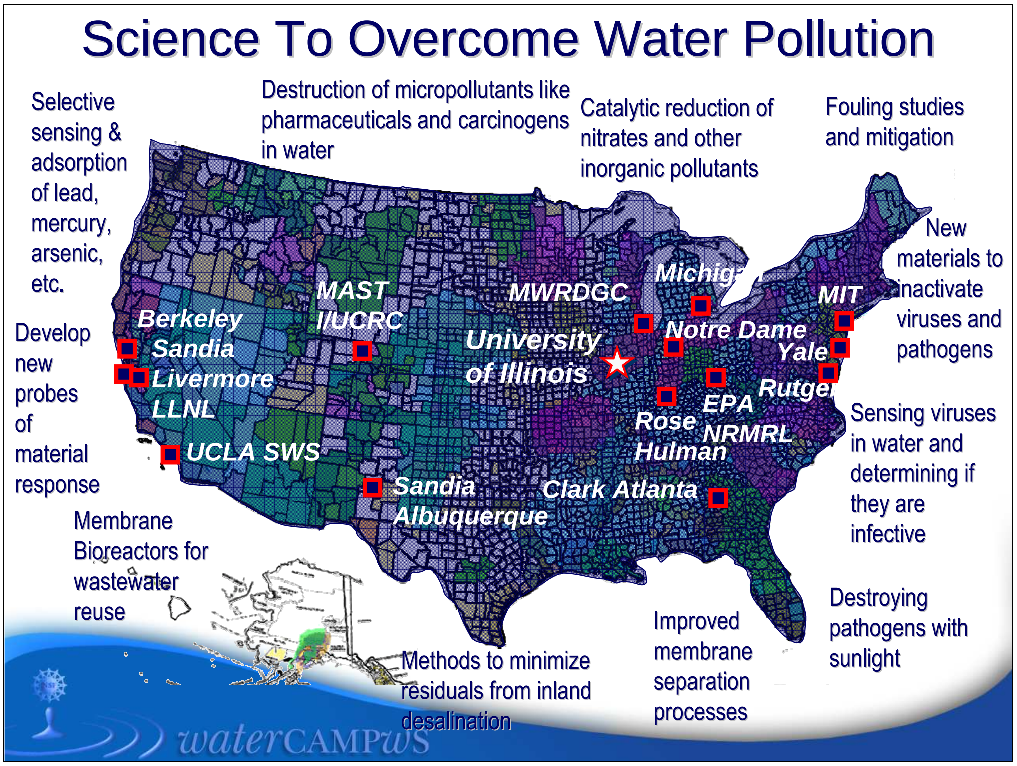
Food production closely tied to water availability. Less water prevents adequate food supply and contaminated water makes food preparation dangerous.

More contamination of water makes less clean water available. Contamination is increasing with greater industrialization.



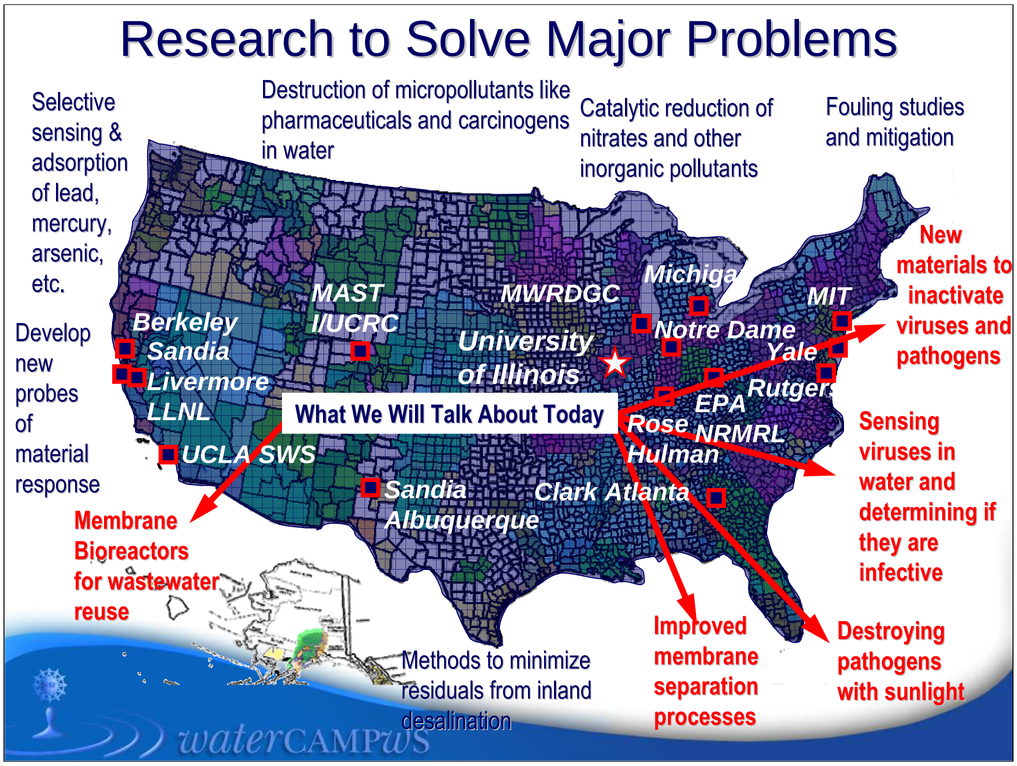
Hundreds of millions of people throughout the world, with large numbers in the developed world, use point-of-source, point-of-discharge, and point-of-use systems for potable water treatment and sanitation. Traditional point-of-source, point-of-discharge, and point-of-use systems are well-water, septic sewer systems, and filtration units. Point-of-source typically require pumps to draw water up from a deep well, where pathogens are not present, or also employ filters to clean the water. Point-of-discharge systems typically use septic tanks to biologically treat organic waste, followed by large percolation fields, where water coming out of the biological treatment tank percolates through the ground to recharge the groundwater aquifer that is supplying the well. Similarly, latrines and pit-toilets with composting and leaching serve as a point-of-discharge. If done correctly, all these processes are safe and sustainable.

Current methods, however, are expensive and require a fair amount of land, which many people of developing world do not have. Fortunately, new technologies can safely disinfect water from shallow wells (point-of-source) and can biologically clean water in a small area, without needing large amounts of land (point-of-discharge). Small enough point-of-use systems can take fresh water from virtually any source and clean and disinfect the water for direct use. The size of these systems can range from very small (size of a breadbox) ones for a single dwelling, to larger for a group of dwellings, a village, camps, to outlying areas in cities, cleaning up water from contaminated distribution systems, cisterns, or trucked water. The number of people that can benefit from such solutions is up to 5 out of 6 people in African countries with low access to clean water and sanitation.



The WaterCAMPWS focus is on all water for use by humans, including potable drinking water, wastewater, storm water, and source waters that can be used to supply water. These waters include the dominant sources currently used by humans: river, lake, and fresh ground water (well water or aquifers). They also include emerging sources: Seawater and brackish (salty) inland waters, such as saline lakes and ground water aquifers, as well as waste waters from sanitary waters and industrial sources, and agricultural and storm runoff. The purity of rain waters stored in ponds and cisterns are also of concern.

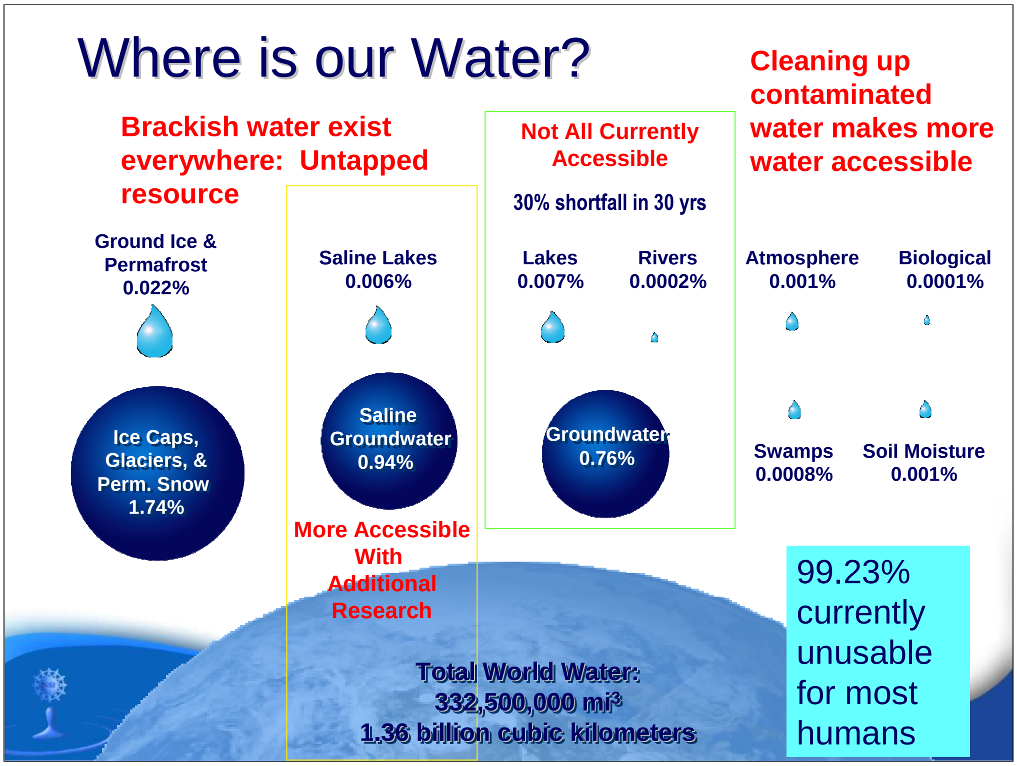
I will present several new technologies that can benefit Africa that can help advance water treatment at a lower cost and can potentially offer more people access to clean water and sanitation.



Research is needed to make distribution of water safe as well.

Distribution systems are made of low cost pipe, for the most part, in much of the developed and developing world. Terra cotta (clay) pipes joined with filling, often crack and heavily leak sewage. Tree roots intrude and can clog pipes. Drinking water pipes made from iron rust and close off quickly in many types of source waters. They frequently fail. In the U.S. there are more than 250,000 water MAIN (large pipe) breaks a year, and many times that for small systems. The failure of distribution systems is one of the critical costs that the developed world faces in infrastructure costs. Little is being done to address how to solve the cost problem with installing and maintaining distribution systems. Due to sanitary and drinking water distribution systems being place in trenches, there are frequent inadvertent interconnections between the systems due to leaks. There are many times more deliberate, but usually unknowing, interconnections made within buildings and dwellings between the supply and waste systems. As such, drinking water, even within central urban areas can have periodic contaminated waters, which is why pressures of the supply side are kept high so that leaks flow readily outward, and residual chlorine is often used to keep pathogens low in centralized systems.

Perhaps the most critical issue in distribution systems in developing world urban areas is pathogens that are harbored within biofilms in the older pipes. The distribution system itself can become a major source of transmitting diseases, should the residual chlorine concentration drop, or the pressures within the pipes fall because of a break in the system or a power outage, which frequently occurs. Point-of-use disinfection systems are needed to prevent diseases from being spread through the system.



The key point to this slide is to show how much water there is on the earth, which is a water planet. The problem is that only 0.7% of all the water is currently usable by humans: Fresh water in rivers, lakes, and groundwater aquifers. With some more research, we can make salty waters more available, by desalinating seawater, brackish waters on land, and saline groundwater aquifers underlying most all continents, including Africa.

Interestingly, a lot of these brackish waters are already being pumped up during mining operations for minerals and oil. Currently, these waters are either discharged to the land, which pollutes the fresh waters already there, making them unusable, or the water is injected deep back into the earth. New technologies that can recover and desalinate these brackish waters can increase water supplies without additional pumping costs, and can prevent pollution of fresh waters on the land, increasing scarce water resources overall in many places in Africa.

But There Are Many Opportunities

- We are far from the natural law limits for separating contaminants from water: Lots of room to improve!
- Traditional methods in developed world are capital, energy and chemical intensive
- New materials and systems are being developed that can dramatically drop the cost of treating water
- New communications systems can be used to control and prevent contamination and illness

waterCAMPWS

Natural laws limit what people can do to clean up water. However, even the best ways humans have created for purifying water is still not close to those limits. Biological systems, such as kidneys in animals, are much closer to natural law limits so we know that it can be done. By changing our mindset as to what is appropriate, we can be open to try non-traditional technologies that do not use lots of energy and chemicals, and which cost less in the long run. New systems using membrane separators are being made which use very little energy and chemicals, such as the membrane filter installed below this village water tank shown in the picture, which cleans up the water coming out of the well, reducing diseases and contaminants coming from the shallow well.

Sensors that detect pathogens and contaminants in the water can also be installed in the holding tank after the filter, which can warn authorities if something has gone wrong with the system, using wireless communications set up in the village, thereby ensuring a safe supply.

To INCREASE the Amount of Clean Water Available to People

There are three major goals:

Goal I. Increase potable water supplies, to gain new waters from **reuse** and **desalination** from all sources of water.

Goal II. Selectively remove contaminants from all types of water sources, to make water safe from poisons.

Goal III. Disinfect water from current and potentially emerging pathogens **without producing toxic substances** from disinfection.

waterCAMPWS

By reusing and reclaiming water that would normally be discharged and potentially lost to a watershed, the amount of water supply can potentially be increased by up to 400%. Desalinating waters, particularly from those coming out of industrial and mining processes where energy is already being spent to produce needed products (oil, food, minerals), new water can be supplied for human use (industrial, agriculture, and domestic) using new desalination technologies, at a relatively low-cost. Reducing the contamination of the environment and other fresh waters can also be helped at the same time by limiting discharges.

Decreasing contamination of waters by just removing the harmful compounds, such as heavy metals or organic toxic compounds, without having to remove all the desirable potable compounds we prefer to have in water (such as calcium), can also help to increase clean water supplies while improving people's health.

Many treatment systems use central systems, with high capital costs (billions of dollars) and huge costs for operation & maintenance. More than a trillion dollars have been spent in U.S. over last 20 years for operation and maintenance of central systems. These types of systems are in many cases unsustainable and not appropriate for the *developed or developing* world. The only reason they are still used is because of the initial investments over 50 to 100 years ago.

Traditional systems often need large sources of intake waters, which now cost hundreds of dollars per acre/ft (1233 m^3) to newly develop, which is an additional cost for new systems today. Older systems have already paid for the development of water supplies.

They use large amounts of energy and chemicals, at high cost, and with poor environmental impact. Chemical treatment is difficult without infrastructure in place, even a relatively easily applied disinfectant such as hypochlorite (used in swimming pools in developed nations).

They require extensive distribution systems, which are the most costly part of the overall system. In addition, distribution systems fail most often in the total system. There are over 250,000 water main breaks a year in the U.S., and there is over a 200 billion dollar backlog of maintenance on decaying distribution systems.

Current systems need highly trained workers to run them. Appropriate systems need to be effective when managed and operated by people who are not highly trained.

New water purification technologies and methods are needed that are appropriate around the world. Africa needs a new set of technologies that can deliver high-quality water at low-cost without duplicating the problems of the developed world.

Appropriate sanitation needs to consider gender and religious practice (e.g. water for women)

Appropriate deployment of technology needs to consider buy-in and ownership of treatment systems (e.g. village leaders or Micro-bank loans)

Distribution System Issues

- Distributions systems expensive to install and maintain. They are failing all over the world due to age and neglect.
- Distribution systems can be a source of transmitting disease. New pipes connected to an older system, particularly in peri-urban areas, rapidly degrade and cause disease.

Hard water struvite

- Point-of-source and point-of-use treatment systems can be much lower cost. Point-of-use treatment can prevent disease of contaminated distribution systems.
- But these Point-Systems need the efficacy of large controlled systems, without oversight of trained personnel. Robustness needed similar to the air break and chlorine.

waterCAMPws

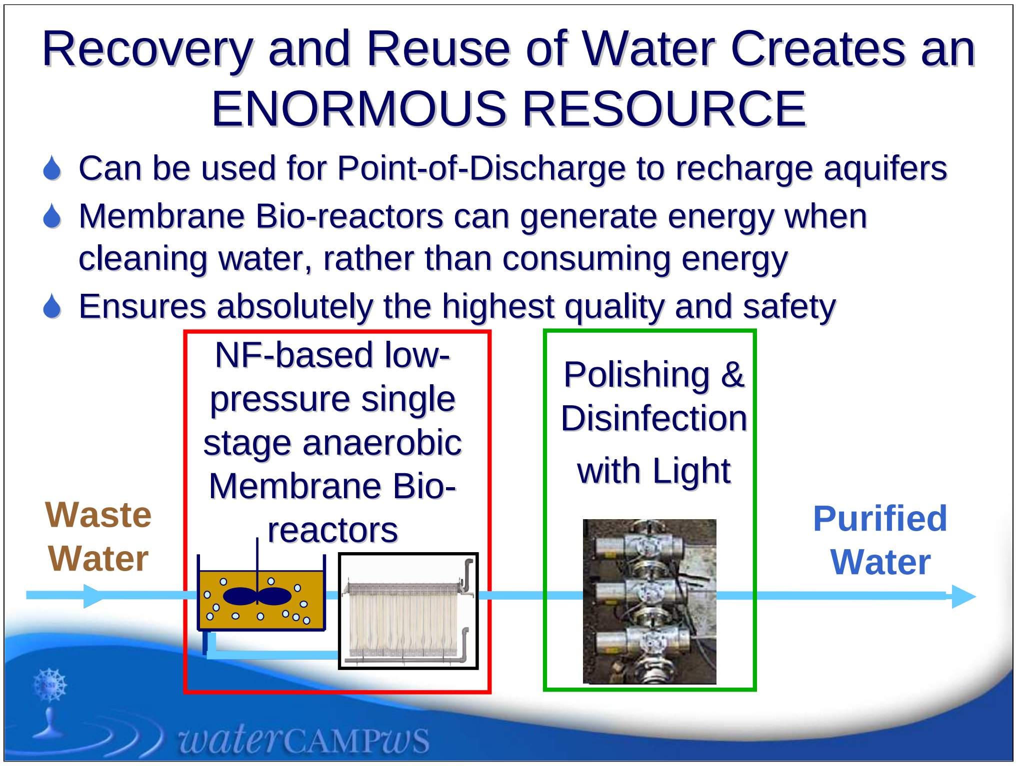
Common Current Low-Cost Treatment Methods in Use in Africa and Developed World

Filtering with gravel & sand: While low-cost, gravel and sand filters keep out only large particles, and they decontaminate by biological microbial action, where microbes digest organic compounds in water. They are highly variable in performance, and often fail with changes in weather, temperature, and incoming source water. They do not filter out salts, toxic compounds, pharmaceuticals, viruses, many pathogens, fuels, and smelly, bad tasting compounds.

Coagulants & absorbents like activated carbon & clays: Coagulants and absorbents remove small particles and undesirably substances from water. Most flocculants use chemicals such as alum and polymers to cause particles to settle out, which are not available in many parts of the world. Activated carbon only removes certain compounds, and is rapidly growing in cost. Clays can color water and is very slow.

Physical separation & activated sludge processes: Large-scale screens, settling tanks, shear flow flocculation, floatation, and membrane-based separation remove unwanted matter from water, but at the cost of high capital cost and energy use. Activated sludge processing often uses expensive air pumping for aerobic microbial decomposition, and sealed tanks for anaerobic nitrification. Residual disposal costs high.

Chemicals & oxidants: Use of chemicals such as lime, hydrochloric acid, lye, and soda ash to adjust acidity of water, reductants such as ammonia, and oxidants such as ozone, chlorine, and combined chlorine such as monochloroamines are unavailable in many parts of the world, are rapidly increasing in cost, and require highly skilled workers to apply and control. Also, their use can lead to the creation of highly toxic disinfection byproducts.



A delegate from India told the Organization of Economic Cooperative Development that the way in which we traditionally treat wastewater, by using powerful aerobic digestion pumping lots of air through the wastewater, followed by powerful oxidants to convert as much of the organic waste to water and carbon dioxide was "immoral." "We are using lots of energy and chemicals to destroy the energy and chemicals in the wastewater, while people are going without food and energy." While this statement is perhaps hyperbole, there is a nugget of truth. Traditional methods do use a tremendous amount of energy and chemicals to purify the water. New methods have appeared, based on a very old concept, to get useful products out without using energy to do so.

Composting waste is an old concept. Create microbial colonies that without air (anaerobic) digest the waste, producing a nitrogen rich fertilizer to help grow food. If one can compost, they should as compost is a valuable product. A modern concept to recover the water from the wastewater while creating products is to use anaerobic membrane bio-reactors (MBR). Microbe colonies digest the organic sludge and produce methane and ammonia, which can be extracted to use for energy and fertilizer. To make it energy efficient, low pumping power is needed. A special nanofiltration (NF) membrane that cannot foul from organic compounds has been created to make the MBR.

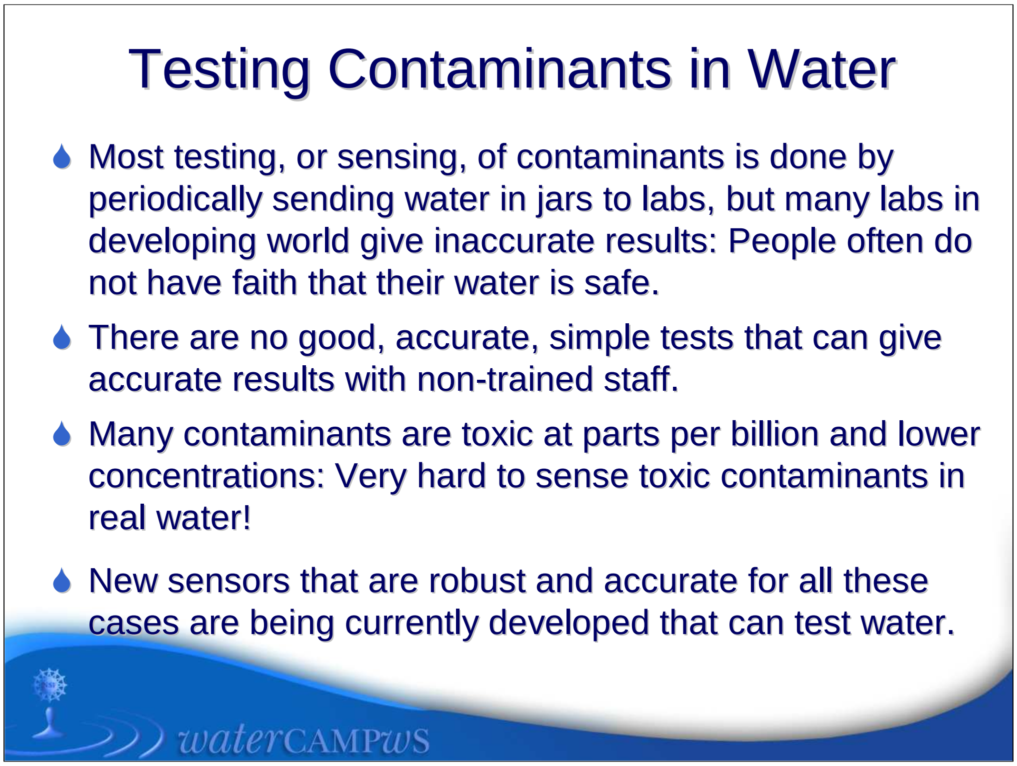
To ensure that no pathogens or organic compounds make it through the NF membrane, the process can be followed by a polishing step using light, to be talked about later. The final purified water can be as clean as natural deep artesian well water.

Even if all larger compounds are removed from waste and other impaired waters, there may be other compounds in water that are contaminants and should be removed for healthy, high quality water.

Many contaminants find their way into water sources from mining, industrial and agricultural activities, but many are also natural (arsenic). Many others are caused because of chemical treatment of water itself. No matter the source, once it is present, there can be profound health consequences. Distillates from oil and gas production and use is affecting large numbers of people through drinking water throughout the world, including Africa.

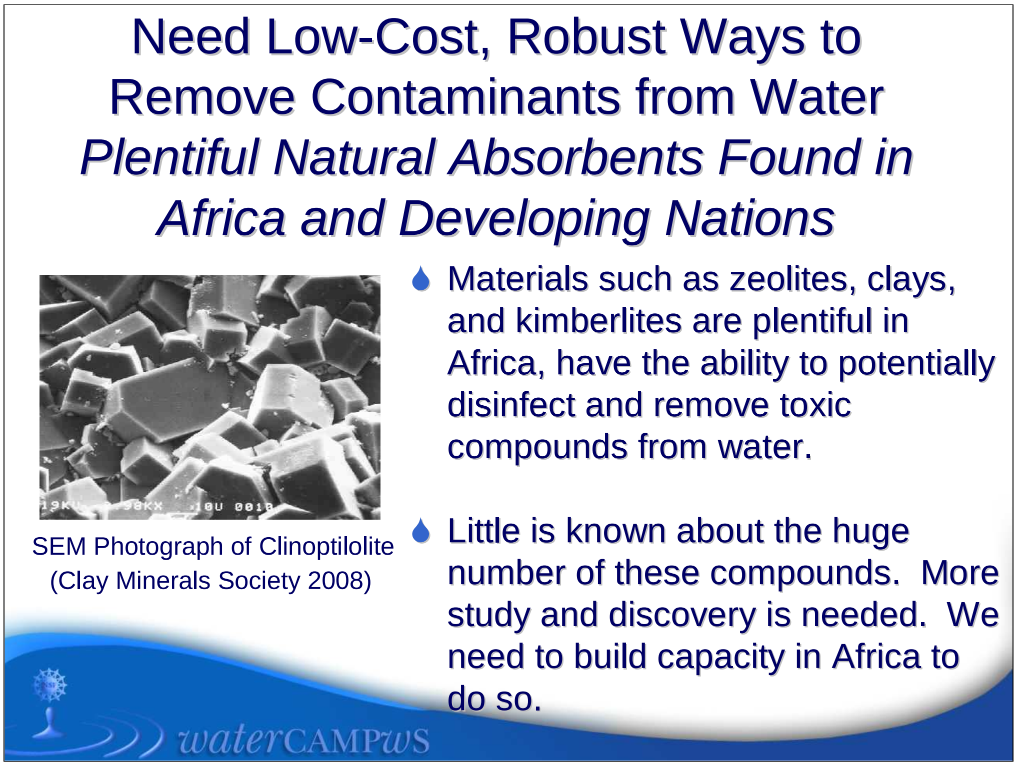
A key issue, however, is not all toxic elements are the same. The chemical specie that the element is in matters greatly. Hexavalent chromium, Cr(Vi), is much more toxic than other oxidation states of chrome. Small amounts of elemental chrome are actually thought to be useful to humans, but Cr(VI) is deadly. Similarly, while mercury is a heavy metal and never good for humans, methyl mercury is highly toxic is miniscule quantities. Therefore, we really need to know the form (speciation) of the contaminants in water.

Unfortunately, we currently need highly trained scientists to do this type of analysis to sense or detect what is in water.



Testing for toxic compounds in low amounts in water is difficult, particularly when there are so many safe compounds that are in water in much higher amounts that can interfere with the testing, creating false positives (saying it is present when it is not), and false negatives (saying it is not there when it is). High numbers of false positives and negatives make the tests almost useless, as no one knows what to believe. Unfortunately, up to now, there is no good way to test for contaminants in water that make people sick without highly trained scientists, other than simply watching people over a long time to see if they get sick.

New sensors are being developed that can either be tested by a trained worker (where a highly trained scientist is not needed), or can be combined with wireless communication system to report the results to a central laboratory somewhere in the world. Such use of modern communications where available can permit well waters and larger systems to be monitored remotely. If a contaminant is found, it can then be reported and action taken before people get sick. Such a system is already in place in India for trials.



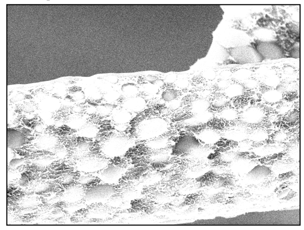
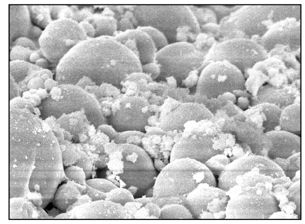
Once it is known that a contaminant is in water, in order to make that water safe again, it needs to be removed, or separated out from the water. Many types of materials can absorb compounds, such as heavy metals, into the material, pulling it out of water. Other compounds can act as catalysis, transforming other compounds, such as nitrates, into nitrogen and water, also removing it. Finally other materials can have photoactive properties, so that when light shines on the contaminant, such as a virus, it can oxidize the outer shell of the virus, rendering it harmless and disinfecting the water from the virus.

Africa is a continent rich in minerals, and many of these minerals may have exactly the properties one wants to absorb, transform, or oxidize the contaminant in water. Where minerals are being mined for say diamonds in kimberlite, the left over minerals may have just the properties desired. However, there are literally millions of possible materials of interest, so much more discovery and study is needed.

We need to build the scientific capacity in Africa to help find these solutions.

Cleansing Water of Organics with Sunlight

Templated porous structures and fibers

$Ta_2O_5 – SiO_2$ composites 17 days of aging with nodules 1-3 µm in diameter

Ndiege, Chandrasekharan, and Shannon, UIUC

- Can use low-cost treated silica (sand) to remove all organic compounds from water at high rates using free sunlight. Can remove carciogens, toxic compounds, and pathogens too, all without using chlorine.

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Organic compounds are often found in water that cause people to get sick, or not to drink due to the color, smell, or taste, leading to dehydration. Powerful oxidants can be used to remove these compounds, changing them to carbon dioxide and water. However, many pollution byproducts can result in this process that may be worse than the original compound, and it is costly. Chlorination and the presence of halogens such as bromine and iodine in natural water sources, and in particular desalinated seawater, with ammonia can combine with natural organic matter to produce highly toxic halogenated organic and nitrogenous compounds. We must avoid solving one problem and creating another with disinfection byproducts (DBPs). Some of these DBPs are thousands of times more toxic than cyanide!

New materials using low-cost but highly effective materials have been developed that when sunlight shines on them while in water with organics present, the organics are oxidized to carbon dioxide and water, without producing toxic byproducts. By their very nature, they are self-cleaning, since any organic that attaches to the surface will be oxidized and removed. Therefore, with more research, we should be able to learn if they can be installed in point-of-source, point-of-discharge, and point-of-use systems to clean water while the sun shines in many locations throughout Africa that have problems with organic compounds, such as distillates from oil.

Health Issues with Water

- Shallow wells a major source of disease
- Impact of viruses large but difficult to detect and disinfect.
- Rural areas impacted by lack of supply and contaminated groundwaters from lack of sanitation.
- Major issues in peri-urban area are interconnections between the waste and supply distribution systems that harbors pathogens, plus low pressures.
- Robust point-of-source/discharge/use treatment can prevent disease from being transmitted, saving literally millions at low-cost in both rural and urban settings.

Biosand Filters

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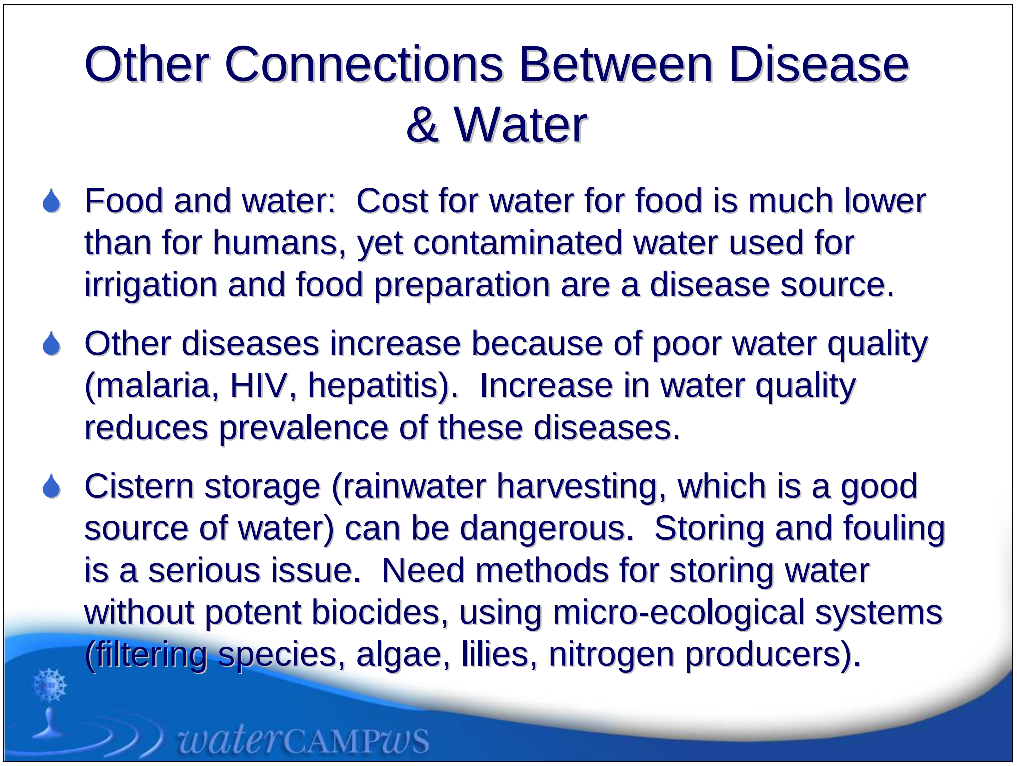
Shallow wells have long been known to transmit diseases, particularly those that are open to air and to hands contaminating the sources. Sealing of wells is one step. Point-of-source disinfection is another that can reduce infections. But it must be able to handle all types of pathogens, including viruses.

Lack of sanitation in rural areas a critical problem in causing drinking water contamination. Point-of-discharge treatment can reduce the amount of disease transmitted from wastes, before they enter the water supply.

While the source of disease in urban areas is a little different, arising from cross-contaminated distribution systems and tanker trucks, many of the same problems in rural areas exist in slums and outskirts of towns, but with higher population densities making lack of sanitation more severe.

Similar solutions of point-of-discharge and point-of-use systems can help solve the problems of urban systems.

In arid areas, point-sources may be difficult to find, or the wells very deep, requiring high energy use pumps. Storage ponds and cisterns are often used in arid areas to supply water. These covered storage systems can become fouled and unhealthy, transmitting disease if the water is not boiled, and contamination with toxins, even if the water is boiled. Point-of-use systems may be of some efficacy, but much more research is needed. More on other solutions next.



Waterborne diseases
Caused by the consumption of water contaminated by human or animal excreta (feces, urine) containing disease-causing organisms (pathogens) such as bacteria, viruses, worms and amoebas.
Examples: dysentery, cholera, typhoid, other diarrheal diseases, as well as viral diseases (hepatitis A, polio, rotavirus, norwalk agent, echonovirus, coxsackie virus).

Water-washed diseases (Water-scarce diseases)
Caused by poor personal hygiene, and skin or eye contact with contaminated water and/or insufficient quantities of clean water for personal hygiene and washing.
Examples: scabies, trachoma (eye infections), and flea, conjunctivitis, lice and tick-borne diseases such as typhus.

Water-based diseases
Caused by parasites found in intermediate organisms living in contaminated water. These diseases are usually passed onto humans when they drink or wash with contaminated water.
Examples: dracunculiasis (guinea worm), schistosomiasis (bilharzia), other helminthes (worms)

Water-related insect-vector diseases
Caused by insect, especially flies and mosquitoes that breed in or feed near contaminated water sources. These diseases are not usually associated with lack of water supply and sanitation facilities, and are typically excluded from estimates in water-related deaths.
Examples: malaria, dengue, onchocerciaisis (river blindness); trypanosomiasis (sleeping sickness); yellow fever, filariasis.

Sources: Maggy Momba (2008), WHO (2000), Werner (2001), Gleick (2002)

Filtering: Gravity Fed Water Purifiers

Siemens Water SkyHydrant

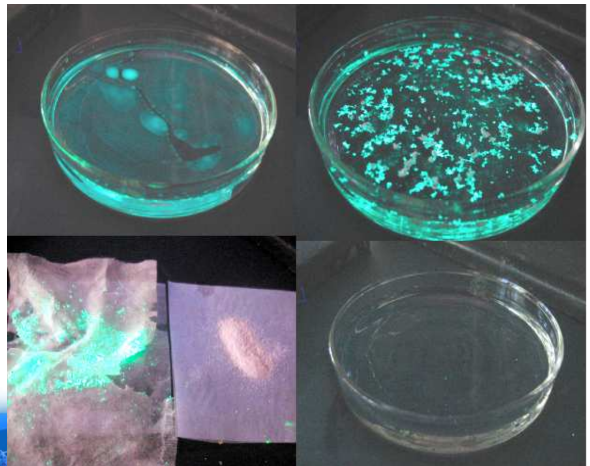
- Ultrafiltration barrier filters prevent non-viral pathogens from passing through, keeping them out of drinking water. If gravity fed, no power is needed to push water through the barrier. Can create safe water from impaired water, at low cost, even though the membrane is "high-tech."
- Deaths can decrease by nearly 2/3rds, *only if viruses are not present.* New technology can have huge effect here.

When the primary cause of disease is bacteria and larger pathogens, which are bigger than microns in size (one-hundredth of the diameter of a human hair), using a membrane filter to let water flow through but as a barrier to prevent the pathogens from moving through the filter can prevent waterborne disease. Siemens Water has created a low-cost ultrafiltration membrane, which has pores sizes below a micron, so water molecules, which are ten thousand times smaller can go through the filter, but bacteria and larger pathogens cannot. Water can flow through with only gravity to drive it. So if the water tank is above the filter, the water purifier will easily work, as shown in the pictures. However, if waterborne viruses are present, as they often are, they are so small that they can go through the ultrafiltration membrane. Smaller pore nanofiltration and reverse osmosis membranes can stop many viruses, but now a motor will be needed to push the water through, needing reliable electrical energy. Problems with the current system is that the membranes need to be cleaned periodically, with chemicals.

New technologies being developed combine ultrafiltration membranes with photocatalytic polishing of water to kill viruses and remove organic compounds. This process will only need to be gravity fed, and will be "self-cleaning" without chemicals (still will need to be backwashed). But it potentially can knock out viruses as well as all other pathogens. New technologies can have huge effect here.

Removing Petroleum Byproducts from Water

"Organic–Inorganic Hybrid Materials that Rapidly Swell in Non-Polar Liquids: Nanoscale Morphology and Swelling Mechanism," Burkett, Underwood, Volzer, Baughman, and Edmiston, Chemical Materials 2008



New low-cost absorbable glass can remove virtually all petroleum byproducts like benzene, distillates, and oil from water. Can be used over and over again. Large numbers of people are sickened by these compounds.

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New materials are being developed that can remove hard to treat compounds like petroleum distillates and by-products, which are found in huge number of waters, particularly in urban and peri-urban areas. Affects shallow and deep water wells, as well as surface waters.

Removing Pathogens and Turbidity from Water

The product is a small sachet containing powdered ferrous sulfate (a flocculant) and calcium hypochlorite (a disinfectant).

A new Point-of-Use technology, a combination coagulation, flocculation and disinfection treatment system, has been developed through collaboration between the Procter & Gamble Health Sciences Institute and the US Centers for Disease Control and Prevention (CDC).

The water purification process can be done at home:

- Add 1 sachet to 10 litres of water and stir to begin process of separating the cleaned water from the murky masses;
- Stir water for 5 minutes until clear;
- Filter water through a cloth and dispose of separated floc in the latrine;
- Let clear water stand for 20 minutes to allow for complete disinfection;
- Store in a suitable container to prevent recontamination.

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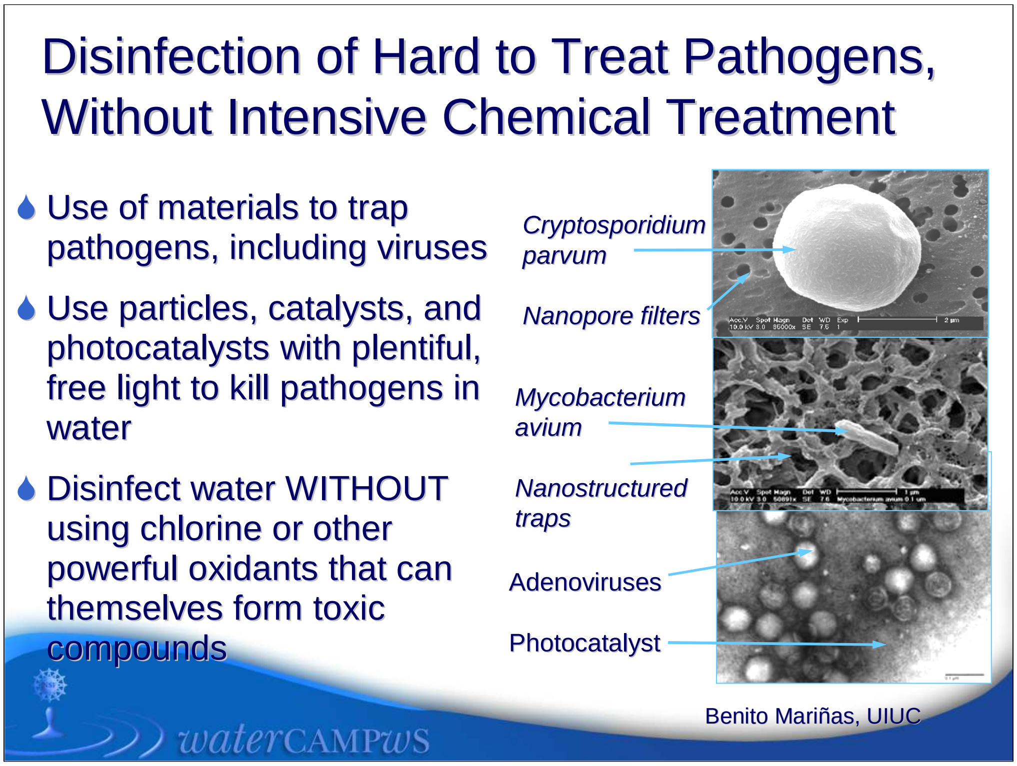
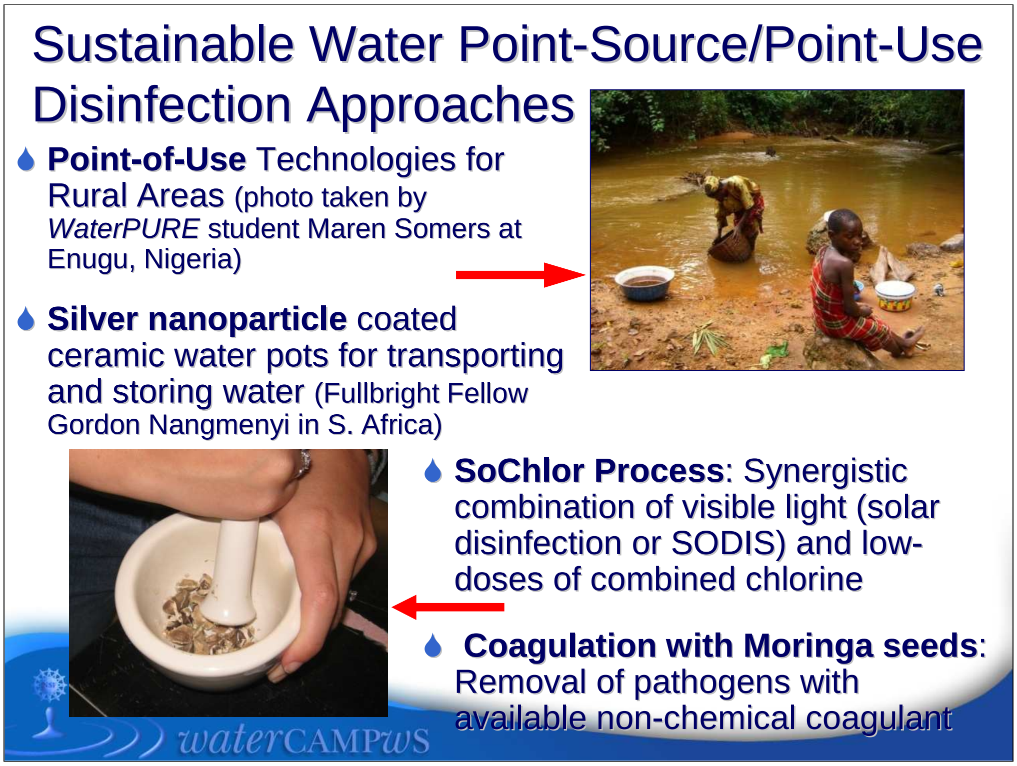
Low-cost point-of-use treatment system gives basic treatment, similar to that done in large scale distributed system.



There are numerous types of pathogens, from large parasites that can be removed by simple sand filters, to protozoa that will make it through many of such filters to bacteria and viruses that need more sophisticated barriers to stop them, or methods to kill and inactivate them so that they cannot infect people. While membrane barriers seem to be high-technology, due to their high effectiveness, in smaller sizes they can be a more effective, lower cost method than many traditional filters that have been in use for generations.

Chemical oxidants such as chlorine and ozone also can be used to kill pathogens, but many are resistant. Many of these oxidants can also produce toxic compounds when in the presence of naturally occurring matter found in water.

One goal is to kill or inactivate pathogens with plentiful low-cost or free light, without using large amounts of powerful oxidants. We have made highly effective photocatalytic technologies that can inactivate pathogens from hard to treat oocytes, spores, and viruses, as well as toxic organics, WITHOUT using chemicals and energy or producing toxic DBPs. These photocatalysts oxidize the hydrocarbons on outer shell of the pathogens, in a manor similar to how they destroy hydrocarbons in water, turning them into harmless carbon dioxide and water. Without the outer shell, the pathogens die or cannot infect people, thereby making the water safe. If low-cost fluorescent light bulbs can be used, the water can be disinfected around the clock, with a small amount of energy needed, often much less than pumping water up a deep well. Else, if the water can be stored to daylight, it can be disinfected with sunlight.



Many point-of-source and point-of-use technologies are being developed that can potentially impact different regions of Africa, in both rural and urban areas.

Examples include point-of-use technologies for preparation of food to prevent toxic cyanide from entering the water supply when removing the skins off cassava root, and to prevent bacteria and protozoa from contaminating the food. Another includes ceramic water carriage and storage pots coated with a thin layer of silver nanoparticles in the interior that kills pathogens on contact, without the silver leaching out into the water.

Point-of-source examples include a solar activated disinfection process where small amounts of combined chlorine are added at the source for residual pathogen control, the So-Chlor process, where sunlight enhances the killing pathogens by very low doses of monochloroamine to keep the process safe and low cost.

Another example includes the use of crushed Moringa seeds to naturally coagulate viruses and other pathogens in water, causing them to be easily filtered or settled out of water by many times more than chemical coagulants such as alum would do.

The *WaterCAMPWS* has a large education program, designed to increase the knowledge of a diverse group of students and practitioners around the world. We are also seeking to work with UNESCO to advance water treatment technologies for purifying water for human use in developing world, in particular Africa and Latin America. We are working with the National Science Foundation to set up workshops in Africa in the coming year to identify and develop partners in advancing science and technology of water purification, with universities and government facilities in Africa.

To achieve our goals, we need to build capacity between U.S. and African countries in the science of water treatment, discovering and creating new materials that can purify waters in new and better ways with lower cost, energy, and chemical use, and then to integrate them all into appropriate new water treatment systems. The process is a continuous one, where implementation of treatment systems will drive both the science and discovery process, and vice versa.

We need two-way participation between scientists and engineers in Africa and the U.S., where discoveries on both continents can inform the others. We need to build the capacity of students and faculty in Africa to learn about the science and technologies being developed in the U.S. for water treatment, and we need to inform students and faculty in the U.S. about the advancements in treatment and the discovery of materials in Africa. We all need to learn about what is appropriate science and technologies that can be applied to solve the pressing problems of drinking water and sanitation in Africa and the world. We need to develop new sensors to know what contaminants are in the water, and treatment processes and materials needed to remove them.

The Global Innovation Imperative For Water

- Conduct Regional Workshops in Africa on R&D and education for Drinking Water and Sanitation, and Integrated Water Resources Management (IWaRM)
- Offer short-term distance learning and in-country courses and graduate degree programs with established water institutes in Africa in water science and engineering and IWaRM.
- Develop R&D and Technology Innovation partnerships between member institutions of the NSF *WaterCAMPWS*, and universities and research institutes in Africa.
- Promoting private sector and NGOs partnerships for water science,engineering and technology transfer, and business development in water provision and treatment, and sanitation.

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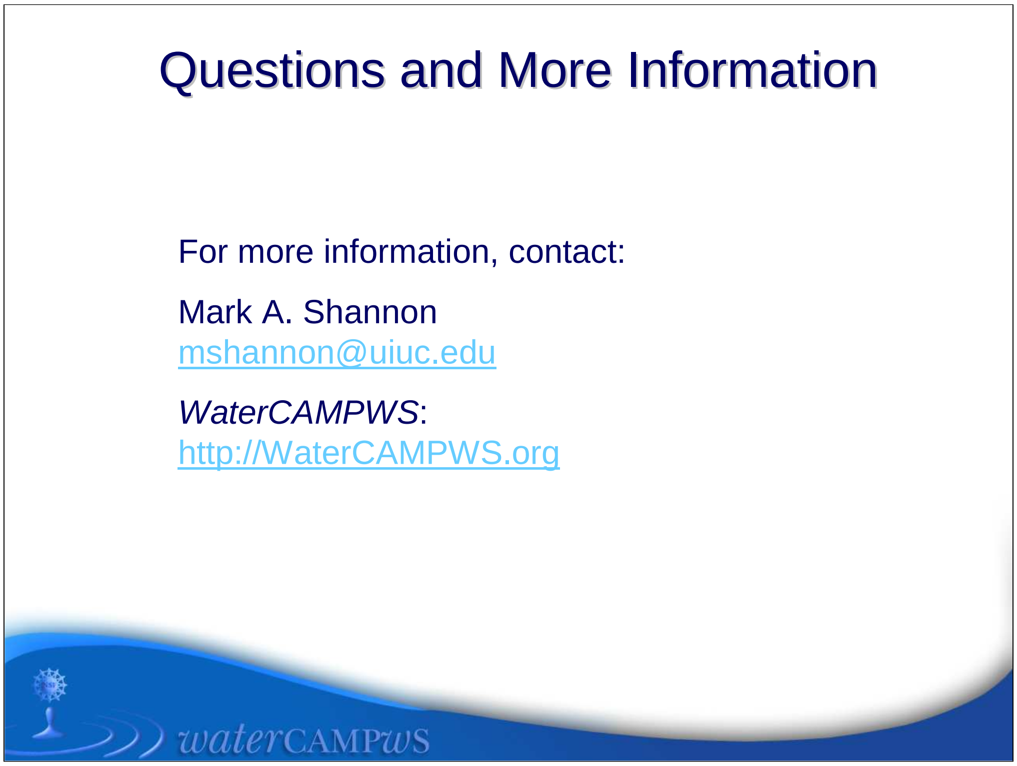
The world can join together to provide innovative solutions to the problems of supplying drinking water and sanitation. Continuing on the current path will not solve the problems, and they will only get worse. But by rapidly employing proven and new technologies, conducting major education programs, and enlisting the private and public sectors, we can provide solutions.



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