Supercritical Water Oxidation (SCWO) Technology an Alternative to the Conventional Wastewater Treatment Plant

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ABSTRACT

Clean water is essential for human survival. One issue to be face is the impact of wastewater treatment on water sources. For that reason, is essential to bring alternative solution for the wastewater treatment. There are many technologies regarding wastewater treatment. But over the years, the day to day practice have shown that the technologies associated with this are complicated, expensive and are no strangers to facing issues. For example; operational efficiency, cost, sustainability and the possible waste/water output of the technologies, between others.

One new technologies applied to the wastewater treatment is called Supercritical Water Oxidation (SCWO for its initials). SCWO is the destruction of wastewater is performed beyond the critical temperature (374.2 °C) and critical pressure (22.1 MPa) of water. During SCWO the wastewater and the added oxidants become homogenous, so that the oxidative ability increases and the pollutants are oxidized quickly. Supercritical water oxidation (SCWO) is a powerful technology to treat hazardous wastewaters with many advantages. However, this has two main weaknesses as salt deposition and corrosion.

INTRODUCTION

According to the World in Data organization developed by the Oxford Martin School, from 1750 to 1980 the world population increased 2.1% (see figure 1).

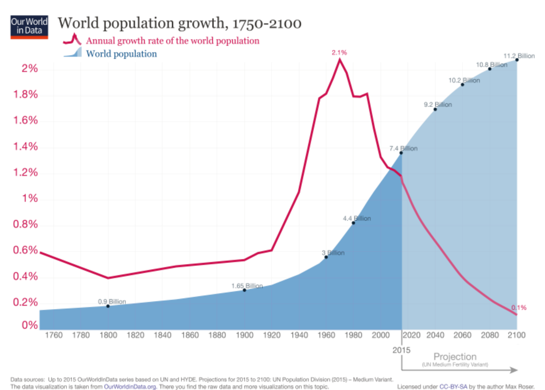

Figure 1: World Population growth form 1760-2100. Taken from https://ourworldindata.org/world-population-growth/

Over the years, population growth has impacted the sustainability of the world resources and direct impacted the environment, specially the water resources. Many studies have established a direct relationship between population growth and environment degradation because more individuals claim more resources and produce more waste. Evidently one of the challenges of a growing population is to develop and stablish new technology to overcome the environmental problems. Is essential to prevent and stop further degradation of water sources and put in place the necessary technologies to clean up polluted waters. Supercritical Water Oxidation is an advance wastewater treatment. In order to understand this advance treatment is important to explain some chemistry.

SUPERCRITICAL FLUIDS

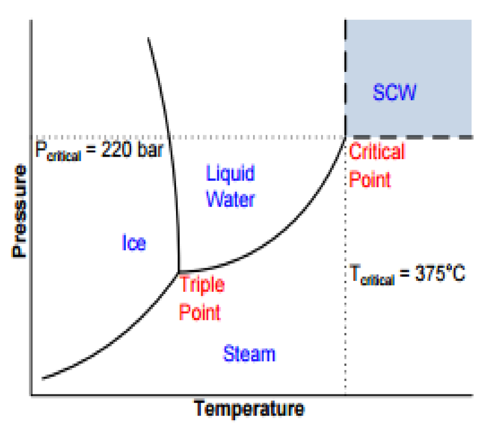

Figure 2: Phase diagram of water showing supercritical water conditions.

A substance has three phases; solid, liquid and gas. As shown in figure 2, phase diagram of water, the triple point is the temperature and pressure at which the three (3) phases (solid-liquid-gas) of water coexist in thermodynamic equilibrium, as well, there is a zone call the Critical Zone, mark in the graph as SCW which means Supercritical Water. A supercritical fluid is a substance at which its temperature and pressure is above its critical point. The supercritical zone is characterized by the incapacity to distinguish whether the substance is a liquid or a gas. For instance, supercritical fluids (SCF) do not have a definite phase. Supercritical Fluids are useful for science due to its characteristics [1]-[2].

These unique characteristics of the supercritical fluids has aroused scientific interest to apply it into wastewater treatment technology.

For example, supercritical fluids:

- have the diffusion coefficient 10-100 times more than liquid fluid, which is beneficial to mass transfer and heat exchange.
- are compressible, slight change of temperature or pressure will cause great change of its density, and impacts its dissolving ability.
- can lead to reactions, which are difficult or even impossible to achieve in conventional solvents.
- have solvent power similar to light hydrocarbons for most of the solutes
- the fluids are commonly miscible with permanent gases (e.g. N_2 or H_2) and this leads to much higher concentrations of dissolved gases than can be achieved in conventional solvents.

SCWO *(SUPERCRITICAL WATER OXIDATION)*

Under standard temperature and pressure (STP), water is a polar solvent that can dissolve electrolyte (e.g. salts) but hardly can dissolve gases and organics as well at STP water density slightly changes with pressure. On the supercritical conditions, the physical proprieties of water change. Density is less than that of the liquid; viscosity is the same as the gas, diffusivity is between the liquid and the gas. However, Supercritical Water small change of temperature will cause a big decrease of density.

At the critical point the density of water is 0.322 g/cm³, this means that supercritical water is a good solvent for non-polar organic molecules, due to its low viscosity and relative permittivity (dielectric constant) and deprived hydrogen bonding. In essence, SW has high dissolve ability for non-polar organics, while significantly low for inorganic matter, causing precipitation of inorganic substance. With this characteristic supercritical water is completely miscible with gases (e.g. carbon dioxide, air, nitrogen) [5]. During this process when water hydrogen bonds are broken, water molecules can dissolve chemicals that were previously insoluble. When oxygen is present, the organic component of biomass undergoes an exothermic oxidation reaction in SCW which converts the biomass into carbon dioxide vapor and releases heat [6]. This is called supercritical water oxidation (SCWO).

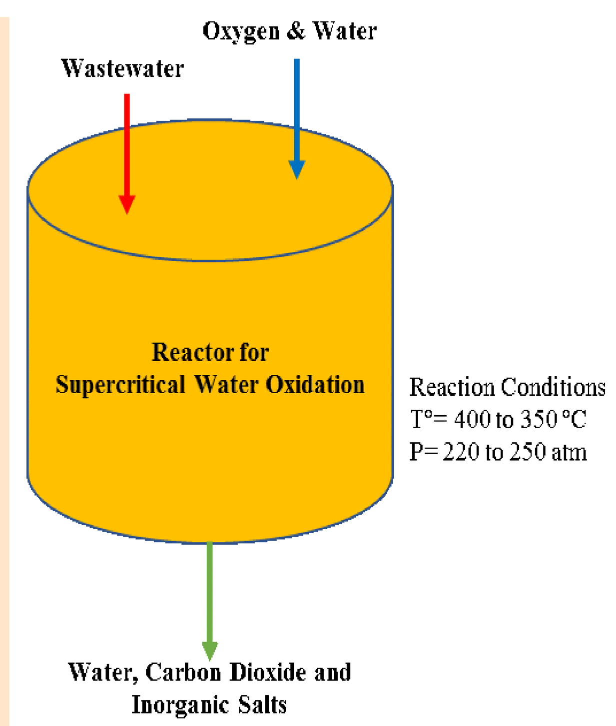

Figure 3: SCWO Reactor Inputs / Outputs

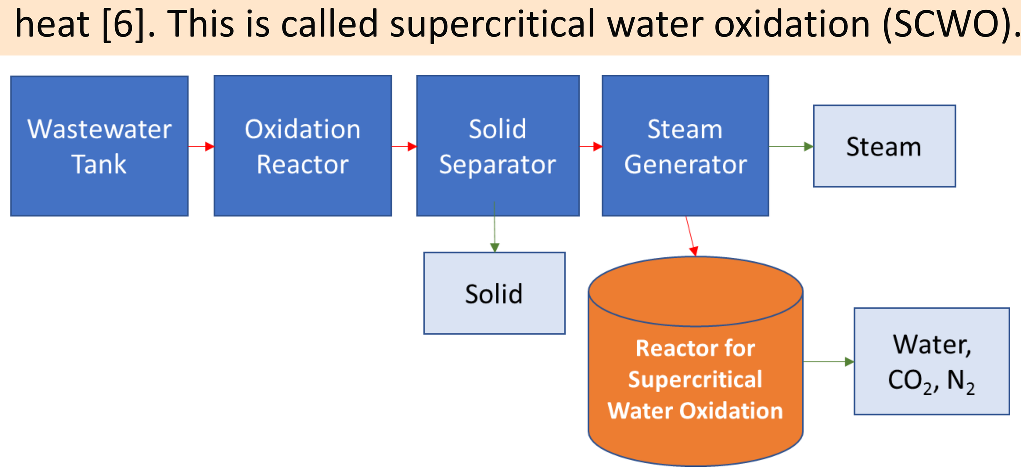

Figure 4: Typical process of the supercritical water oxidation.

Simplifying the process the wastewater and an oxidant enter a reactor at supercritical conditions and the total organic compounds (TOC) are dissolved. The output area carbon dioxide, water and other, depending upon the reactor conditions and process efficiency. See figure 3 for more details. According to some studies with the proper temperature, pressure and reactor residence time almost any pollutant can be completely destroyed by SCWO with residence time less than 1 minute [7].

ADVANTAGES	DISADVANTAGES
– Complete conversion of toxic compounds – Water, organic compounds, oxygen or oxidants become homogeneous in one single phase, avoiding two-phase reaction. – The oxidation speed of organic is fast and reaction time is short, facilitating adiabatic operation and total recycle off waste heat. – Oxidation of organic compounds is complete, eliminating the need for secondary treatment of exhaust. – Negligible NO_x and SO_2 production. – Under supercritical conditions, sewage sludge will combust, releasing energy as heat. – Process stability and Control – Contained process	– SCWO has two major limitations corrosion and salt deposits [7]. – Substances that contains no carbon (inorganic substances) are not soluble in supercritical water and tend to form precipitates. Some effluents substances as halogens and sulfur will form strong acids, which are very corrosive. – Expensive Site due to the material of construction (resistant to corrosion). – SCWO process, requires a big quantity of energy, but this can be recover during the steam production process as show in figure 4. – SCWO process usage of high pressures and temperatures will require some safety precaution equipment's, impacting the cost of the Plant.

CASE STUDY

The Department of Civil and Environmental Engineering in Duke University in North Carolina, USA has been researching about a prototype to treat fecal sludge using the Supercritical Water Oxidation Reactor as a solution for low income cities.

Figure 5: Supercritical Sanitation System Prototype

This study show the potential of SCWO in wastewater treatment. Their study validates a removal of 99.97% can be achieved, this means that this process produces clean water without odor, Sox or NOx, a common issue for conventional wastewater treatment technologies. Besides, SCWO achieves both waste treatment and pathogen control fast. In the other hand this study mentioned that many challenges remain, including slurry pumping, long term operation (plugging and corrosion) and process economy.

CONCLUSION

This project has compile a literature background that present the process SCW as the process at which organic waste and metals are oxidized to inert species (e.g. CO_2, water). Some researchers agree that this process is rapid and a complete reaction, without harmful by-products. According to many studies and references listed on this project all subject matter experts agrees that the supercritical water oxidation technology provides a powerful alternative to treat hazardous and toxic organic wastes in an efficient and effective way. However, given the process parameters necessary to achieved the supercritical water this technology present some concerns in the process cost necessary to operate a wastewater treatment plan with this technology. I think that this technology is a good option of private companies as pharmaceuticals and other industries that have private wastewater treatment plant with high quantities of organic compounds. Besides, these industries could make good use of the steam and other products generated by this technology.

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