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Meticulous Review on Potential Nano – Sized Catalysts for Air and Water Purifiers

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ABSTRACT

This review focuses on the usage of nano–sized catalysts in eco–remedial for polluted air and water. The metal nanomaterials, metal oxide-based nano-photocatalysts, and non-metallic nanomaterials have the proficiency for inactivating viruses and purifying air. These nano catalysts have more active sites at their surface in comparison with normal materials and hence more effective catalysts. In eco-remedial, the nano–sized catalyst provides increased possibility for effective deletion of contaminants and organic impurities from air and water. Nano–sized catalyst in several forms/structures, like nano–sized particles, fibres, wires, tubes etc., serves as adsorbents and catalysts which are used for the elimination of toxic gases in air, polluted elements, biological contaminants and organic materials such as viruses, bacteria, parasites and antibiotics. Nano catalysts enhance the chemical reaction speed and can make the reaction more effective and more efficient. Nano–sized catalyst provides an improved act in eco remedial measures than other regular methods due to their high surface area and their accompanying great reactivity. Numerous nanosized materials were synthesized and designed for environmental protection purpose. Novel developments in the making of new nano–sized catalyst and procedures are stressed for action of - intake water and industrialized wastewater polluted by poisonous radionuclides, metal ions, organic and inorganic solutes, bacteria and viruses and action of air. There are two important ways through which nanotechnology is being used to reduce air pollution: a) nano-sized catalysts, which are constantly being improved and widely used in various areas and b) nano-structured membranes, with highly active adsorbing and absorbing sites.

***Keywords**: Nano – Sized Materials, Catalyst, Eco Remedial Activities, Air Purifier and Water Purifier.*

1. Introduction

Environment pollution is undoubtedly one of the most important concerns faced by today's society. The new technologies based remedial measures for pollutants in the air and water are constantly being investigated [1]. Particle material, heavy metals, pesticides, herbicides, fertilisers, oil spills, poisonous gases, industrialized wastes, waste, and organic compounds are only a small fraction of the numerous sources of pollutants, of concern [2–4].

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Since various categories of resources can be used in eco remedial, an extensive variety of methods can be used. Innovative investigations have concentrated on the usage of nano–sized resources for the making of novel eco remedial methods [5], as the capture and degradation of eco pollutants can be problematic owing to the size of the combination of dissimilar chemicals, great instability, and small reactivity. Because of the peculiar physical properties of nano scale materials, nanoscience has developed a lot of care in recent periods.

Nano materials need a higher surface-to-volume ratio than their bulkier counterparts, resulting in improved reactivity and hence greater effectiveness. Furthermore, nano materials have the potential to take advantage of unique surface chemistry, allowing them to be attached by functional groups that can target exact molecules of attention (contaminants) for effective remedial. Furthermore, deliberate change of nano materials' physical characterizations can impart extra beneficial properties that effectively affect the material's efficacy for pollutant remedial. The electronic, optical, and chemical properties of nanoparticles are significantly changed from bulk materials [6]. The nanomaterial's rich surface alteration chemistry, as well as its tuneable physical parameters, provides major advantages over traditional methods for dealing with environmental pollution [7]. As a result, methods combining many dissimilar resources to obtain exact required characteristics from each of their materials can be additionally effective, careful, and steady than approaches based on an "only nano field". As opposed to using nanoparticles alone, adhering nano – sized materials to a support may be another way to improve the material's strength [8, 9]. Functionalizing materials with chemicals that target particular pollutant particles of attention can increase the material's properties and efficiency [10]. It's critical that the products used to clean up waste don't become another pollutant after they've been used. Consequently, biodegradable materials are highly attractive for this purpose [11].

The usage of decomposable resources could not only rise user trust and approval of a skill by removing need to dispose of material waste after management, then it may also provide an environmentally friendly and harmless option targeting pollutant remediation in the environment. Also, novel skills that trust happen the arrest of pollutants on a target-specific basis are particularly appealing, as they can overcome low efficiency caused by off-targeting [12]. As a result, numerous studies have concentrated on integrating nanotechnology concepts with chemical and physical surface alteration of materials in order to achieve engineered resources that can solve many of the difficulties associated with contaminant remediation [13]. Certain main tasks that must be measured when emerging novel nano – sized sources for eco remedial include aim particular capture, price, less equipment for production, green chemistry, less toxic, biodegradability, recyclability, and possible for retrieval after usage.

Despite the potential benefits of the nano- sized sources stated above, particles are fundamentally unstable under normal conditions, necessitating the use of special nano scale formulation techniques. To avoid agglomeration, improve mono dispersity, and increase stability, additional operations are needed. Another consideration that may restrict their use is the potential toxicity of metal nano–sized sources used in the remedial procedure, as well as by-products and cost of retrieval from the remedial place [14]. This is why, in order to progress worthy nano – sized source accomplishment of addressing eco problems, a thorough consideration of the material platforms, their construction procedure, and enactment control is needed [15–17].

The ultimate goal of this analysis is to offer a broad summary of current growths in the making of functional nano - sized sources and nano - composites for eco – remedial on a wide range of contaminants. Absorption, adsorption, chemical reactions, photo catalysis, and filtration are only a few of the many ways the contaminant can be eliminated [18–20]. The nano-adsorbents such as activated carbon, carbon nanotubes, grapheme, manganese oxide, zinc oxide, titanium oxide, magnesium oxide, ferric oxides etc., were employed in removal of heavy metals from wastewater. Also nano-catalysts namely electrocatalyst, Fenton based catalyst, chemical oxidant etc., were utilized in removing organic and inorganic contaminants [21].

To the best of our knowledge, no common sorting exists for the various types of sources that can be used for eco - remedial. As a result, the emphasis of this review is on three types of nano materials that have been identified in the collected works: inorganic, carbon-based, and polymer-based materials. The following sections will investigate each of these groups and their applications. Different types of nano–sized sources should be utilized aimed at methods labelled in **Fig. 1**. Some of the challenges in using nanomaterials are: collection of nano materials after treatment, prevention of agglomerationand leakage of new contaminations.

2. Nano–sized catalyst act as water and air purifier

Nano materials used in water and air treatment can be categorised in a number of ways, depending on their application size and purpose. Nano materials can be categorised into three categories based on their application: nano – sized sources for water purification, nanotechnologies for water remedial activity, and bio-active nano sized materials for water disinfection [22]. Nano materials are known as nano-sorbents, nano-catalysts, and redox active nano- sized materials, nano-structured and nano-reactive membranes, and bio-active nano-sized materials based on their use in water remediation [23].

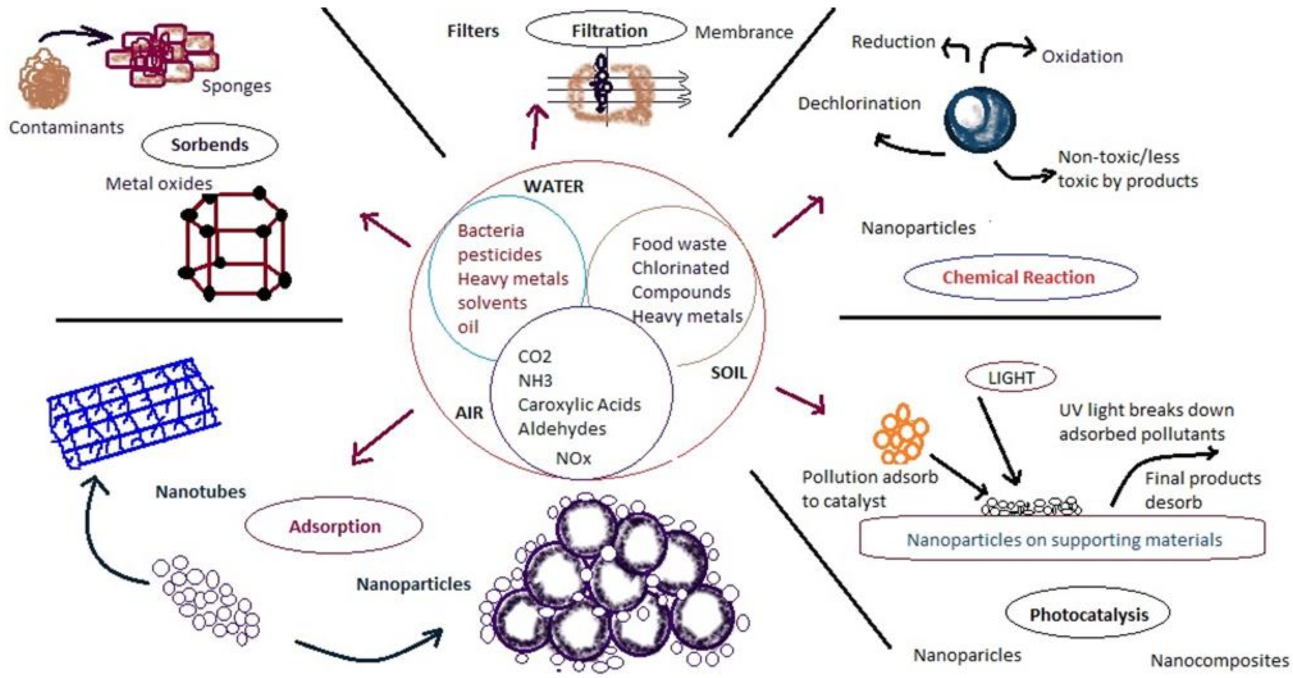

Fig. 1. Eco – remedial activities of Nano – sized sources.

2.1 Nano - sorbents

Nano-sorbents are nano-sized materials made of organic and inorganic materials with a strong ability to absorb materials through physical or chemical interactions. Nano - materials have slightly higher surface area than traditional materials, which results in a substantial increase in sorption potential. It is often likely to improve the absorbent attraction for aimed materials by adding chemical groups to nanoparticles. Because of its good balance and cost-effectiveness, activated carbon is broadly used sorbent resources. Furthermore, the prospect of eliminating a wide variety of pollutants has attracted the scientific community's interest in various carbon-based resources and metal oxides. Carbon nanotubes (CNTs), Self-Assembled Monolayer on Mesoporous Supports (SAMMS), and zeolites have also sparked particular interest among them. The schematic representation of nano – sorbents are depicted in **Fig. 2**. High surface area γ-alumina adsorbents, nanoscale zerovalent iron, dendrimers, ferritin, Metallo porphyrinogens, titanium dioxide nanotubes etc., are also effective nano–sorbents. Recently, a natural biodegradable, renewable resin containing abundant hydroxyl and carboxylic groups, on iron oxide magnetic nano-particle's surface was used [24].

2.2 Carbon nanotubes (CNTs)

Several studies have shown that carbon nanotubes (CNTs) have more advantages than easily obtainable granular activated carbon (GAC) [25]. Su and Lu found that CNTs had greater adsorption and desorption capacities than GAC filters when used to extract natural organic matter (NOM) from water systems [25]. This ability, combined by minor reactivation heat needed and CNTs' minor weight reduction, suggests that this technology may be more cost-effective than GAC for removing NOM from water systems [25, 26]. Well aligned carbon nanotubes consistin of highly ordered, vertically aligned arrays of individual CNTs show superior properties. Extra pollutant eliminations, such as cyano - bacterial poison, showed CNTs to have superior sorption capacities to GAC. Yan et. al., showed that basic surface area and exterior diameter of CNTs determine the amount of MC adsorption [27]. The diagram for Carbon nanotubes-based filtration is given in **Fig. 3**.

2.3 Zeolites

Zeolites are hydrated alumina silicate raw materials with a three-dimensional extremely systematic crystal structure made up of aluminium, oxygen, and silicon, with alkali or alkaline-Earth metals surrounded in the gaps among them [28]. Zeolites are primarily used as metal ion sorbents and ion-exchange media. Furthermore, zeolites' high surface area, which makes them excellent sorbents, is accompanied by great mechanical and chemical resistance, which justifies their usage as a catalyst and ion-exchanger [29]. The science field is actively moving toward constructing novel zeolite matrix frameworks in order to create new materials. Nonetheless, the International Zeolite Association (IZA) Structure Commission has authorised

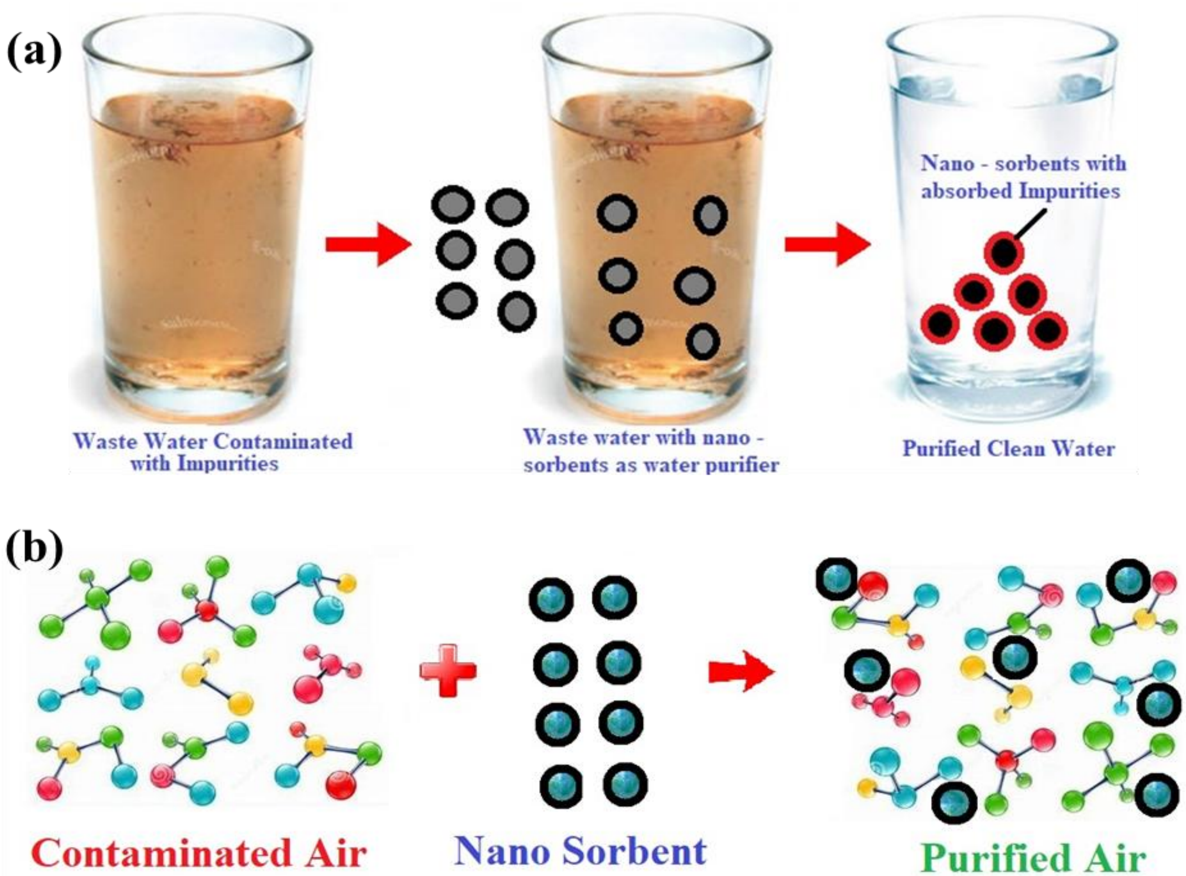

Fig. 2 (a): Nano – sorbents as water purifier, (**b).** Nano – sorbents as air purifier.

231 system style codes (IZA-SC). Zeolites sizes ranging from 1 to 100 nm can be produced using traditional synthesis methods. Nano scale zeolites (dimensions ranging from 5 to 100 nm) have been effectively developed using modern synthesis methods [30, 31]. Song et. al., related the possible adsorption of commercial ZSM-5 and nanocrystalline ZSM-5 with a Si/Al ratio of 20 in 2004. They discovered that the ZSM-5 sample with a speck size of 15 nm adsorbed about 50% additional toluene than the other ZSM-5 samples, due to toluene adsorption on the external surface [32]. Song et. al., studied the adsorption of toluene and nitrogen dioxide on nanocrystalline NaY Zeolites once more [33]. They observed at two samples made with Si/Al ratios of 1.8 and particle dimensions of 23 and 50 nm, as well as a viable NaY sample for comparison. Song et. al., showed by via nano-crystalline samples, the adsorption capacities for toluene and nitrogen dioxide deduction increased by approximately 10% and 30%, respectively, when compared to viable NaY [34]. Nanocrystalline Zeolites based filtration process is shown in **Fig. 4**.

2.4 Nano - sized catalysts and Redox Active Nano – sized materials

A nano-sized catalyst is a source that has catalytic characteristics as well as at least one nano-scale element, external or internal. Nano–sized catalysts have a higher catalytic activity due to their small scale. Because of the porous nanostructure of the material, it consumes high surface to volume ratio, which means there is extra surface area obtainable to relate with the reactants. Combining nano-sorbents with catalysts is also a promising choice [35]. Because of the adsorption possibilities of the particulates, density of impurity at particle surface promotes the contaminant's decomposition by the catalyst throughout this situation.

Titanium dioxide (TiO_2) is possibly the most common catalyst among the many choices. As light absorption causes a charge separation, a photo catalytic reaction occurs [36]. The TiO_2 particle is extremely unstable in this state, and it may react with a variety of contaminants adsorbing on the surface, as well as water, to produce the extremely reactive hydroxyl radical [37]. good characteristics can be attributed to its comparatively extraordinary photo activity under UV radiation, great strength, small price, and human and eco safety [38]. The most common forms of TiO_2 are anatase and rutile,

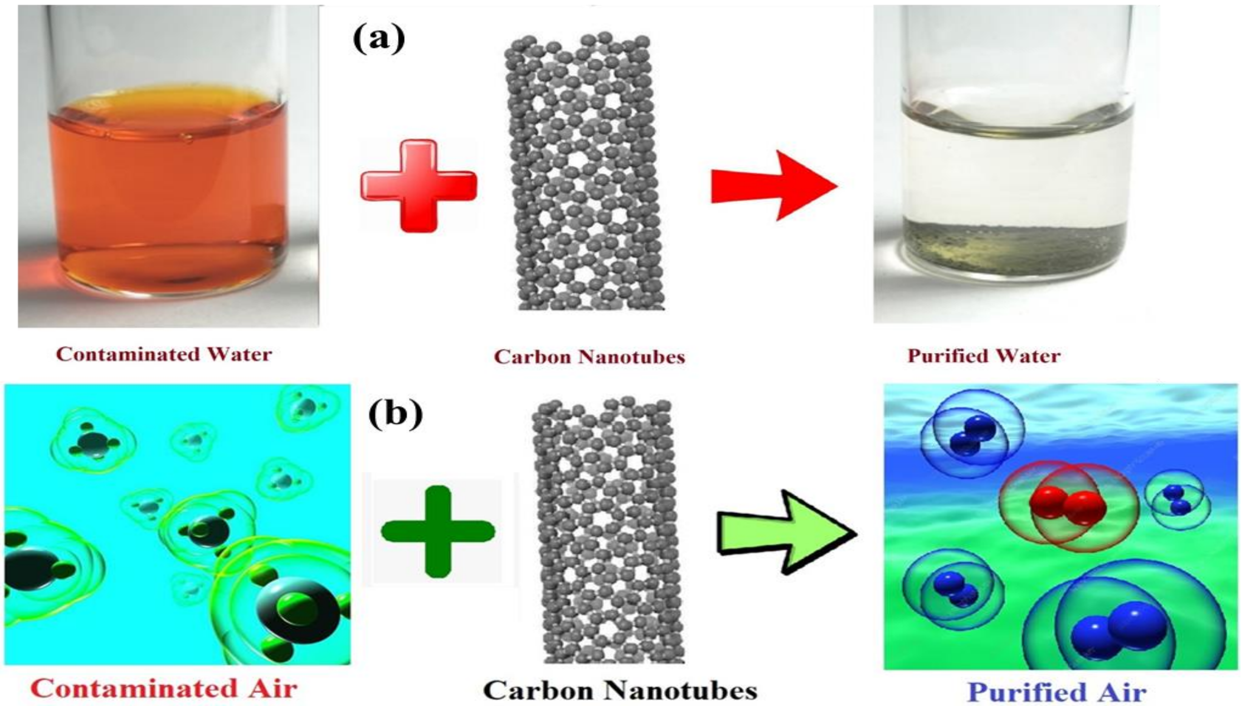

Fig. 3 (a): Carbon nanotubes as water purifier, **(b).** Carbon nanotubes as air purifier.

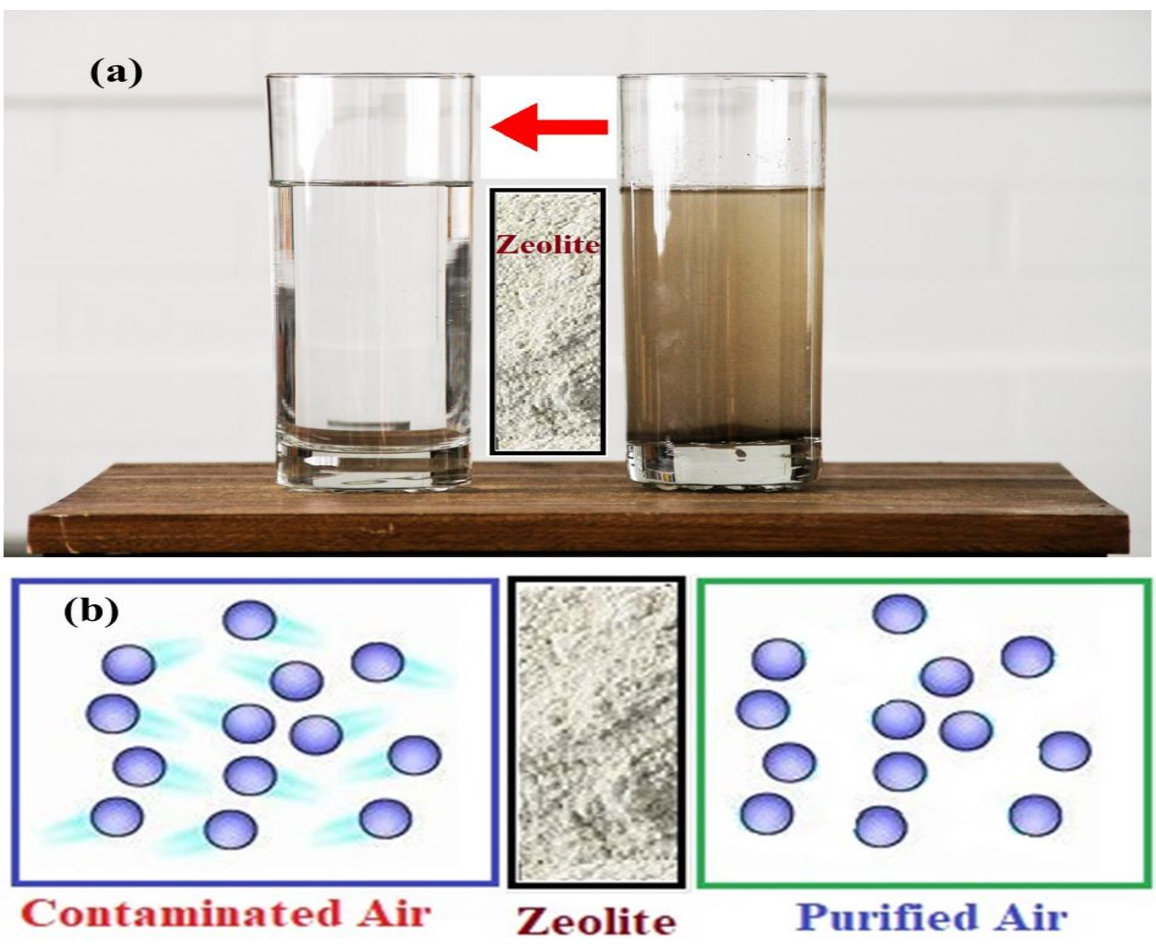

Fig. 4 (a): Zeolites as water purifier, **(b).** Zeolites as air purifier.

with the rutile form having a crystalline size that is often superior to the anatase phase [39]. The third structural type, Brookite, is an orthorhombic arrangement that remains seldom used [40]. TiO_2 has extensive history of usage as a straight powder use into a solution [41]. Recent research has shown that when TiO_2 is used in nanoparticle form, its photoactivity is significantly increased [42]. The importance of filtration of the catalyst after treatment has restricted the use of TiO_2 nanoparticles on a large scale. This drawback, which leads to a high cost, can be resolved by immobilising TiO_2 nanoparticles on a variety of substrates [43, 44]. Furthermore, TiO_2 has been extensively demonstrated to be highly efficient in the no selective degradation of carbon-based contaminants. However, photo catalytic activation of traditional TiO_2 requires UV radiation (k 385 nm for anatase phase and 410 nm for rutile phase) to resolve its large band gap (*3.2 and 3.0 eV for anatase and rutile phase, respectively) [45, 46]. As a result, single photons with a great energy, such as UV photons, can initiate the reaction. This suggests that a minor portion of sun light is suitable for TiO_2 photo - catalysis. In fact, only 5% of the solar energy reaching the is in ultraviolet region [47]. The relative degree of branching of the reactive electron–hole pairs into interfacial charge-transfer reactions influences photo catalytic performance of TiO_2 [48]. Doping has proved to be promising technique for enhancing the catalyst's optical properties and lowering the band gap photo - catalytic activity. The use of sun radiation for treatment could be possible with this method. Doping by transition metal ions, for example, may add extra energy levels to a semiconductor's band gap. As a result, transferring electrons from one of these stages towards conduction band takes less photon energy than in an undoped catalyst [38]. Photo catalytic process of TiO_2 nanomaterials-based method is presented in **Fig. 5**.

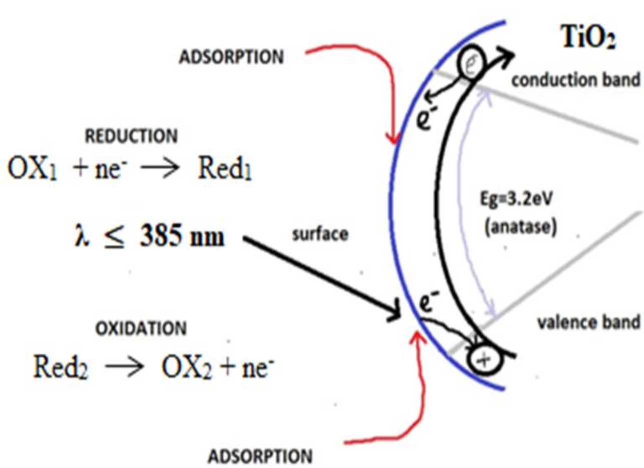

Fig. 5. Photo - catalytic procedure of TiO_2

2.5 Nano - structured and Reactive Membranes

Membrane procedures are becoming increasingly vital in water cleansing as traditional water treatment methods such as sedimentation, flocculation, coagulation, biological treatment, and activated carbon are unable to effectively eliminate a widerange of pollutants [22]. Due to developments in the area of nano materials, water cleansing using water cleansing skill has made significant progress. Nano filtration can be traced back to the 1970s and 1980s, when "loose RO" membranes were formed as a bridge among ultra - filtration and reverse osmosis [49, 50]. Although the asset price of a nano - filtration plant is similar to that of brackish water reverse osmosis plant, the energy savings from using nano - filtration as a substitute of reverse osmosis can be important [49]. The properties of the membrane for the various membrane processes are summarised in **Table 1**. Nano-structured and Reactive Membranes enabled filtration is shown in **Fig. 6**. The dechlorination of 2-chlorobiphenyl in the aqueous phase by a reactive membrane system. Fe/Pd bimetallic nanoparticles (NPs) were synthesized (in-situ) within polyacrylic acid (PAA) functionalized polyvinylidene fluoride (PVDF) membranes for degradation of polychlorinated biphenyls (PCBs). polyvinylidene fluoride (PVDF)/polyacrylic acid (PAA) membranes for trichloroethylene (TCE) and PCB dechlorination. These functionalized membranes have been used as the porous supporting materials to control NP synthesis [51].

2.6 Nano - filtration through membrane

Nano-filtration is basically a fluid level procedure somewhat related to reverse osmosis. As fluid remains allowed towards permit through the membrane, certain inorganic and organic solvents could be disallowed then efficiently filtered. This is achieved via diffusion through membrane at a pressure that is less than in reverse osmosis but substantially higher than in ultra-filtration. Capability to isolate small ionic and little molecular weight species was then greatly enhanced by the advent of thin film composite membranes. The method of nano filtration was then verified as a accepted one. It should be evident that membranes act a critical part in a treatment's efficiency and applicability [52]. The rapid advancements in membrane synthesis and processing have resulted in the widespread use of membrane processes for a variety of applications. Nano-filtration's broad variety of applications make it appealing for groundwater remedial activity, surface remedial, water potable treatment, and purification. Removal of cations, natural organic matter, organic pollutants, biological toxins, nitrates, and arsenic from drinkable water has already been investigated [53].

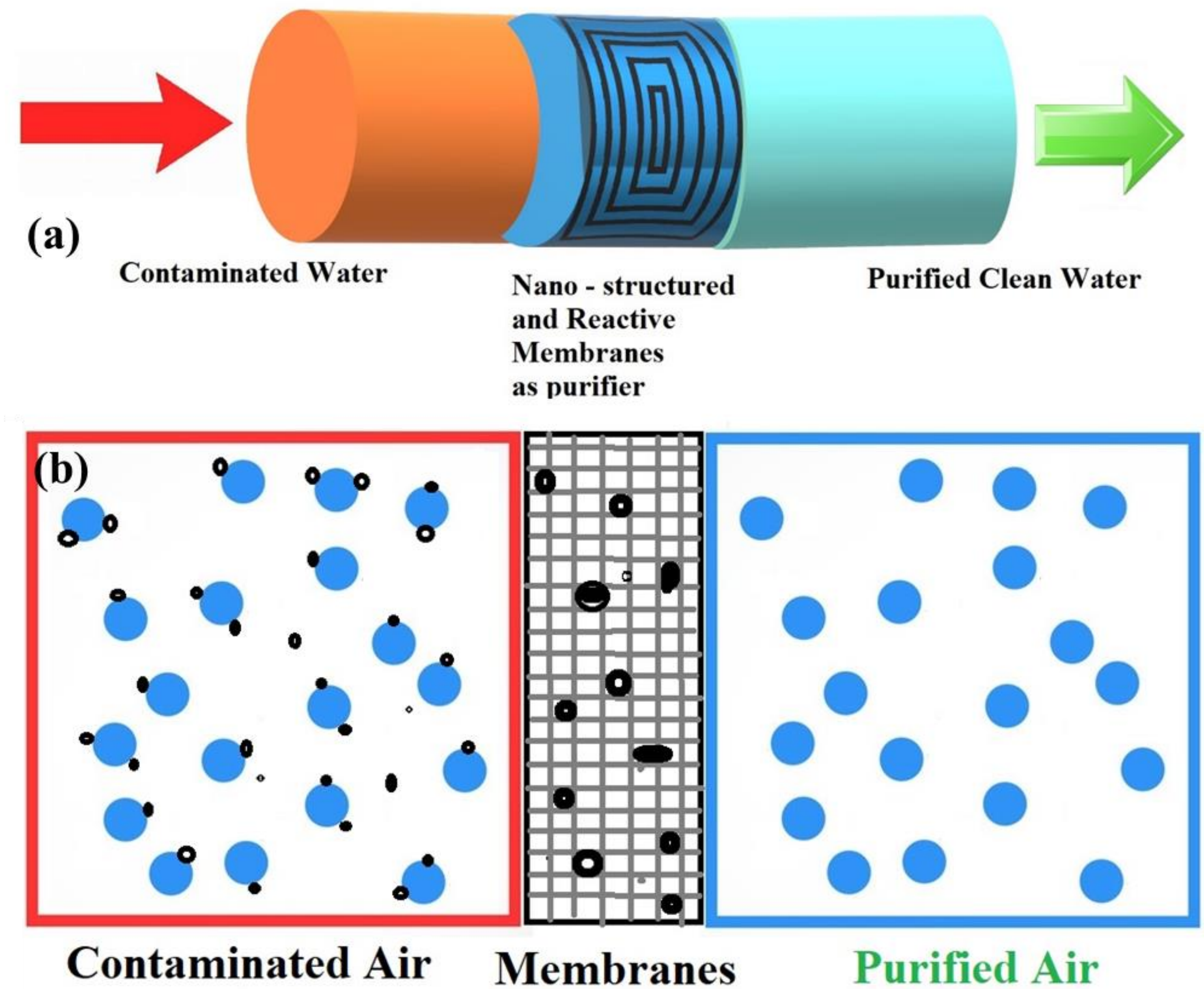

Fig. 6. (a): Nano - structured and Reactive Membranes as a purifier, **(b):** Nano - structured and Reactive Membranes as a purifier

Micro-filtration (MF), ultra-filtration (UF), and nano-filtration (NF) are the most widely used membrane methods for water and wastewater management [54–55]. Nano filtration and reverse osmosis (RO) are more widely used for purification and water salvage [56]. In comparison to the concept of nano-filtration, the membranes were engineered with nano-sized structures [57]. Suspended cells, bacteria, macromolecules, viruses, colloids, organic compounds, and multivalent ions may all be rejected by using them. Nano reactive membranes, which use functionalized nanoparticles to decompose contaminants and help the filtration process, are another form of nanotechnology membrane that could be very effective in water purification.

2.7 Bioactive Nanoparticles

In the field of water disinfection, nanotechnology may also make a significant contribution. The need to reduce the threat of waterborne infection is a hot topic right now. Infectious diseases are thought to be responsible for almost 40% of the world's 50 million yearly deaths [58]. Chlorine is often used to treat drinking water, and it also offers residual protection against the re-growth of bacteria and viruses for a period of time [59]. Unpleasant flavour and odours of chlorinated water, as well as the potential for harmful disinfection by-products, negate the advantages in many respects [60]. As a result, nano-Science could be a viable choice for creating new chlorine-free bio codes. Metallic and metal-oxide nano-materials, particularly silver, and titanium dioxide catalysts for photo catalytic cleansings are among the most promising antimicrobial nano

Table 1. Different Material for removal target

Material	Applications (removal Target)
Ag	Water disinfectant—*E.Coli*
TiO_2	Water disinfectant, soil—MS-2 phage, E. coli, hepatitis B virus, aromatic hydrocarbons, biological nitrogen, phenanthrene.
Metal-doped TiO_2	Water contaminants—2-chlorophenol, endotoxin, E. coli, Rhodamine B, Staphylococcus aureus
Titanate nanotubes	Gaseous—Nitric oxide
Binary mixed oxide	Water—Methylene blue dye
Iron-based	Water—Heavy metals, chlorinated organic solvents
Bimetallic NPs	Water, soil—Chlorinated and brominated contaminants
ZnO-doped TiO_2	Azo Dye
N-F-codoped TiO_2	Microcystin-LR
Nitrogen (N)-doped TiO_2	Methylene blue, Azo Dye
Fe(III)-doped TiO_2	Phenol
Carbon-Nanotube-TiO_2	Organic, inorganic and biological agents
Silica-supported TiO_2	Aromatics compounds
NaY zeolite-supported nZVI	Potassium acid phthalate (KHP)
Activated carbon	Arsenic
Pd-nZVI	Trichloroethene
TiO_2 nanowire membrane	Humic acid and TOC removal

materials [61, 62]. Because of their high toxicity to a broad variety of microorganisms, numerous investigations have conducted using silver (Ag) ions and silver compounds as biocides [63, 64]. Nonetheless, tests on nitrifying bacteria revealed that the result of Ag-NP is greater than that of liquefied Ag^+ or AgCl colloids [65]. Ag-NP has been suggested to reach the bacterial membrane of Escherichia coli and other gram-negative bacteria [66, 67]. Furthermore, experiments on Gram-positive bacteria revealed that the bactericidal characteristics of silver nanoparticles are influenced by their size and shape. Morones et al. verified the bactericidal characteristics of Ag nano - sized materials by sizes ranging from 1 to 100 nm in 2005, finding only nano - materials have a straight contact with bacteria have a diameter of 1–10 nm [67]. Pal et al., on the other hand, looked at how Gram-negative bacteria interacted with silver nano – sized materials of various shapes. They discovered that the shape of these nanoparticles has a significant impact on their bactericidal influence. As compared to spherical and rod-shaped nano - materials, as well as Ag^+ (in the form of $AgNO_3$), truncated triangular silver nanoplates with a (111) lattice plane as the basal plane, showed the best biocidal action [68]. Bioactive nanoparticles have also been studied for their stability and immobilisation in various matrixes. For example, Dankovich and Gray investigated percolation of pathogenic bacteria through a paper sheet including silver nanoparticles to deactivate them [69]. Application of silver nanoparticles suggests that aim is towards inactivating the bacteria rather than towards extracting them by filtration. The antibacterial properties of the AgNP sheets were demonstrated against E. coli and Enterococcus faecalis suspensions, with log reduction values in the effluent of over log 6 and log 3, respectively. Through values under 0.1 ppm (the new US EPA and WHO cap for Ag in drinking water), the Ag loss from the AgNP sheets was negligible [69]. **Table 1** lists additional examples of bioactive nanoparticles that have been stabilised and immobilised.

2.8 Air purifier using nano - sized semiconductor photocatalyst

Normally in air, more than 200 individual gaseous components, mostly volatile organic compounds are present. Some volatile organic compounds namely, formaldehyde and benzene are poisonous, toxic, odorous and benign. The photocatalytic air purifier must describe the ability of humans to tolerate an environment with any given mixture of contaminants during action [70, 71]. Photocatalysts include products including TiO_2, ZnO, Fe_2O_3, and WO_3. This photocatalyst can be used as a white pigment in colour paper and paint, as an ultraviolet light-absorbing material in sunscreen, antioxidant antimicrobials, and automatic cleaners, among other things [72, 73]. In general, TiO_2 is used in advanced photochemical oxidation methods for water remediation because of its low toxicity, high photoconductivity, and high photostability, as well as the fact that it is a readily available and inexpensive material [74]. Natural wastes can be oxidised by light using the semiconductor theory. The charge transfer mechanism from the valence band to the conduction band occurs at a necessary level of light, causing the surrounding material to be oxidised [75]. Semiconductor photo-catalysts are being improved in terms of reactivity and selectivity as a result of the advancement of nanotechnology. Under the SITE programme of the United States Environmental Protection Agency (US EPA), one semiconductor photo catalyst was recycled for water remedial activities [76]. Photocatalyst will extract pollutants including 1,1-dichloroethane, cis-1,2-dichloroethane, 1,1,1-

threechloroethane, xylenes, and toluene from ground water. TiO_2 was also found to be accomplished at removing benzene, toluene, ethylbenzene, and xylene (BTEX) from ground water on a pilot scale. In contrast in regard to normal TiO_2 powder, the surface of TiO_2 catalysts that can be formed using nano - tubes has been exposed towards more efficiency on removing the material [59]. ZnO photocatalysts are currently being produced in addition to TiO_2 photocatalysts, which are now widely used in industry. ZnO is intended to have two purposes as a concept: detection and remediation of pollutants. A ZnO photocatalyst was effectively used to identify and remove 4-chlorocatechol in laboratory experiments [60].

2.9 Nano Science for purification of poisonous gases

Nanoscience is not just for water remediation; it can also be used to clean contaminated gases in the air. The adsorption of carbon nanotubes and Au particles is a sample of nano Science in regards to poisonous gas purification [79]. CNTs are made up of graphene sheets with a hexagonal organization of carbon atoms that circle the tube axis. The two benzene rings of dioxin have a strong interaction with the surface of CNTs. Furthermore, dioxin molecules relate by whole surface of porous nano-tubes, i.e., 2.9 nm, as well as probability of simultaneous events that increase the adsorption possible within the pores. CNTs' high oxidation resistance is useful for adsorbent renewal at peak temperatures. CNTs, which come in two varieties: single-walled nanotubes (SWNTs) and multi-walled nanotubes (MWNTs), are one-dimensional macromolecules with excellent thermal steadiness and chemical characteristics. Nano–sized sources have exposed to ensure great possible as greater adsorbents for removing a variety of organic and inorganic contaminants from both air and water. The pore structure and presence of a wide range of surface functional groups of CNTs are primarily responsible for the adsorption ability of contaminants by CNTs, which was achieved through adjusting chemical or thermal action to tune the CNTs to provide best output for a specific application [80]. Researchers are interested in improving the possible applications of SWNTs and MWNTs due to their specific electronic characteristics and structures. SWNTs, for example, have been used as a chemical sensor for NO_2 and NH_3. The electrical resistance of SWNTs changed dramatically when subsequently exposed to NO_2 or NH_3 gas, either going up or down. SWNTs and MWNTs are used to store hydrogen as well. CNTs ar also used as quantum nanowires, electron field emitters, catalyst supports, and other applications. **Fig. 7** shows the schematic cleansing by nano catalysts in air pollution.

2.10 Removal of dioxins

Dioxin and associated compounds (such as polychlorinated dibenzofuran and polychlorinated biphenyls) are extremely poisonous contaminants that are steady. The methyl, chlorine and phenolic substituent groups can greatly promote gas adsorption, especially the phenolic group [81]. Dibenzo-p-dioxins are a group of compounds that are made up with two benzene rings bound by two oxygen atoms. It has a ring of zero to eight chlorine atoms connected to it. Any one of the bonds between two benzene rings is bridged by oxygen in dibenzofuran, a related but distinct compound. Dioxin toxicity differs depending on the amount of chloro atoms in the compound. Dioxins with none or one chloro atom are non-toxic, whereas those with more than one chloro atom are harmful. The compound 2,3,7,8- Tetraklorodibenzo-p-dioxin (TCDD) is believed to cause cancer in humans. The immune and endocrine systems, as well as foetal growth, are all affected by dioxins. The burning of carbon-based combinations in waste incineration is the primary source of dioxin compounds. The concentrations of dioxin compounds produced during combustion range from 10 to 500 ng/m^3. Dioxin emission regulations are complicated and differ by region. Nonetheless, dioxin concentrations must be kept below 1 ng/m^3 in most situations. Two critical studies on the prevention and reduction of dioxin have been released [82, 83]. In Europe and Japan, activated carbon adsorption was commonly used towards removing dioxins from waste incinerators since 1991. Since the bond energy between dioxin and activated carbon is higher than that of other adsorbents, such as clay, -Al_2O_3, and zeolites, the efficiency of dioxin removal using an activated carbon adsorbent is far higher than other adsorbents [84]. Since dioxin's extreme toxicity, added effective adsorbent than activated carbon is needed to minimise dioxin emissions to a lower level. Long and Yang [85] discovered that dioxin's interaction with CNTs is nearly three times greater than dioxin's interaction with activated carbon in this situation. The findings showed that CNTs were substantially better than activated carbon and -Al_2O_3 at eliminating dioxins, despite the fact that this was not stated specifically. This change is most likely to be due to the curved surface of nanotubes than to flat sheets, which offers stronger dioxin-CNT interaction forces [86].

2.11 NO_x filtration

The development of technologies to remove NO_x (a combination of NO and NO_2) emissions from fossil fuel combustion has been a major effort. Ion exchange zeolites, activated carbon, and FeOOH dispersed on

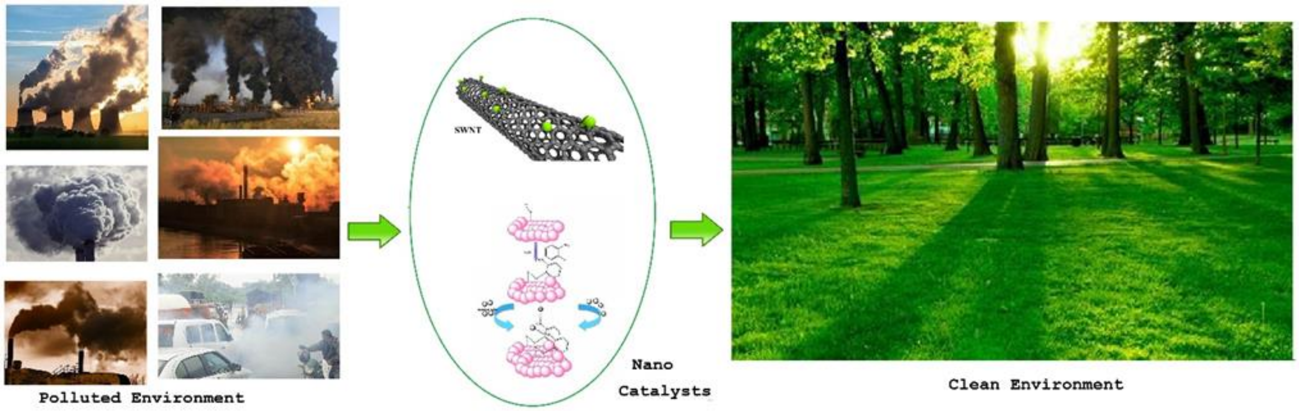

Fig. 7. The schematic cleansing by nano catalysts in air pollution

active carbon fibre are all common adsorbents used to extract NO_x at low temperatures. Novel surfactant modified zeolite was also very effective in the removal efficiency of NOx under diverse environments [87]. This enhanced proficiency is attributed to the capability of zeolite as an adsorbent of nitrate which evolved from the photocatalytic oxidation of NOx. Since, reactivity of surface functional groups, NO efficiently adsorbed to activated carbon, though number of adsorbed species is still small. CNTs may be used as an adsorbent for the removal of NO, according to Long and Yang [88]. NO_x absorption was estimated to be about 78 mg/g CNTs. The specific structures, electronic characteristics, and surface functional groups of CNTs can be linked to NO_x adsorption. NO is oxidised to NO_2 and then adsorbed on the surface of nitrate species as NO and O_2 pass via CNTs. Mochida et al. [89] confirmed this theory by reporting the oxidation of NO to NO_2 on activated carbon fibre at room temperature. In comparison to NO or NO_2, SO_2 can also be adsorbed on CNTs, but at a low rate, while CO_2 is much less adsorbed on CNTs.

2.12 CO_2 purification

Since the Kyoto Protocol went into effect on February 16, 2005, the capture and storage of carbon dioxide emitted through fossil-fuelled power plants has attracted a lot of attention. Absorption, adsorption, cryogenic, membrane, and other CO_2 capture technologies have all been studied [90, 91]. The adsorption–regeneration process has been identified as the most mature of these technologies. It is the amine-based absorption procedure, also known as ammonia absorption. The system for the removal of hydrocarbon and sulphur from carbon dioxide utilizes a sulfur tolerant catalyst which oxidizes the contaminants to carbon dioxide, water and sulfur dioxide. Then, they are removed by adsorption and/or absorption procedures [92, 93]. However, since the energy needed for the absorption procedure is still too great, alternate methods are currently being researched all over the ecosphere. Intergovernmental Panel on Climate Change (IPCC) decided production of a novel group of materials capable of professionally adsorbing CO_2 would inevitably increase the competitiveness of adsorptive separation in a flue gas use [94]. Activated carbon, zeolite, silica adsorbents, SWNTs, and nano porous silica-based molecular baskets are among the adsorbents used. Chemical alteration of carbon nanotubes has a high possibility for capturing CO_2. After the CNT was modified/combined with other chemical solutions such as ethylene diamine (EDA), polyethyleneimine (PEI), and 3-aminopropyltriethoxysilane, the values of q_e increased (APTS). In the absence of water, the solution holds amine groups that can react with CO_2 to form carbamate, increasing the value of q_e. The EDA- and PEI-modified CNTs increased q_e more than the APTS-modified CNTs. In general, the efficacy of CO_2 adsorption on modified CNTs improves with increasing relative humdity but reducing as temperature rises.

2.13 Elimination of unstable carbon-based mixtures from air

Many chemicals, including soot, nitrous acid, polyaromatic compounds and unstable carbon-based compounds, are formed by atmospheric reactions in addition to nitrogen oxides and sulphur oxides (VOCs) [95 – 98]. Since such particles are potentially harmful to human health, clean air standards have become more stringent. Photocatalysts, adsorbents such as activated carbon, and ozonolysis are used in the majority of industrial air purification systems [99]. Conventional devices, on the other hand, are ineffective at removing organic contaminants at room temperature. Japanese investigators have produced a novel material that is effective at extracting VOCs, nitrogen, and sulphur oxides from the air [100]. It consists of a porous manganese oxide that has gold nanoparticles developed into it. Sinha and Suzuki tested the efficacy of this catalyst by three main components of carbon-based internal air contaminants: acetaldehyde, toluene, and hexane [100]. When compared to traditional catalyst systems, the results showed that this catalyst effectively eliminated and degraded all three contaminants in the air. Porous manganese oxide, which has a considerably larger surface area than all previously recognised compounds, is one explanation for its popularity. The adsorption of volatile molecules is improved due to the wide surface area. Furthermore, the toxins that have been adsorbed are essentially decomposed. Because of the presence of free radicals, surface degradation is very successful. The presence of gold nanoparticles helps to lower the normally high barrier to radical formation. Other nano-metal components can now be used as a consequence of this technique. Although, the nanoparticles have been widely employed, a few potential difficulties such as sensitivity, selectivity and cost are still a concern for practical executions [101].

3. Limitations

While nanotechnology has wide range of potential applications and is rapidly developing, it may also have unforeseen consequences for human fitness and the eco system. Resources that are safe in bulk can develop to be extremely toxic at the nano-scale, for example, if they enter and accumulate in drinking water sources and the food chain and also do not bio - degrade. Breathing of airborne nano–sized materials and its effects on lung disease is a particular concern, with new research displaying those certain types of CNTs have a similar reaction to the human as do asbestos particles when inhaled in appropriate amounts [102]. The current lack of information around the fate and actions of nano- sized materials in humans and the environment exacerbates these concerns. However, since this technology is still in its initial steps of growth, the amount of testing has been minimal. Several worldwide organizations, including the Royal Commission on Environmental Pollution (RCEP) and the European Union are aware that lab investigations on certain nano – sized sources point out that they have properties that may be problematic [91, 103]. Toxicity and possible health threats related with nano–sized sources are poorly understood [104]. Nano–sized materials risk assessment research is important for assessing the possible effects of nano–sized sources on human fitness and the eco system, and for balancing the acknowledged welfares and unintentional significances [105]. Monitoring the vast amount of diverse nano–sized sources being produced and used as well as their effects, is extremely problematic to track, according to scientific authorities. This supports our argument for further and different types of research to determine if these theoretic threats are actual and to track their performance in the field.

4. Conclusions

Different forms of materials, such as inorganic, carbonaceous, and polymeric nano–sized sources, can be positively used targeting a range of eco remedial activities to prevent air and water pollution. Choosing finest nano–sized sources to decrease a specific contaminant in an exact ecological context necessitates a thorough examination of the type of pollutant to be removed, availability to the remedial place, the quantity of material required for effective remedial activities, and whether it is beneficial to improve the remedial nano–sized sources. We have presented an overview of several nano – sized sources that have been used in the sense of eco remedial, as all sources have its individual benefits and problems relevant to its uses. Despite the fact that a range of studies have been performed to examine the usage of nano science, questions about its use for environmental remediation have yet to be answered. Furthermore, although several studies have shown efficiency in lab settings, extra investigation is needed to fully comprehend how nano science will dramatically impact ecological pollutant remedial in real-global circumstances (e.g., the remedial activities of polluted water, soil, and air from industrialized processes). Additionally, while the processes by which various nano sciences are used are well understood, what happens to these materials after they have been used for pollutant capture or degradation is unknown. Despite the fact that the recyclability of certain sources has been identified, it seems that their effectiveness diminishes over time, rendering them useless. As a result, investigation is needed to determine the fate of these products after they are introduced to the atmosphere for remedial activities, in order to eliminate the risk that they will become a source of ecological contamination. To realise the complete possibility of nano science for eco-friendly uses, these obstacles must be resolved. Hence, nanotechnology offers a plethora of tools for dealing with environmental pollution.

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