SWASTIIK

Safe Water and Sustainable Technology Initiative from Indian Knowledgebase

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Abstract

Safe drinking water is necessary to prevent occurrence of large number of waterborne diseases and to save millions of lives, one of the most priority themes for developing country like India. It is essential to develop methodology which provides safe and healthy drinking water at low cost with substantial ease of operation, scale-up and without harmful disinfection by-products. CSIR-NCL's water disinfection technology, SWASTIIK, a hybrid hydrodynamic cavitation technology, can provide alternative to existing disinfection processes, mainly for chlorination. The technology is effective for eliminating harmful bacteria, gram-negative (*Escherichia coli*) and gram-positive (*Staphylococcus aureus*). Also, complete removal was achieved for antimicrobial resistant (AMR), gram-positive methicillin resistant, *Staphylococcus aureus* and relatively less researched, gram-negative opportunistic pathogen, *Pseudomonas aeruginosa*. The present study, for the first time, reports possible use of different natural oils such as eucalyptus oil, clove oil, peppermint oil etc. in conjunction with hydrodynamic cavitation. Exceptionally high rates were obtained for practically complete removal of all types of bacteria, within less than 10 minutes, for a very small concentration of oil, 0.1%. The increased rates of disinfection using oil/extract can drastically reduce the time of operation and consequently reduce cost of disinfection. A possible mechanism indicates cell destruction through the rupture of cell wall, oxidative damage and possible DNA denaturation. The developed methodology, Safe Water and Sustainable Technology Initiative from Indian Knowledgebase, SWASTIIK, has the potential to provide viable alternative to chemical disinfection methods with operating cost of only 0.036 $\$/m^3$ (~Rs. 2.5/ m^3 or 0.25 Paisa per liter).

Introduction

In the recent times, availability of safe drinking water has become a major challenge as a result of an increasing human population and environmental pollution. As per the WHO estimates, approximately 785 million people lack access to a basic source of drinking water, while the drinking water supplies of some 2 billion people are contaminated with pathogenic bacteria associated with feces, resulting in diarrhea, dysentery, typhoid, and polio (WHO, 2019). WHO endorses that "*The potential health consequences of microbial contamination are such that its control must always be of paramount importance and must never be compromised*". Thus, it is utmost important to effectively remove the pathogenic bacteria using economic and sustainable technology.

Even though water disinfection can often be accomplished with conventional treatments such as chemical and physical methods, most of these have limitations or drawbacks in the form of inadequate efficacy and limited applicability (Gogate et al., 2001). The problems associated with conventional physical methods (e.g. heating, radiation, microwave, filtration, UV irradiation, plasma) are difficulty in large scale scalability, high cost and prolonged treatment times. UV irradiation typically has insufficient light scattering ability and is ineffective towards bacterial photoreactivation repair mechanism. Membrane technology such as Reverse Osmosis also have operational difficulties along with fouling problem, many times requiring frequent replacement of membrane thereby increasing the cost of the treatment. Despite widespread use, chlorination and ozonation have been viewed as environmentally unfriendly in recent years due to their unpleasant odors and due to generation of disinfection by-products that can be poisonous and mutagenic (Gogate et al., 2007).

Some of the disadvantages of chlorination methods can be eliminated using adsorption technologies employing newer adsorbents/nanocomposites that are capable of eliminating bacteria (Kirti et al., 2018). Recently, hydrodynamic cavitation is being considered as a suitable greener process for disinfection due to its simple operation, easy scale up, and no harmful byproduct formation.

Philosophy behind SWASTIIK process

India is rich in its culture and its vast knowledgebase of over 5000 years or so. Also, the ancient Indian philosophy views symbiotic relationship of human and nature and suggests many solutions to the health related problems by going back to the nature and natural medicines. Ayurveda is an ancient scientific literature that provides many guidelines in this regard. SWASTIIK, a modern hybrid hydrodynamic cavitation technology draws its inspiration from this Indian philosophy while contemplating solution to the age old problem of sustainable technology for safe drinking water. It has potential to provide alternative to the existing disinfection technology such as chlorination. The SWASTIIK technology, for the first time, reports hybrid cavitation methodology using number of natural oils such as clove oil, eucalyptus oil, peppermint oil for disinfection of water. The antibacterial properties of a large number of essential natural oils such as Eucalyptus, clove oil are well reported (Bachir et al., 2012). However, there are no reports for the real life application in drinking water treatment or in cavitation. The developed hybrid technology using natural oil in cavitation can achieve 100 % disinfection of bacteria with significantly reduced cost of operation.

SWASTIIK is effective for destroying common bacteria such as *E. coli*, *S. aureus*, and also antimicrobial resistant bacteria (AMR) and difficult, opportunistic pathogen *P. aeruginosa* and therefore has positive implications for possible commercial applications and for rural use. Its relevance is also because the World Health Organization (WHO) listed *P. aeruginosa* as one of the critical bacteria due to its adaptive response towards several antibiotics (WHO, 2019).

The Process

Hydrodynamic cavitation is a physico-chemical process involving formation, growth and collapse of cavities, by using specific cavitating devices such as orifice and vortex diode. The collapse of the cavities/bubbles (implosion) produces conditions of extreme pressure (~1000 atm or more) and temperature (~5000 K or more) at the point of implosion and as a consequence, homolytic cleavage of water molecule occurs resulting in generation of hydroxyl radicals that

can participate into chemical oxidation of organic species (Mane et al., 2020a,b, Mane et al., 2021, Ranade and Bhandari, 2014). CSIR-NCL developed a newer type of cavitating device employing vortex flow, called as vortex diode, for water and wastewater treatment that is found to be highly effective in the disinfection of water. The vortex diode requires low pressure drop of just 1 bar or less, as compared to conventional device orifice (2 - 10 bar) for complete destruction of bacteria. A water disinfection technology developed by the CSIR-NCL known as SWASTIIK (Safe Water and Sustainable Technology Initiative from Indian Knowledgebase) makes use of natural oils having antimicrobial properties in the cavitation process. Extreme conditions of cavitation, localised high temperature and pressure, shock waves, oxidizing species such as hydroxyl radicals or hydrogen peroxide and consequent oxidation destroy harmful microorganisms, without using any external chemicals or reagents.

SWASTIIK gives high efficiency and high disinfection rates, no disinfection by-product, and is a green process to eliminate pathogenic bacteria.

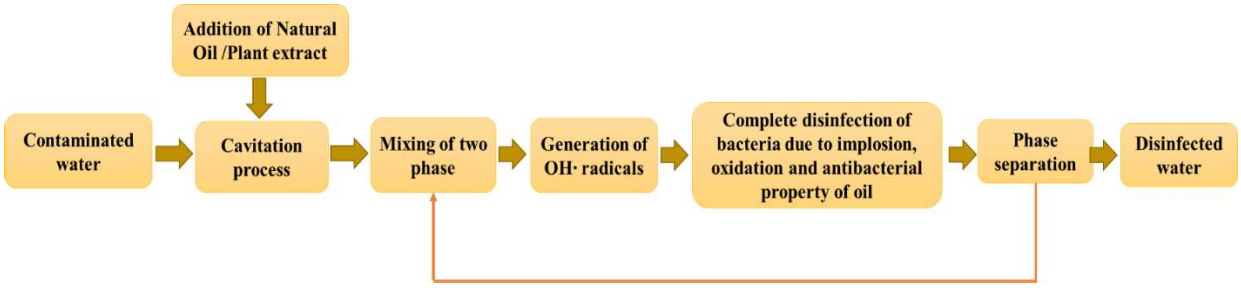

Fig 1: SWASTIIK process for disinfection of water

SWASTIIK, for the first time, provides a proof of concept for hybrid cavitation process using different natural oils (0.1% v/V) such as peppermint oil, clove oil, eucalyptus oil etc. and for eliminating different microorganism such as *Escherichia coli*, *Staphylococcus aureus*, *Pseudomonas aeruginosa* and antibiotic resistance bacteria. SWASTIIK demonstrated very high rates of disinfection and complete disinfection within 5-10 min. with vortex diode, at low pressure drop of 1 bar and a low dose of 0.1% natural oil as an additive. Plausible mechanism of disinfection involves extreme conditions due to cavitation, and oxidative damage of the cells due to hydroxyl radicals generated during the cavitation. It is reported that important constituents of

microorganisms such as proteins, lipids, DNA and polysaccharides can also be affected by oxidation. Moreover, the active compound present in the natural oil can react with the phospholipids of the cell membrane thereby altering its permeability and also denature cell protein. The denaturation of cell protein causes cell death (Zupanac et al., 2019).

Possible Applications and Societal Benefits

The conventional processes for water disinfection are in general not sustainable due to complex, not so environment friendly nature and cost-intensive features. Thus, practical and affordable application of such techniques is not difficult for either household use or for large scale water treatment installations. CSIR-NCL's SWASTIIK technology has the potential for household as well as large scale implementations. SWASTIIK process operating cost for disinfection is only ~ 0.036 $/m3 (~ 0.25 Paisa per litre). The technique can also be integrated with other established methods such as adsorption for increased effectiveness/ cost optimization.

A very interesting possibility emerges in the form of exploiting health benefits of specific oils, with appropriate designs. Peppermint oil is used in food and pharmaceutical cosmetics. Menthol, as a raw material, is used in toothpaste, confectionary, etc. and can be taken orally in dietary supplements. Peppermint oil seems to reduce spasms in the digestive tract. Similarly, clove oil is known for healing properties etc. Detailed investigations in the regard are therefore required, especially from the Medical fraternity to establish the health benefits.

Conclusion

SWASTIIK technology, for the first time, revealed the effective combination of ancient Indian knowledgebase and modern cavitation technology for complete destruction of pathogenic bacteria. The developed green process eliminates the use of harmful chemicals and can provide alternative to existing chemical processes such as chlorination with comparable operating cost of only 0.036 $/m3 (~0.25 Paisa per liter). The developed approach highlights importance of going back to nature for finding solutions to the problems of modern times.

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Innovator's brief profile

Dr. Vinay M. Bhandari is presently working as a Chief Scientist and Professor-AcSIR, in the Chemical Engineering & Process Development Division of the CSIR-National Chemical Laboratory, Pune, India. He worked as a visiting faculty at Tohoku University, Sendai, Japan in 1998-99 and also as visiting scientist at Korea Institute of Energy Research, Daejeon, South Korea during 2004-05. He has more than 200 publications/presentations; 2 US patents; filed >10 patents and has recently co-authored book entitled, "Industrial wastewater treatment, recycling and reuse" (Elsevier, 2014). He has developed 3 technologies based on hydrodynamic cavitation for Disinfection of water, for Industrial wastewater treatment (commercialized in India & abroad) and for Desulfurization of fuels. His desulfurization work received GYTI award for Technological Innovation, conferred by the Hon. Vice President of India on 6th July, 2019. His research interests include Chemical and Environmental Engineering, and Industrial wastewater treatment, recycle and reuse.