SPARK CHALLENGE 22/23

SPARK

ENTC
Electronic and Telecommunication Engineering

EC

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1. Details of the Team

Group Name *– Amicis*

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External Support received

- *H.M.S.D. Bandara – In designing the BOT's aesthetics and design*

2. Problem Description

2.1 Primary area of development

- *Environmental conservation and preservation*

2.2 Other Supporting Areas of development

- *Food production and preservation*
- *Healthcare improvement*

2.3 Problem statement

<u>Eutrophication and algal growth in freshwater bodies</u>

Eutrophication is the process of excessive nutrient enrichment, particularly nitrogen and phosphorus, in a water body, leading to an overgrowth of algae and aquatic plant life. It is a natural process that can also be accelerated by human activities such as agricultural fertilisers mixed with water, sewage discharge, and industrial activities.

The consequences of eutrophication can be destructive to the aquatic fauna and flora that live in the water body and to humans who use the water from the waterway for various uses such as food, drinking water, and recreational activities. As the algal bloom grows and spreads, it can reduce water clarity, block sunlight penetration, and disrupt the ecosystem's natural balance.

Validation process

The following includes some significant adverse effects of eutrophication and algal growth.

1. Oxygen Depletion*: As the algal bloom dies and decomposes, bacteria and other microorganisms consume oxygen while breaking down the organic matter. This can lead to oxygen depletion in the water, resulting in hypoxic (low oxygen) or anoxic (no oxygen) conditions. This creates dead zones that are harmful or fatal to fish and other aquatic organisms.*

2. Harmful Algal Blooms*: Some algae in the bloom may produce toxins, leading to harmful algal blooms. These toxins can negatively impact human health and the health of fish and other aquatic organisms, raising an issue in people's food safety. These can contaminate drinking water sources and harm fisheries and aquaculture operations. In addition, people might get irritations if in contact with these waters, and the usability of the water body for recreational or other activities will be limited due to that.*

3. Aesthetic and Recreational Issues: *Eutrophication can cause aesthetic problems, such as unpleasant odours, scum formation, and discoloured water. These issues can impact the aesthetic appeal of water bodies and reduce recreational activities like swimming, boating, and fishing. In addition, due to these unappealing conditions, businesses surrounding that water body will have concerns about attracting customers.*

4. Economic issues*: Due to the unpleasant conditions, tourism in affected areas can decline, leading to reduced revenue from hotels, restaurants, and other tourism-related businesses. In addition, in, fish hatcheries and other aquacultures might suffer due to toxicity killing the fish and other organisms.*
In Addition, the property value near these waterbodies will be reduced due to the unpleasant and unhealthy conditions created due to eutrophication, causing an economic impact.

Identified affected user segments and impacts of the problem

1.Fishermen and commercial fisheries: *Changes in water quality, oxygen levels, and food availability can impact commercial fishing operations such as hatcheries and, thereby, the livelihoods of fishermen. This will reduce catch volumes and question the safety of fish consumption and other freshwater seafood, causing economic losses for the fishing industry.*

2.Property owners: *Properties located near eutrophic water bodies can experience declines in value due to foul odours and poor water quality. People in the real estate industry may face financial losses or reduced market demand due to the negative impacts of eutrophication.*

3.Water suppliers: *Eutrophication can affect water suppliers responsible for providing safe drinking water to communities. Water treatment facilities may face increased challenges and costs in treating water contaminated by algal toxins and other by-products of eutrophication. Ensuring a safe and reliable water supply becomes more difficult and expensive for water suppliers.*

Figure 4
A dead African buffalo (*Syncerus caffer*) found in a reservoir with a dense bloom of the toxic cyanobacterium *Microcystis* at the Loskop Dam Nature Reserve in South Africa.

4.Recreational users*: Recreational users such as swimmers, boaters, kayakers and water sportspeople will be affected by eutrophication as se algal blooms and poor water quality resulting from eutrophication can make water bodies* *unattractive or unsafe for recreational activities, causing a threat to the health of them leading to a decline in tourism and reduced enjoyment of those activities.*

Impact on the animal: *The aquatic organisms and other animals who live near water bodies and use them for drinking will be affected. There are instances when the toxins from harmful algal blooms cause the death of those animals. In addition, eutrophication causes issues in animals' natural habitat such as identifying predators using chemical cues and in migratory and reproductive actions. Furthermore, fish kills occur due to the reduced oxygen levels and toxins in these waters.*

2.4 Direct and indirect impacts of algal blooms to the causes of climate change.

- **<u>Direct Impact on Climate Change:</u>**

The emission of greenhouse gases *caused by eutrophication aids in climate change. The decomposition of the algae consumes oxygen and releases carbon dioxide (CO2) and methane (CH4) as too many nutrients, such as nitrogen and phosphorus, enter water bodies and fuel algal blooms. Eutrophicated water treatment reduces the discharge of these greenhouse gases, directly aiding against climate change.*
Eutrophication also leads to oxygen depletion in water bodies, resulting in hypoxic or anoxic conditions. In such situations, anaerobic bacteria release large amounts of nitrous oxide (N2O), a potent greenhouse gas. Reducing eutrophication and improving oxygen levels in water reservoirs indirectly helps mitigate their production, thereby reducing its contribution to climate change.

- **<u>Indirect Impact on Climate Change:</u>**

Lower Chemical Usage
Chemicals are frequently used in other traditional water treatment procedures to disinfect and remove algae. These compounds can cause environmental pollution. Ozone, an effective oxidant, is the primary disinfection in Nano Bubble Ozone Technology, eliminating the need for chemical additions and indirectly addressing climate change.

3. Solution Description

3.1 Arriving at the solution

- **<u>Available alternatives</u>**

Biological Treatment:
<u>Constructed Wetlands</u>: Wetland systems utilise natural processes involving wetland plants, microorganisms, and sediment to remove excess nutrients and pollutants from the water.
<u>Bioaugmentation</u>: Addition of specific microorganisms or enzymes that can metabolise pollutants and reduce nutrient levels in the water.
<u>Disadvantage</u>: Even though these solutions are environmentally friendly, these processes take a long time to come into effect and could be ineffective in practically deploying in many scenarios, especially in artificial water bodies.

Chemical Treatment:
<u>Coagulation and Flocculation</u>: Add alum, ferric chloride, or polymers to destabilise and aggregate suspended particles, facilitating their removal through sedimentation or filtration.
<u>Chemical Precipitation</u>: Add chemicals to induce the precipitation of excess nutrients, forming insoluble compounds that can be separated from the water.
<u>Disadvantages</u>: Even though this method has proven effective in clearing algae due to the use of chemicals, there could be significant damage to the existing aquatic habitats and, if not handled properly,

could pose threats to the health of communities using the water bodies. And also, cost and long-term sustainability are a question in this method.

Physical Treatment:
<u>Filtration:</u> Use physical barriers or media, such as sand or activated carbon filters, to remove suspended solids, organic matter, and some nutrients from the water.
<u>Sedimentation:</u> Allowing water to settle in a tank or basin, allowing heavier particles and solids to settle at the bottom for removal.
<u>Disadvantages:</u> These methods' limitations include issues in the scalability of this method, needing high maintenance and manual labour, and the inefficiency in removing some types of algae.

Ultrasonic Treatment: *This is one of the leading effective technologies where ultrasound waves will be used to prevent algae from reaching the surface and from, entering the sunlight and eventually dying off.*
<u>Disadvantages:</u> This process requires an extended period of exposing algae in the surrounding area to prevent them from reaching the surface. It might not be one of the quickest solutions for removing algae. In addition, the reaction of different algal species to sound waves might differ, and some might be resistant and not be as effective to this treatment.

*After considering several alternatives, we believe that utilising **Nano Bubble Ozone technology (NBOT)** would be one of the most effective and environmentally friendly methods to clean up and maintain a eutrophic lake. Some companies already utilise this technology and have effectively cleaned up lakes affected by algal blooms.*

The following video inspired us to explore how we can utilise NBOT.
<u>https://www.youtube.com/watch?v=Fxc0duggULw</u>

However, some areas could have been improved in using this technology.

1. *This technology was used with devices like a nano bubble generator, ozone generator and other devices mounted on a barge or a boat.*
2. *Humans were involved in the cleaning process to handle the devices, which could harm their health as some harmful algal blooms emit toxic gasses to which they could be exposed. They could get in contact with the eutrophic water and get irritations.*
3. *Lakes and rivers affected due to algal blooms need recurrent cleaning. And this would consume considerable time and human resources, which could be ineffective in the long run. For example, the above-mentioned video cleaned Port Mayaca, Florida, two years ago, but has algal growth again in 2023.*
4. *Since there are no monitoring processors to predict algae growth and since there are no maintenance procedures, a full-grown algae bloom is possible again since cleaning is not automated and purely depends on the decision of authorities*

Solution
*Our solution to this problem is a **Semi-autonomous surface vehicle to monitor and clean algae growth and eutrophication using Nanobubble ozone technology**.*

Working procedure
We expect to place the Bot in waterways that tend to eutrophication and algal growth due to being enriched with nutrients, closely located to agricultural farms, sewerage being directed, or any of the above reasons. The bot will have sensors that allow it to measure the real-time water quality, predict algal blooms, and release ozone nanobubbles according to the conditions it identified to clean it and maintain the water quality.

3.2 Proof of Concept

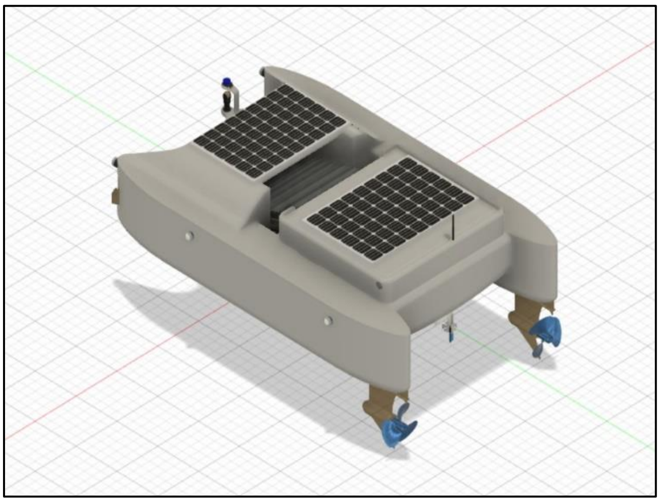
The following videos were used to identify the usage of ozone nano bubble technology for cleaning water with algal blooms.

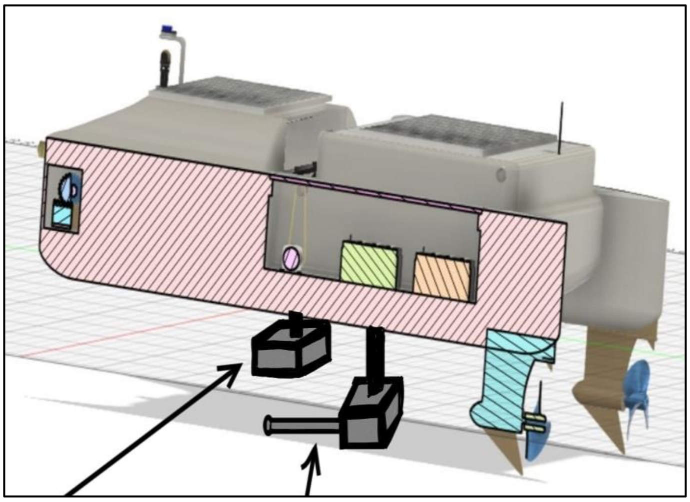
- *https://www.baynews9.com/fl/tampa/news/2018/10/23/nano-bubble-technology-could-be-answer-to-red-tide-woes#*

The following videos were used to identify the scalability of this technology so that it could be used to clean waterways

- *https://www.news-press.com/story/news/2018/08/02/use-bubbles-not-chemicals-control-algae-experts-urge/866800002/*
- *https://www.youtube.com/watch?v=cJvHTABnPPw*
- *https://www.youtube.com/watch?v=Fxc0duggULw*

3.3 Design





View from above

Ultrasonic Transducer Ozone nozzle

- ***Ozone nozzle and Ultrasonic transducer***
- ***Sensors***
- ***Floatation***
- ***Solar panels for power***
- ***Hull design***

Design Specifications

- ***Water quality measurement, monitoring and data collection***

Remote Sensing and GIS

We expect to use satellite data to map the area of the water body and identify the areas of algal bloom spread. Then, an algorithm will analyse the satellite images and route itself to clean the water body. Required measurements and sensors that are needed to monitor the water quality and detect algal blooms

Path detection - As the algal spread will change with the flow waves and due to the nanobubble treatment, we might need to reroute the BOT using remote sensing after each complete cycle.

Measurements	***Sensor***
Chlorophyll a concentration	*chlorophyll fluorometer*
Phycocyanin	*Phycocyanin Fluorometer*
Turbidity	*Turbidity meter*
pH	*pH/ORP sensor*
Dissolved Oxygen	*Optical DO Sensor (Hach LDO(Luminescent dissolved Oxygen sensor))*
Temperature	*Submersible thermistor sensor (Sensorex CDTN 353/356)*

Sensor inputs
After the bot arrives at a particular location, it takes measurements of the water to evaluate the level of eutrophication and algal bloom. Then it decides on the amount of ozone that needs to be released to clean the water and not intoxicate it and the system.

- ***Ozone nanobubble generation and release to the water***

Ozone generation

An oxygen concentrator will absorb atmospheric air and produce 85-100% concentrated oxygen at 10 Litres per minute.

Nanobubble generation

Ultrasonic Agitation, Electrolysis, and Dissolved Gas Saturation are some of the ways that can be used to form nanobubbles. Out of them, for the bot, we are using the ultrasonic-based method due to the following reasons.

1. ***Good dispersion and scalability.***
   Ultra-sonic agitation promotes the dispersion of gases and the creation of tiny bubbles throughout the water. This ensures better contact between the nanobubbles and the algae, leading to more effective cleaning. In addition, these could be scaled up to handle larger volumes of water treatment.

2. Easy operation and maintenance - *Ultrasonic agitation can provide continuous cleaning and maintenance and allows for long-term operation*

3.Versatility - *This method could be incorporated easily into any device, especially a portable bot.*

- ***Treatment***

Ozone formed in the ozone generator will be injected into the lake using a nozzle. Simultaneously, ultrasonic waves generated using an ultrasonic transducer will cause ozone nanobubbles from the lake water mixed with the ozone.

- ***Robots design***

- *Autonomous control systems for navigation algorithms to plan cleaning routes, obstacle detection and avoidance mechanisms*
    - *The bot can access satellites to use remote sensing and GIS technology to get to the algae-affected areas in the water body it is deployed. Then it will use its navigation algorithm to plan the route it will be taking to clean the water body. While in motion, it will detect obstacles in the path of motion and avoid them using algorithms that will be implemented.*

- *Implement intelligent decision-making algorithms to assess water quality parameters and optimise nanobubble applications based on real-time data.*
    - *We will be using a set of water quality measurement sensors mentioned above to measure the parameters required to identify the level of eutrophication, and the decision-making algorithms will be making calculations on the amount minimum amount of ozone (without becoming toxic) that needs to be released and the duration of the treatment on that area.*

- ***Waterproof and buoyant design***
    - *Since the bot will be working with eutrophicated water bodies, the design needs to be waterproof and corrosive resistant to any chemicals in the water. In addition, it needs to withstand weather conditions like rain. Therefore, we will use materials and sealing techniques to withstand water exposure and prevent water leakage into sensitive components.*
    - *Carefully designing the hull using materials less dense than water, displacing enough water to support the BOT's weight, and using Buoyancy Chambers at the bottom of the BOT to help the floatation.*

- ***Mobility and structure:***
    - *High-power propellers will be used to navigate the bot.*
    - *The design will be carefully considered for easy maintenance, repair, and upgrade by using different modules for nanobubble generation, sensors, and control systems.*

- ***Power and Energy Management:***
    - *Rechargeable batteries and solar panels will power the robot. A high-capacity rechargeable lithium-ion batteries with good energy density and a long lifespan will be used. The panels will be mounted on top of the BOT to harvest energy.*
    - *Power optimisation techniques will be considered to minimise energy consumption and extend the BOT’s battery life. Low-power microcontrollers or processors will be used, and for components not in use, sleep or power-down modes are used to activate them only when necessary.*

- ***Communication and Data Transfer:***
    - *The BOT will use satellite imagery to get real-time water quality measurements and detect algal growth spreads in the water body. 4G will be used to remote control and get real-time data transfer from the robot.*

- ***Safety Features:***
  - *Even though the ozone released into the water will be calculated in such a way it will not be toxic to humans or aquatic organisms, the bot will be continuously detecting the ozone level in the water after the treatment to monitor the ozone decomposition and compare it with a predicted decomposition rate using a previous database and cease further operation and alert the humans in case it has a probability of making the water unsafe. And after a time window, if the bot decides there is no improvement in the water condition, it will use an aeration system to dilute the water and reduce the ozone level.*

- ***Impact assessment***
  - *Ultrasonic Waves: The frequency and intensity of the ultrasonic waves used in the BOT are typically chosen to minimise harm to humans or aquatic organisms. Ultrasonic frequencies outside the hearing range of most marine organisms (e.g., above 20 kHz) are generally employed.*
  - *Ozone Toxicity: Ozone is carefully controlled and monitored to ensure it remains within safe and practical levels. Water quality regulations and guidelines are adhered to prevent any adverse effects on the animals in the water.*
  - *Environmental Impact Assessment: An environmental impact assessment will be conducted before implementing ozone nano bubble technology for algal bloom treatment in a lake. This assessment evaluates the potential effects on the ecosystem, including aquatic organisms.*

- ***Data needed***
  - *A database that considers all the conditions like the type of algae, amount of eutrophication, oxygen concentration, the flow of water and several other factors that could decide on how much ozone nano bubble concentration is required to clean up the water body and the robot will constantly measure the ozone concentration and adapt its output according to it.*

- ***Limitations***
  - *Power - Due to the high-power consumption of ozone generators and nanobubble generation using ultra sound waves, we cannot just power it up using solar panels but needs to consider a combination.*
  - *Navigation using propellers - As we work in an environment with debris and algae, they could entangle the propellers, causing maintenance needs.*

3.4 Sustainability (C5)

Sustainability of our project aligning with Spark's mission Statement and the SDGs.

*Our project aligns with Spark's mission of tackling the **global climate crisis**, as algal blooms can damage aquatic ecosystems, water quality and biodiversity. Eutrophication and algal blooms reduce the oxygen level of waters; harmful algal blooms release toxic gases into the atmosphere and impact the natural food chains and natural habitats of aquatic animals. Developing BOT is a solution that is sustainable as it does not need a human presence to operate, allowing the BOT to be fully deployed in water bodies and become cost-efficient due to reduced use of manual labour and eco-friendly as the ozone added to the water will be carefully regulated and monitored as not to toxic and by the end of the treatment, the oxygen level of the water will be increased without the addition of toxic chemicals.*

*In addition, BOT aligns with delivering an impact today for all tomorrow whilst also introducing and teaching innovation to the students of tomorrow as not only the technology of using nanobubbles is a developing technology **but could be extended** to use in addressing many global issues such as **cleaning algal blooms in saline waters** which could be a solution for massive damaging algal blooms like Florida's algal bloom, **could be utilised to clean oil spills and oilfield water** which has currently solutions very harmful to the environment like in situ burning or chemical usage which is detrimental to the corals and **to clean shorelines affected due to oil** which presently has very ineffective methods. All these explained situations are still in research on optimising nanobubbles in these areas and are showing positive signs of future improvements to the BOT*

Not only that, the bot has a significant contribution to the SDGs as well

SDG 6 - Clean Water and Sanitation *- As algal blooms could be present in waters that people use to drink water from, the water supply authority must thoroughly clean them before they supply the water. Our BOT supports keeping these water bodies clean and making more sterile water accessible to people. In addition,*

SDG 14 - Life Below Water *- The ability of the BOT to clean the algal water and increase the water's oxygen levels will improve the life below water for aquatic organisms. It will protect and support natural food chains and ensure the balance in natural habitats.*

SDG 11 - Sustainable Cities and Communities - *Algal blooms and eutrophication affect the water quality and aesthetics of the surrounding damaging the businesses and property value and reducing the quality of life of communities surrounding these water bodies. BOT will be able to mitigate all these damages by having a eutrophic lake and enhance the quality of the surroundings by having a clean and pleasant water body.*

SDG 13 - Climate Action *- Algal blooms and their impacts are influenced by climate change. By mitigating the effects of these algal blooms, we can support the balance of ecosystems and the aquatic habitats to face climatic changes. Further, the emission of greenhouse gases like carbon dioxide or methane that contribute to climate change by these algal blooms is prevented by using BOT to maintain the water bodies clean.*

SDG 3 - Good Health and Well-*being - SDG 3 ensures healthy lives and promotes well-being for all ages. Our project will support this as it prevents risks of health issues like irritations, bowel issues due to ingestion of water or aquatic animals in these waters or even death due to the toxins of these algal blooms.*

SDG 12 - Responsible Consumption and Production and SDG 2 - Zero Hunger
Many fish, shrimp or other hatcheries are affected by these algal blooms and fishing activities done in water bodies (ex: Beira lake) that are affected by eutrophication and poses risks to the health of people who consume them. In addition, the harvest of these hatcheries will be reduced due to the lack of oxygen and other nutrients, which will impact food production. Therefore, using BOT to clean these lagoons, hatcheries, or other bodies will ensure food safety and activity.

4. Social and Environmental Impact Assessment (C4)

Society

Overall improvement of health and quality of life of communities associated with the water *body - From business owners, property owners, people who use the water for recreation purposes, and those who use the water for water and freshwater seafood supply and Usage, as explained In previous topics, will have direct and indirect benefits in health, economy and overall life experience.*

Health and Safety - *Before implementing the BOT, we will conduct thorough research on maintaining the water quality standards at a safe level from ozone toxicity and on safety procedures in case of excess ozone addition to the water due to unforeseen events.*
Improving water quality and freeing them from algal toxins will enhance the health and safety of people who get the contact with water by direct or indirect means.

Collaborations with experts -
Further research to optimise the performance of different water bodies needs to be done together with experts in water flow and management and environmentalists on different types of algal blooms. Collaboration with authorities that regulate water quality and experts who know the use of ozone in water treatment is also needed to identify the safe ozone levels in water and maintain water safety during the treatment. Collaborating with companies like Moleaer experts in finding Advance nanobubble technology to

find the ideal solutions to different types of water bodies and application is also critical in making the product more efficient.
To realise the BOT, we must collaborate with electronic and electrical, computer science, mechanical, chemical, material, environmental, engineers and other related professionals to gather knowledge and efficiently make this product work cost and power in cleaning algae.

Economic Benefits -
A study on the economic disadvantages done to communities surrounding it will be done; excess cost, time and labour used in cleaning these bodies using existing methods, and health and safety risks of having such a water body and using these current methods will be assessed. Then the advantages of cleaning and maintaining these water bodies clean and the cost of production, deploying and maintaining our BOT will be done to make a cost-efficient product that benefits the community.

Environment

Overall, the quality of life below water and on animals using these water bodies will be improved d, due to higher oxygen levels, allowing diverse habitats, and support in maintaining natural food chain communities' ins. This will contribute to enhancing ecosystem health. Moreover, the improved water quality and the benefits of the improved oxygen level to the ecosystems in these waters will be considered. Furthermore, extensive research and evaluation will be done on any adverse effects on non-target organisms in these water bodies due to the ozone, ultrasonic waves used to generate, and any possible by-product formations and will focus on taking necessary precautions in minimising any damage.

5. Logistics(C3)

1. Task breakdown

Name	Contribution
W.M.E.P.B.B. Wijesekara	Research, Design the robot, Videography
K.D. Wijeratne	Research, Sensor selection, Report writing
G.L.S.M Perera	Research, Design the robot, Report writing
R.W.H.M.T.A. Ranaviraja	Research, Sensor selection, Report writing,
A.G.D. Gamidu	Research, Design the robot, Videography

2. Time frame

2022 November - problem identification

2022 December – Research

2023 January - Research

2023 February – Research, Idea generation

2023 March – Find the most suitable solution and design the robot.

2023 April – Sensor selection and

2023 May – Report writing and videography

3. contribution to Pi-Mora and the Raspberry Pi-related activities

All team members were involved in several programs related to Pi-Mora and the Raspberry as participants.

Ex: Online and physical workshops about Ethical hacking

4. References

- *Validation process*

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- *Identified affected user segment/s and impacts of the problem*

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- *Available alternatives*

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- *Ozone Nano Bubble Technology and shortcomings of the existing use of this technology*

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- *Possible extensions of this technology*

https://www.researchgate.net/publication/308111450_Remediation_of_oil-contaminated_sand_with_self-collapsing_air_microbubbles

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