CRITICAL NATIONAL NEED IDEA

Development of UV-based water purification systems for point of use/point of entry

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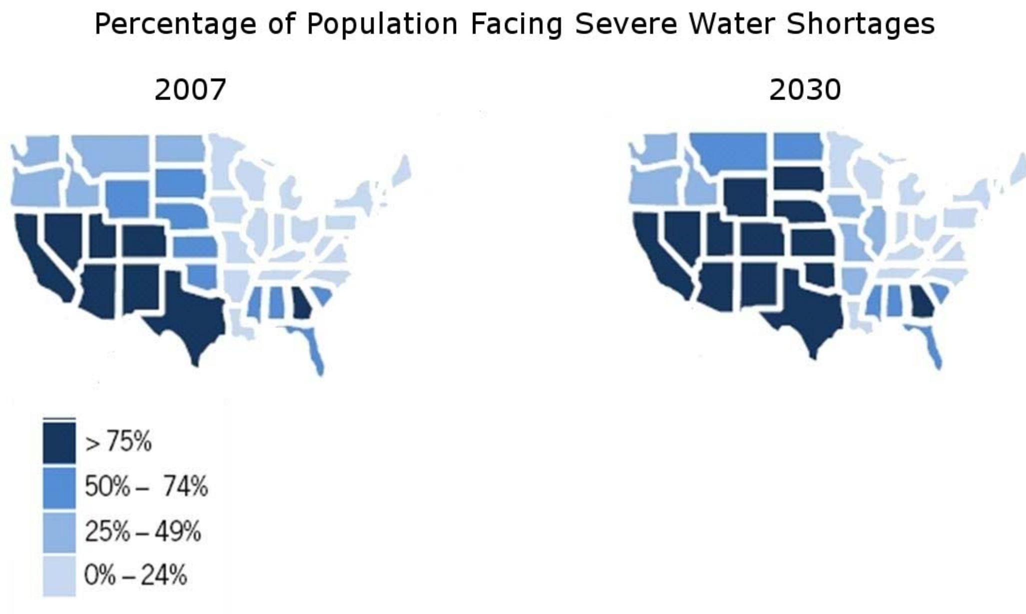
Summary: *The increasing stress on the clean water infrastructure, as well as public perceptions, will make a decentralized system very attractive if cost effective point of entry (POE) and point of use (POU) purification units can be developed. These POE and POU systems will probably have a filter component, such as activated carbon or reverse osmosis, and a disinfection component, most likely based on ultraviolet (UV) irradiation. A primary technical hurdle to the commercialization of these systems is the lack of a small, robust and versatile UV lamp. Ultraviolet light emitting diodes, when available, will be the ideal, energy efficient light source to make these systems ubiquitous.*

The US demand on water will increase by 50% between 2007 and 2030 [1,2]. The aging water system means that many states will be faced with severe water shortages.



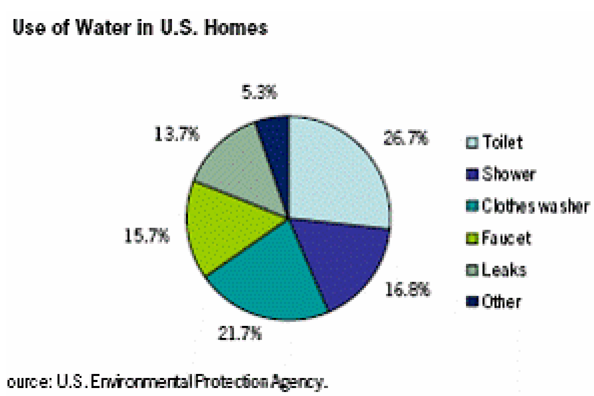
This need for clean water encompasses not only drinking water for household use, but also clean water for irrigation of fields and farms, clean water for food processing plants, clean water for the beverage industry.

The fact that the need for clean water is an issue of national importance even today can be exemplified by the interstate water conflicts between Georgia, Alabama and Florida and by the number of interstate freshwater and groundwater compacts that cover issues that vary from water supply, pollution, hydropower, etc.[3]

From a municipal point of view, it is very difficult to insure a safe "upstream" municipal water supply without addition of chemicals that, when accumulated, can be carcinogenic. Even when accepted chemicals are used, there is an inherent difficulty in insuring the population that a safe "upstream" water supply will translate into a safe water source at the point of use (POU) because of potential contamination in pipes and lack of infrastructure maintenance. In this sense, it is also very important to insure a safe treatment of wastewater and the absence of non-potable run offs into clean, processed water.

It is estimated that in order to bring the water infrastructure in line with demand, $1 trillion will need to be spent over a five year period[4].

According to a recent survey of the Water Quality Association[5], more than two thirds of Americans are concerned by the quality of the water coming out of their taps, in particular regarding the presence of hormones and pharmaceutical drugs in water. 50% of Americans believe that the government standards for drinking water should be stricter, and 70% believed that home filtration plays a role, together with their municipality, in ensuring safe drinking water. Meanwhile, a clear tendency towards the use of bottled water can be observed in the US by following the amounts of money spent on bottled water. US consumers who are not happy with the current water quality are spending $11B annually on bottled water (globally, this market is $70B). US consumers use nine billion gallons of bottled water and constitute the largest group in the world. [6, 7] In some cases, this use is caused by lack of trust on municipally/community provided tap water, in some other cases is a matter of the taste of the water that comes out of the tap. In all cases, bottled water use has consequences in terms of production costs (plastic bottle fabrication, water bottling, etc.), garbage disposal (about 60 billions of plastic bottles that may or may not be recycled), dependence on oil (plastic is an oil derivative). Manufacturing the plastic bottles consumes 17M barrels of oil per year in the US alone and these very same bottles will eventually occupy huge amounts of space in a landfill (estimates state that only 14% are recycled).[8, 9] The Environmental Protection Energy estimates that about a quarter of the clean water consumed in a US home is used in toilets, closely followed by laundry.



Clearly, given the current stresses on oil production, energy generation and fresh water availability, a future based in bottled water looks quite grim. It is more likely that the water distribution system will be eventually decentralized, with municipalities ensuring a reasonable degree of filtration and cleanliness, and consumers utilizing point of entry (POE) or point of use (POU) systems to ensure safety. The recycling of used water (from bathing, dishwashers, laundry, etc.) into “grey” water (for use, for example, in toilets) may also be an option. The idea of a decentralized water treatment system might play well with the individualistic American mentality.

A key component of a decentralized water treatment system should be an ultraviolet (UV) disinfection unit. Water disinfection (and disinfection in general) by short wavelength ultraviolet radiation is well understood. The US Environmental Protection Energy recognizes UV light as an important water disinfection tool that does not give origin to regulated disinfection byproducts, and that has proven effective against some chlorine-resistant pathogens such as Cryptosporidium.[10] Despite this knowledge and the convenience of a decentralized water treatment system, point-of-entry and point-of-use units are far from proliferating because most of the current, commercially available systems are based on hundred year old, outdated, technology that is not easily integrated with existing infrastructure. This happens at a municipal level and, more specifically, at a consumer level (POE, POU systems).

Point of entry and use systems consist of a filtering unit (e.g., activated carbon, reverse osmosis, etc.) followed by a disinfection unit that, so far, can involve application of chemicals or ultraviolet radiation. The systems based on ultraviolet radiation, although they do not originate undesirable disinfection byproducts, and, as explained before, are very effective against chlorine-resistant pathogens, are far from being user friendly: they are based on mercury lamps that are bulky, heat up the water they disinfect, need to be permanently on in order to be able to disinfect water "on demand", and have a lifetime of one year. In addition, the disposal of mercury lamps has to be carefully controlled in order to avoid the accumulation of mercury in landfills, or the release of mercury vapor to the atmosphere. Mercury lamps emit the bulk of their UV radiation at a wavelength of 254 nm. The emission wavelength of a plasma-based lamp such as a mercury one is fixed by the atomic energy levels of the element involved. The ideal wavelength for disinfection is 265 nm. Light of this longer wavelength is about 10% more effective in disinfection than light of 254 nm.

A much more user friendly and effective system would be one in which the disinfection unit is based on UV light emitting diodes (LEDs). Some of the advantages of UV LEDs are that the wavelength can be varied by design, and so it is possible to emit light at 265 nm, are tiny compared to the footprint of a mercury lamp, do not heat up the water, and so they would be applicable to very small POU systems, such as water fountains or water dispensers in refrigerators. In the table below some of the benefits of UV LEDs compared to mercury lamps are summarized.

Versatility	Operational	Economic & Environmental
○ Compact light source ○ Many different packages ○ Can be packaged in large arrays ○ Mechanically robust	○ Cool running ○ Switchable – no warm-up period ○ Directional Light ○ Single Wavelength	○ Energy efficient ○ Long life ○ Mercury free

It is clear that a system incorporating a combination of a filtering process such as reverse osmosis or activated carbon, together with UV LEDs in the purification unit would be an ideal POU arrangement that could be scaled up to POE.
The possibility of introducing UV LEDs into purification systems would impact areas as diverse as health care, in terms of air purification in hospitals (where, for example, the proliferation of MRSA bacteria is a concern), surface decontamination, wound care, etc., to homeland security, where they would solve issues such as bioagent detection, non-line of sight data communication, explosives detection, etc. The availability of UV LEDs would allow some applications that are not achievable with mercury lamps, for example, a disinfection unit in a cool water dispenser such as a refrigerator, air and water purification inside of airplanes, portable/emergency water purification systems, etc. Utilization of point of use or entry units based on UV-LEDs would also translate into energy savings because of the switchable nature of LEDs, as the light up of the disinfection unit and its output power could be synchronized with the water flow.

Most manufacturers in the water purification industry are used to the constraints and limitations of mercury lamps, and place similar requirements in terms of emission wavelength, power, size and geometry on LEDs. Incorporating UV LEDs into existing purification systems is neither practical nor efficient. There is need for innovation and device a whole new approach to the design of LED-based purification units that take advantage of the versatility and possibilities of UV-LED lamps.

Likely proposers to a solicitation on this topic would be POE and POU systems manufacturers as well as municipal disinfection manufacturers, who could then offer a complete package encompassing the central, municipal facility, enhanced by a local, POE system, assuming they can design a system that will be user friendly, either based on a better UV light source or another technology. Another type of proposer would by light source manufacturers that might be able to provide a technology alternative to the incumbent mercury lamps. Most likely, the proposers will be joint ventures formed by partners from the semiconductor industry with an interest in solid state devices and from the water purification industry.

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[1] "Water Cultivation: The Path to Profit in Meeting Water Needs" (Oct 2008); LuxCapital Report
[2] Organization for Economic Cooperation and Development
[3] US interstate freshwater compacts database - Program in water conflict management and transformation - Institute for water and Watersheds - Oregon State University
[4] Water Innovation Alliance
[5] Water Quality Association - March 2008
[6] International Bottled Water Association
[7] Beverage Marketing Corporation
[8] The Earth Policy Institute
[9] Treehugger.com
[10] USEPA, "UV disinfection guidance manual for the final LT2ESWTR", November 2006