A REVIEW REPORT ON USE OF NANOTECHNOLOGY FOR ENVIRONMENTAL REMEDIATION

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ABSTRACT: "Nanotechnology is a field of applied science, focused on the design, synthesis, characterization and application of materials and devices on the nano-scale." It generally deals with materials in the range of 1 to 100 nm. It has a wide range of applications like in medicine (for the targeted treatment of cancer using Magnetic Hyperthermia and the site specific drug delivery), in biotechnology (for the process of Targeted Gene Transfer), in environmental pollution control, etc. Environmental remediation using nanoparticles includes the degradation, sequestration or other related approaches that result in reduced risks to human and environmental receptors posed by chemical and radiological contaminants. The benefits, which arise from the application of nanomaterials for remediation, would be more rapid or cost-effective cleanup of wastes. 1. The iron nanoparticles can help in remediation of contaminated ground water and soil. As iron is non-toxic and is abundant in nature, industries have started using "iron powder" to clean their new wastes. 2. Iron oxide nanoparticles can be used to remove arsenic from water using a magnet. 3. Aerogels are nanomaterials which act as sponge and help in removal of oil in case of oil spills. 4. Nano-membranes can be used for decontaminating air and water. "Nano traps" can be designed for certain contaminants, having specific pore size and reactivity. 5. Nano-filters allow filtering water from contaminants like arsenic and other heavy metals. 6. Gold nano-particles are extremely reactive and so these can be used to carry out various catalytic reactions. 7. This Pilkington Activ glass has a special coating made of nano crystals of TiO_2 and has a self cleansing property.

Keywords: Nanoparticles, Aerogel, Nano-membrane, Nano-filter, Super Hydrophilic filters

1. INTRODUCTION

"Nanotechnology is a field of applied science, focused on the design, synthesis, characterization and application of materials and devices on the nano-scale." It generally deals with materials in the range of 1 to 100 nanometres. It has a wide range of applications like in medicine (for the targeted treatment of cancer using Magnetic Hyperthermia and the site specific drug delivery), in biotechnology (for the process of Targeted Gene Transfer), in environmental pollution control, etc. In many industrialised countries the air is contaminated with various pollutants like sulphides of nitrogen and sulphur, carbon monoxide, chlorofluorocarbons, particulates, etc. The sulphur and nitrogen oxides in the air can generate acid rain that can cause harm to the soil as well other water sources. The majority of the world's water supply has too much salt for human consumption and desalination is an option but expensive method for removing the salt to create new sources of drinking water. Carbon nano tube membranes have the potential to reduce desalination costs. Similarly, nano-filters could be used to remediate or clean up ground water or surface water contaminated with chemicals and hazardous substances.

"Nanoparticles are solid particles with a size in the range of 10-1000nm." The small size of nanoparticles together with their high surface to volume ratio can lead to very sensitive detection. These properties of nanoparticles can help in developing highly miniaturised, accurate and sensitive pollution monitoring devices (nano-sensors). These nanoparticles can also be engineered to interact with a pollutant and decompose it into less toxic species. Environmental remediation using nanoparticles includes the degradation, sequestration or other related approaches that result in reduced risks to human and environmental receptors posed by chemical and radiological contaminants. The benefits, which arise from the application of nanomaterials for remediation, would be more rapid or cost-effective cleanup of wastes. Despite their potential benefits, there is a major concern over the exposure of humans and environment to nanoparticles that may exert deleterious effects. Toxicological risk assessment demands information on both exposure and uptake of

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nanoparticles and their immediate effects once they enter the human system.

II. REMEDIATION AND MITIGATION

Soil and groundwater contamination arising from various industrial processes are a matter of great concern. Affected sites include contaminated industrial sites with lakes and rivers in their vicinity, underground storage tank leakages, landfills and abandoned mines. Pollutants in these areas include heavy metals like mercury, lead, cadmium, etc. and organic compounds like benzene, chlorinated solvents, etc. Nanotechnology can help to develop techniques that would allow for more specific and cost effective remediation tools. Most of the methods employed currently for the removal of toxic contaminants involve laborious, time-consuming and expensive techniques. Nanotechnology can help to develop technologies that can perform in-situ remediation and can even reach inaccessible areas like cracks and aquifers, thus, eliminating the necessity of expensive "pump and treat" operations. Nanotechnology can even be used to develop remediation tools that are specific for a particular pollutant like metals, thus, improving the selectivity as well as the sensitivity of the technique. Drinking water quality and its contamination is another area of concern. Arsenic, Fluoride and Mercury are few of the extremely toxic metals that pose high level of health risk. Remediation methods for fast, effective and economic treatment of water that is polluted with such contaminants is needed with a sense of urgency. It can help to find out new methods for the treatment and purification of water from these pollutants as well as can help in wastewater management and desalination of sea water. Studies are being carried out in an effort to improve the efficiency and overall performance of current nanomaterials. Also, research is underway to understand the fate and transport of nanomaterials in the environment, whether they are persistent and whether they have toxicological effects on various biological systems. Nanomaterials that are being used currently for various treatment strategies include iron nanoparticles, magnetic nanoparticles, gold nanoparticles, etc.

A. REMEDIATION USING METAL NANOPARTICLES

The iron nanoparticles can help in remediation of contaminated ground water and soil. When iron oxidises around contaminants like trichloroethylene (TCE), CCl4, dioxins or PCB's, these organic molecules are broken into simple, less toxic carbon compounds. As iron is non-toxic and is abundant in nature, industries have started using "iron powder" to clean their new wastes.

But the iron particles of micron size become less reactive with time as well these cannot percolate easily into the ground surface and thus, are less effective. So, iron nanoparticles can be used instead of the micron sized particles. Such particles have reactivity 10 to 1000 times more than the normal "iron powder". These nanoparticles have a larger surface area available for reacting with organic contaminants and their small size (1-100 nm) allows them to be more mobile, so they can be transported effectively by the flow of groundwater. Also, nanoparticle - water slurry can be injected to the contaminated plume where treatment is needed. **Fig.1.** depicts the process

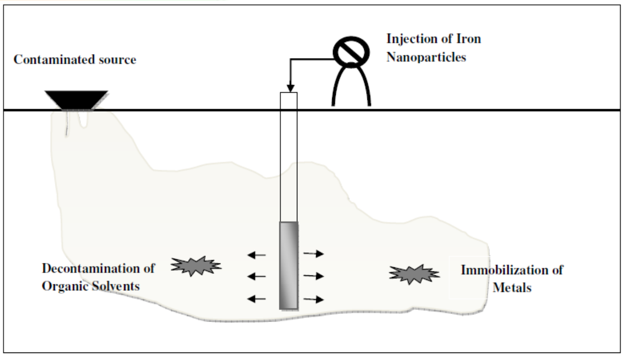

Fig.1. Nano-scale iron particles for in-situ remediation

Iron at the nano-scale can be synthesized from Fe (II) and Fe (III), using borohydride as the reducing agent. They have a typical core shell structure. The core consists primarily of zero-valent or metallic iron whereas the shell is formed as a result of oxidation of the metallic iron. The iron nanoparticles are generally preferred for remediation because they have large surface area and have more number of reactive sites than micro-sized particles. It also possesses dual properties of adsorption and reduction as shown in **Fig.2.**

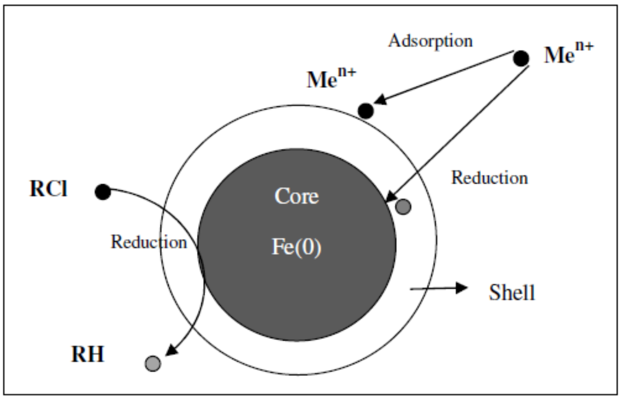

Fig.2. Schematic diagram of Iron nanoparticle

Iron oxide nanoparticles can be used to remove arsenic from water using a magnet. Arsenic sticks to rust i.e. mainly iron oxide, which is generally magnetic so it can be removed from water using a magnet. Nano-sized rust about 10 nm in diameter, with its high surface area, improves removal efficiency and uses less material. This technique is useful over other arsenic removal techniques, as it is simple and doesn't use electricity.

B. REMEDIATION USING AEROGELS FOR OIL SPILLS

Aerogels are nanomaterials which are modified with hydrophobic molecules to enhance interaction with oil. They act as sponge: once the oil has been absorbed, the "oil soaked sponge" can be removed easily. These aerogels have large surface area so, they can absorb upto 100 times their weight of oil.

The hydrophobic aerogel floats on the surface of water contaminated with oil and selectively absorbs oil. The oil-saturated aerogel is then removed by mechanical means. Hydrophobic absorbant materials like hydrophobic cellulose and wood waste have been developed.

An aerogel-CF_3 combination has been tested for the absorption of crude oil from water at an oil-aerosol ratio of 3.5:1 respectively. In **Fig. 3**:

1. The 30% sample shows clear, colourless water at the bottom and the aerogel with all the oil absorbed at the top.

2. The 10% sample also shows similar result. While the 1.5% sample shows all the oil absorbed into the aerogel, however, some colours and solids are seen in the water.

3. The 0% sample i.e. unmodified silica aerogel shows the oil floating on water, aerogel mixed in and colours and solids in the water.

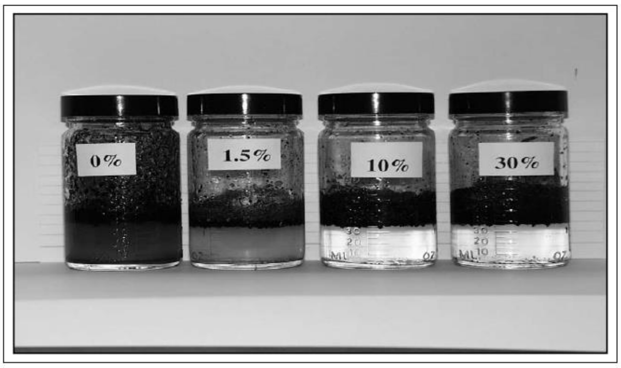

Fig.3. 30%, 10%, 1.5% and 0% CF_3-aerogel mixed with crude oil and water

C. REMEDIATION USING NANO-MEMBRANES AND NANO-FILTERS

Nano-membranes can be used for decontaminating air and water. "Nano traps" can be designed for certain contaminants, having specific pore size and reactivity. Researchers at "University of California", Los Angeles have developed nano-membranes in the form of a new Reverse osmosis (RO) membrane for seawater desalination and waste water remediation. The membrane consists of "uniquely cross linked matrix" of polymers and nanoparticles designed to draw in water ions but repel contaminants. This is possible due to the nano size of the holes that form the membrane, which are "tunnels" that only allow water to pass.

D. USE OF SUPER-HYDROPHILIC FILTERS

Nano-filters allow filtering of water from contaminants like arsenic and other heavy metals. Example – "The Lifesaver Bottle". This bottle has a "super-hydrophilic filter" inside that can block materials up to 15 nm in size that includes virus and bacteria. The filter is inserted in a plastic bottle and allows cleaning of contaminated water on-site.

The bottle's interchangeable filter can purify between 4,000 and 6,000 litres of water. The carbon filter used in the bottle does not require chemicals. The process of filtering water takes 20 seconds, allowing for 0.71 litres of water to be filtered. Once a filter has reached its limit, it will not allow contaminated water to be drunk. This bottle has been used by soldiers for drinking water.

To filter the water, contaminated water is filled in the back of the bottle and the lid is screwed. The lid has a built in pump which is operated manually with hand. The pumping action forces the contaminated water through the nano-filter and safe drinking water collects in another chamber in the bottle. The user can then open the top of the bottle from which safe drinking water comes out. **Fig.4.** shows parts of a Lifesaver bottle

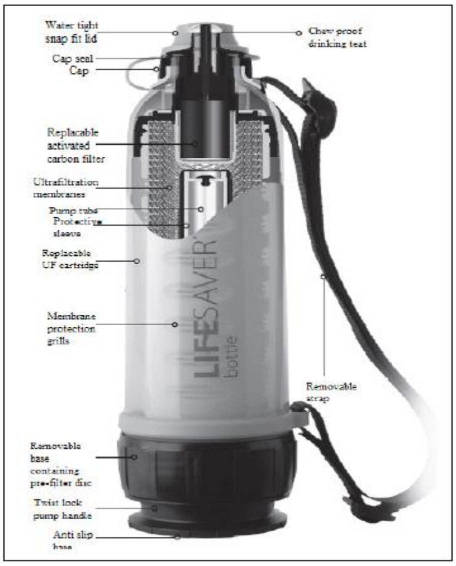

Fig.4. Lifesaver Bottle

E. USE OF CATALYTIC GOLD

Catalysis involves the modification of a chemical reaction rate, mostly speeding up or accelerating the reaction rate by a substance called catalyst that is not consumed throughout the reaction. Usually, the catalyst participates in the reaction by interacting with one or more of the reactants and at the end of process it is regenerated without any changes.

Gold is generally an inert material and it does not react with chemicals including strong acids and bases. But at nano-scale gold becomes extremely reactive and so it can be used to carry out various catalytic reactions. Nano-gold can act as an extremely efficient catalyst for control of pollution.
For example: It can be used to remove carbon monoxide from room air under ambient conditions. Also, Silver Platinate (Au-Pt) co-catalyst can breakdown TCE 100 times faster than a catalyst that is made up of other earth materials like Platinum (Pt) and Palladium (Pd).

F. ACTIV GLASS

The Activ Glass from Pilkington has a special coating made of nano-crystals of TiO_2. Here, TiO_2 is found in the form of a thin layer of 2-20 nm deposited by high-temperature gas phase. The coating is hydrophilic (water contact angle is 20 compared to normal soda glass which has contact angle of 40). On the deposition of dirt the contact angle of the surface increases, but is then reduced on irradiation. TiO_2 is not used up in the reaction and acts as a catalyst that decomposes organic materials to CO_2. The process of coating is shown in **Fig. 5.**

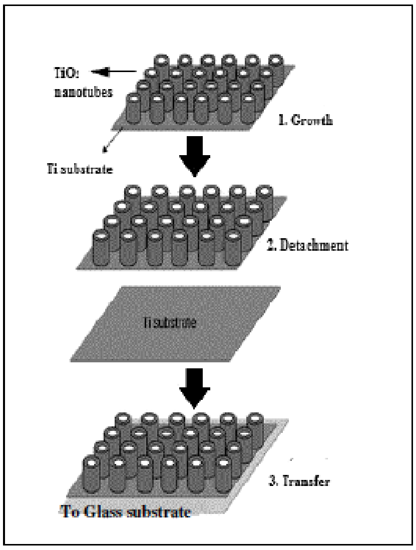

Fig.5. TiO_2 coating process on Glass Surface

The TiO_2 coating on the glass when exposed to daylight reacts in two ways as shown in **Fig.6.** :-

1. Breaking down organic dirt

Using a 'photocatalytic' process, the coating reacts with ultra-violet rays present in natural daylight to break down and decompose organic dirt.

2. Washing dirt away

The second part of the process happens when rainwater hits the glass. The glass is 'hydrophilic' which means that instead of forming droplets, the water spreads evenly over the surface and as it runs off takes the dirt with it. Compared with conventional glass, the water also dries off very quickly reducing unsightly 'drying spots'.

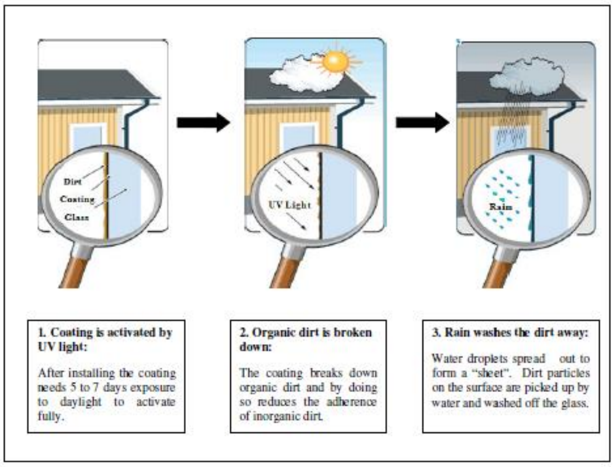

Fig.6. Working of Pilkington Active Glass

III. ADVANTAGES OF NANOPARTICLES

Nanoparticles have many advantages over the macro scale particles that can be used for Environmental Remediation. Some advantages are:

1. The nanoparticles of iron when used for treatment of the contaminant site, gives out less amount of hazardous waste during the treatment process.

2. The aerogels can have high porosity, low density and are hydrophobic that helps them to absorb oil from water in the case of oil-spills.

3. Nano-membranes repel organics and bacteria, due to the chemical composition of the nanoparticles that are embedded in the membrane as well as compared to conventional RO membrane, these are less prone to clogging, that increases the lifetime of membrane that is an economic benefit.

4. The Lifesaver bottle can filter out objects bigger than 15 nanometres - including viruses, bacteria, cysts, fungi and heavy metals. Also, the bottle does not use any of the foul tasting chemicals like iodine or chlorine for the treatment of water neither it requires any power for working.

5. Gold nanoparticles are cheaper than other materials like Platinum and Palladium as well as gold is easily available as compared to Pt and Pd.

6. Unique coating on Pilkington Activ glass cannot be worn away or rubbed off –lasts the lifetime of the glazing itself in normal use, reducing cleaning and maintenance costs and gives windows a better appearance for longer.

IV. DISADVANTAGES OF NANOPARTICLES

Some drawbacks of nanoparticles are given below:

1. There is little information or research being conducted based on the potential toxicological effect the iron nanoparticles might pose. There is insufficient data on the potential for accumulation of nanoparticles in environmentally relevant species and there have been few studies on the effects of many nanoparticles on environmental microbial communities.

2. Aerogels are quite expensive as well as better and detailed study needs to be carried out to increase and improve their use.

3. The Lifesaver bottles can remove the microbiological contamination however there will be an amount of dissolved salts that cannot be removed.

CONCLUSION

The aim of this study is to give an overall perspective of the use of nanoparticles to solve potential issues such as treatment of contaminated water for drinking and reuse more effectively, than through conventional means.

The use of nanotechnology for the remediation of the environment has the potential to clean-up large contaminated sites in-situ, that can help in reducing clean up time and eliminate the need for removal of contaminants and hence reduce the contaminant concentration to near zero.

As given above, a great degree of care needs to be taken if it has to be implemented in real life in order to avoid the harmful effects. With the developing of the different aspects of nanotechnology, the various environmental impacts will also need to be considered. Such considerations may include models to determine potential benefits of reduction or prevention of pollutants from industrial sources.

Nanoscience technology also holds great potential for the continuous improvement of technologies regarding environmental protection. The above study gives further evidence to this issue and it has also tried to address what all the potential environmental impacts of the technology might be.

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