Plasma for water disinfection

My name: Lina Nawwash Abu-Ghunmi

Email: linagh22@yahoo.co.uk

My home institute address: The University of Jordan, Water energy and environment center, Amman 11942, Jordan

My host institute address: KTH-Royal institute of technology, department of production engineering, Brinellvägen 68, SE-100 44 Stockholm, Sweden

Water is not only vital for life on the planet, but also it plays a crucial role in economic development and poverty alleviation. Water resources are not only limited but also distributed unevenly across nations. Furthermore, increase in world population, the rapid industrial growth and the worrying climate change, in addition to other factors, make water a priority issue at the international, national and local levels. Therefore, one of the targets of the millennium development goals is halving the world population who are without access to safe drinking water and basic sanitation.

Providing population with safe drinking water involves four stages; collection, treatment, transportation and storage for use. For drinking purpose quality, raw water is treated using different stages, of which disinfection is always a mandatory step. Currently the conventional disinfection process is chlorination, which is the cheapest disinfection process. But chlorination is not efficient in disinfection microorganism spores, and carries the risk of producing carcinogenic by-products THMs. Thus, according to the European REACH directives guide, chlorination along with other chemical treatment processes should be replaced by other treatment techniques. The need for an alternative disinfection process is even more important in situations when chlorinated drinking water is pumped non-continuously, transported by tankers and stored for use. Non-continuous supply and storage of water considerably increases the risk of water quality deterioration, as it leads to the exposure of water to a range of chemical, microbial and biological pollutants as well as to micro-pollutants. Furthermore the need for a new disinfection/treatment technology becomes a challenging and urgent need in rural and remote areas, as well as in disasters areas; natural or human made, that lack access to improved drinking water and sanitation. The reason for this is that in such cases, the possibility of water-borne and water-related diseases increases. Therefore, a robust, portable, efficient and affordable treatment technology is an inevitable.

The research methodology that was applied to develop an alternative concept for water disinfection was: (1) reviewing the relevant literatures on the techniques that rely on Nano-sciences for water treatment to select a technique for water disinfection. Based on outcomes (2) plasma for water treatment was further searched and studied to understand its potentials and limitations in water disinfection. Then (3) experiments were carried out in Nano-coating material lab, in the department of production engineering at the KTH Royal institute of technology, in order to test and deep our understanding of the plasma concept.

(4) Experimental setup was designed for generating non-thermal plasma in water and was tested under different conditions to examine the effect of number of different variables on the process.

The study results showed that different types of Nano techniques have been tested and applied for treatment of water. The techniques are mainly relying on the production of Nano-scale material that are originated from synthetic (e.g. zinc oxide, ferric and ferrous oxides, titanium oxide, Nano-fiber …etc.) or natural sources (e.g. volcanic tuff, oxides for natural sources and plasma …etc.). The criteria of selecting the appropriate treatment technique includes: characteristics of raw water, the targeted pollutants to be removed, the environmental conditions: Temperature and pH; the operational conditions; i.e. residence time, pressure and method of separation; and the socio-economic factors; capital and operation costs and public acceptance. Furthermore, it was found that one of the main challenges of applying Nano-science in water treatment is the method of separating treated water from added nanomaterial. I selected plasma to be the focus of my research. Plasma is classified as the fourth state of matter that consists of ions, atoms and molecules at both levels; stable and excitation, in addition to radiating waves of different length. Plasma is generated naturally on the earth by thunderstorm, and so by mimicking this natural process, scientists were able to produce plasma in the lab. Ozone, is a specific case of plasma, and is used extensively in water disinfection in Europe from early 20th century. Plasma can be used directly and indirectly in water treatment; in the former case the plasma itself disinfects water based on the functions of its constituents; UV, free radicals, waves…etc. In the indirect case, plasma is used to coat material with Nano-particles, such as silver and TiO_2, and then the coated materials are used for water disinfection. In lab work, I have joined the research group working on coating different substrates with Nano-copper particles, where coating was carried out under vacuums, using mixture of gases and applying high voltage power supply. These coated materials were very effective in fatigue resistance. Following this I was able to generate plasma from air under different operating conditions (pressure, voltage and electrode gaps) to determine the optimal conditions to generate atmospheric non-thermal plasma. After that I worked on generating Non-thermal atmospheric plasma using a pin-electrode configuration. This configuration was tested by applying different amount of voltage, frequency and electrodes gaps.

The outcomes of this post-doctoral research period are deep knowledge and concrete lab experience that would shape my future research where the focus will be on using plasma in water treatment. This field that is identified as a new promising branch of science, has a great potential in providing sustainable, not only disinfection but also, treatment of water even from the most recalcitrant pollutants. Plasma will be my future track in water treatment.