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Membrane process and Graphene nano-particles in Water treatment

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Abstract*— The suspended and dissolved particles presented in the water and wastewater in the size of 1-1000 nm which is more toxic and it causes severe effects to the aquatic life and living organisms. Nanotechnology is the method, which is newly developed in this world, to remove the very tiny particles presents in the water as well as wastewater with the help of nano-particles. Many nano-particles were used to remove the toxic contents presented in water and wastewater such as heavy metal concentration, dyes and some of the virus and bacteria etc. Compared to various nano-materials, Graphene is the type of smart material which is derived from the graphite, most widely used in all industrial sectors for various purposes. This review paper discussed about the importance of graphene usage in water and wastewater treatment technologies in recent days.

Keywords: Graphene, Membrane Technology, Water Treatment.

1. INTRODUCTION

Water is one of the important things for all living organisms and also the clean water is mandatory to the life. When water gets polluted it becomes unhealthy for everyone. Water pollution has become an increasing problem on our earth which is affecting the human and animal lives. Water pollution can occurs when chemicals, waste stored and other particles pours body of water become harmful to everybody. Also, natural water contains many organic and inorganic impurities in it. Contamination of source water can cause disease and has become very costly to clean. And, sometimes the contaminated water might be impossible to clean and the source must be highly polluted. Treatment of wastewater is an important thing in current situation. The reason for treating the wastewater is to get the good quality of water, save money by recycling wastewater and the quality must meet the rules and regulations. Treatment of wastewater can be achieved by various methods to remove the physical, chemical, biological impurities and suspended & dissolved particles presents in it. Various advanced treatment technologies have been used to treat the wastewater such as Adsorption, Ion-Exchange, Membrane process, Electo-coagulation etc., in recent days. But, due to some kinds of problems (High reagent requirement, Unpredictable ions generation, Cost of the equipment and reagents etc.) these methods has not been widely used in all kinds of wastewater treatment process in this world. The contaminants presents in the wastewater are very tiny particles (<1nm in size) and it is very complicated to remove that in easy way. Fig 1.1 refers the polluted river stretches in INDIA which have been contaminated due to the excess amount of wastewater disposal into the water bodies without any prior treatment. Huge water treatment plants are extremely expensive to install, takes a lot of space and repeatedly requirements. Also, the existing water filters are too expensive to install in such areas or too bulky to carry. To conquer all these issues, this review paper will discuss about the list of membrane technologies available to treat the industrial wastewater and also the usage of graphene nano particles in the water treatment in recent days.

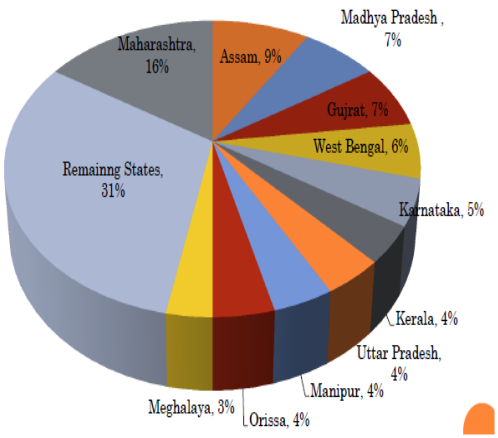

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Fig 1.1 Polluted Rivers Stretches in INDIA

II. GRAPHENE

Carbon is an ever-present material that has been found whereas the period making material and graphene is the allotropy of carbon [2]. Graphene is a nano- tope of carbon, two dimensional honeycomb electrostatic structures with a single layer of atomic thickness (Fig 1.2). The constituent atoms of graphite, fullerenes and graphene share the same basic structural arrangement in that each structure begins with six carbon atoms which are tightly bound together (chemically, with a separation of *0.142 nm) in the shape of a regular hexagonal lattice. Due to the strong hydro feasibility of graphene oxide it should be used for desalination and the water flux can be increased by several orders of valuable compared to the other water treatment process. Graphene is a one atom thick material which conducts the electricity better than silver and conducts the heat better than diamond then it is stronger than steel. It has SP^2 (overlap of 1 S orbital and 2 P orbitals) honeycomb structure and the band gap energy is nearly zero. Also, the graphene has outstanding properties such as more electrical conductivity, very large surface area and thermal stability [3]. In between the graphene sheets, the Van-der Waals force is very strong and the application of graphene material directly to which leads to the difficult. To avoid this force action, graphene oxide can be used and it is common derivative of graphene. In general, the Graphene Oxide membranes are prepared by many methods, such as Vacuum Filtration, Spray Coating, Spin Coating etc [5]. Graphene Oxide (GO) is a single layer material with high oxygen content and its atomic ratio between C/O is in between 2–3 [6]. The harmful gases are restricted to flow inside thin graphene oxide membranes. At that same time, the GO generates homogeneous colloidal suspensions the resulting CMGs are electrically insulating owing to disruption of the 'graphitic' networks. To solve this issue, the electrically conducting Chemically Modified Graphene (CMG) can be used to produce the reduction of the graphene oxide by chemical methods using reluctant such as hydrazine, dimethyl hydrazine, hydroquinone and NaBH4, thermal methods etc [8]. Fig 1.3 shows that the various layers of structures of graphene before and after the synthesis process.

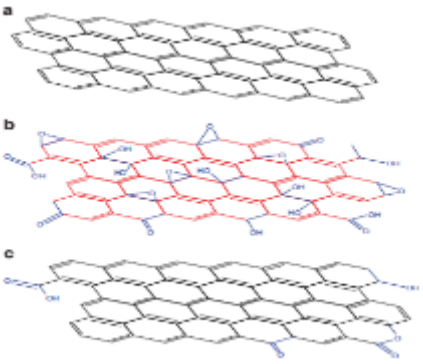

Fig 2.1 Graphene oxide layer

Due to the various needs and uses of the graphene, the industries and global market made up of several attempts to synthesize graphene nano-composites [1]. In water treatment technology, there are two different ways (Photo-catalysis and Adsorption) to use the graphene effectively [4]. Compared to the Photo-catalysis process, Adsorption process gives the various options to remove the contaminated pollutants in the wastewater and produce the adsorbents due to the surface area and useful groups of chemicals in carbon materials with greater efficiency [14, 15].

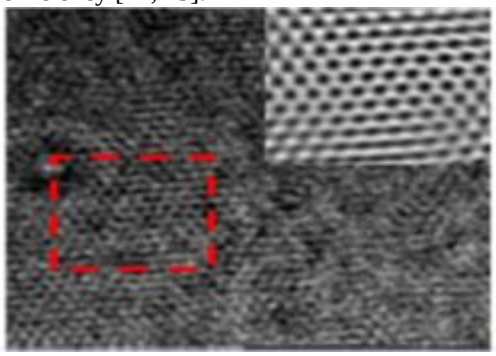

Fig 2.2 Structural Models of a) Single layer Graphene, b) Graphene Oxide (GO) and, c) reduced Graphene Oxide (rGO)

III. TYPES OF MEMBRANE TREATMENT PROCESS & RESULTS

Membrane Adsorption - Adsorption is one of the easiest and cheap processes for the best water treatment by which a substance is transferred from the liquid phase to the surface of a solid by the mass transfer process, and bounded by the interaction of physical and/or chemical properties. The adsorbent (a substance that adsorbs another) is made by linking well-designed groups on the surface and pore wall of polymer membranes; and the target pollutants are selectively adsorbed to the functional group [4]. There are two types of adsorption process 1. Physical Adsorption and 2. Chemical Adsorption. Compared to the physical adsorption process, the chemical adsorption is more popular in heavy metal recovery from the wastewater [4] because of their stronger interaction and very high adsorption capacity. The physical adsorption process is generally occurred in any Solid/Liquid or Gas/Solid system. Due to the van der Waals force attraction the binding of adsorbate (a substance that is adsorbed) on the adsorbent is caused. On other hand, the chemical adsorption can form the single layer (Monolayer) of adsorbent also called as activated adsorbent. Many adsorbents (Coconut shell, Date pits, Seeds, Aloe vera etc.,) have been used to remove the toxic pollutants from the wastewater. The size and shape of the adsorbate were not in the unique and the characteristics of each adsorbent are relatively different from each other [10]. The efficiency of the adsorption is commonly affected by certain parameters such as pH, temperature, size of the particle, initial and final concentration of the adsorbent [09]. To overcome all these issues, the nanotechnology is a new modern method which has been implemented to remove or reduce the concentration of tiny particles (sizes from 1nm to 100nm) presents in any medium. The water purification membranes are applied in the nanotechnology process and these filtration membranes are produced from the nanomaterials such as carbon nanotubes, dendrimers, nano reactive membranes etc [11].

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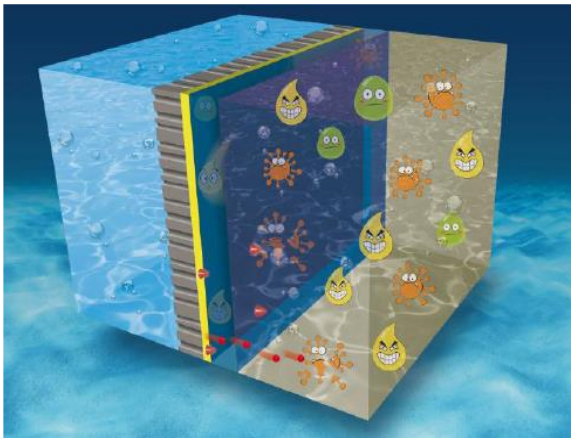

Fig 3.1 Principle of membrane adsorbent

Membrane Nano- Technology –

A membrane is a barrier which allows the pure water to pass and stops the other fine particles. It is a thin sheet or cell layer with different pore size of 0.08-2 µm. This is a thin sheet of material in semi permeable nature which separates the substances when a force is applied. The advantages of this membrane technology are a) high water quality with easy maintenance, b) Stationary parts with compact modular construction, c) Low chemical sludge effluent and d Excellent separation efficiency. In this membrane process, the Nanomaterial and Nanotechnology have emerged as the best possible methods to develop high performance membrane.

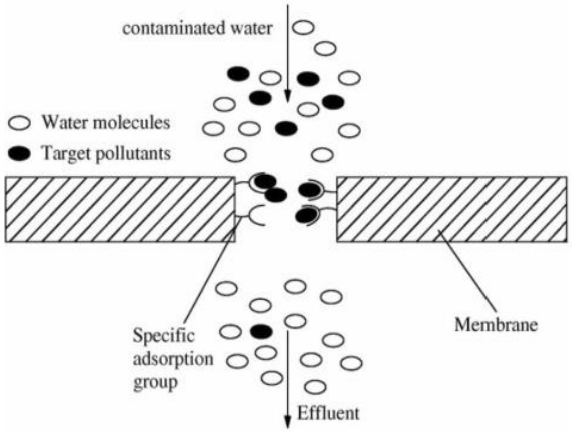

Fig 3.2 Membrane Technology Treatment

This Nanomaterial based membranes, including nanoparticles, nanofibers, 2D layer materials and other nanostructured nanomaterials and their composites are widely used in wastewater treatment technology. Also, the nanomaterial based membranes exhibit extraordinary permeation properties as well as some additional properties like antifouling, antibacterial, photo-degradation etc. This opens up a new avenue to ultra-fast and highly selective membranes for water purification. Membranes in Desalination – The process of removing dissolved salts and other minerals from sea water to obtain water suitable for human consumption, irrigation and industrial uses. There are two major desalination methods a) Thermal Process and b) Membrane Process. The thermal process evaporates the water with the help of energy and condenses it again. It is a simple process to remove the dissolved salts in water by the process of heating and cooling. The membrane process is the major type which utilizes the electric current to separate the water and salt. Also, the electric current will be used to drive ions across a selectively permeable membrane, carrying the dissociated salt ions with it. The energy requirement depends on how much salt is initially present in the water. Consequently, it is suitable for water with initial salt concentrations but too energy intensive for sea water. The main disadvantage of the desalination process is too much of electricity consumption for boiling to treat the water. Instead of Reverse Osmosis (RO) process, the sea water desalination techniques implemented at very low cost [6]. The pressure is used to drive water through a selectively permeable membrane, leaving the salt behind.

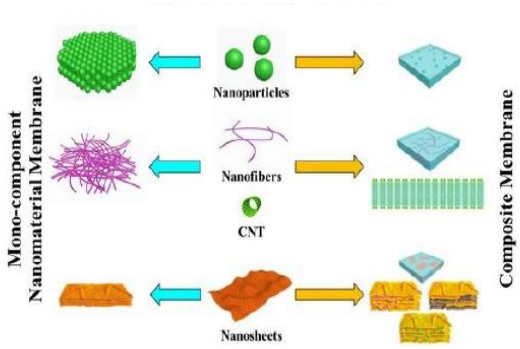

Fig 3.3 Nano-material based membranes

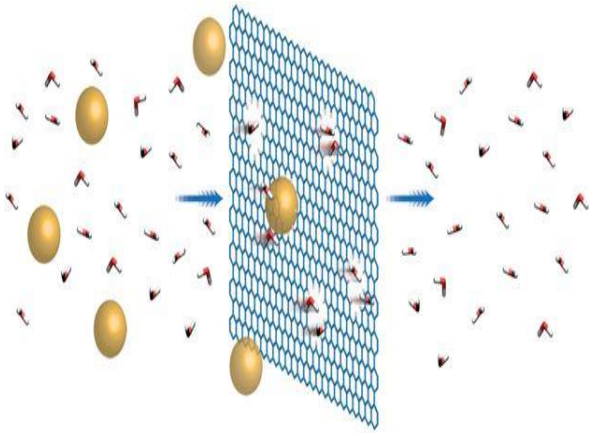

Fig 3.4 RO Membrane with Graphene

Graphene Coated Membrane Process in Water Treatment –

To overcome this issue graphene membranes are used in the water treatment technology [7]. The advanced graphene nanomaterials membranes are the most widely used technology in recent days and it has been classified in to two different structures: 1.Monolayer graphene membranes and 2.Stacked multilayer graphene membranes. The Monolayer graphene membranes are weaker in its mechanical strength and it is too difficult to prepare the nano –pores [13] when compared to the multilayer graphene membranes. Even the

Helium (He) is the very smallest molecule which cannot pass through the monolayer graphene membranes [7]. Graphene oxide coated thin membranes allow the water flow throughout the process and toxic particles have been blocked (Fig 3.5).

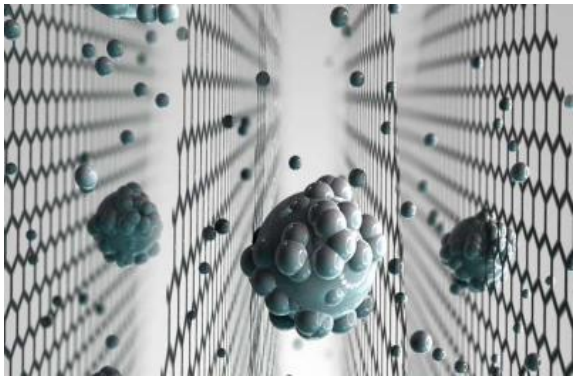

Fig 3.5 Process of membrane coated with Graphene oxide nano-particles

IV. CONCLUSION

In recent days, Graphene and Membrane process are widely used to remove/reduce the toxic contaminants from the industrial and commercial wastewater. Compared to other treatment methods, the membrane process given their excellent efficiency rate of removal of toxic contaminants presents in the wastewater, because of its unique physical and chemical properties. But, membrane fouling is the major problem during the treatment process of wastewater. Anti – fouling reagents may be used to avoid the fouling rates during the treatment process. But, the sizes of toxic metals and contaminants may be varying from 10^{-9} to 10^{-1}mm. Removing these tiny particles are very complicated one and cost of this treatment is very high. Graphene nano - particles can be used to remove the tiny particles presents in the wastewater. The size of the Graphene is very small and it has very large surface area. So the accumulation of contaminants on the surface of Graphene will be very high and the nano – particles also can be removed from the wastewater because of its unique size. This review paper concludes that, the membrane process and Graphene nano-materials are the best technology will be used in the recent days to remove/reduce the toxic metals and contaminants from the industrial wastewater in very low cost

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