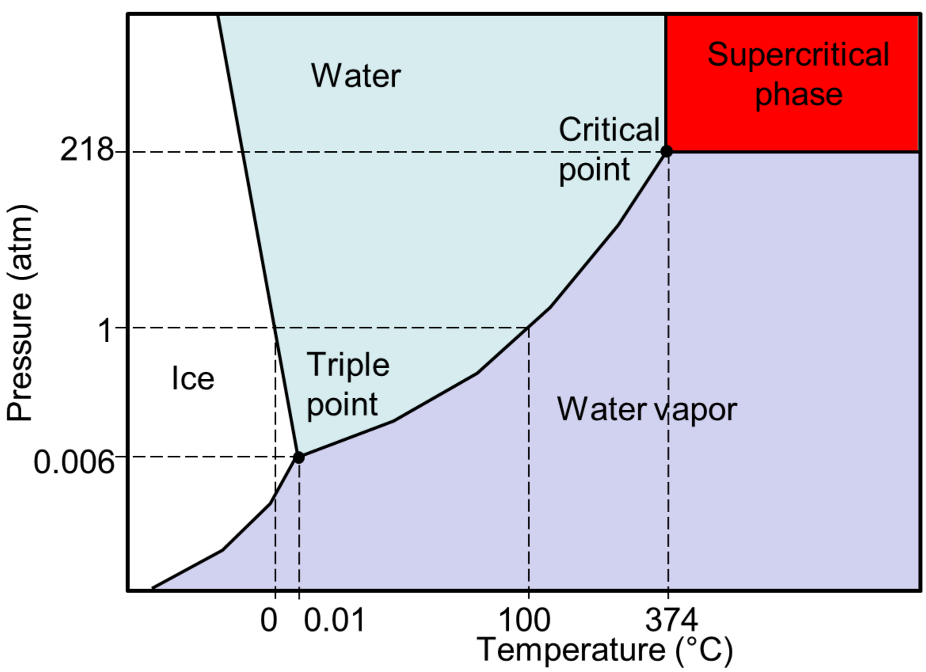
Sanitation Solutions at Duke University
Community Treatment Project

About Supercritical Water Oxidation or SCWO

The supercritical phase of water

We are often taught that water exists in three phases: liquid, gas (steam) and solid (ice). However, when heated to temperatures of over 705°F and pressures of more than 3200 pounds per square inch (psi; atmospheric pressure is about 15 psi at sea level), water enters a unique, supercritical phase. This supercritical water flows like a gas but still is able to dissolve things like a liquid. Supercritical water can dissolve suspended sewage, and with the addition of oxygen, one can oxidize (i.e., burn) the sewage sludge, producing a sterile combination of water, carbon dioxide and salts.

Similar to waste incineration, this supercritical water oxidation (SCWO) process produces heat, despite the presence of water. Some of this heat can be used to preheat the incoming fecal sludge to supercritical temperatures, eliminating the need for an external heat source to sustain supercritical combustion once it is has begun. The remaining hot water may be supplied to the community directly or used to power an electrical generator.



SCWO technology for sanitation applications

SCWO shows promise because it works quickly and generates energy in the forms of hot water and steam from the treatment of human waste. Furthermore, it does not require any prior dewatering or drying of fecal sludge, and it effectively eliminates all types of harmful organisms.

Has this technology been tried before?

Supercritical water oxidation has already been implemented in several research and commercial applications to treat waste products, including polychlorinated biphenyls (PCBs), chemical weapons and sewage. Operations involving the destruction of toxic and harmful chemicals have encountered problems with reactor corrosion, due to the composition of the waste that they are combusting, but corrosion controls are being developed to solve these problems. Moreover, SCWO ventures are becoming more successful as reactor designs and applications evolve. Although some SCWO operations are no longer in operation, eight new plants have been contracted to be built as of January, 2012.[i]

Does the process produce toxic by-products or wastes?

No. Sewage and oxygen go into the SCWO unit, and clean water, heat energy (e.g., steam and hot water), carbon dioxide (CO_2), nitrogen gas (N_2), and inert salts—all non-toxic and easily utilized, released or disposed of—are produced.

How clean is the water that is produced?

Once any suspended salts are allowed to settle out of the SCWO output water, or effluent, the resulting water is potentially potable. As one might imagine, cultural norms and personal biases will influence the extent to which the water flowing from the SCWO unit will eventually be utilized as drinking water or wash water by end users. Given the frequent scarcity of water in target regions, however, clean hot water is likely to have intrinsic value.

Could SCWO be used to treat other kinds of wastes?
Could this be used for wastes that would otherwise go to the landfill?

SCWO can treat other input materials beyond sewage sludge. For example, SCWO plants exist to treat chemical weapons, PCBs (polychlorinated biphenyls) and to recover precious metals (e.g., platinum) from spent chemical catalysts. In theory, SCWO could also be used to treat solid wastes that would otherwise go into a landfill. While initial investigations will focus solely on sewage waste, we hope to eventually expand our investigation to consider the possibility of accommodating some volume of other waste streams in the future.

Why is this good for the environment?

While SCWO is a high temperature process, operating temperatures are still below those of conventional combustion and lower than the temperatures at which air pollutants associated with smog, acid rain and ozone depletion are produced (e.g., NO_x and SO_x). SCWO converts the organic waste in the sewage into nitrogen gas (N_2), which comprises 78% of our atmosphere, and carbon dioxide (CO_2).

Does SCWO produce any greenhouse gas (GHG) emissions?

When the carbon in sewage is 'burned' (oxidized) in a supercritical environment, carbon dioxide (a greenhouse gas) is produced and released into the atmosphere, comparable to when waste is incinerated. However, when waste is incinerated, it must first be dried, which requires a significant investment of energy. Thus, while incineration produces a similar amount of CO_2 as SCWO, incineration requires much more energy to pre-dry the waste than is required to initiate the SCWO process. Moreover, incineration releases harmful air pollutants (namely NO_x and SO_x), while SCWO does not because it operates at lower temperatures.

What electrical infrastructure will be required to operate a SCWO reactor?

The SCWO process only requires an external energy source when starting the unit. Energy is needed at start-up to pressurize and preheat the incoming waste stream to a temperature of about 480°F – 525°F, at which point the reaction proceeds quickly and exothermically (releasing energy). Energy is also needed to pressurize the oxygen supply. Once the reaction is underway, the energy released sustains the reaction and can be harnessed to generate electricity or to heat hot water for bathing. Therefore, since an energy input is only required at start-up, it is desirable to run the unit continuously, to the extent that feedstock availability and maintenance requirements allow.

What is the cost of SCWO and how does it compare to other sewage treatment alternatives?

When considering the cost of sewage treatment, it is important to note that the underlying sewage infrastructure—standard in western countries—does not exist in the regions of the world for which solutions like this are being developed. In order to compare the cost of a sewage treatment technology that depends upon the installation of public sewer lines, the cost of installing the underlying infrastructure would have to be included and would be cost prohibitive in most cases.

The value proposition of a SCWO sewage treatment unit includes equipment and operating costs, the local value of sewage treatment services and the revenue-generating potential of the output byproducts, like hot water and steam. We are investigating all of these factors to better understand what the gross and net costs would be in a given location. Comparing reports from several existing SCWO systems and excluding, for now, any potential revenue from byproducts, early calculations indicate that the total cost could achieve the foundation's goal of less than five cents per person per day.

As we progress further along in the development lifecycle, we will be better able to compare costs.

What is supercritical water gasification (SCWG)? Does it play a role?

Supercritical water gasification is a reaction that, similar to SCWO, takes place above the supercritical point of water (temperatures above 705°F and pressures above 3200 psi). While gasifying sewage waste has the advantage of not requiring added oxygen, it has the drawback of requiring energy to sustain the entire reaction, instead of producing heat energy. SCWG gives off methane and hydrogen gas as byproducts, which can be burned to create energy in a subsequent step.

Our team will be evaluating both SCWG and SCWO and considering their application both independently and in combination to achieve the desired design goals.

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[i] Marrone, P. Supercritical Water Oxidation – Current Status of Full-scale Commercial Activity for Waste Destruction. http://issf2012.com/handouts/documents/384_004.pdf

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