*Section A-Research paper*

# DEVELOPING NEW TECHNOLOGIES FOR WATER TREATMENT AND PURIFICATION

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## Introduction

It can be seen that there are many wastes generated from different sources and polluting different water sources. All of the sources are mainly created because of the different activities of humans. So, it can be noticed that there is a high demand for pure water that can be used for different purposes. The best way out of this is to treat water for making it pure. Although it can be noted that the different traditional methods of water purification are not effective anymore. It is because the severity of the waste & pollutants has also changed. So, there is a need for the introduction of new methods that can be used for the purpose of purifying water more effectively. In this project, the description of the views of the different scholars regarding these technologies was described. Moreover, the need for different methods along with thor method of preparation was also described. The recommendations for the betterment of the current research are also presented here.



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## Literature Review

According to Tijing *et al*. 2020, one of the most useful things for the purification of water is the use of ozone. It can be seen that the efficiency of the removal of bacteria is very much with the use of ozone.

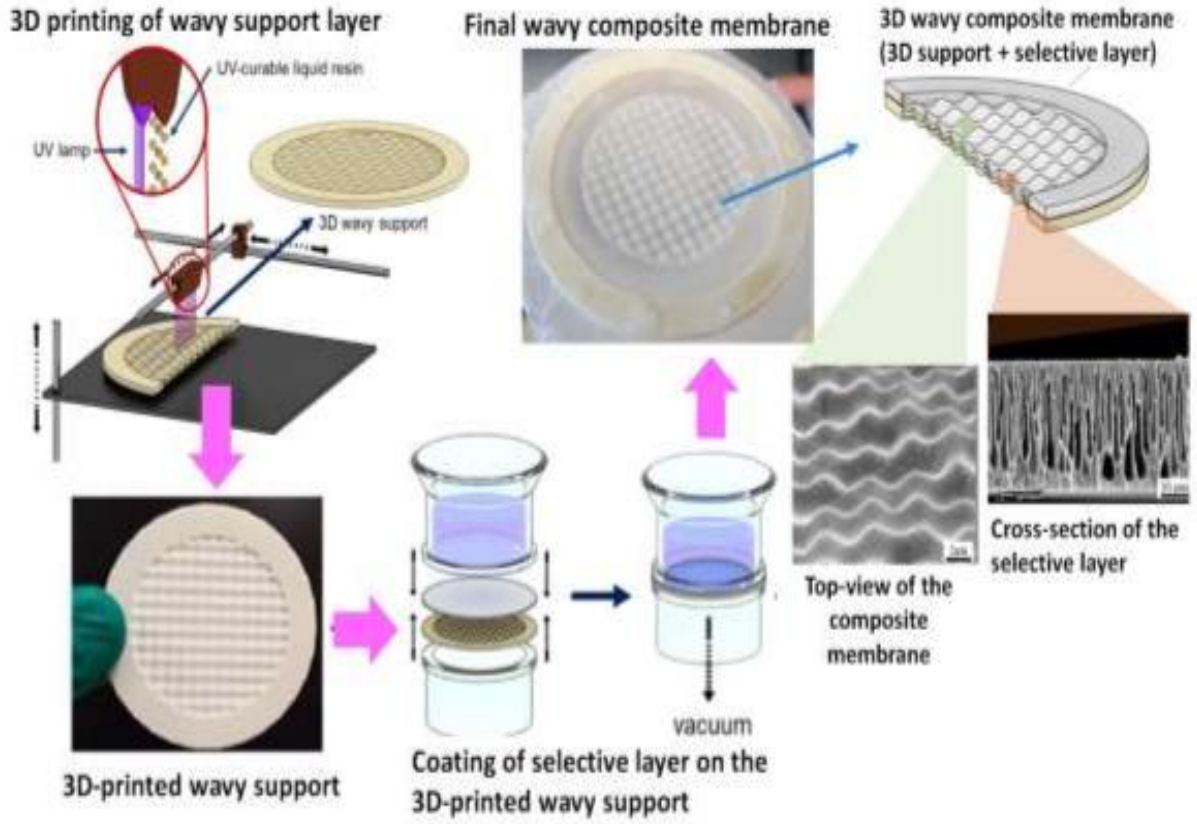


**Figure 1: Schematic of the composite membrane**

(Source: Tijing *et al*. 2020)

According to Rashid *et al*. 2021, there are different methods for the purification of water. All of these methods are selected on the basis of the type of pollutants present in the water, and the resources available for purification (Rashid *et al*. 2021). This is also dependent on the cost incurred for purifying the water.

According to Yang *et al*. 2019, one of the main impurities that are present in water is the suspended matter. It is to be noted that there are other matters like colloidal matters are also present in water (Yang *et al*. 2019). Both of these together is called Total dissolved solids.

According to Beyene *et al*. 2019, It can be observed that there are some sources of pollution of water that make the water hard. There are two types of hardness of water. These are temporary & permanent hardness (Beyene *et al*. 2019). There are separate methods for the removal of these hardnesses.

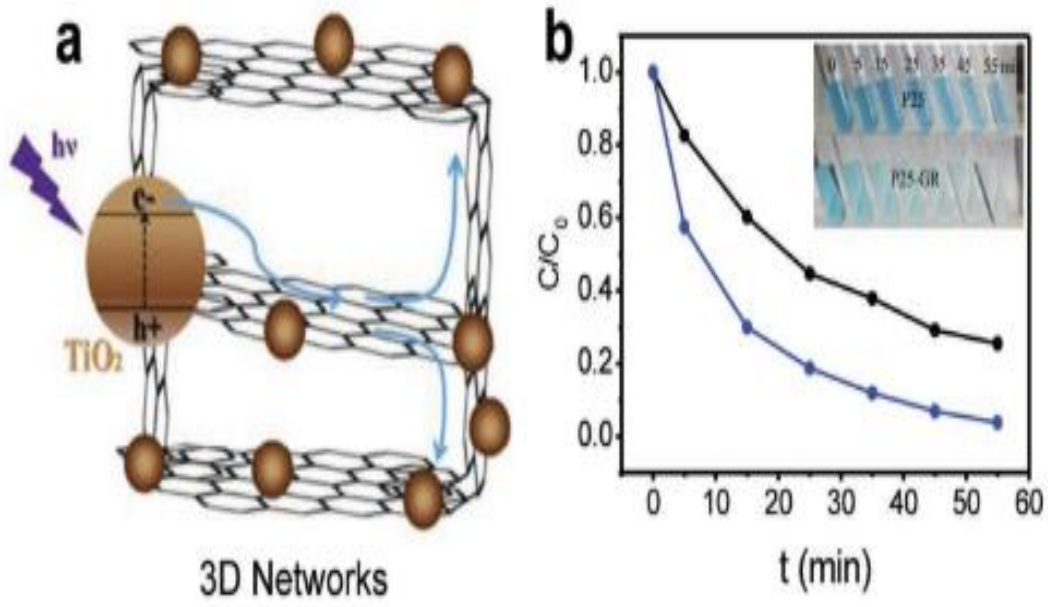


**Figure 2: Monolithic photocatalysts**

(Source: Wang *et al*. 2020)

According to Wang *et al*. 2020, It is to be noted that the water should be free from bacteria & coliforms. These are the impurities that have the potential of creating different diseases in humans. The many tests conducted regarding this suggest that there should not be any coliform colony present in a 100 ml sample of water.

According to Wollmann *et al*. 2019, there are different types of impurities in water that makes water unsuitable for use. These can be mainly classified into two types (Wollmann *et al*. 2019). These are organic & inorganic materials.

According to Crini *et al*. 2019, there are different sources of pollution of water. This mainly depends on the type of activities that are conducted in the place either by nature or any human activities (Crini *et al*. 2019). Both of these sources contribute different forms of pollutants to water.

According to Barhoum *et al*. 2019, color is one of the main pollutants of water. There are different types of materials present in the water that contribute different colors to water (Barhoum *et al*. 2019). The main objection that vis created from the color of the water is the absence of a pleasing feeling after seeing the water.

According to Garrido *et al*. 2020, one of the main things that are considered for the purification of water is the turbidity of the water. Turbidity defines the amount of light scattered or absorbed by the water when an incident light falls on it. Turbidity is created because of the presence of different organic or inorganic matter.

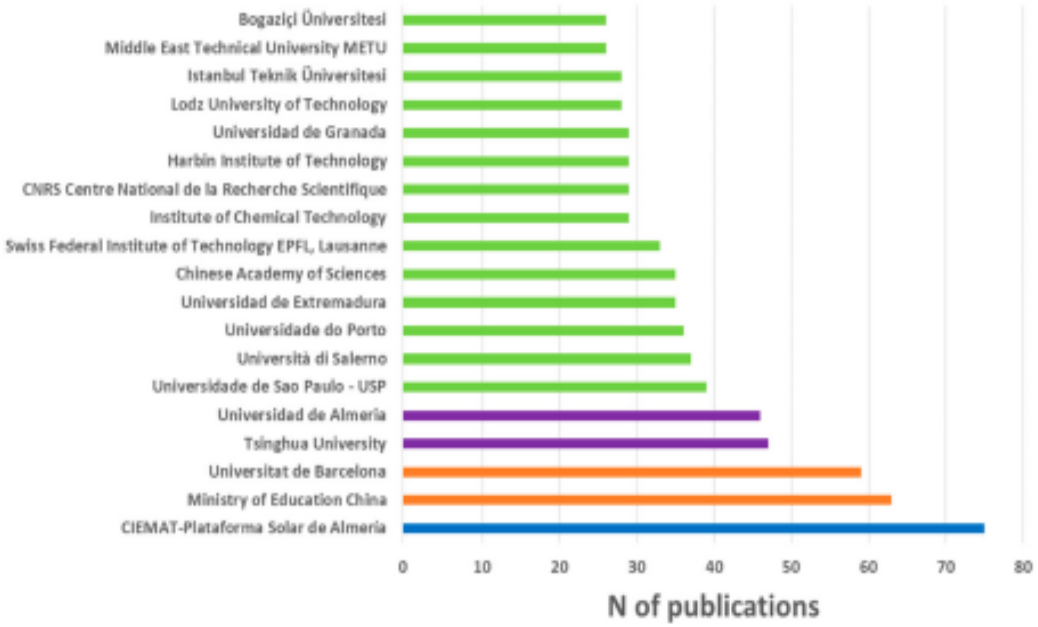


**Figure 3: Main institutions related to scientific production in wastewater and advanced oxidation**

(Source: Garrido *et al*. 2020)

According to Sun *et al*. 2019, one of the main things that are used for the removal of bacteria from water is chlorine. There are many ways of using chlorine in water (Sun *et al*. 2019). It can be seen that these can be used in either solid, liquid, or gaseous form.

According to Nguyen *et al*. 2019, one of the major pollutants of water is colloidal matter. It can be noticed that these matters cannot be removed only by plain sedimentation (Nguyen *et al*. 2019). For this, it is needed to add materials like coagulants.

According to Al *et al*. 2020, the odor coming out from water is another thing that is considered in the purification of water. This can be created because of the presence of different inorganic as well as organic materials (Al *et al*. 2020). Methods like aeration are proven to be effective for the removal of odor.

According to Palansooriya *et al*. 2020, it is to be noted that the pH of the water should be such that that is not too acidic or too alkaline as both of these have their ill effects. From the different analyses, it was found that the pH of drinking should be in the range of 7-8.5.

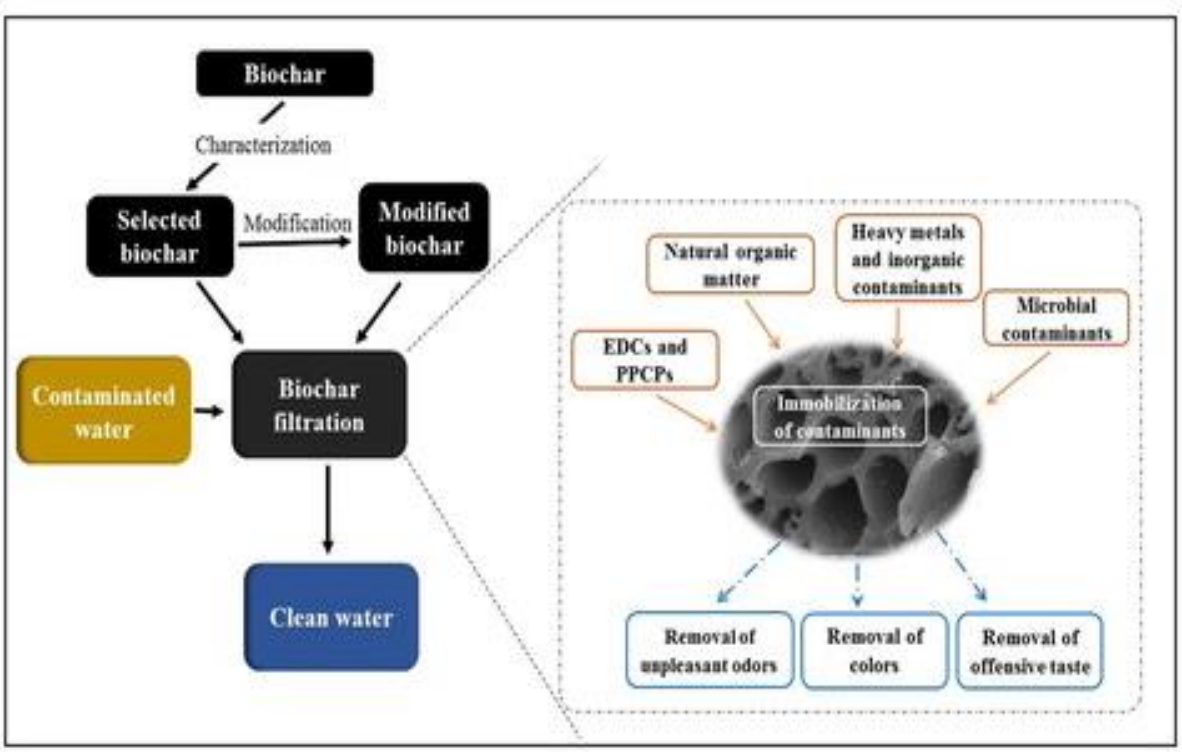


**Figure 4: pH level measurements**

(Source: Palansooriya *et al*. 2020)

According to the author, one of the new methods for the treatment of water is the use of nanotechnology (Sharma *et al*. 2020). The basic idea of this method is to apply materials for the purification of it that can be acted on water at the atomic level.

According to Sharma *et al*. 2020, fluoride is one of the major pollutants that is present in water. It is also necessary for the human body. If this is present in less amount then it is bad for the bones. At the same time, excess of this material creates abrasion of the enamel of teeth.

According to Varjani *et al*. 2020, one of the most harmful things that is present in water as a pollutant is mercury. It is needed that water that is used for the purpose of drinking should be free from mercury (Varjani *et al*. 2020). The maximum limit of this that can be permitted in water is 0.05 mg/l.

According to Li *et al*. 2019, among the different technologies one of the most popular technologies that are used these days is the nanotube technology (Li *et al*. 2019). The results obtained from this technology are also very much satisfactory.

According to Shindhal *et al*. 2021, It can be seen that in the water there are different forms of microorganisms can be present. One of the useful methods of killing those is the use of UV rays. It can be observed that this provides almost 100% efficiency in killing microorganisms present in water.

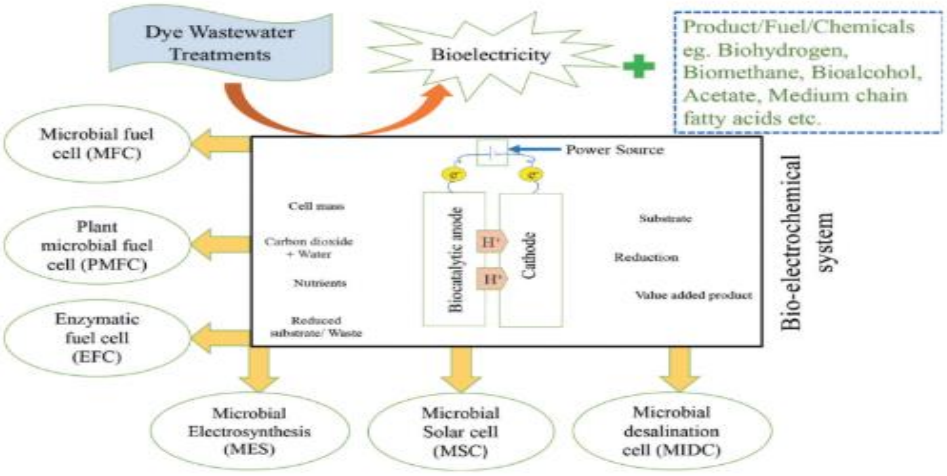


**Figure 5: Schematic presentation of BES**

(Source: Shindhal *et al*. 2021)

According to Chrispim *et al*. 2019, one of the primary methods of treatment of water is to use screens. This process is called screening. In this method, large matters present in water are screened off before the later stages of treatment (Chrispim *et al*. 2019). Both coarse & fine screens are used for this purpose.

According to Wei *et al*. 2019, one of the most destructive pollutants that are present in water is nitrite. It can damage the health of humans in many ways. Especially, in children it creates the disease Blue baby (Wei *et al*. 2019). It should not be present in water.

According to Reza *et al*. 2020, there are different characteristics of water are considered for the treatment of water. These are physical, chemical & biological characteristics of water. For all of these different tests & treatments are used in the process of treatment of water.

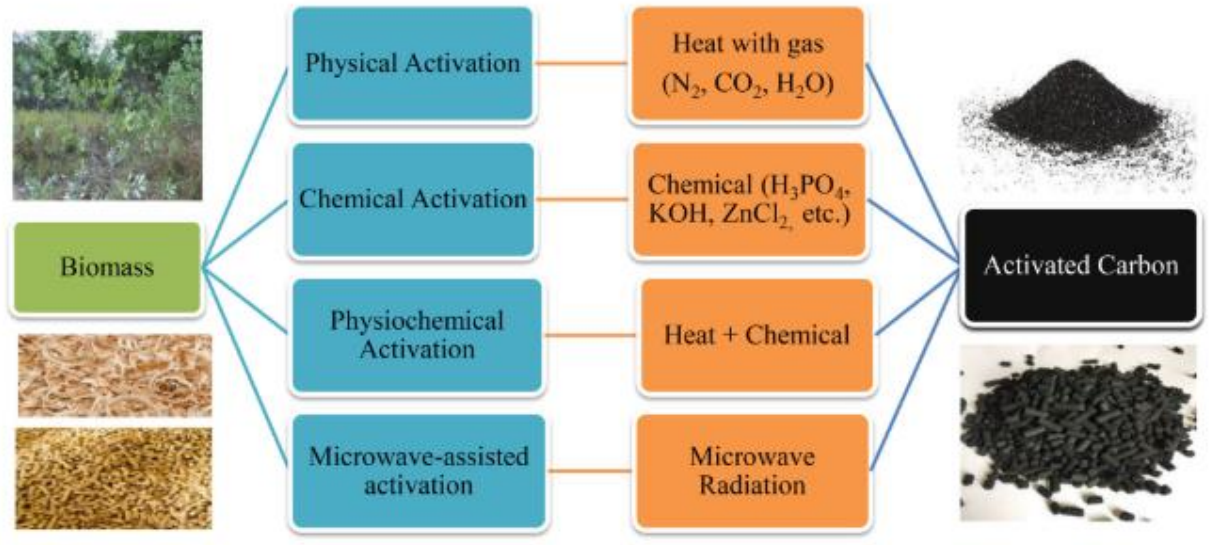


**Figure 6: Activation Process**

(Source: Reza *et al*. 2020)

According to Dalawai *et al*. 2020, disinfection is one of the most important stages of the treatment of water (Dalawai *et al*. 2020). In this stage, the main work that is done is to make the water free from the disease-causing micro-organisms.

According to Maaz *et al*. 2019, one of the most used materials in the stage of disinfection is to use chlorine. This is called chlorination (Maaz *et al*. 2019). Other materials that can be used for this purpose are ozone, and potassium permanganate.

According to Yao *et al*. 2020, the presence of organic matter like algae causes color to water. It also imparts a bad taste to water. Moreover, the presence of this has the potential to use the phosphorous present in water that is necessary for aquatic life (Yao *et al*. 2020). This results in damaging the life of aquatic animals.

According to Yaqoob *et al*. 2020, the alkalinity of water is another major aspect of the treatment of water. It can be seen that the presence of more alkalinity provides a bitter taste of water. Also, it affects damages the intestine of humans. In no case, it should be present at more than 200 mg/l.

$$TiO_2 + h\nu \rightarrow e^-_{cb} + h^+_{vb}$$

$$O_2 + e^-_{cb} \rightarrow O_2^-$$

$$H_2O + h^+_{vb} \rightarrow OH + H^+$$

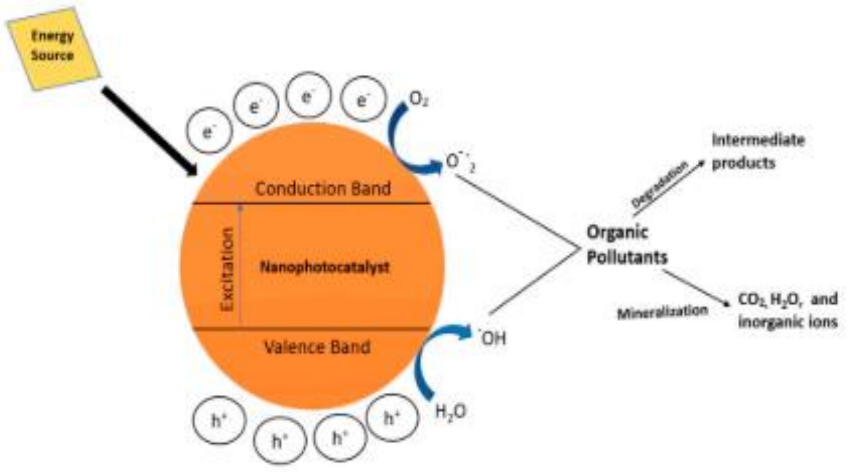


**Figure 7: Toxic organic compound degradation through nanophotocatalysts**
(Source: Yaqoob *et al*. 2020)

According to Peter *et al*. 2021, different materials present in water provide different colors to water. Iron provides reddish color while magnesium provides blackish-brown color to water (Peter *et al*. 2021). There are methods like color matching are used for the purpose of testing in this regard.

According to Al *et al*. 2020, one of the best methods of treatment of water that are used these days is the use of automatic variable filters (Al *et al*. 2020). This is an upgrade of the traditional filters that are used for the purpose of filtration.

According to Esfahani *et al*. 2019, among the different methods that are used in the current situation for the purpose of the treatment of water is the inside technology (Esfahani *et al*. 2019). The main idea behind this is that it uses the osmotic pressure of the human intestine.

According to Perera *et al*. 2019, there are different forms of chlorination used in the treatment of water. These are pre-chlorination, post-chlorination, and double chlorination (Perera *et al*. 2019). All of these are used based on the type of pollutants and their amount in water.

According to Nunes *et al*. 2020, the last stage of the treatment of water in the general condition is the softening of water (Nunes *et al*. 2020). There are methods like ion exchange, base exchange and zeolite process that are used for the softening of water.

## Materials & Methodology

| Sl No. | Method | Pollutant removed | Materials used | Method used |
|---|---|---|---|---|
| 1 | Automatic variable filtration | Micro-organisms, small materials that have a density less than water. | Sand, gravels | In this method, the flow is passed upward. At the same time, the filtering media is passed in a downward direction (Qu *et al*. 2019). There is the provision of two filtering media that operates either in parallel or in serial. |
| 2 | Photocatalytic water purification | Micro-organisms, organic materials, pesticides, crude oil, dyes, inorganic materials. | UV rays, Zeolite, titanium dioxide | In this process, UV rays are passed through the water. The different organisms in the water get killed by the radiation of UV rays (Diaz *et al*. 2019). More the catalyst that is used in this process is zeolite. |
| 3 | Aquaporin inside technology | Selected entry of materials into the cell. | Bio-mimetic membrane | This method uses one membrane that has the potential of passing selective materials through it (Wang *et al*. 2019). This is a protein. Here the main work that is done is to regulate the osmotic pressure changes in the intestine. |
| 4 | Nanotechnology | Absorption of chemical & biological particles, metallic compounds. | Silver, copper, zero valent nanoparticles of iron, nanomembranes | Here, the manipulation of the materials is done on the atomic level. |

| | | | | |
|---|---|---|---|---|
| 5 | Aquostic nanotube technology | Suspended & colloidal particles | Carbon nanotubes | Water passed through small nanotubes of carbon (Yasin *et al.* 2021). The small water particles pass through it & the polluted bigger particles cannot pass through it. |

## Results & Discussion

### Automatic variable filters

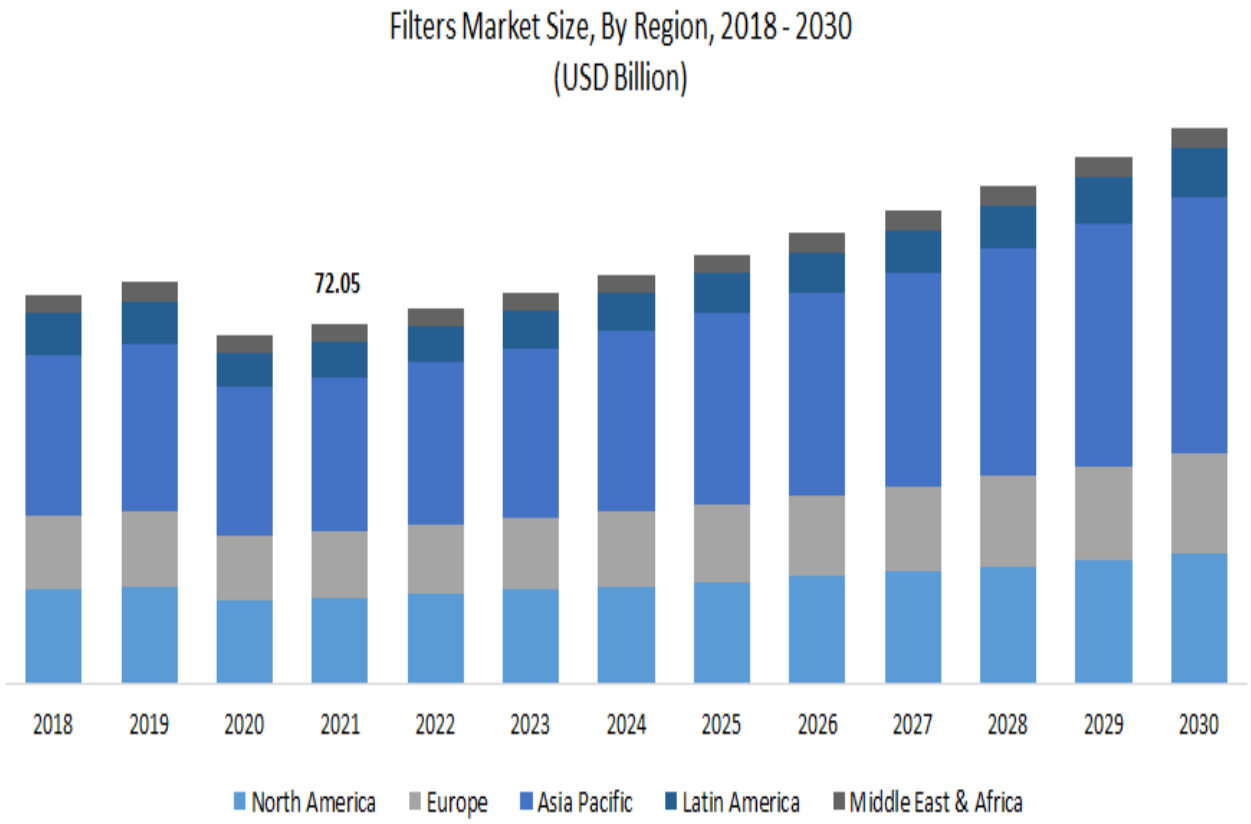


**Figure 8: Automatic variable filters market size**

(Source: https://www.techsciresearch.com)

From the market research it was found that the use of automatic variable filters have increased a lot over the past few years.

## Photocatalytic water purification

| Treatment System | Classification | Characteristics | Materials | Pollutant | Light Source | Con. (mg/L)/(cfu/mL) | Volume (mL) | Irradiate Time (h) | Eff. (%) |
|---|---|---|---|---|---|---|---|---|---|
| Organic compounds | Dyes | Water-soluble, not readily biodegradable, harmful to the ecosystem | Ag@AgC@MIL100(Fe)/CCF | MB | Vis light (500 W) | 20 | 40 | 2/3 | 99.2 |
| | | | $TiO_2$/ZnO/ rGO | MB, RhB, MO | UV/simulated solar illumination (300 W) | 20 | 1000 | 2 | 99.6<br>99.2<br>99.4 |
| | | | $BiFeWO_6$/ α-$AgVO_3$ | RhB | Vis light | 0.01 mM | 50 | 3/2 | 90.4 |
| | | | $SnO_2$-$MoS_2$ | MB, RhB | Vis light (200 W) | 20 | 100 | 2 | 96.4<br>93.1 |
| | | | ZnO/PALFs f | congo red | Vis light (300 W) | 20 | 10 | 5 | >95 |
| | Petroleum hydrocarbons | | K-doped g-$C_3N_4$ | Naphthalene | Vis light (200 W) | 20 | 100 | 3 | 82.2 |
| | | | g-$C_3N_4H_x^+$ | N-tetradecane | Vis light (300 W) | 5000 | 10 | 4 | 87.3 |
| Phenolic compounds | Highly soluble in water, acutely toxic, biologically recalcitrant | | Au@ Ni/rGO | Phenols | Sunlight | 1000 | - | 7/2 | 87.7 |
| | | | Cu-NiO | Phenols | UV–Vis (150 W) | Real effluents | - | 5/2 | 85.7 |
| | | | CuO-$TiO_2$ | | UV light (96 W) | 15 mM | 100 | 1 | 100 |
| | | | $TiO_2$-x @ZIF-67 | BPA | Vis light | 50 | - | 1 | 95.3 |
| Cr | Carcinogens, harm human skin and internal organs | | $TiO_2$-$ZrO_2$ | Cr(VI) | UV light | 0.5 | | 1/12 | 100 |
| | | | PW12/CN@ $Bi_2WO_6$ | Cr(VI) | Simulated xenon light (1000 W) | 20 | 50 | 3/2 | 98.7 |
| | | | CdS | Cr(VI) | Vis light (300 W) | 20 | 60 | 1/6 | 94.9 |
| | | | $ZnIn_2S_4$/ CdS | Cr(VI) | Vis light (300 W) | 50 | 50 | 1/2 | 100.0 |
| | | | $Mn_3O_4$@ ZnO/$Mn_3O_4$ | Cr (VI) | Sunlight (300 W) | 10 | 200 | 7/6 | 94.0 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Heavy metals** | **Pb** | Toxicologica, fatal | $TiO_2$/Alg/ FeNPs | Pb(II) | 254 nm ultraviolet C (30 W) | 20 | 100 | 6/5 | 99.6 |
| | | | $Fe_3O_4$@ C@$TiO_2$ | Pb(II) | UV-Vis (300 W) | 20 | 100 | 3 | 92.0 |
| | | | $TiO_2$ | Pb(II) | 300-450 nm (15 W) | 0.5 mM | 450 | 4 | - |
| | **Hg** | High toxicity, tendency to bioaccumulate | α-$Fe_2O_3$/ g-$C_3N_4$ | Hg(II) | Vis light (400 W) | 100 | 500 | 1 | 90 |
| | | | CuO/g-$C_3N_4$ | Hg(II) | Vis light (150 W) | 100 | 500 | 1 | 100.0 |
| | | | $CoFe_2O_4$/g-$C_3N_4$ | Hg(II) | Vis light (300 W) | 100 | 500 | 1 | 100.0 |
| | **Anti-biotics** Water-soluble, not readily biodegradable, harmful to the ecosystem | | MgO/ZnO/ Graphene | Sulfamethoxazole | UVA (30 W) | - | 200 | 7/2 | 94.4 COD |
| | | | $TiO_2$/CuO/MCM-41 | Tetracy-cline | UV light (125 W) | 20 | 200 | 1 | 70.5 |
| | | | $MoS_2$/ $Ag_2Mo_2O_7$ | Levofloxacin | Vis light (150 W) | 5 | - | 3/2 | 97.0 |
| | | | $Ag_3PO_4$/GO film | Norfloxacin | Vis light (250 W) | 15 | 120 | 5/3 | 83.6 |
| **Pharmaceutical** | **Anti-inflammatories** | High polarity, hydrophilicity, the absorption coefficient in the soil is low | $TiO_2$ | Ibuprofen | Simulated solar irradiation (500 W) | 10 | 500 | 4/3 | 87.0 |
| | **Lipid regulators** | Highly soluble in water, acutely toxic, biologically recalcitrant | $TiO_2$-$ZrO_2$ | Metformin | UV light (125 W) | 1 | | 1/2 | 50.0 |
| | | | $TiO_2$ | Amoxicillin metformin | UV lamp (125 W) | - | 200 | 3/2 | 90.0 98.0 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | $Ag/Ag_2O$-$TiO_2$ | Imazapyr | Vis light (1 $mW/cm^2$) | 0.08 mM | | 3 | 100 |
| Pesticides | Toxicity, biological resistance | $TiO_2$/Ce | Profenofos triazophos | Simulated xenon light | 20 | 50 | 3/2 | 98.7 |
| | | $Au/TiO_2$ | Phenoxyacetic acid | Vis light | 0.15 | - | 7 | 87.0 |
| | | $Ag/LaTiO_3$ | Atrazine | Vis light (300 W) | 50 | - | 2/3 | 100.0 |
| Micro organisms | Causing a variety of gastrointestinal diseases, adenoviruses | $Co\text{-}BiVO_4$ | Escherichia coli, Chlamydomonas pulsatilla | - | - | 70 | 5<br>1 | 81.3<br>65.6 |
| | | $g\text{-}C_3N_4$@ $Co\text{-}TiO_2$ | Escherichia coli | Vis light (300 W) | $1 \times 10^6$ | 10 | 3/2 | 6 log inactivation |

**Figure 9: Photocatalytic water purification**

(Source: https://www.ncbi.nlm.nih.gov)

The different results of this method can be understood from the picture above.

**Nanotechnology**

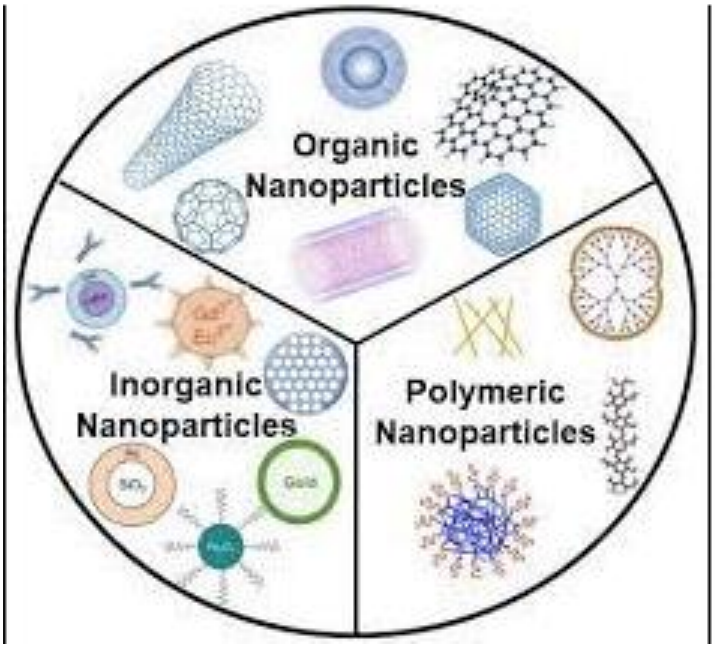


**Figure 10: Nanotechnology in water purification**

(Source: https://www.researchgate.net)

The results of this method are described here

**Aquostic nanotube technology**

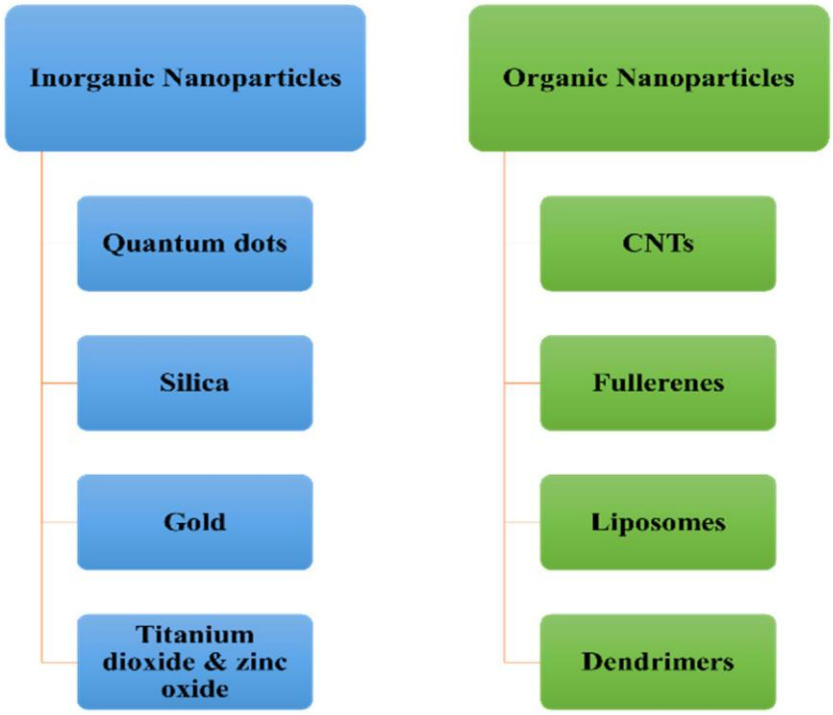


**Figure 11: Aquostic nanotube technology in water purification**

(Source: https://www.mdpi.com)

The two forms of nanoparticles are presented here [***Refer to Appendix 1***].

## Conclusion & Future Scope

In this project, the different methods that have the potential of making polluted water fit for use were presented here. Moreover, the different types of pollutants in water were also identified here. In addition to this, the different methods of treatment were also elaborated here. The different views of the different authors can also be obtained from here. From this research, it was identified that the devastating effects of the pollutants are increasing day by day on the water. This is mainly because of the activities of humans. So, there is a great need of doing this kind of research in the future also.

## Recommendations

This research, it was tried to find out the different key aspects of the treatment of water. Also, different ideas regarding the treatment of water were also obtained in this research. Despite of great efforts, there were some areas that could not be covered by this research. The comparison of the current new method with the traditional methods is not present here. If it was present then it would be made easy to adopt the newly proposed methods easily.

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## Appendices

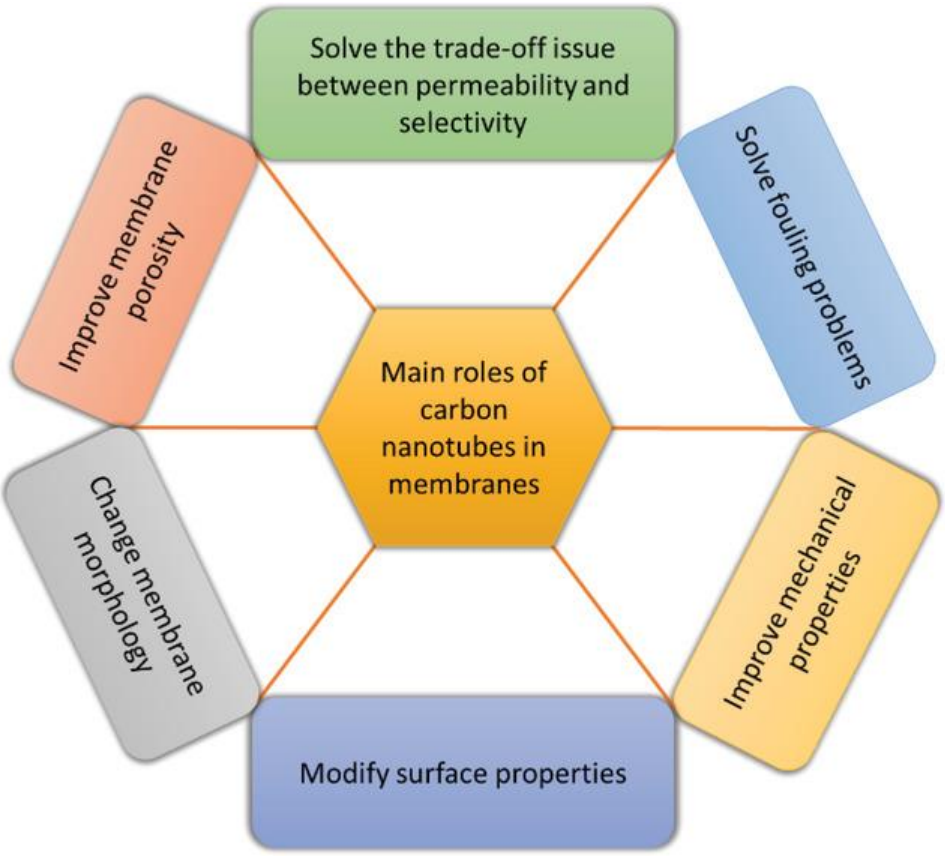
### Appendix 1: Nanotechnology in water purification

water treatment

| Sl.No | Type of Nanoparticle | Type of pollutants removed |
|---|---|---|
| 1 | Carbon nano tubes | Organic Contaminant |
| 2 | Nano Scale metal Oxide | Heavy metals Radionucleides |
| 3 | Nano catalyst PCB | Azodyes, Pesticides etc |
| 4 | Bioactive nanoparticle | Removal of Bacteria, fungi |
| 5 | Biomimetic membranes | Removing Salts |

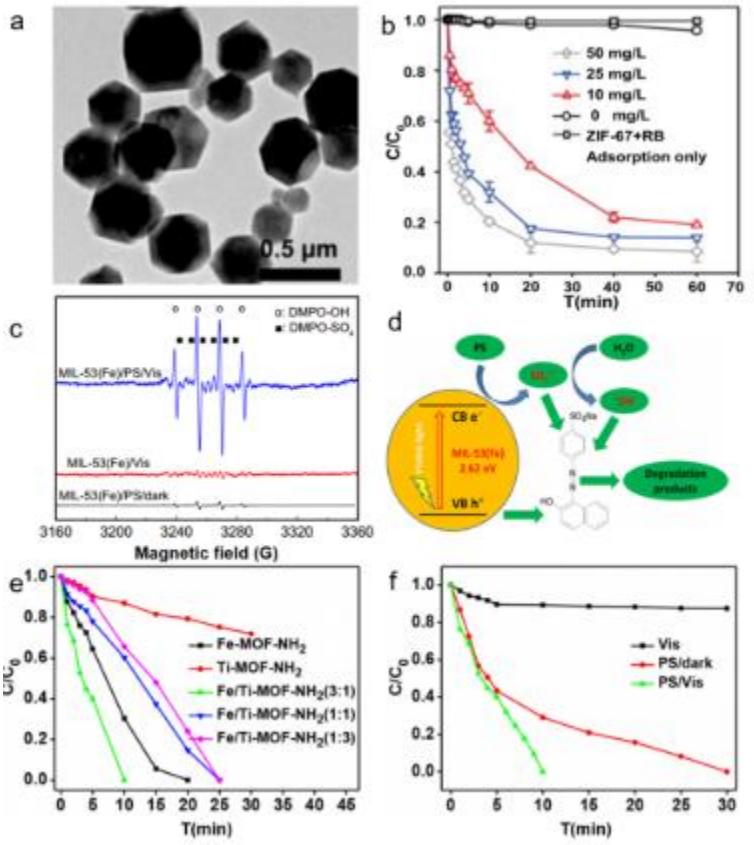
(Source: researchgate.net)

**Appendix 2: Roles of carbon nanotube in water treatment**




(Source: https://onlinelibrary.wiley.com)

**Appendix 3: TEM images**




(Source: Wang *et al*. 2019)