Team Hermetica

WATER PURIFICATION THROUGH TiO_2 POWDER AND POLY CATALYTIC ACTIVITY

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Introduction: -

Traditionally, industries for a long time have been dumping their polluted water in rivers which causes water pollution and left water unfit for further use. Pollutants can be very diverse molecules, occurring as aromatic compounds, pesticides, chlorinated compounds, heavy metals, or petroleum hydrocarbon. A different method exists to reduce them, such as photocatalysis, which is an efficient process for degrading organic pollution. But nowadays, industries no doubt are dumping water by purifying it to a certain level but it is not 100% fit it is still causing damage to our environment.

We have come with an idea which not only clears the polluted water but also makes it fit for drinking purposes and agricultural purposes also. The water purification system comprises four multistage. TiO_2 envisaged that it would replace other processes in water treatment, such as Chlorination. It is also non-toxic and cheap. Plastic macroparticles and microparticles have the potential to affect marine ecosystems and human health. An innovative approach for the removal of microplastics from industrially used seawater combines chemical-induced silane-based agglomeration as a new technology implementation step. Heavy metal pollution of the aquatic environment can be detrimental to human health. Rice husk membrane is used to filter out these heavy nanomaterial contaminants such as Pb, Cr, Cd. For ultrafiltration, a graphene membrane will be used.

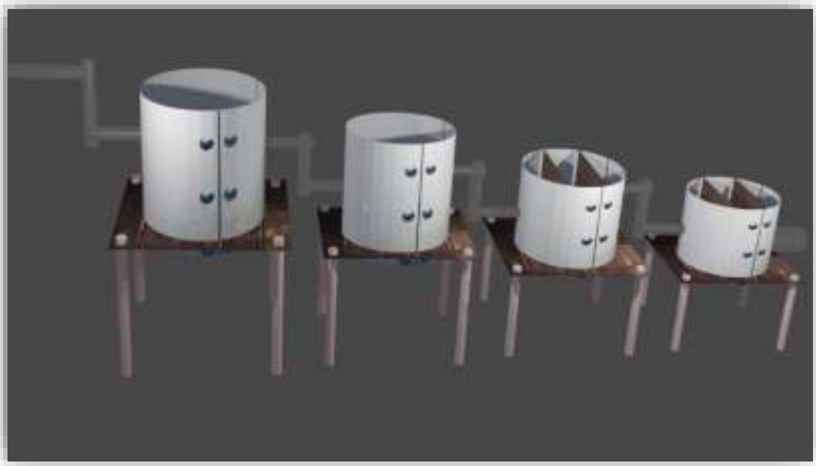

Figure 1 – Front view of Setup

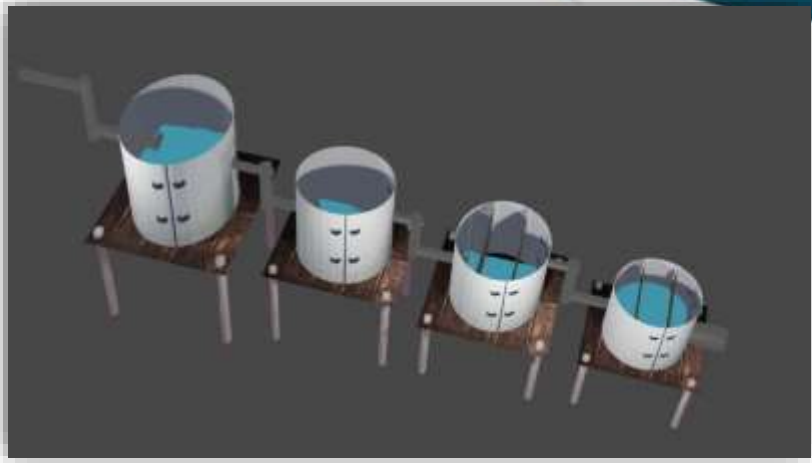

Figure 2 - Top View of Setup

This technique is highly efficient and cost-effective when compared to conventional water purification methods. This method can be a boon to solve the water crisis and make the unfit water resources fit for drinking, agriculture, and other purposes.

Past techniques: -

- Oxidation pond or activated sludge process is the most commonly employed technology for wastewater treatment, covering 59.5% of total installed capacity.

- Ash ponds use gravity to settle out large particulates (measured as total suspended solids) from power plant wastewater. This technology does not treat dissolved pollutants. The ponds generally have not been built as lined landfills, and therefore chemicals in the ash can leach into groundwater and surface waters, accumulating in the biomass of the system.

- Reverse osmosis (RO) is a water purification process that uses a partially permeable membrane to separate ions, unwanted molecules, and larger particles from drinking water. In reverse osmosis, anapplied pressure is used to overcome osmotic pressure, a colligative property that is driven by chemical potential differences of the solvent, a thermodynamic parameter. Reverse osmosis canremove many types of dissolved and suspended chemical species as well as biological ones (principally bacteria) from water, and is used in both industrial processes and the production ofpotable water. The result is that the solute is retained on the pressurized side of the membrane andthe pure solvent is allowed to pass to the other side. To be "selective", this membrane should not allow large molecules or ions through the pores (holes) but should allow smaller components of thesolution to pass freely.

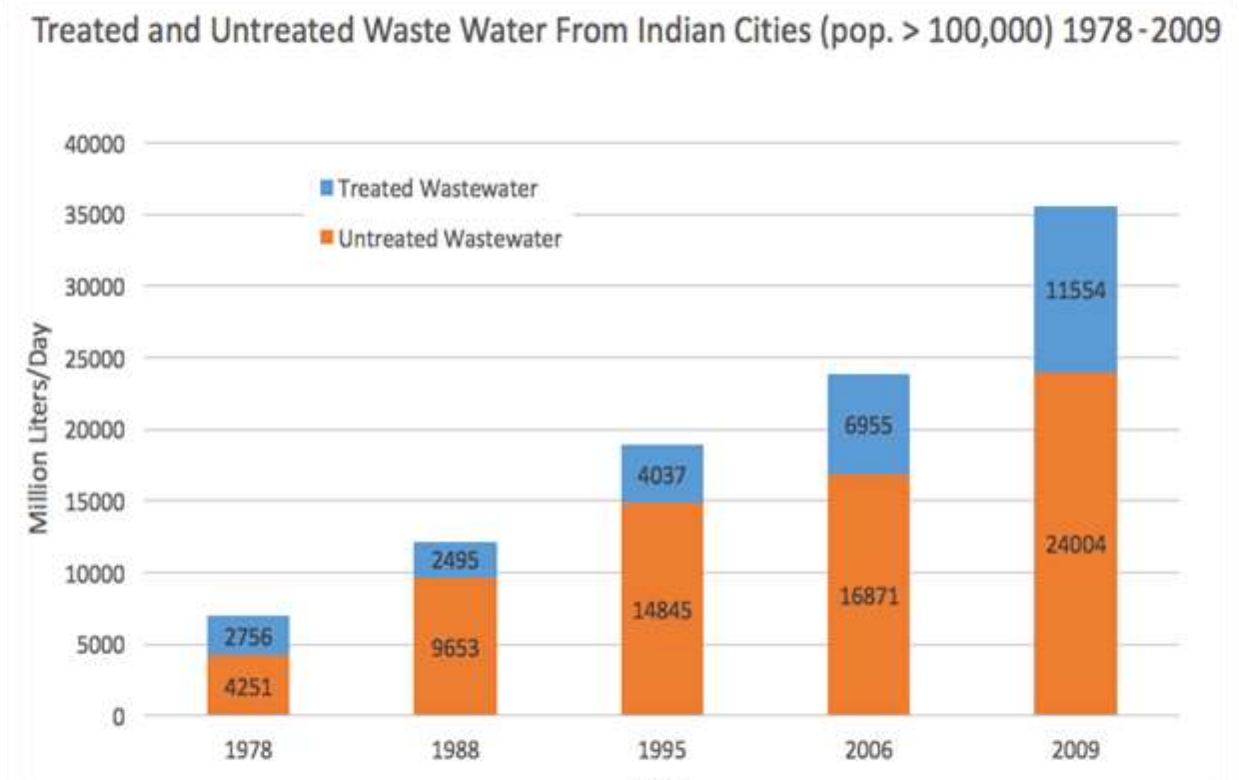

Figure 3- Ratio of treated and untreated water done by past technology

- Household reverse-osmosis units use a lot of water because they have low back pressure. As a result, they recover only 5 to 15% of the water entering the system. The remainder is discharged as wastewater. Because wastewater carries with it the rejected contaminants, methods to recover this water are not practical for household systems. Wastewater is typically connected to the house drains and will add to the load on the household septic system. A reverse-osmosis unit delivering 19 litres (5.0 U.S. gal) of treated water per day may discharge between 75 and 340 litres (20 and 90 U.S. gal) of wastewater daily. This has a disastrous consequence for megacities like Delhi where large-scale use of household RO devices has increased the total water demand of the already water-parched National Capital Territory of India.

Description: -

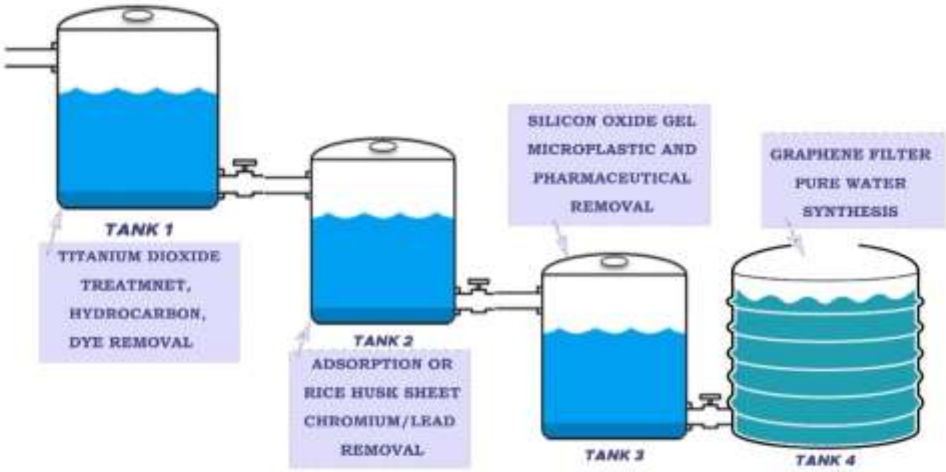

Figure 4 – Blue sketch

- **Tank 1 –**

TiO$_2$ is prepared with an aqueous sol-gel synthesis by peptization process is doped with *nitrogen* precursor to extant its activity towards the visible region. The photon energy required to activate the TiO$_2$ is 3.2eV; This value corresponds to radiation with a wavelength lower than 388 nm (UV rays). However, in the case of illumination by solar light, only 5-8% of the spectrum will be used for activation. When energetic light illuminates TiO$_2$, electrons are promoted from the valence band to the conduction band, leading to the formation of positive holes in the valence band. When these photoactive species reach the surface of the material, they react with water and oxygen to produce radicals, such as superoxide and hydroxyl radicals, and then these radicals can degrade adsorbed organic molecules.

Titanium dioxide occurs in nature as the mineral's rutile and anatase. Additionally, two high-pressure forms are known minerals: a monoclinic baddeleyite-like form known as Akaogiite, and the other is an orthorhombic α-PbO$_2$-like form known as brookite, both of which can be found at the Riis crater in Bavaria. It is mainly sourced from Ilmenite ore. This is the most widespread form of titanium dioxide-bearing ore around the world. Rutile is the next most abundant and contains around 98% titanium dioxide in the ore. The metastable anatase and brookite phases convert irreversibly to the equilibrium rutile phase upon heating above temperatures in the range of 600–800 °C (1,110–1,470°F).

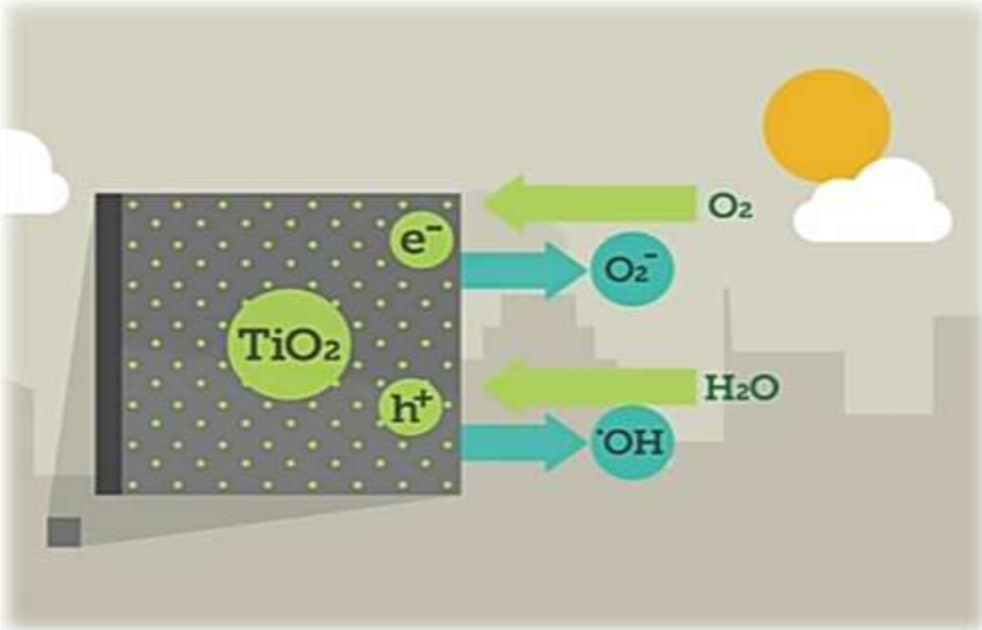

Figure 5 - Reaction in tank 1

However, in the case of illumination by solar light, only 5–8% of the spectrum will be used for activation (only the UV part). When energetic light illuminates TiO_2, electrons (e-) are promotedfrom the valence band to the conduction band, leading to the formation of positive holes (h+) in thevalence band. When these photoactive species reach the surface of the material, they react with water and oxygen to produce radicals, such as superoxide and hydroxyl radicals, and then these radicals can degrade adsorbed organic molecules.

A Yellow color precipitate of *Titanium Alkoxide (Ti(OR)$_4$ ..., R is Alkyl group).*

- **Tank 2 –**

An increasingly serious and widespread problem is the introduction of plastics into the water cycle. The poor degradability leads to the plastic waste remaining in water for a long time and over time it fragments into smaller and smaller plastic particles. Over 80% of the plastic material entering the ocean annually originates from land-based sources, which correlates with the fact that half of the world's population lives in coastal regions. Large plastic waste represents the main contribution, including everyday objects like drink bottles and other types of plastic packaging. An estimated 4.8–12.7 million tons enter here annually. The remaining input comes from plastic, which is released at sea, mainly from fishing—for example, due to lost and discarded fishing gear, which is estimated at 0.6 tons a year. About 94% of the large plastic parts, which end up in the sea, sink with time to the ocean floor. Today, an average of 70 kg of plastic can be found on every square kilometre of the ocean floor.

Plastic disintegrates into smaller and smaller fragments and from the microplastic, the so-called secondary microplastics are formed. If the directly enters the environment, it is designed as primary microplastic. Microplastics are small, solid, and water-insoluble plastic particles under 5mm in size.

Figure 6 – Ratio of Microplastic in Parts of World

Bonded in microplastics, pollutants like, for example, DDT, dioxins, or heavy metals can be transported and accumulated in organisms via ingested food. Due to the manufacturing process, most polymer blends also contain harmful substances like softening agents or monomers, whichin return can be released upon ingestion of the particles via food and exert a direct influence on theorganism, since these substances are mostly classified as potentially harmful and/or carcinogenic. It has already been shown in laboratory experiments that microplastics smaller than 150 µm can, after ingestion via food, enter the surrounding tissues, the bloodstream and, through these, the internal organs and also the brain. There is then the risk of the formation of lesions and inflammations. Furthermore, oxidative stress, necrosis, and damage to DNA can be triggered, whichagain increases the risk of cancer. Neurological behavioral disorders are also possible. Thus, thereis a potential risk to human health from microplastics.

An innovative approach for the removal of microplastic from industrially used seawater combines a chemically induced agglomeration and a new technological implementation step. The process developed by silane-based microplastic agglomerates is formed according to the cloud point principle through the application of special organ silane-based precursors, which, via **Van der Waals** forces, have a high affinity to unreactive microplastics and at the same time a high reactivity in water. Ports and industrial areas are especially contaminated with microplastic particles.

Through the selection of the functional groups in the organic unit (functional design), it is possible to exploit an adaptable system for the respective application (e.g., the removal of reactive and/or inert organic-chemical compounds). Utilizing the substituent pattern within the organic unit and also directly on the silicon atom, the affinity of the organ silanes can be adapted to various polymer types and, simultaneously, the reactivity respectively the stability can be controlled. Organ silanes with corresponding reactivity can react to organic-inorganic hybrid silica gels in the sol-gel process. In the first step, disposal groups are split off and reactive silanol groups are generated through hydrolysis. The silanol groups subsequently form silicone bonds in a condensation reaction and link the organ silanes via a bridging unit. three-dimensional networked hybrid silica gel forms, which are stabilized via the respective bridging unit. Through the selection of the disposal groups and the organic groups, the properties and reactivity of the organ silanes can be specifically controlled. The selection of the disposal groups is decisive for the hydrolysablity of the organ silanes.

In distilled water, an aggregation of the microplastic particles begins 15 s after the addition of the agglomeration reagent. After 2–3 min, the agglomeration is completed and an aggregate is present, which contains all of the microplastics. In the artificially produced saltwater samples, the agglomeration process begins after 10 min and is concluded after 15 min.

Figure 7 - Agglomeration

- **Tank 3 –**

Heavy metals are thus commonly defined as those having a specific density of more than 5g/cm3. The main threats to human health from heavy metals are associated with exposure to lead, cadmium mercury, and arsenic. They are carcinogenic. The removal of heavy metals from wastewater is a serious problem. The absorption process is widely used for the removal of heavy metals from wastewater because of its low cost, and availability.

Constipation, headache, memory problems are some common threats due to lead poisoning. Kidney stones, adrenaline imbalances, and heart disease via cadmium toxicity are often the result of cadmium damage to the kidneys which regulates the heart. The heavy metals of most concerns from various industries include lead (Pb), zinc (Zn), copper (Cu), arsenic (As), cadmium (Cd), chromium (Cr), nickel (Ni), and mercury (Hg). They originate from sources such as metal complex dyes, pesticides, fertilizers, fixing agents, mordants, pigments, and bleaching agents. In developed countries, legislation is becoming increasingly stringent for heavy metal limits in wastewater. In India, the current maximum contaminant level (ppm–mg/mL) for heavy metals is 0.05, 0.01, 0.25, 0.20, 0.80, 0.006, 0.00003, 0.050 for chromium, cadmium, copper, nickel, zinc, lead, mercury and arsenic, respectively. Various treatment technologies employed for the removal of heavy metals include chemical precipitation, ion exchange, chemical oxidation, reduction, reverse osmosis, ultrafiltration, electrodialysis, and adsorption. Among these methods, adsorption is the most efficient as the other techniques have inherent limitations such as the generation of a large amount of sludge, low efficiency, sensitive operating conditions, and costly disposal.

Such type of contentment comes under nano-particles. Heavy metals are discharged in water from various industries. They can be toxic or carcinogenic and can cause severe problems for human and aquatic ecosystems. Thus, the removal of heavy metals from wastewater is a serious problem. The adsorption process is widely used for the removal of heavy metals from wastewater because of its low cost, availability, and eco-friendly nature. Both commercial adsorbents and bio adsorbents are used for the removal of heavy metals from wastewater, with high removal capacity. Rice husk is mixed with formaldehyde (HCHO) to form a semi permeable membrane

Rice husk is mixed with formaldehyde (HCHO) to form a semi permeable membrane. This membrane can be used to filter out nano particle's contaminant e.g., Pb, Cr, Cd.

- **Tank 4 –**

Graphene is an allotrope of carbon consisting of single-layer atoms arranged in a 2D honeycomb lattice. The name is portmanteau of graphite and suffix "ene", reflecting the fact that the graphite allotrope of carbon consists of stacked graphene layers. Each atom in a graphene sheet is connected to its three nearest neighbours by a sigma bong and contributes one electron to a conduction band that extends over the whole sheet. This is the same type of bonding seen in carbon nanotubes and polycyclic aromatic hydrocarbon and fullerenes and glassy carbon. A single graphene sheet is nearly transparent due to its extreme thinness.

In chemical exfoliation method, solution dispersed graphite is exfoliated by inserting large alkali ions between the graphite layers. Chemical synthesis is the similar process which consists of the synthesis of graphite oxide, dispersion in a solution, followed by reduction with hydrazine. Similarly, for carbon nanotube synthesis, catalytic thermal CVD has proved most significant process for large-scale graphene fabrication. The graphene film is created by CVD in two steps. The first involves the pyrolysis of a precursor material to form carbon atoms on a substrate material. By pyrolyzing the material on the substrate, carbon clusters are prevented from forming. Due to the amount of energy required to break the carbon bonds (C-C = 347 kjmol-1, C=C = 614 kjmol-1, C≡C = 839 kjmol-1, C-H = 413 kjmol-1), a high heat is required, and therefore a metal catalyst is required during the process. The second step is a heat intensive step which assembles the dissociated carbon atoms onto a substrate (in the presence of a catalyst), which forms a single layer structure.

It would appear to be impervious to practically every liquid and gas. However, scientists have been working on the creation of a membrane that will allow water to filter through graphene, removing impurities along the way. Graphene is very impermeable, even very light gases don't pass through. If we were able to tailor the size of the pores within the graphene lattice, it might be possible to produce a very selective filter. By adding oxygen to graphene makes graphene oxide, space is created in the structure for the water to flow through.

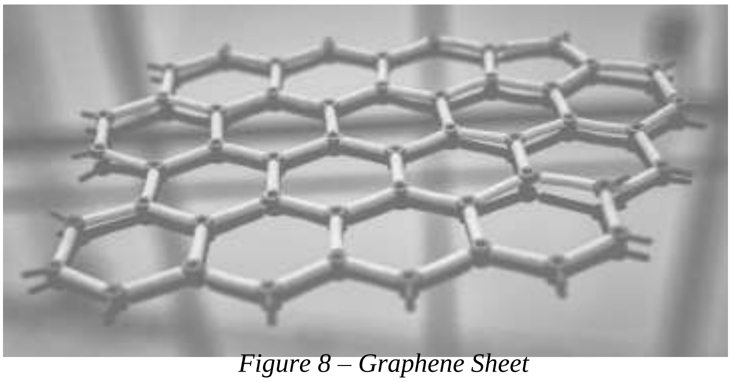

Figure 8 – Graphene Sheet

Advantages: -

- The purified water also decreases the overall amount of chemicals in rivers & seas as it decreases the amount of harmful chemicals from the water hence being less harmful for aquatic species too.
- After passing through the graphene filter the purified water can also be used for the drinking purpose & hence can resolve the issue of obtaining pure drinking water.
- It makes water suitable to be used for agricultural purposes as it increases fertility of soil & make it enrich with mineral content hence the harmfulness that causes due to waste water is curbed with this technique.
- Contamination of the resulting sea salt and thus the transmission to people will be effectively avoided through the removal of microplastic from the seawater flowing into the evaporation basins.
- Used for the purification of waste water from various industries such as Textiles industry, Paper industry, Pulp industry, Plastic industry, Pharmaceutical industry, Petrochemical industry etc.
- The technique used can be highly effective for the ultra-purification of water. It comprises four tanks and is a worthwhile process for the removal of versatile contaminants such as organic pollutants, microplastics, and heavy metals.

Disadvantages: -.

- We have to change the membrane at a particular interval of time because over a particular period of time the filtration capacity of membrane will get decreased.
- All chemicals must be used in limited quantity otherwise it will affect our environment.

Future Aspect: -

The engineering and understanding of semiconductor photocatalyst TiO_2 will continue to advance. Its large-scale application in water disinfection is a matter of when not if. Despite the intensive research of the past decades, desirable photocatalytic efficacy is yet to be achieved to a level suitable for practical applications. The reality is that access to clean water is still a major problem in many parts of the world. The seventh cholera pandemic, since it was started in 1961, arrived in India in 1964 and caused 4700 deaths in one year. Photo catalysis-based water sanitization will play a major role in people's daily lives. Such a reality is not too far away, as the usage of TiO_2 has been widely applied to other industries, including examples such as self-cleaning automobiles with a layer of TiO_2 paint. So, by using this process of water purification We can get rid of water scarcity from becoming any worse. We can also save our Aquatic ecosystem which performs many Important Environmental functions. Undoubtedly, it is the future breakthrough in technology and engineering that will turn photocatalysis into a driving force for maintaining critical water resources.