

Safe Water and Sustainable Technology Initiative from Indian Knowledgebase **SWASTIIK**

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Create Innovations & Knowledgebase to Solve Relevant Problems

CSIR-NCL's HYDRODYNAMIC CAVITATION TECHNOLOGY AND VORTEX DIODE FOR INDUSTRIAL WASTEWATER TREATMENT

Pilot plant, Capacity: 1m³/h



Cavitation increases Gas Yield



Industrial Trials

❑ Application of Cavitation Technology - CSIR-NCL's device - Vortex Diode (Patented)

- ✓ For **distillery wastewater** increases gas yield~20%.
- ✓ For **Dye wastewater** treatment
- ✓ Effective for **Pharmaceutical industry** wastewaters
- ✓ Can reduce **COD** and **Ammoniacal nitrogen**

➤ Commercialized in 2015

➤ Running in 30 installations/ Industries

➤ ~ 30 units of CSIR-NCL designs were sold till 2020 from lab scale to commercial scale with total flow rate of 330 m³/h or nearly 8 MLD

CSIR- NCL's HYDRODYNAMIC CAVITATION TECHNOLOGY AND VORTEX DIODE FOR INDUSTRIAL WASTEWATER TREATMENT

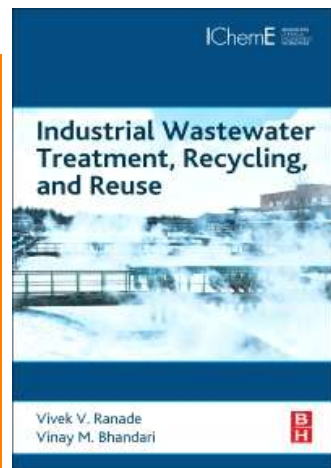
Cavitation Devices

- Diode: CSIR - NCL technology

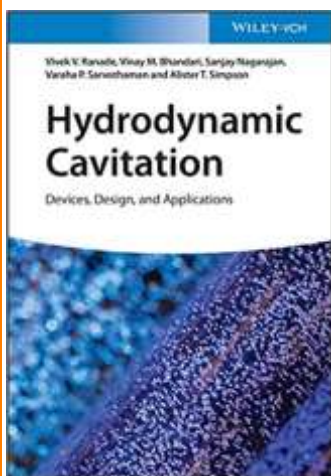
Technology Licensed to
VIVIRA Technologies



Cavitation Trials in Distillery Industry



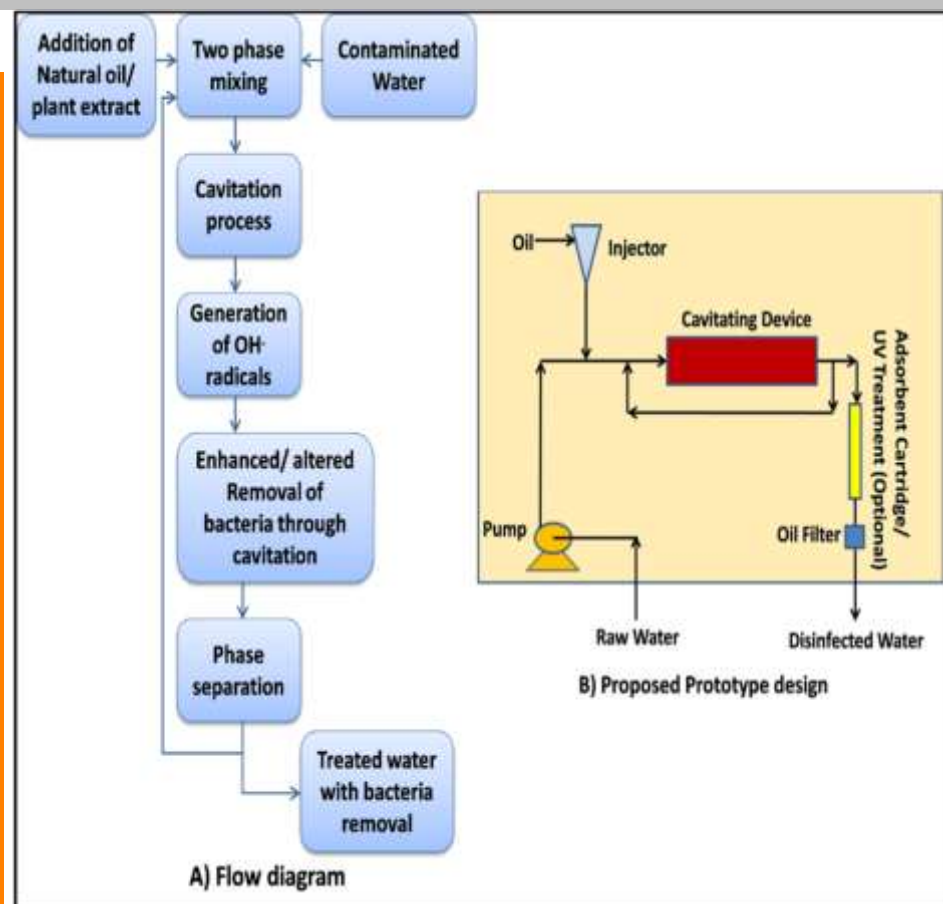
Books



Patents Granted/Filed

1. **Ranade V. V., Kulkarni A. A., Bhandari V. M. 2013.** Vortex diodes as effluent treatment devices, PCT Int. Appl. (2013) WO 2013054362 A2 20130418; **US9422952B2 (2016); EP2766314 (2019).**
2. **Ranade V. V. and Bhandari V. M. 2014.** Apparatus and method for reduction in ammoniacal nitrogen from waste waters. (0166NF2014). **US9725338B2 (2017).**
3. **Ranade V. V., Bhandari V. M. 2015.** Controlled Destruction of Aquatic Microflora using cavitation reactors and a method thereof. (0148NF2015: INV-2014-83) **(2015)**
4. **Bhandari V. M., Maya Mane and Kshama Balapure.** A novel process for enhancing and altering removal of bacteria by use of natural oils derived from plant or extract in cavitation **2019-NCL-0026; 2019-NF-0085, Appl. No. 201911024544 (2019)**
5. **Bhandari V. M. and Patil P. B.,** Solvent assisted cavitation for wastewater treatment, **Appl. No. 201911050122, (2019); PCT/IN2020/051007; WO 2021/111476 A1 (2021), US2021111476.**

CSIR-NCL's HYBRID CAVITATION TECHNOLOGY USING NATURAL OILS FOR DISINFECTION OF WATER- Safe Water and Sustainable Technology Initiative from Indian Knowledgebase (SWASTIIK)

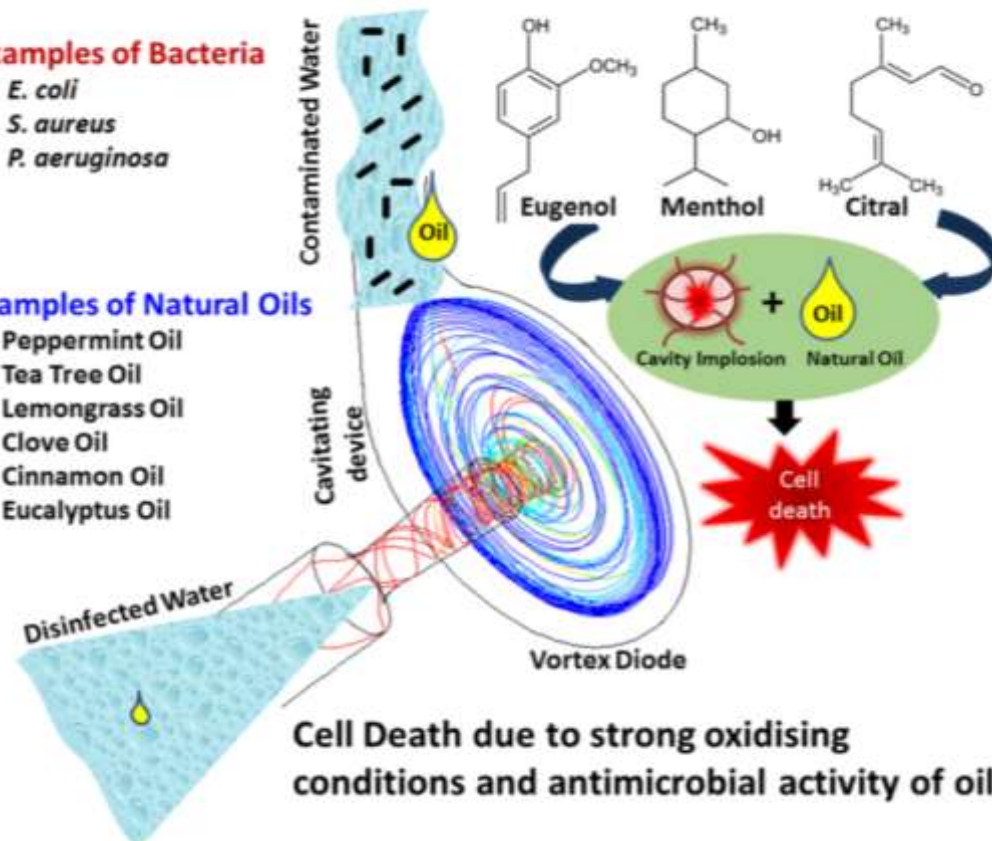


Examples of Bacteria

- *E. coli*
- *S. aureus*
- *P. aeruginosa*

Examples of Natural Oils

- Peppermint Oil
- Tea Tree Oil
- Lemongrass Oil
- Clove Oil
- Cinnamon Oil
- Eucalyptus Oil



Bhandari et al., *Ultrasonics Sonochemistry*, 2019, 2020

Indian Traditional Knowledge

A Novel Hydrodynamic Cavitation Process can Provide Complete & Cost-Effective Disinfection of Water along with Health Benefits of Natural Oils

Patent: Bhandari V. M., Maya Mane and Kshama Balapure. A novel process for enhancing and altering removal of bacteria by use of natural oils derived from plant or extract in cavitation 2019-NCL-0026; 2019-NF-0085, Appl. No. 201911024544, filed on 20th June 2019.

Water Usage (India Scenario)

- Key usage

- Drinking and other domestic uses [$< 10\%$]
- Agriculture [$> 80\%$]
- Industry [$\sim 10\%$]
- Since 1950, world population has doubled – water consumption has increased **SIX** fold, Industrial consumption is expected to grow rapidly
- Industrial Wastewater Treatment is essential
- Disinfection of water is essential for removing pathogenic microorganisms that are responsible for causing a number of water borne diseases- 88 % of diseases in the developing world due to unsafe drinking water.

Key Issues

- Availability of fresh water
 - Reducing day by day
 - Water Recycle & Reuse due to non-availability of water
- Increased need for Safe Drinking Water
 - Pollutants, harmful bacteria
- Essential to adapt effective water treatment processes for complying with regulations, for meeting daily water requirements and to prevent waterborne diseases
- Can Healthy Water be provided to boost immunity ? –
Emerging concern in the current COVID-19 Scenario

Important issues in water disinfection

- Characteristics of water to be treated (source, contamination, pollutants)
- Characteristics of harmful pathogens (nature, concentration etc.)
- Desired quality of water (most stringent for drinking water)
- Treatment technology (chemicals, additives, efficiency etc.)
- Harmful effects of technology (Disinfection by-products, etc.)
- Place and ease of implementation of technology (rural/ urban; household etc.)
- Cost of disinfection (single/hybrid form, scalability, operation, maintenance)

Conventional Water Disinfection Methods

Chemical:

- Chlorination using chlorine, Chlorine dioxide, chloramines
- Hypochlorite based, e.g. Sodium hypochlorite
- Ozone, Hydrogen peroxide
- Electrochemical

Physical:

- Filtration(e.g. sand filtration), Membrane separation
- Heating, UV radiation
- Thermal/ solar

Physicochemical:

- Adsorption (e.g. chemical/metal modified adsorbents/nanomaterials)
- Cavitation

Hybrid:

- UV + Chemical methods(e.g. UV & Ozonation); Membrane + Chemical
- Chemical + Chemical (e.g. Ozone & hydrogen peroxide)
- Cavitation + Chemical (e.g. Cavitation & hydrogen peroxide, ozone etc.)
- Hybrid cavitation process using natural oils

Usage of Disinfection Methods, Worldwide

- Chlorination disinfection technique 93.4 %
- Chloramines disinfection technique 3.7 %
- Chlorine Dioxides disinfection technique 2.2%
- UV and Ozone disinfection technique 5.9%

Disadvantages of Conventional Methods

- Chemical methods- major drawback is the formation of Disinfection By-products (DBP) that are extremely harmful and can be carcinogenic (trihalomethanes, haloacetic acids, bromate, and chlorite).
- Requires dose in appropriate level; overdose of chemical is harmful.
- Chlorination is not effective for all the harmful microorganisms
- Ozone, though a powerful oxidant, can produce toxic by-products such as aldehydes which can be potentially harmful
- The common drawbacks of physical methods include higher cost and long treatment times.
- UV requires high dose for complete destruction, is ineffective when colloidal and total suspended solids are present and also needs regular maintenance.

What are the possible alternatives?

- One easy to implement alternative to lower the formation of toxic byproducts is to reduce the use of harmful chemicals
 - ✓ e.g. reduce use of chlorine or ozone by integrating synergistic effects of various methodologies, such as advanced oxidation processes.
- Develop newer methodologies for water disinfection
 - ✓ Hybrid Technologies that combine Biology, Chemistry and Chemical Engineering
 - ✓ Go back to ***Nature*** for finding effective solutions

Problem Statement in Water Disinfection

Find methodology that can provide

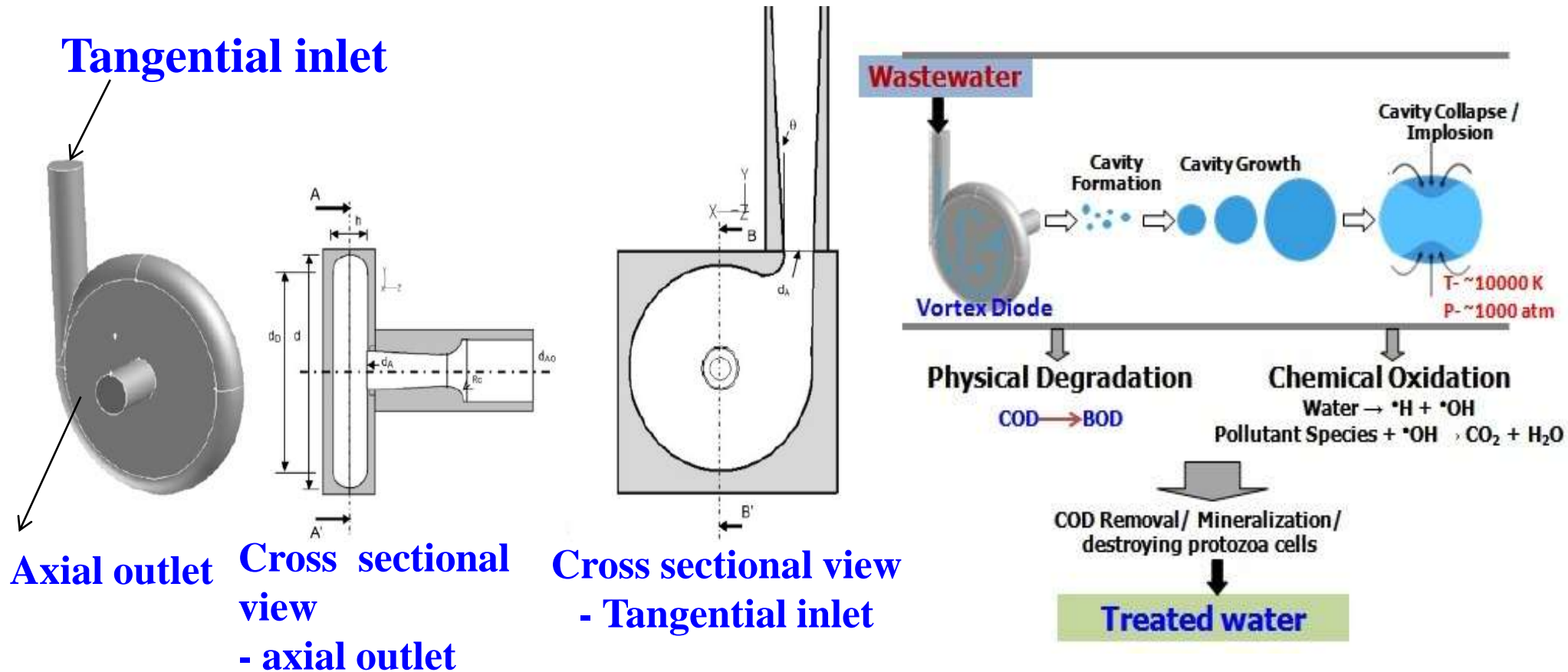
- ✓ Safe and healthy drinking water
- ✓ At low (acceptable) cost
- ✓ With substantial ease of operation
- ✓ With ease of scale-up

and

Without producing harmful disinfection byproducts

Vortex Diode- A New Cavitating Device

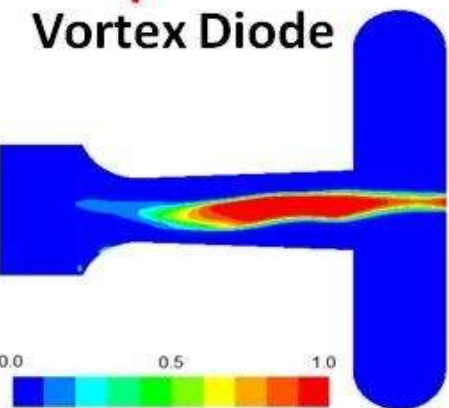
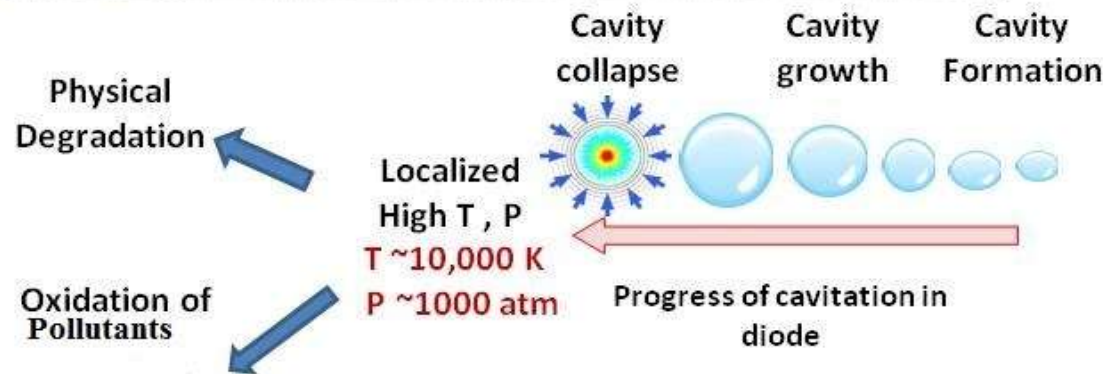
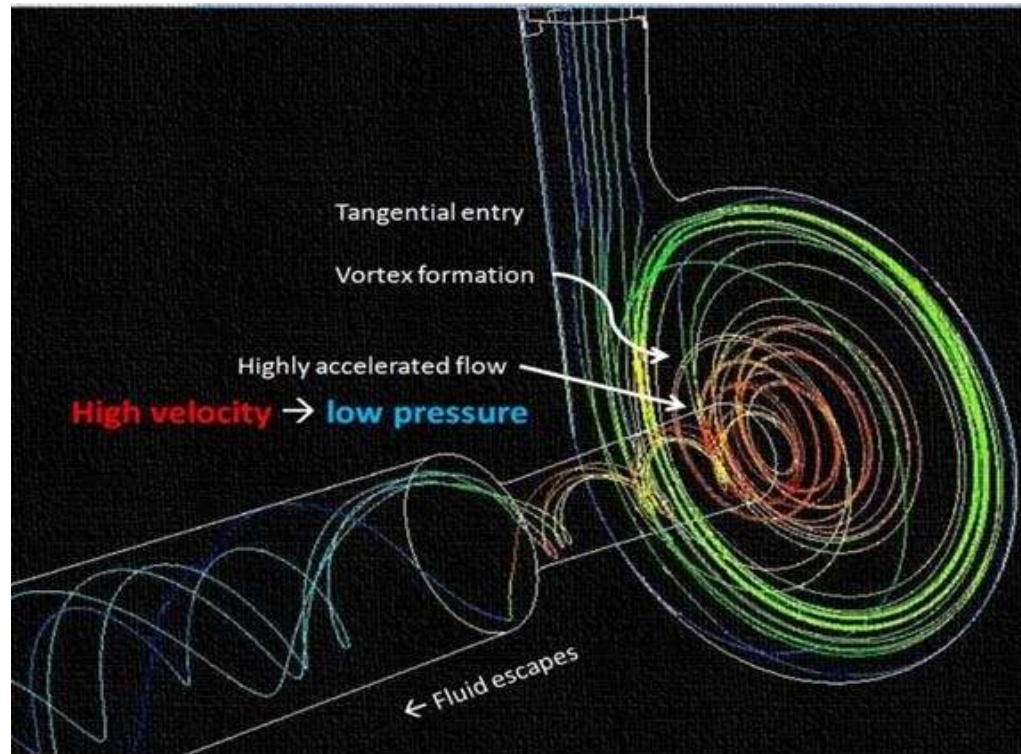
CSIR- NCL's INNOVATION-Vortex Flow for Wastewater Treatment



CSIR-NCL's Technology : Cavitation-Vortex Diode

Cavitation Technology @ CSIR-NCL Pune

Cavitation Devices: Orifice/ ventury/ Vortex Diode: CSIR



Cavitation- Conventional Format

Acoustic Cavitation



Not very Useful

Hydrodynamic Cavitation

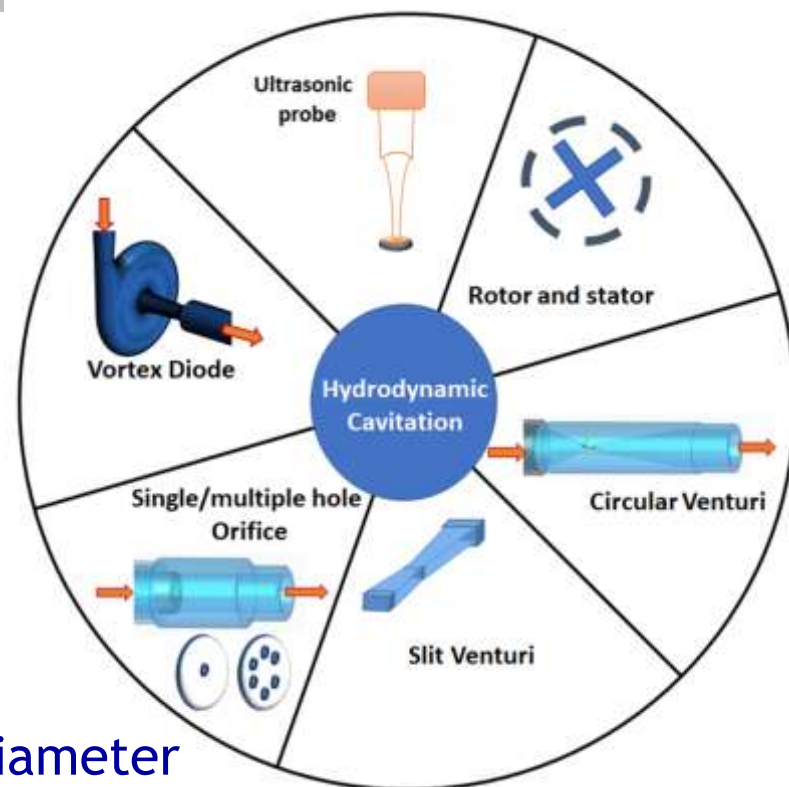


Many limitations

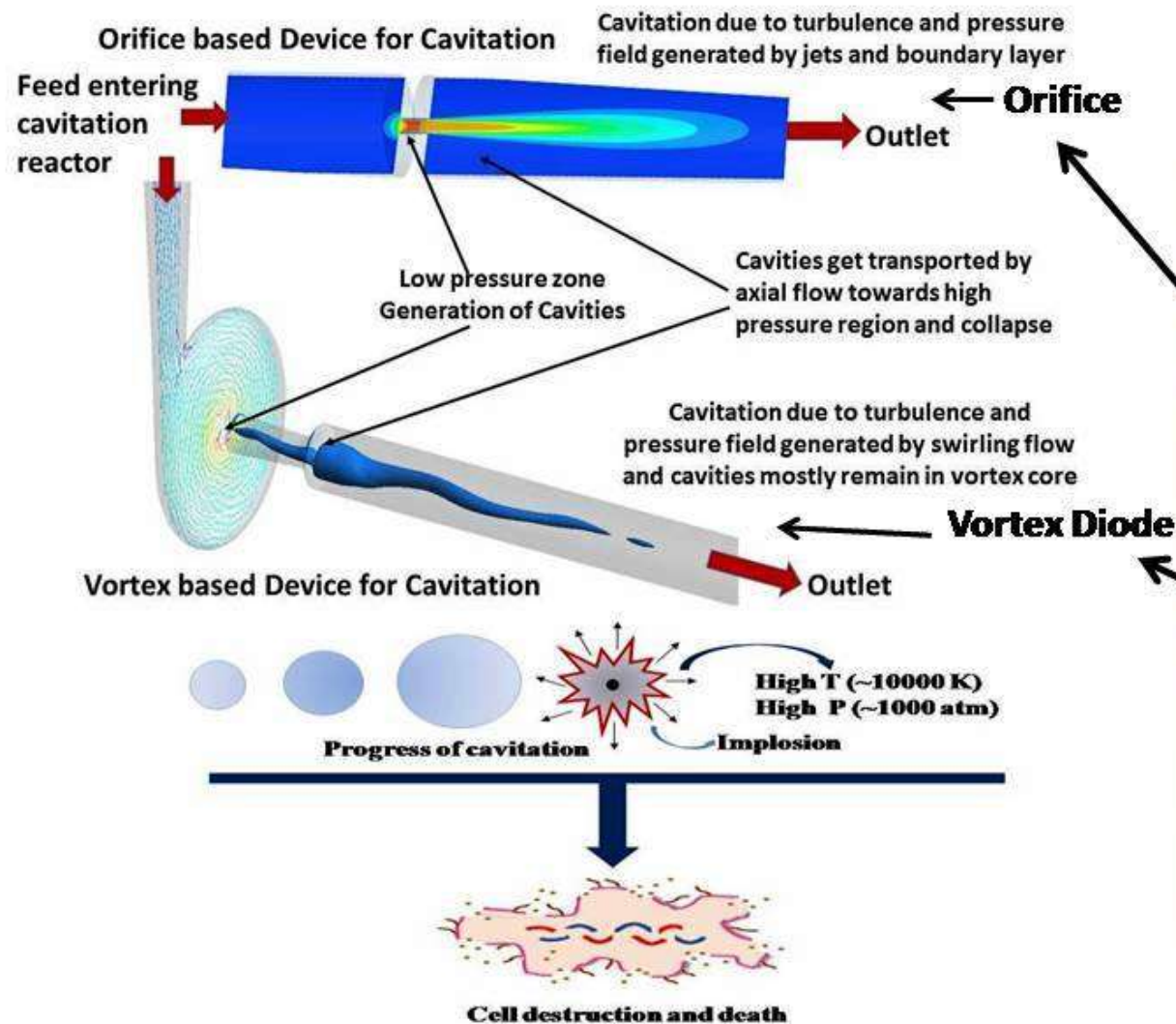
Conventional Devices

- ☐ Orifice with single hole of different hole diameter
- ☐ Orifice/ valves with variations in the open area of constriction
- ☐ Venturi cavitation reactors with different convergent- divergent sections
- ☐ Vortex diode with vortex flow- tangential and inverse flow

*Orifice reactors (49%), Venturi (10%), high pressure homogenizers (10%)
Rotor-stator type (13%), blenders (8%), liquid whistle reactor (3%)
Vortex diode (2%).*



Disinfection of Water using Cavitation

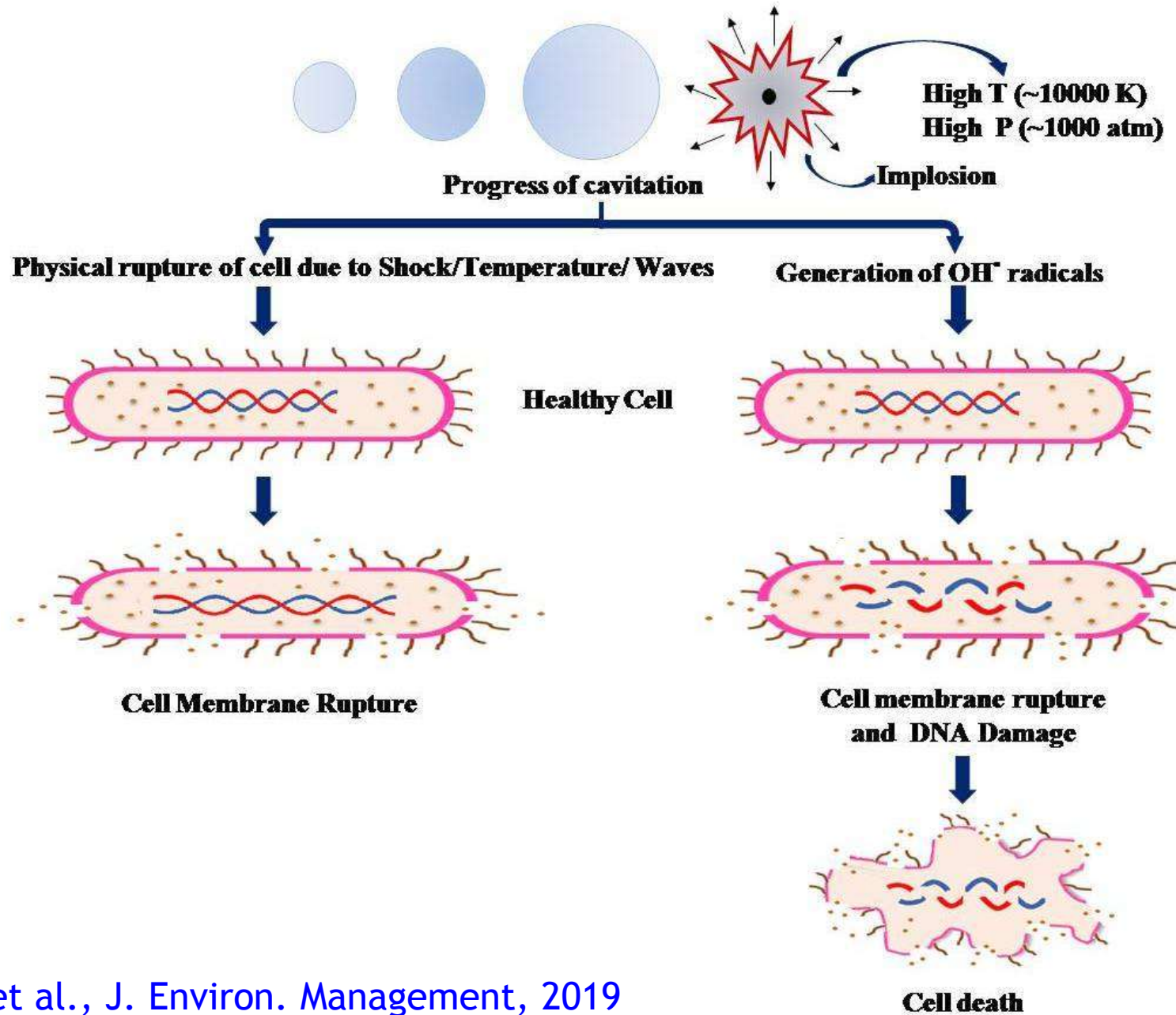


Experimental Set-up

Disinfection of Water using Cavitation
A qualitative comparison between Orifice & Vortex Diode

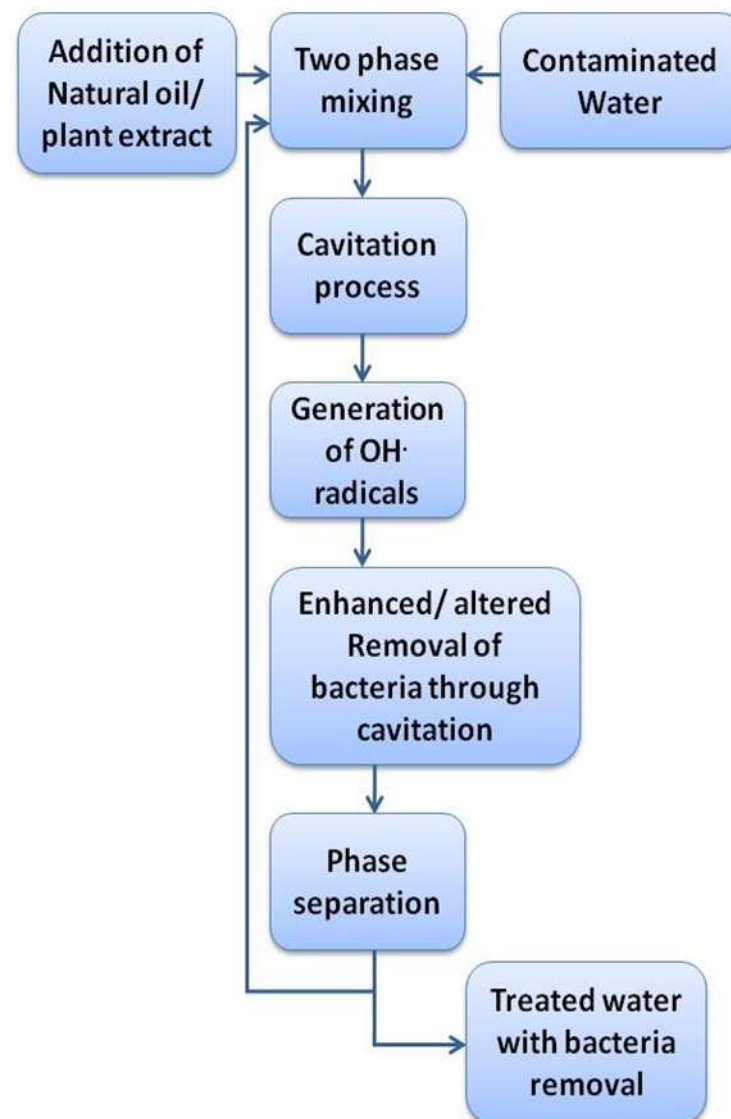
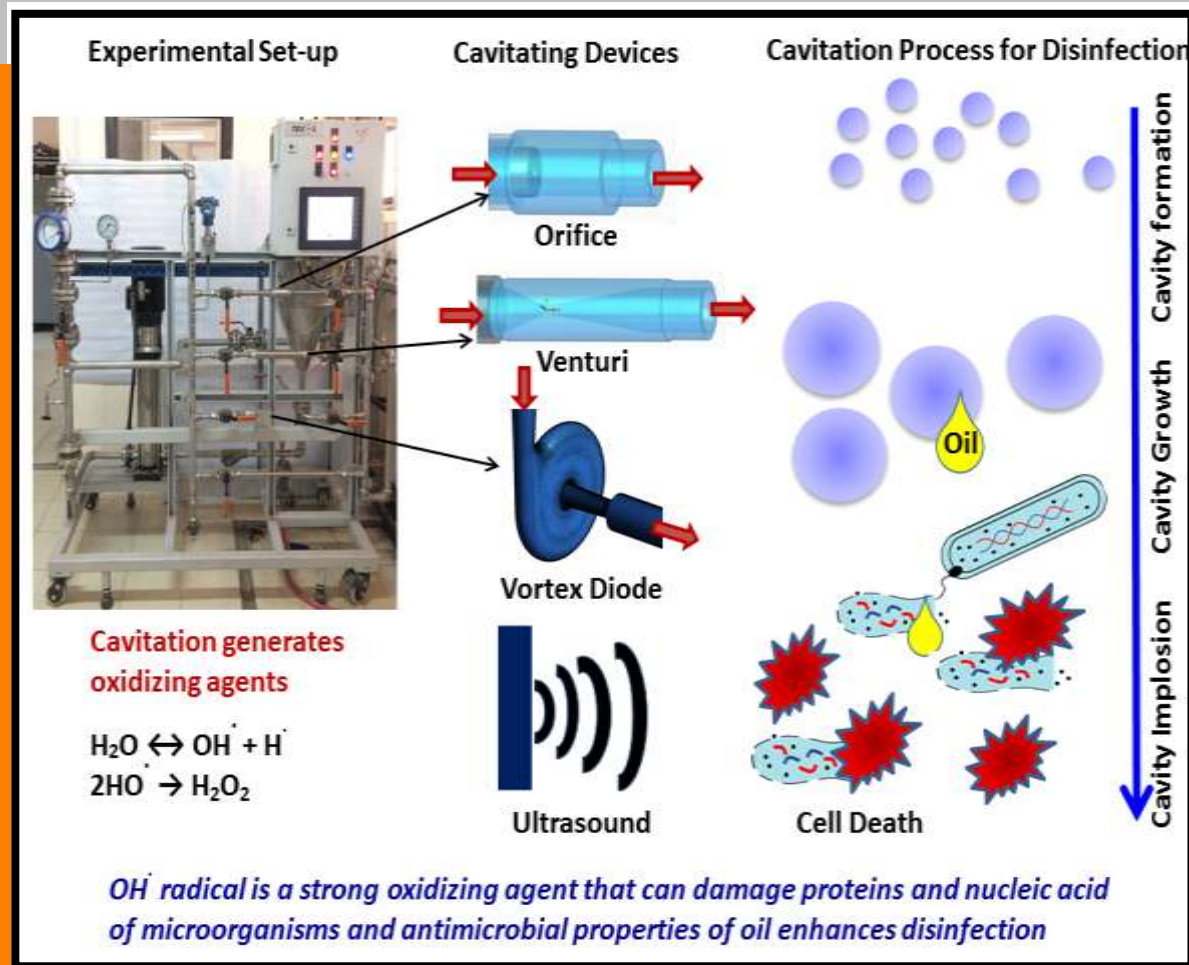
Disinfection using Cavitation

Mechanism of disinfection



CSIR-NCL's Green Technology for disinfection of Water

Safe Water and Sustainable Technology Initiative from Indian Knowledgebase (SWASTIIK)

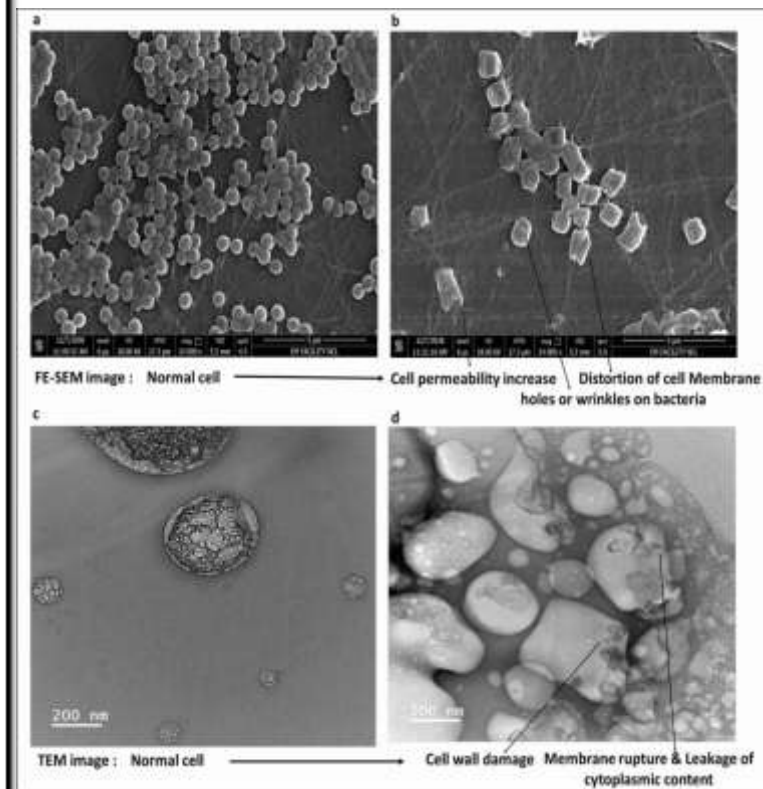
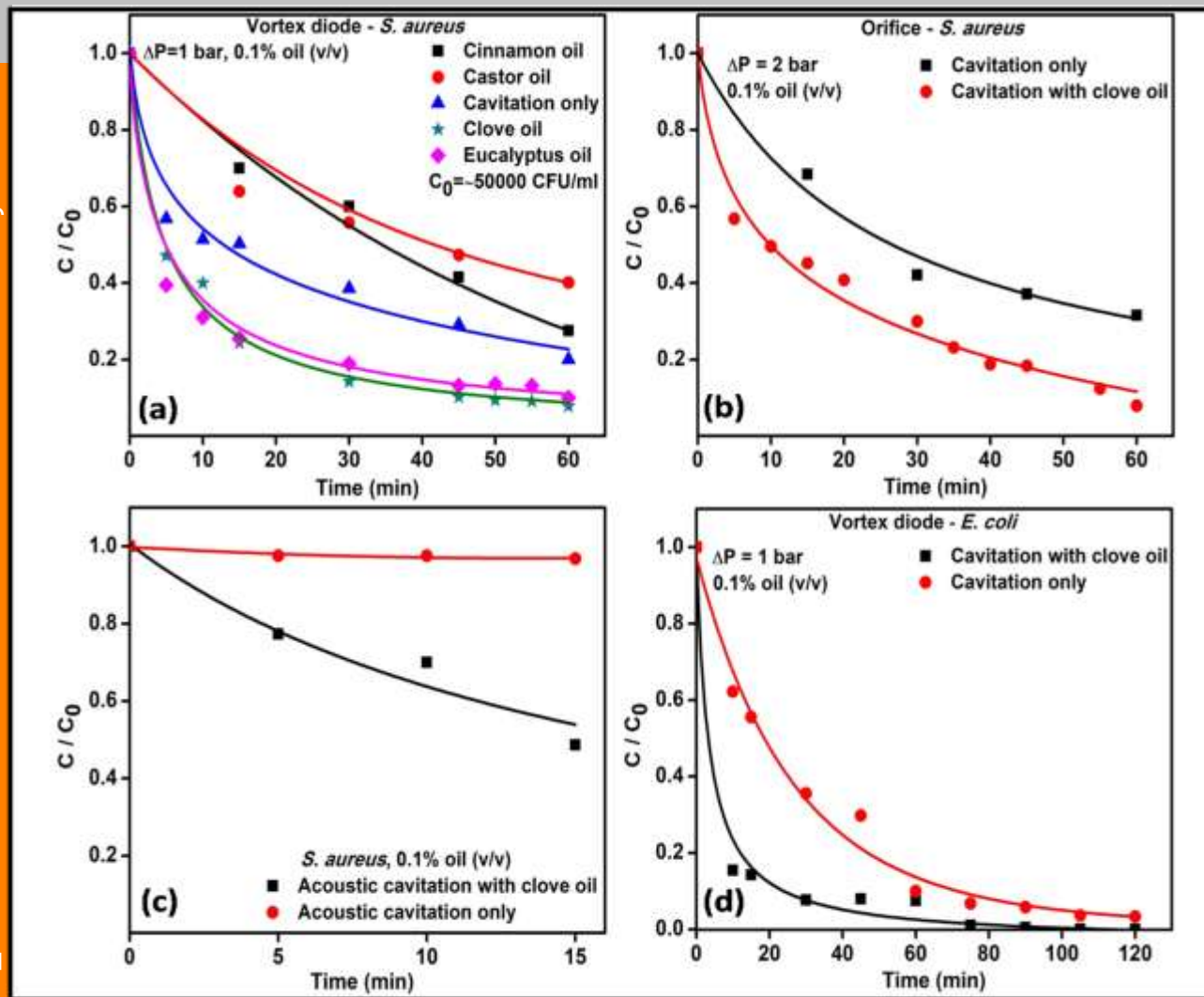


A) Flow diagram

Indian Traditional Knowledge

CSIR-NCL's Green Technology for disinfection of Water

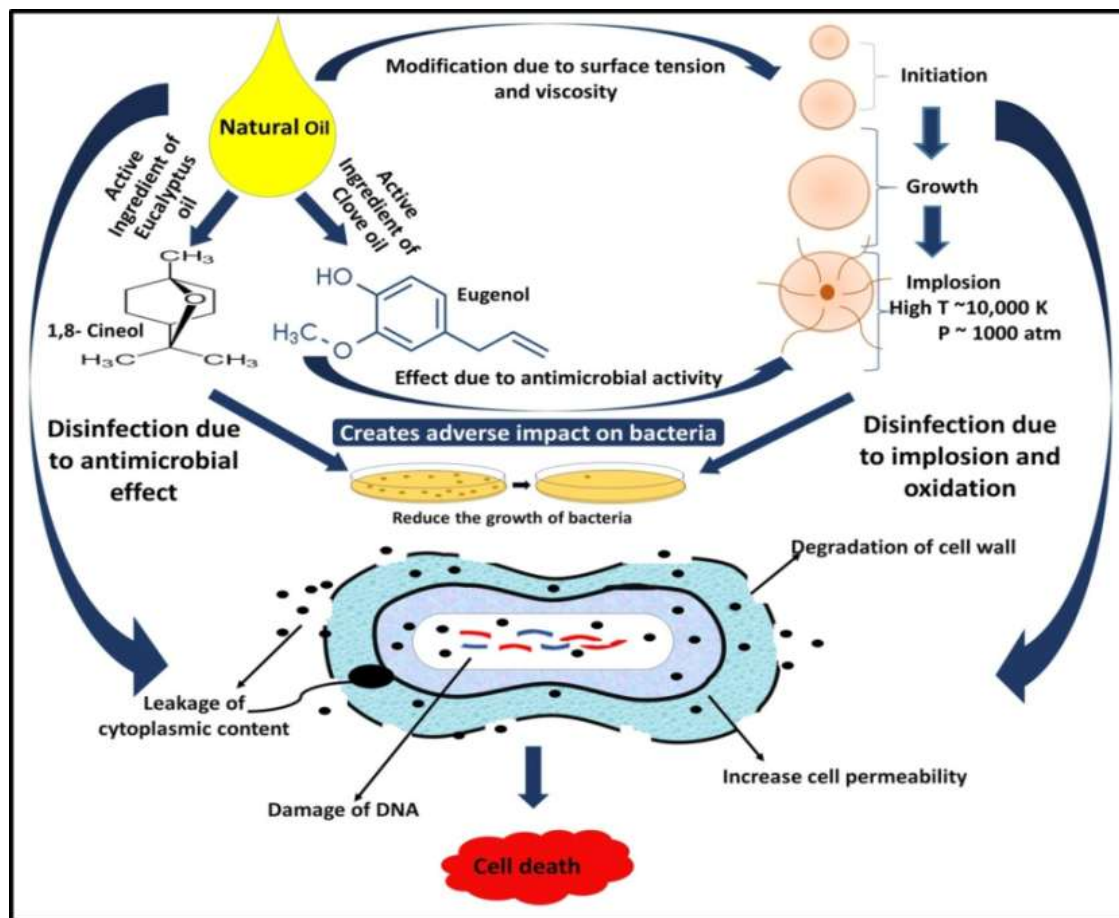
Safe Water and Sustainable Technology Initiative from Indian Knowledgebase (SWASTIIK)



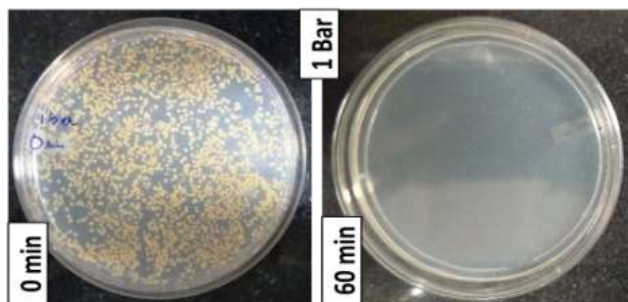
➤ The present study for the first time demonstrates application of natural oils of antibacterial properties in cavitation to enhance disinfection of water.

CSIR-NCL's Green Technology for disinfection of Water

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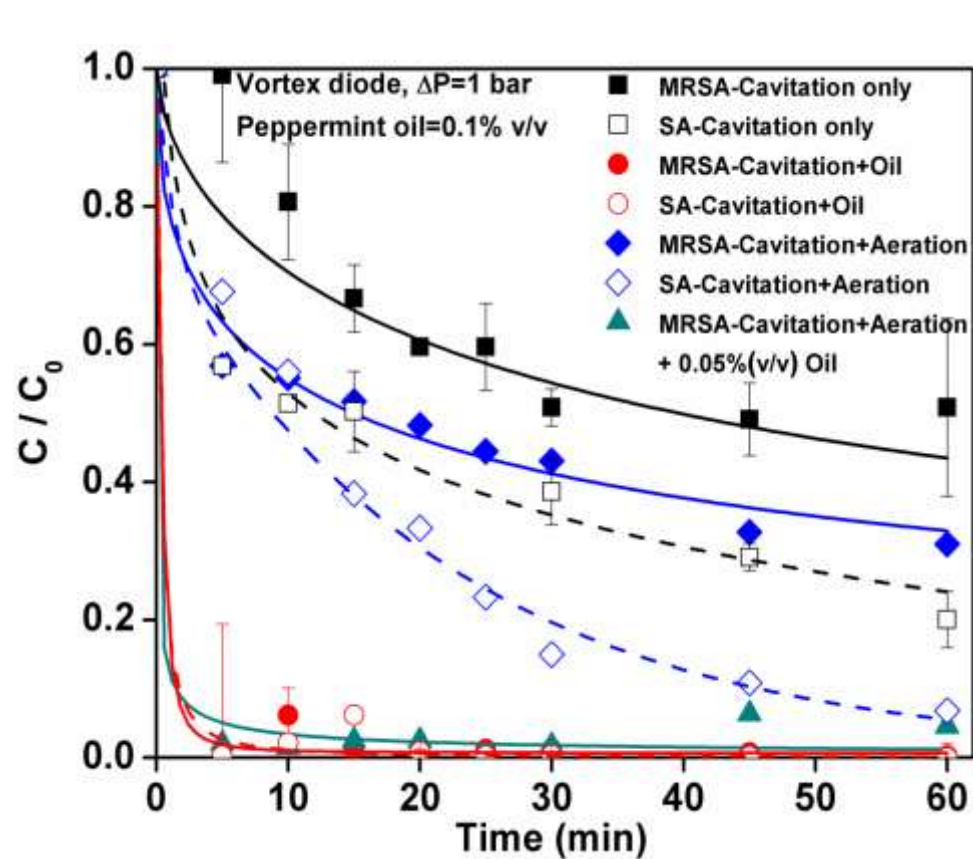


- **Enhancement in rates:**
 - ❑ Complete disinfection in 10-15 minutes
- **Vortex diode:**
 - ❑ Low pressures compared to Orifice
- **Implications:**
 - ❑ The increased rates due to natural oil, along with reduced time & ease of operation, easy scale-up indicate potential applications ranging from house-hold devices to large water treatment plants.



CSIR-NCL's Green Technology for disinfection of Water

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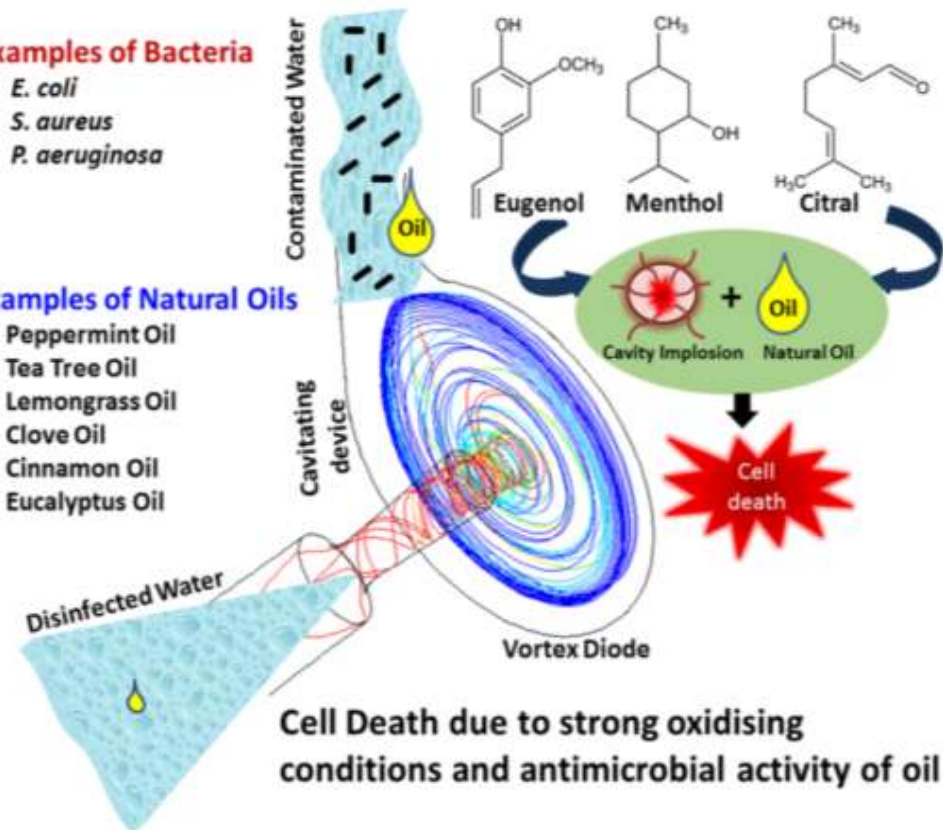


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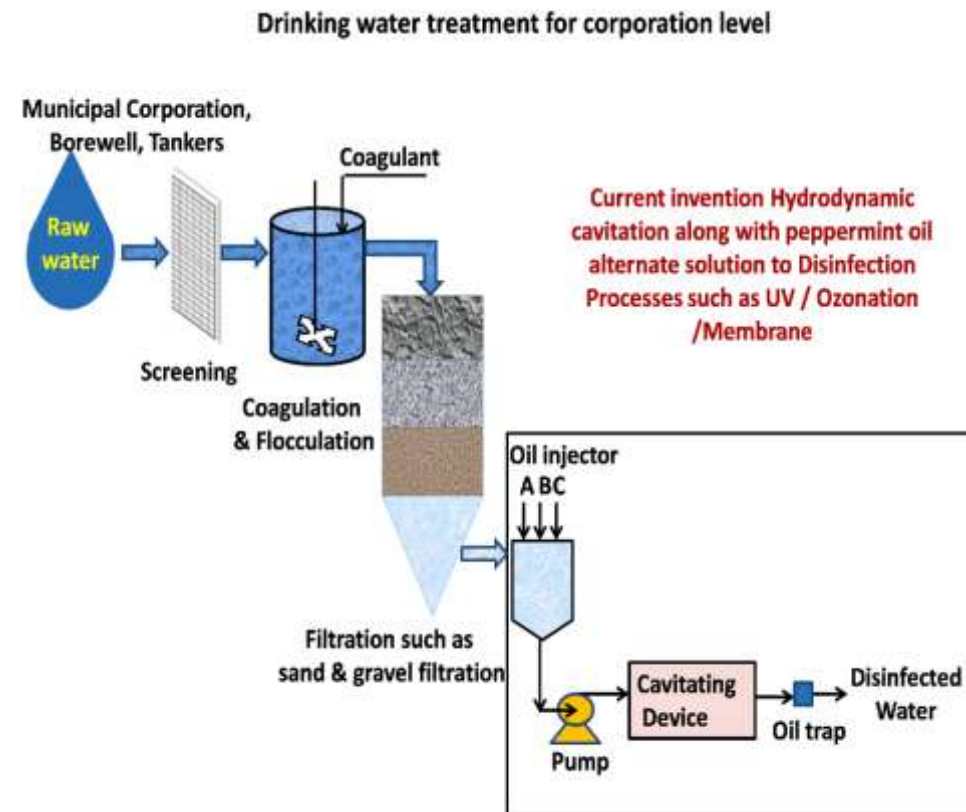
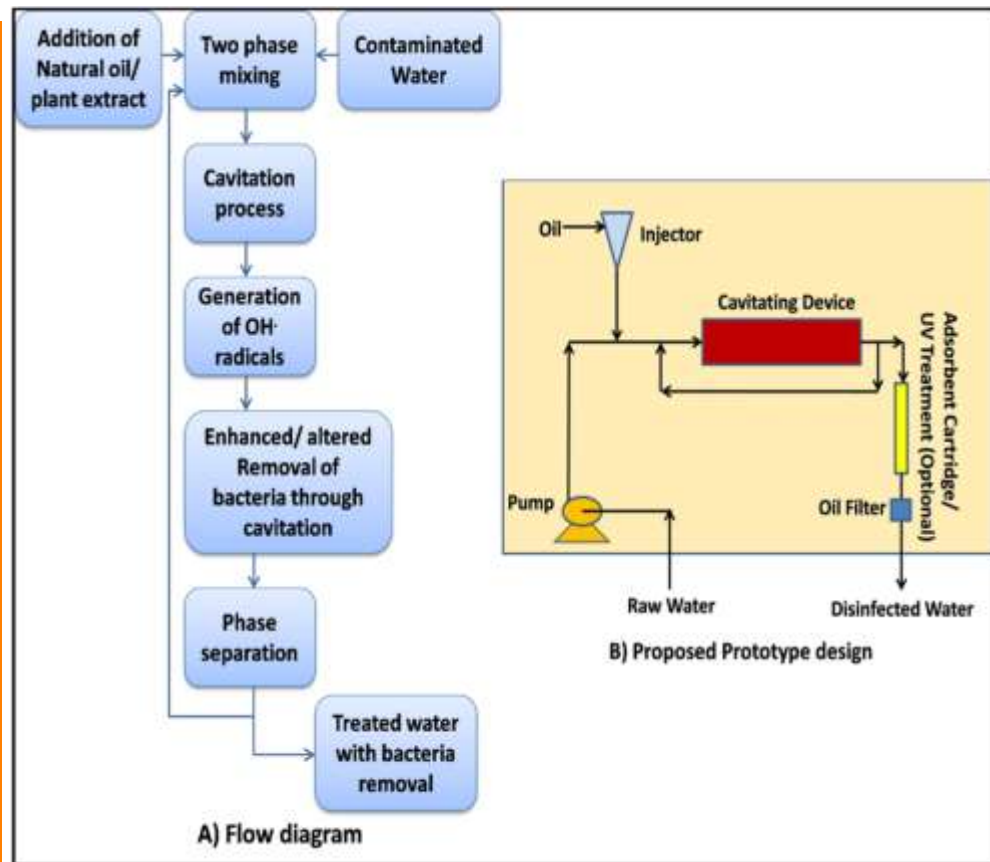
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CSIR-NCL's Green Technology for disinfection of Water

Safe Water and Sustainable Technology Initiative from Indian Knowledgebase (SWASTIIK)



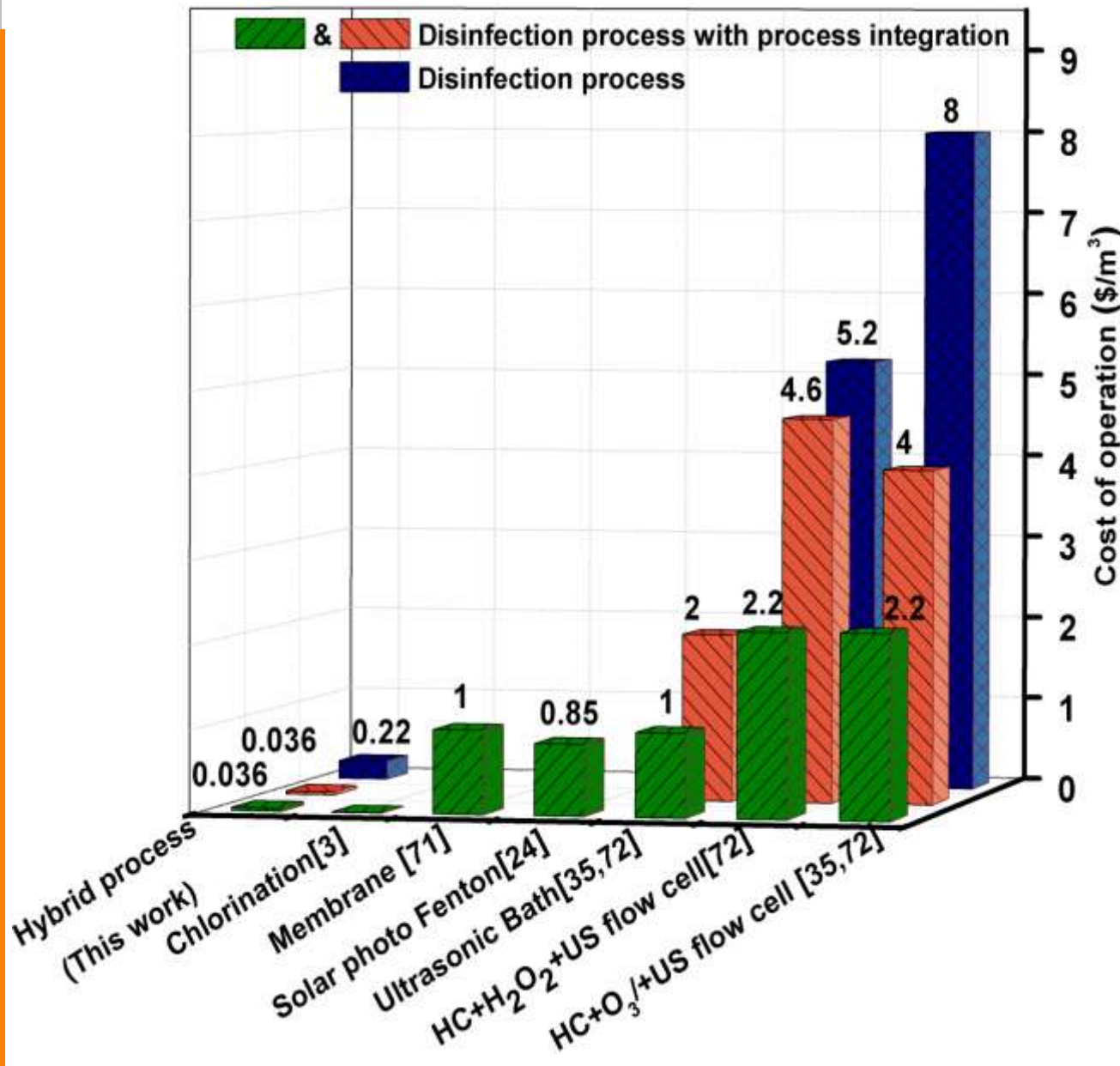
← Household to corporation water treatment →

A Novel Hydrodynamic Cavitation Process can Provide Complete & Cost-Effective Disinfection of Water along with Health Benefits of Natural Oils

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CSIR-NCL's Green Technology for disinfection of Water

Safe Water and Sustainable Technology Initiative from Indian Knowledgebase (SWASTIIK)



➤ The technology is green alternative to chemical processes such as Chlorination.

➤ With vortex diode, cavitation alone has 0.22 \$/m³ as cost of operation, whereas by addition of peppermint oil (0.1%) or with aeration, the cost can be drastically reduced to only 0.036 \$/m³ for complete disinfection of water.

Emerging Technologies & Process Integration

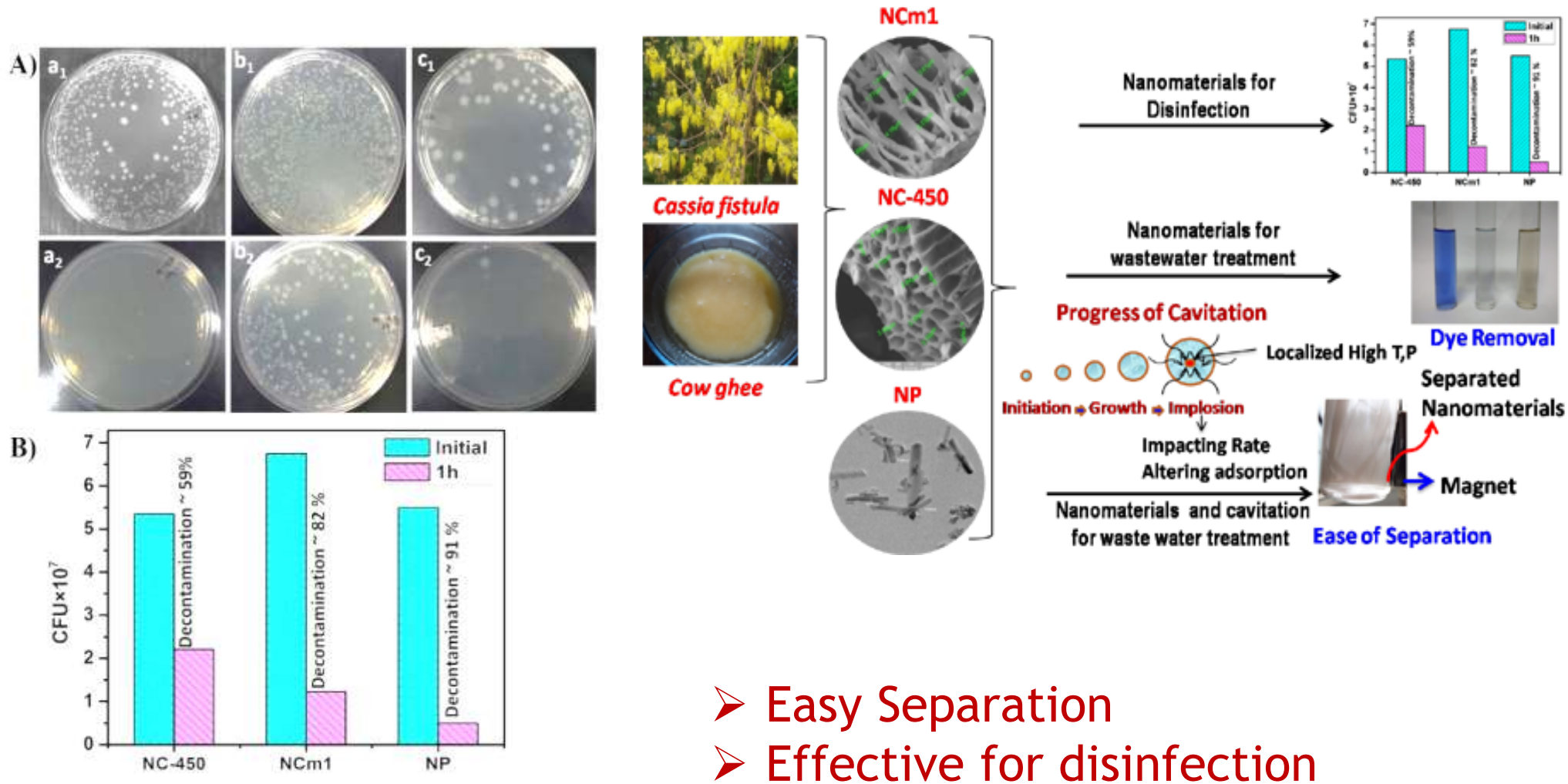
Future Trends- Materials & Methods

- Hybrid technologies
 - To increase the process efficiency along with cost effectiveness
 - Necessary in view of Providing Safe Water
 - To take advantage of various new developments in separations area including new devices/processes
- **Cavitation**
 - + Adsorption/ ion-exchange
 - + Oxidation
 - + Biological treatment
 - + Membrane separation

Newer Materials Developments

Bio-Nanocomposites - Applications

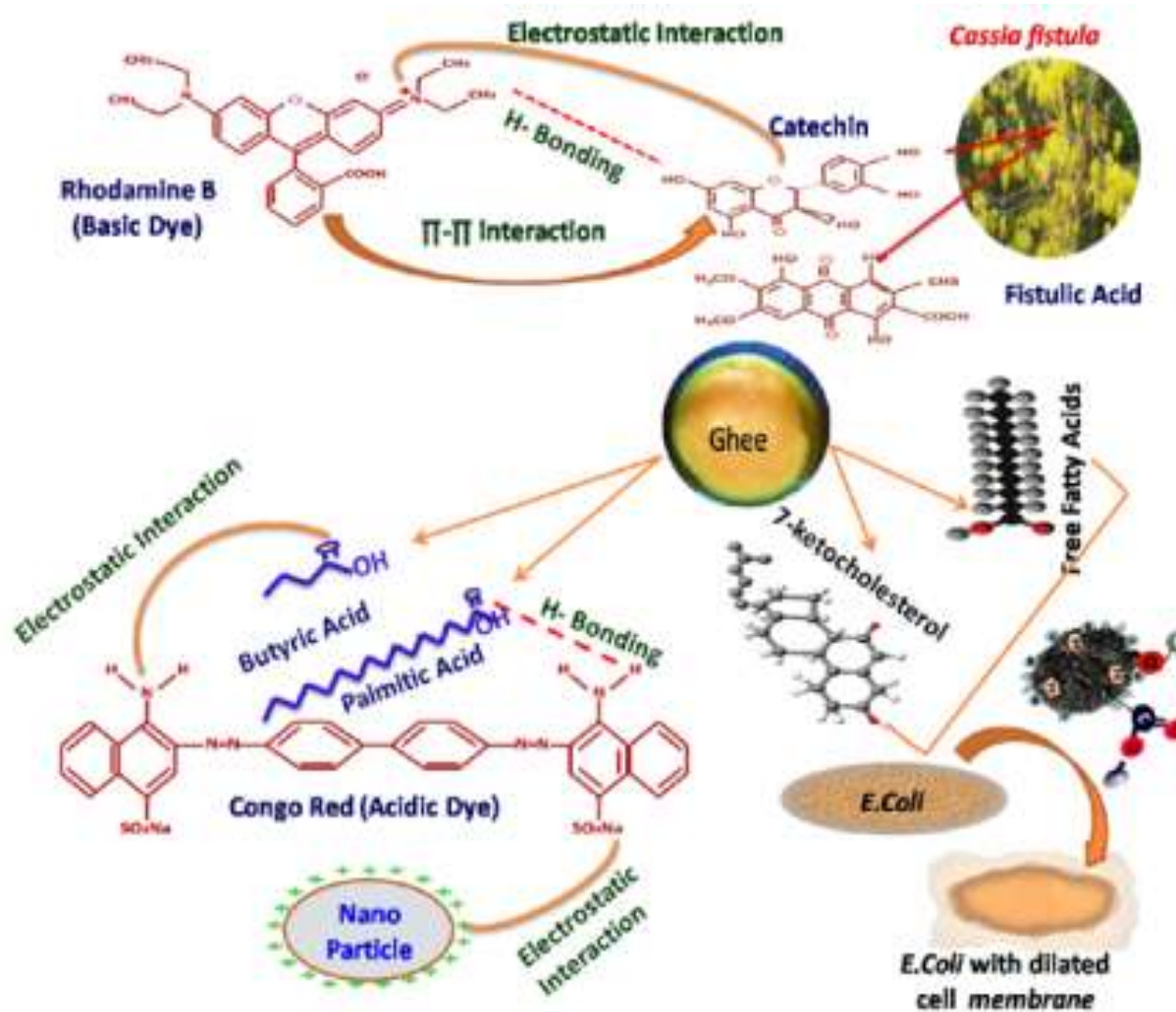
Disinfection



- Easy Separation
- Effective for disinfection

Newer Materials Developments

Bio-Nanocomposites - Application/ Mechanism



- Nanocomposites are excellent materials for disinfection at very low loading.
- The disinfection ability can be attributed to the Cassia fistula matrix & various functionalities that get imbibed in the final nanocomposite.
- Superparamagnetic materials are known to be hyperthermic and generate localized heat that contributes to cell death.

Comments on CSIR-NCL's Technology

Safe Water and Sustainable Technology Initiative from Indian Knowledgebase (SWASTIIK)

- Exceptionally high rates of destruction of common as well as antimicrobial resistant (AMR) *Bacteria*.
- Disinfection within 10 minutes under mild operating conditions.
- The hybrid process is also effective with conventional devices e.g. orifice.
- Simple process intensification such as aeration can further enhance rates.
- The developed green process eliminates the use of harmful chemicals
- SWASTIIK can provide alternative to existing chlorination/chemical process.
- The cost of the hybrid methodology is order of magnitude lower compared to the most conventional processes.

Our technology, for the first time, provides useful method for destroying bacteria, including antimicrobial resistant bacteria (AMR) using cavitation and natural oils or plant extract and also for enhancing removal rates.

Green technology, especially for Household, Corporation & Rural use.

Summary

CSIR-NCL's Technologies for Water & Wastewater treatment

- Continuous improvements in
 - **Process Separations**
 - (New processes/ process modifications/ Materials/ Material modifications /Devices/ Engineering Designs/ Hybrid systems)
 - **Industrial wastewater treatment, recycle & reuse**
 - (Laboratory studies, pilot plant experiments on real effluents and implementation at plant level)
 - Need to work on **industrial effluents**
 - Required- COD, colour reduction, and reduction in ammoniacal nitrogen
- Our technology **SWASTIIK** - *Safe Water and Sustainable Technology Initiative from Indian Knowledgebase* can have significant benefits in terms of technological translation and for societal benefits for providing **SAFE WATER**.

CSIR-NCL contemplating *Industry Consortium on wastewater treatment- Provide assistance in selecting treatment methodology*

Create knowledgebase & IP to solve relevant problems

Acknowledgement

Post-Docs: Dr. Gayatri Sorokhaibam; Dr. Jyotsna Jena; Dr. Kshama Balapure;
Dr. Pooja Thanekar



Students: Saumaya Kirti; Nalineer Suryawanshi; Pooja Jain; M. Chethana; Maya Mane



Monal Salvi; Pravin Patil; Pravin Suryawanshi; Sarika; Anamika Pund; Divya & Others

Societal Commitments

WICTRE- IIT Bombay



Industry Meet- Vapi



JNPT Port



Pollution Control Assessment



TECHNOLOGY AWARD- June, 2019



Hydrodynamic Cavitation
for Deep Desulfurization
of Fuels

SRISTI-Gandhian Young
Technological Innovation
Awards (GYTI) -2019

