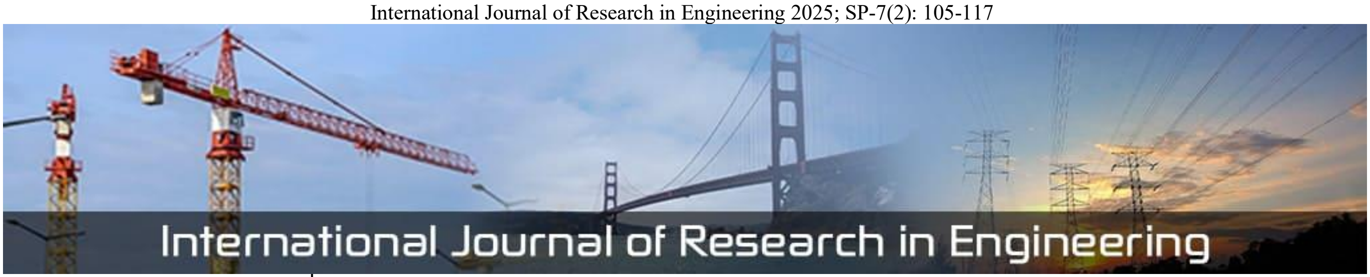

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Role of nanomaterials in the environment

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Abstract
The development of novel approaches, instruments, and strategies to address particular quantitative and qualitative environmental issues is greatly aided by science and technology. Nanotechnology is very effective at removing and detecting pollutants in the fields of air, water, and wastewater. Some of the techniques created using nanotechnology to treat water and wastewater, air, and pollution detection include nano adsorbents, nanofiltration, nano photocatalysts, magnetic nanoparticles, and nanosensors. Given that nanotechnology can remove and regulate environmental pollutants as well as cleanse and stop their spread, it is a useful instrument for achieving sustainable development and can be regarded as green technology.

Keywords: Nanoparticles, nanosensors, carbon nanotubes (CNTs)

1. Introduction

There are several angles from which to examine the direct and indirect consequences of nanotechnology on the environment and air pollution [1]. There are a ton of opportunities for utilizing this new technology. In today's world, nanotechnology is recognized as a significant and impactful technological advancement in science, technology, and business [2]. A wide range of information and tools from fields like physics, chemistry, biology, and engineering are used in nanotechnology. Using nanotechnology to create systems and important applications in environmental challenges is exemplified by the creation of nanomaterials, nanotubes, nanocomposites, nanofilters, and nanoparticles [3]. Numerous chemical companies are engaged in the development of nanoparticle-reinforced polymer materials [4]. In the automotive industry, these novel materials can take the place of metal parts. Widespread use of nanocomposites can cut annual carbon dioxide-related pollution by more than 5 billion kg and save 1.5 billion liters of gasoline over the course of a vehicle's lifetime [5]. The use of nanotechnology in the creation of nanocomposites has resulted in the development of extremely strong and light-weight raw materials that can be used in place of heavy metal components. These materials can also be used to drastically reduce the weight of vehicles and equipment, which will ultimately cut down on energy use and air pollution [6]. Additionally, the use of semiconductor manufacturing technology with nanotechnology in lighting has the nice side effect of averting the release of 2 million tons of carbon compounds and saving billions of dollars in energy costs. This will ultimately reduce air pollution [7]. Direct conversion of biological energy into electrical energy is possible with biofuel cells that are made with nanotechnology [8].

Enzymes and microbes are used by these cells to replenish the metal of regular cells. These cells have the unique and desirable quality of using pollutants like carbon dioxide and human wastewater. However, some think that the application of nanotechnology alone may bring forth fresh environmental issues such novel hazardous materials and associated biological risks [9]. A great deal of information regarding the impacts of nanoprocess and product products on human health and the environment must be gathered before any legislation pertaining to nanomaterials is made. However, despite the present state of scientific uncertainty, there is sufficient data to Nonetheless, there is sufficient data to implement nanotechnology-based preventative measures in the workplace, notwithstanding the present scientific uncertainties. This study looked at how nanotechnology affects the environment, specifically looking at contaminants and how nanotechnology is used to remedy them.

2. Nanosensors for the environment

Pollutant detection technology becomes increasingly affordable and widely available, leading to increased process control, ecosystem monitoring, and environmental decision-making [10]. The capacity of humans to maintain sustainable environmental and human health is enhanced by quick and precise sensors that can identify contaminants at the molecular level [11]. In essence, a sensor is a kind of energy converter that can recognize specific characteristics or events in its environment-physical, chemical, mechanical, etc.-and output that information as a signal. Direct conversion of biological energy into electrical energy is possible with biofuel cells that are made with nanotechnology [8].

The key attributes that have contributed to the high degree of trust in the collected data include high sensitivity, high detection power, and the capacity to measure multiple species at the same time from both nanosensors and sensors. sensitivity and precision at the nanoscale, both subjectively and numerically. The most crucial qualities are high sensitivity, high detection power, and the capacity to measure multiple species at once that have generated a great deal of confidence in the collected data from both nanosensors and sensors.

2.1 Air Pollution

Air pollution is the introduction of any particle, biological molecule, or hazardous compound-solid, liquid, or gas-into the atmosphere that endangers the environment, damages or kills living things, or modifies the ecosystem in a certain area. This kind of pollution is separated into two primary and secondary types and can come from either natural or human resources. Primary pollutants, which include things like carbon monoxide, sulfur and nitrogen oxides, volatile organic compounds, and so on, are typically created by abnormal processes like burning fossil fuels or by natural processes like volcanic eruptions. On the other hand, secondary pollutants are created when primary pollutants combine with one another. For example, peroxyacetyl nitrate is created when nitrogen oxides and volatile organic compounds react [12]. Secondary pollutants do not enter the atmosphere directly.

Continuous air pollution monitoring is one of the most crucial and fundamental requirements for environmental pollution control [13]. Effective progress has been made in reducing air pollution thanks to the use of nanosensors [10]. The development of smart dust samples marked a significant advancement in the manufacturing of these sensors, bringing them closer to the point of scientific use [14]. The primary goal of the smart dust manufacturing process is to create a series of sophisticated sensors in the form of extremely light nanocomputers [15]. Hours can pass while these nanosensors are effortlessly poised in the air [16]. These minuscule silicon particles have the ability to transmit the gathered data to a central server over their own wifi. The prototypes have a data transfer rate of roughly one kilobyte per second [17].

2.2 Emission of Toxic gases

One of the risks of daily industrial life is the emission and dispersion of poisonous and lethal gasses. Regretfully, industry cautions frequently come too late to identify these leaks [18]. Toxic gas molecules can be absorbed using carbon nanotube (CNT) sensors, which are composed of single-layer nanotubes that are roughly 1 nm thick [19]. Additionally, they can identify a few lethal gas molecules in the surrounding air [20]. According to the researchers, these sensors will be used to identify organic compounds in space, air pollution, and biological agents used in warfare [21]. Other sensors that have been widely employed because of their tiny size and great precision are new three-dimensional nanostructures. For instance, the 3D structure nanosensor's ultra-thin SnO_2 sheets can identify extremely hazardous gases ((SO_2 and H_2S) with high sensitivity [22]. One of the risks of daily industrial life is the emission and dispersion of poisonous and lethal gasses. Regretfully, industry cautions frequently come too late to identify these leaks [18]. Toxic gas molecules can be absorbed using carbon nanotube (CNT) sensors, which are composed of single-layer nanotubes that are roughly 1 nm thick [19]. Additionally, they can identify a few lethal gas molecules in the surrounding air [20]. According to the researchers, these sensors will be used to identify air pollutants and war biological agents.

While the presence of platinum nanoparticles in the structure of carbon nanotubes boosts the sensitivity of these sensors, the employment of other metals in the structure of multi-walled carbon nanotubes affords sensors with excellent capacities for selective detection of harmful gasses as NO_2.Presence of Silver and copper also detects harmful gases as NH_3 & H_2S.

2.3. Pollution from heavy metal ions

Scientists have known for a long time that lung cancer, heart disease, and other illnesses can be brought on by exposure to heavy metals and particulate matter. The size of airborne particles in metropolitan areas is usually between 100 and 300 nm, although the amounts of heavy metals vary. Furthermore, heavy metals are not biodegradable because microbes are unable to break them down [24]. The necessity for sensors that can identify heavy metal ions before their concentrations reach dangerous levels is made even more apparent by the numerous issues that heavy metal ions in water, soil, and air can cause [25].

One of the most sophisticated and accurate methods for detecting heavy metals is the use of nanomaterials based on quantum dots. Since quantum dot nanomaterials have high specific surface area, strong reactivity, and unique physicochemical characteristics, they can be used as sensors [26]. Strong detection systems that can identify several metals under challenging circumstances can be put together by utilizing quantum dots nanomaterials and linking them to optical or chemical sensor converters [27] For heavy metal ion nanosensors, for instance, zero-dimensional graphene dots are used due to their intriguing properties, such as good optical properties, adaptable surface groups for absorption, good stability, and an easy fabrication and preparation process through doping in optical detector species [28]. Additionally, some biomass is utilized in the quantum dot nanomaterial technology. Because these nanobiosensors are highly compatible with both the environment and living things, they are used as visually appealing fluorescent nanosensors. For instance, Fe (III) in effluents is detected using carbon quantum dots that are isolated from green algal waste.

Because gold-silica nanocomposites have a more sophisticated surface plasmon resonance bond than gold nanoparticles, they are more sensitive to the detection of minuscule levels of heavy metals in drinking water. When heavy metal ions collide, nanocomposites with a gold-silica core-shell structure accumulate to identify the presence of these pollutants. Additionally, because of their chemical adsorption on the surface of the nanocomposite containing gold, these ions cause alterations in the location of the plasmon adsorption link when they are present [30]. When zinc and lead ions were present in the water, comparable outcomes were observed for cadmium ions. Put another way, there will be a partial shift in the bands toward longer wavelengths when these ions are present. Gold nanoparticle suspensions have a vibrant red hue as a result of surface plasmon adsorption. Its red hue remains unchanged in the presence of zinc and lead ions. Only when electrons are moved from adsorbed ions to metal particles can color change occur. This event raises the metal's plasma frequency and the density of free electrons in the metal's conduction band [31].

Because of the cumulative electron interactions between metal atoms and electrons, metal nanoparticles, like gold and silver, have very strong and desirable absorption capabilities in the ultraviolet-visible region of the electromagnetic spectrum. Because their surface plasmon resonance connection is more developed than that of gold nanoparticles, nanocomposites with a gold-silica core-shell structure are more sensitive to detecting very small amount of heavy metals in drinking water. When heavy metal ions collide, nanocomposites with a gold-silica core-shell structure accumulate to identify the presence of these pollutants.

3. Toxic gas adsorption

Nanotechnology has the potential to eradicate harmful gasses from the environment. As an illustration, consider the adsorption procedure that uses CNTs enhanced with gold or platinum nanoparticles [32]. Carbon atoms are arranged hexagonally in the graphene layer surrounding the tube axis to form carbon nanotubes (CNTs). CNTs are special molecules having one-dimensional structure, thermal stability, and remarkable chemical capabilities. They can be single-walled or multi-walled nanotubes [33]. It has been demonstrated that CNTs have a strong chance of being better adsorbents for the removal of many kinds of airborne and aquatic pollutants, both inorganic and organic. The primary causes of CNTs' adsorption ability are their porosity structure and the abundance of a variety of surface functionalized nanotubes this can be accomplished by altering the CNTs chemically or thermally to give them the appropriate functionality. Different harmful pollutants found in the atmosphere in industrial locations include benzene, dioxin, toluene, ethyl benzene, and ρ-xylene [34]. The two benzene dioxin rings and the nanotube's surface are strongly connected. Furthermore, a 2.9 nm-diameter porous wall connects the dioxin molecule to the entire surface of the nanotube, causing overlap that raises the adsorption potential inside the pore. Furthermore, CNTs' strong resistance to oxidation is beneficial for the regeneration of adsorbent at high temperatures [35].

3.1. Dioxin Adsorption

Persistent environmental contaminants, like dioxins, can linger in the environment for a very long time [36]. Dioxins are persistent and extremely harmful pollutants, as are their related chemicals (polychlorinated dibenzofurans, polychlorinated biphenyls, etc.) [37]. Two benzene rings connected by two oxygen atoms and zero to eight chlorine atoms attached to the ring comprise the dibenzo-p-dioxin family of chemicals [38]. Similar in structure to dibenzofuran, but with only one oxygen contact between the two benzene rings [39]. The quantity of chlorine atoms in different dioxins determines their level of toxicity. Dioxin has more than one dangerous chlorine atom; it either contains no chlorine atom at all or a chlorine atom with no toxicity [40]. 2.3.7.8-TCDD, or tetrachlorodibenzeo-p-dioxin substance that is known to cause cancer in people [41]. Additionally, dioxin impacts prenatal growth and the immunological and endocrine systems. The incinerator's combustion of organic materials is the primary source of these chemicals [42]. There are between 15-555 ng/m2 of dioxin chemicals that are produced during burning. Dioxin emission regulations are intricate and differ between nations. On the other hand, a dioxin concentration below 1 ng m2 is usually required. In Europe and Japan, activated carbon adsorption has been routinely employed since 1991 to remove dioxins from incinerators [43]. Compared to other adsorbents like clay, Al2O3, and zeolites, activated carbon has a far better dioxin removal effectiveness; Dioxin is extremely poisonous, thus a more effective In order to limit the formation of dioxin emissions, a more effective adsorbent than activated carbon is needed [44]. The connection and interaction between dioxin and CNTs was demonstrated by the researchers to be roughly three times stronger than that between dioxin and activated carbon. According to the findings, CNTs [35] were far more effective at removing dioxins than activated carbon and Al2O3 γ [45, 46]. This enhancement is most likely the result of the nanotubes' curved surface as opposed to their smooth surface, which strengthens the forces of contact between dioxins and CNTs [37, 47].

3.2. NOx Adsorption

Pollutants as carbon monoxide (CO), unburned hydrocarbons (HC), and nitrogen oxides (NOx) are produced when the fuel-air mixture is not completely burned [48]. Since methane makes up a large portion of natural gas, the majority of unburned hydrocarbons in gas engines are methane [49]. Because methane has a lower carbon to hydrogen (C/H) ratio than any other hydrocarbon, during gas burning, less carbon dioxide and carbon monoxide are released [50]. In actuality, though, it is impossible to overlook the quantity of carbon dioxide and carbon monoxide present. Compared to carbon dioxide, methane has a far stronger greenhouse impact. Catalytic converters have been a key component in the fight against internal combustion engine pollutants for many years. These converters lessen nitrogen oxides and carbon monoxide [54]. Perovskites as catalysts for the removal of pollutants from cars have been researched and tested, and the combination of metal oxides, spinels, and perovskites has proven to be a viable alternative [55]. The development of technology to remove NOx emissions from the burning of fossil fuels has received significant attention. Dispersed FeOOH in activated carbon fiber, activated carbon, and zeolite ion exchange are common adsorbents utilized to remove NOx at low temperatures [56]. These adsorbents have a low absorption of NOx [57]. The outcomes demonstrate that CNTs can absorb NOx [58]. For instance, NO and O2 flow through the CNT substrates, resulting in the synthesis and adsorption of NO2 on the CNT surface [59].

3.3. CO2 Adsorption

The absorption and storage of CO2 generated by fossil fuel power plants have drawn a lot of attention lately. A variety of CO2 recycling technologies are employed, such as membrane technology, cryogenic adsorption, and adsorption. Adsorption-desorption technology is regarded as the most advanced of these processes. This procedure is based on ammonia or amine adsorption. However, a lot of energy is needed for these devices for the process of adsorption. Researchers are working on creating membranes built around carbon nanotubes, nanosilica, and zeolite, which can capture CO2 on a big minimize greenhouse gas emissions and remove scale from factory chimneys [60].

3.4. Elimination of organic volatiles

Many other molecules, such as nitric acid, polyaromatic compounds, volatile organic compounds (VOCs), soot production, and nitrogen and sulfur oxides, are produced by atmospheric processes. Particles that may be hazardous to human health are coming under increased attention in clean air legislation [61]. The majority of sophisticated air filtration systems relied on photocatalysts and adsorbents, including ozonolysis and activated carbon. But at room temperature, typical methods are ineffective in eliminating organic contaminants [62]. New materials have recently been created by researchers that effectively remove nitrogen oxides, sulfur, and volatile organic compounds from the air at ambient temperature [63]. For instance, a catalyst based on manganese oxide provides a very porous area coated in gold nanoparticles that can break down acetaldehyde, toluene and hexane and remove it from room air [64].

4. Water and wastewater treatment

Ceramic and polymer membranes are now produced in the water treatment industry using nanotechnology [69]. These membranes at the nanoscale include biomimetic membranes, organic-inorganic hybrid nanocomposite membranes, and ceramic membranes covered with zeolite and catalytic nanoparticles. Carbon nanotube membranes, block copolymer membranes with comparable porosity, and biopolymer membranes with protein molecules are examples of bio-mimic membranes. These membranes' increased performance is dependent on their mechanical strength, pollutant molecular selectivity, and water permeability. Despite their exceptional performance, biomimetic membranes often have very little marketing potential. While nanocomposite membranes are already mass-produced in addition to having a high level of efficacy in the treatment of water. Apart from modest to moderate enhancements in the functionality of traditional membranes, zeolite and catalytic membranes are hardly utilized in the water treatment industry.

4.1 Nanofibres

Utilizing nanofilters in the treatment of water and wastewater is a significant additional application of nanotechnology in environmental management. Large molecules are typically repelled by the membrane used in the nanofiltration process, which uses less energy to clean surface or well water than other techniques. Numerous bacteria, viruses, pesticides, organic contaminants, and ions of calcium and magnesium can all be eliminated from the water with this method [70].

The use of nanofiltration to soften water has significantly less of an adverse environmental impact than traditional chemical approaches because no chemicals are needed in the process. Furthermore, nanoparticles can be used to treat contaminants in a very flexible way. For the quick treatment of soil, sediments, solid waste, water treatment, and liquid waste, for instance, nanostructured particles are employed.

Studies reveal that a wide range of uses for nanostructured bimetallic particles, including iron-silver, zinc-palladium, and iron-palladium, have been identified for the treatment and purification of environmental pollutants, including organic pesticides with chlorination and halogenated organic solvents. Based on empirical evidence, the use of bimetallic nanostructured particles renders all hydrocarbons including highly dangerous chlorinated chemicals environmentally benign hydrocarbons [71].

Furthermore, a wealth of research suggests that iron-based nanostructured particles can break down extremely stable pollutants including nitrates, perchlorates, heavy metals like mercury and nickel, and radioactive substances like uranium dioxide. Furthermore, drinking water can be made to appear lighter by using nanostructures. For instance, soil, sediments, solid waste, water treatment, and liquid waste are all immediately treated with nanostructured particles. Not only should the dye in drinking water be eliminated for aesthetic reasons, but it may also be the cause of the highly harmful trihalomethane formation. It reacts with chlorine to produce chloroform and other dangerous and cancer-causing halogen chemicals [72]. Up to 88% of these materials may be readily removed from the water with the use of nano-membranes, a feature that most conventional water treatment methods are unable to accomplish [73]. Additionally, studies demonstrate that utilizing nanotechnology in water treatment can significantly lower treatment expenses [74]. Alcohols like ethanol are frequently utilized as detergents or solvents in industry. When consumed, these compounds absorb significant amounts of different contaminants. They need to be prepared for reuse since discarding them after eating has negative environmental effects. Traditional techniques, such distillation, pollute the environment and waste a lot of energy [75].

An efficient way to save energy and safeguard the environment in this regard is to utilize nanofilters. Microfilters, ultrafilters, and nanofilters are the three categories of filters based on the size of their pores. Since nanofiltration essentially involves lower pressure filtration than reverse osmosis, nanofilters are more reasonably priced. Furthermore, nanofilters can eliminate germs and viruses, so they are helpful in removal of contaminants from potable & agricultural water [76, 77].

4.2. Zeolite-coated ceramic membranes

The creation of membranes whose water permeability in the ultrafiltration membrane range and their pollutant species selectivity are comparable to that of nanofiltration and reverse osmosis membranes is one of the main difficulties facing the ceramic membrane industry [78]. Molecular dynamics simulations demonstrated in 2001 that saline water may be desalinated using reverse osmosis zeolite membranes. Subsequently, aqueous waste treatment and desalination of salty water have been the subject of intensive research. Good mechanical stability at high pressures, strong resistance to pore clogging, and good chemical resistance are the key benefits of utilizing zeolite in the production of reverse osmosis membranes [79, 80].

The effectiveness of zeolites for water treatment or separation is largely dependent on their pore size and frame density (FD). The degree of water permeability of channels in zeolite structures is really determined by a number of parameters, including frame density, ion selectivity, and pore size [81]. In the structure of zeolites, silicon and aluminum can be replaced with different elements by ion exchange. Since the width of these structures' nanoscale channels determines their capacity for molecular screening, altering the channel width by swapping out atoms in the zeolite framework's structure affects the screening properties, particularly the membrane strength that determines the species' permeability. Furthermore, the relative density of the frame structure affects the mobility of ions and water molecules across the zeolite membrane, making open porosity structures advantageous for the transfer process [82]. Zeolite membranes are used for the separation of pollutants by the use of ion exchange, competitive adsorption, or molecular screening. Ions that have a hydrodynamic radius smaller than a specific value can flow through porous zeolite structures quickly thanks to a process known as molecular screening.

It will be harder to go through the cavities the higher the ion radius. Additionally, the chemical adsorption of analyte species on negative zeolite surfaces forms the basis of the competitive adsorption mechanism [83, 84].

4.3 Catalytic Ceramic Membrane

Catalytic ceramic membranes (such as TiO2, ZnO, and Fe2O3) are semiconductor materials that are subjected to oxidation-reduction reactions by ultraviolet or sunlight, destroying organic compounds and dyes. The photocatalytic properties of nanoscale systems appear when semiconductor nanoparticles are exposed to radiation, so that this amount of energy is greater than the width of the forbidden band of matter [85]. As a result of this excitation, electron-hole pairs are formed in the material that may recombine after a few nanoseconds or react with the surrounding environment. The reaction of excited charge carriers with the surrounding organic agents is only possible if they are trapped by surface defects or electron/hole-friendly material called a scavenger and prevented from recombining [20]. In semiconductor bulk materials, only one of the charge carriers (ie, electrons) can effectively participate in catalytic reactions, but in nanoscale materials, both types of charge carriers can reach the surface and form effective interactions. Most photocatalytic materials are used as dispersed particles in an aqueous medium; because in this case they have a larger free surface and produce a more desirable photocatalytic efficiency. However, the main problem with the dispersion processes of nanoparticles in aqueous solutions is their low efficiency in material recovery after optical degradation. One of the effective ways to increase the efficiency is the catalyst coating on magnetic iron oxide nanoparticles, which allows the magnetic recovery of the particles [71]. Now a days photocatyltic material has been coated on polymer membranes to create active surfaces that can help remove impurities from aqueous media more effectively. The recovery of catalytic materials won't be a significant problem with this approach. Because TiO2 has antibacterial and photocatalytic qualities against UV radiation, it is frequently employed as a coating. Pathogens are rendered inactive by UV radiation that breaks down their DNA, produces reactive oxygen species, and breaks down the cell walls of microorganisms. For instance, high-efficiency UV light can filter a nanoparticle suspension utilizing a TiO2 layer on porous polymer membranes. Moreover, titanium oxide nanoparticles can be added to reverse osmosis membranes to make them self-cleaning. When UV light is present, this characteristic manifests. These membranes appear to be self-cleaning because of the hydrophilicity of the membrane and the photocatalytic qualities of TiO2 [85].

4.4 Nanotubes and Nanofibres

The first generation of nanoproducts was identified and made available to the public in 1991: carbon nanotubes. Granite sheets are wrapped in a configuration resembling a honeycomb to create nanotubes. These pipes feature robust, flexible construction and are incredibly long and thin. The strongest known fibers, nanotubes can replace traditional ceramics and even metals in aircraft, gears, bearings, machine components, sports equipment, medical gadgets, and industrial food production equipment. They are one to one hundred times stronger than the weight unit of steel [92].

In watery media, carbon nanotubes are insoluble. Thus, the creation of electrically conductive membranes is one of the uses for carbon nanotubes. Carbon nanotubes have a high length-to-diameter ratio that allows them to be changed into conductive polymers. These polymers can be utilized to create new membranes, which will improve the way flavors and nutrients are separated. This material is an additive that is applied during the nanocomposites' creation. Merely 3-5% of this plastic material is enhanced by the addition, making it lighter, stronger, and more heat resistant. It also improves the material's barrier qualities against moisture, volatiles, carbon dioxide, and oxygen. Boost these characteristics for food packing, including canned goods, processed meats, cheeses, baked goods, and cereals [93].

Because of their special qualities, biological treatments are highly significant among wastewater treatment techniques. Nowadays, more wastewater treatment is done using this technique due to its advantages, which include the removal of organic debris and reduced environmental harm [94]. The development medium of biofilm is one of the primary elements in biological techniques. A suitable substrate should have the following qualities: it should create an environment that is conducive to the growth of microorganisms; it should be physically and chemically stable; it should have a high specific surface area on the surface; it should have a relative density relative to wastewater; and it should be the right size to be installed in the wastewater treatment system. Given the forementioned characteristics, nanofibers' shape makes them an excellent substrate for biological reactions and speeds up the biodegradation process [95]. Nanofiber-based substrates are modest in porosity and have a high specific surface area [96, 97]. Nanofibers can have both chemical stability and well-formedness, depending on the kind of polymer that is utilized. The primary benefit of nanofibers over microorganisms is their surface shape and biocompatibility, which speeds up the pace at which microorganisms gather on the surface of nanofibers [4]. Flexible polymeric materials are used to create nanofibers. Biofilm forms inside the substrate (near the core) as well as on the surface when flexible fiber is prepared. Microorganisms and bacteria inside the bed are shielded from shear stresses and the harmful effects of sewage [98]. This is because it is feasible for components such as oxygen to quickly permeate the substrate and interact with bacteria. The bacteria stick to the nanofibers' high specific surface area more readily, which keeps the microbes stationary and speeds up the accumulation process at the substrate surface [99]. Systems that need to operate more quickly can make use of this feature. Without the assistance of nanofibres, the bacteria can proliferate in situ following the microbial accumulation stage. One of the most effective methods for treating water and wastewater is the use of adsorbent materials. Adsorption is the process by which molecules or ions are transferred from the liquid phase to the solid phase in water treatment utilizing adsorbents (Akbar [100]. It has been observed that a variety of sorbents, such as biomass from branching polymers, industrial wastes, agricultural wastes, and natural sorbents, may remove different kinds of toxins from contaminated wastewater and water [101]. The adsorption of water contaminants is a useful approach for treating polluted water because of its ease of use and affordability. The type, concentration, efficiency, and adsorption capacity of each type of contamination determine which adsorbent is most suited for eliminating it from water (A [102]. several kinds of sorbents, including Water and wastewater are treated using natural resources, agricultural waste, industrial effluent, and biomass materials. Various natural resources like wood, coal, plant fertilizers, chitin or chitosan, clay minerals, and natural zeolites are examples of inexpensive absorbent materials. II) agricultural wastes include straw, corn stalks, sunflower stalks, sawdust, husks, bran, and kernels of fruits and nuts. III) Industrial wastes, including red mud, sugarcane pulp, sugarcane stems and kernels, blast furnace slag, and ash. One natural adsorbent that can be used to remove pollutants from water is clay, or hydrated alumina silicate. The three main components of the clays are kaolinite, bentonite, and montmorillonite [79]. These materials feature a wide surface area, a high chemical and mechanical stability, a low permeability, and a high adsorption capacity. On the clay surface, there are numerous cations (Ca^{2+}, Mg^{2+}, H^+, K^+, NH_4^+, Na^+) and anions (SO2 4, Cl, PO3 4, O3) that are readily replaced by ions in the adsorbents. These clays are utilized to absorb pollutants in either their unmodified or modified form [103, 104]. Pb^{2+} and Cd^{2+} ions are adsorbed from aqueous solution using kaolinite, montmorillonite, and their acid-activated forms. Elevated pH facilitates these ions' surface adsorption on clay [105]. The adsorption capacity of clay materials is affected by a number of variables, including contact time, temperature, pH, and the initial concentration of pollutants. Up to 90% of safranin-O has been successfully removed using natural raw kaolinite [106].

5. Nanobiomaterials

One of the main drivers of the creation of novel environmental systems with appealing applications has always been the availability of new materials [107]. These substances have the ability to dismantle obstacles to earlier procedures and, in the end, result in applications that may have worldwide advantages [108]. Materials classified as nanoscale have features that are controllable at a smaller scale than microscale (less than 6-10 or 9-10 nano) [109]. Because of the fundamental differences between the properties of materials with these dimensions and sizes and those of normal materials, research on nanomaterials is gaining momentum every day [110]. Colloidal and solid particles with intricate surface chemistry that have macromolecular components ranging in size from 10,000 to 100 nm are called nanoparticles. Depending on how they are made, nanoparticles can take the Nanocapsules are vesicular systems, whereas nanospheres are matrix structures [111].

Nanoparticles with a shell and empty space within to contain and transport the required components are called nanocapsules. When phospholipids with hydrophilic and hydrophobic heads are dissolved in an aqueous solution, the hydrophilic head of the molecule is on the outside and the hydrophobic head is inside the capsule. Nanocapsules can also be made from polymers like proteins and lipids [112]. Because of their high active group density, dendrimers are macromolecules with a regular, branched three-dimensional structure and a wide range of applications.

In comparison to nanopores, nanocapsules, and nanoparticles, dendrimers have the most promise due to the competition for design and manufacture with absolute atomic precision. Cochleates are persistent bivalent phospholipid sediments found in nature. Cochleates are bivalent deposits of stable phospholipids found in natural materials [97]. These materials are made up of enormous, continuous, helical fat structures with several layers. They transport their contents to the target cells' membrane by passing through the outer fluid layer [113]. Cochleates are immune to environmental stressors and, even in the presence of harsh circumstances or enzymes, are shielded from brittle molecules by their robust layered structure [114].

Chips with electronic functionality can be made using nanostructures like biopolymers. The information that is now available states that 16 kg of water, 85 g of chemicals, and fossil fuels are needed to make one gram of a 32 MB microchip [115]. The traditional process of making semiconductor chips can be significantly enhanced by using nanoprocesses. Furthermore, the application of nanotechnology results in the synthesis of safe compounds as opposed to hazardous ones. For instance, monitors are more efficient since they are constructed of cathode ray tubes, which are hazardous materials. Liquid crystal displays are tiny, free of lead, and require a lot less energy than comparable cathode kinds [115]. Furthermore, utilizing carbon nanotubes in computer monitors contributes to a decrease in the usage of heavy metals.

6. Environmental catalysts

HOCs, or halogenated organic compounds, are among the most significant contaminants of water. These organic compounds have significant uses in a variety of industries, including medicine, as additives and solvents. These substances are poisonous, hazardous, and can lead to diseases including cancer. Consequently, it is crucial that these chemicals completely decompose in water and wastewater [121].

Such an issue cannot be resolved by conventional water treatment techniques. Palladium nanocatalysts are a novel way to selectively degrade heavy organic compounds (HOCs) and detoxify water. This process transforms stable HOCs into organic molecules, which are readily eliminated in water treatment facilities by biodegradation [64]. Additionally, palladium/magnetite nanocatalysts have been

designed to efficiently remove organic contaminants containing halogens from wastewaters. Several tests have demonstrated that across a range of water conditions, palladium/magnetite nanocatalysts function with consistency. The fact that they can be extracted using magnetic separation technology from the needed water or effluent is another benefit [122].
The main air contaminants are nitrogen monoxide, carbon monoxide, and hydrocarbons. These contaminants can be reduced in emissions by using catalytic converters. The air-to-fuel ratio in catalytic converters today must adhere to a specific stoichiometry, and the converters contain costly metal catalysts. This is why there is a great need to create catalysts that are both inexpensive and highly effective [123]. Because of its straightforward kinetics, carbon monoxide is employed as a model reaction in the study of oxidation reactions. When it comes to CO oxidation, Cu π CeO2 and Au π CeO2 catalysts have significantly higher activity and stability than copper oxide or sodium oxide catalysts. The Cu □ CeO2 and Au ʀ CeO2 catalysts undergo complete CO conversion at a spatial velocity of 80 and 20 ◦C, respectively. When it comes to CO oxidation, Cu + CeO2 has greater catalytic activity than platinum metal [3, 61]. It is possible to use nanotechnology and materials with extraordinary properties to solve some of the current problems facing human societies, such as pollution of the environment, a shortage of raw materials for production, and a lack of energy resources. Modern catalysts can be created that have a higher specific level than conventional catalysts and also demonstrate higher efficiency while consuming less precious metals.

7. Nanocoatings

Advanced nanostructured coatings work well on a wide range of surfaces, including plastics, metals, glass, and ceramics. The thickness of these coatings is just a few microns. The enhanced anti-corrosion characteristic of these nano-coatings is what makes them unique [124]. Consequently, increasing the resistance of light metals like aluminum and magnesium to corrosion is one use for these coatings [125]. These coatings have a high heat resistance, reaching temperatures of up to 700 °C [126]. By using this kind of coating, metal corrosion will be lessened, and by using less raw materials, the environment will be protected [127]. Nanostructured coatings can also be used to reduce the need for cleaners by eliminating dust from a variety of surfaces. These nanoparticles are applied to a variety of surfaces, including automobile glass, in a very thin coating [7]. Because of this, the liquid stays on the coated surface in the form of droplets and is rapidly removed rather than wetting it. This expedites the process of drying. It is evident that both environmental pollutants and detergent use are significantly decreased [128].

8. Using nanotechnology to fight pollution

Nanotechnology is a hot topic both now and in the future. Researchers, governments, and artists alike have high hopes for this technology's ability to solve current issues. Environmental protection and the availability of energy are two of the biggest issues facing the globe today. Fossil fuels are becoming scarcer while also causing harm in the environment due to their consumption. Using nanotechnology is one of the most promising approaches to regulate and treat pollution, as well as to generate clean and sustainable energy. Reducing pollution sources and using energy, water, raw materials, power, and other resources efficiently to cut down on or completely eliminate waste are all considered forms of pollution prevention. Numerous novel approaches to lowering pollution are provided by nanotechnology, including streamlining manufacturing procedures, cutting back on dangerous chemicals, cutting greenhouse gas emissions, and using less plastic and substituting them with biodegradable materials.

8.1. Eco-friendly materials

Materials that are safe for the environment or materials that can frequently replace harmful ones can be produced using nanotechnology [129]. For instance, the less hazardous liquid crystal display (LCD) in computers has taken the role of the extremely hazardous cathode ray tubes (CRT). In addition, LCDs use less energy than CRT panels and are free of lead [130]. Radiation display is also substituted with CNT display technology. Through the removal of harmful heavy metals, a reduction in the extreme demand for resources and energy, and performance enhancement in accordance with user requirements, the use of CNTs in computer screens lessens their adverse effects on the environment [131]. Furthermore, the use of nanotechnology to composite materials may result in the creation of materials with improved mechanical and other desirable qualities.
Because nanotechnology may create structures that are smaller and lighter without sacrificing the quality of their properties [132]. Utilizing this technology lessens the detrimental effects on the environment, lowers the cost of the system and all alternatives, and boosts robustness. The following are some instances of eco-friendly materials that might be created with nanotechnology: Lithium graphite electrodes in rechargeable batteries, self-cleaning glass, and biodegradable plastic are replaced by non-toxic nanocrystalline composites, which are composed of polymers with easily degradable molecular structures [9].

8.2. Green production

There are always a variety of environmentally hazardous waste products generated during the production process. The production process should ideally be planned to consume as little energy, raw resources, and trash as possible [133]. A typical term for the approaches and technologies used to accomplish these goals is "green production" [134]. The creation of environmentally friendly industrial processes, such as designing water-based processes and substituting them with organic solvent-based processes, as well as the elimination of hazardous materials, the creation of environmentally friendly chemicals, and the application of energy-efficient processes are all included in green production [110].
Chloroform, hexane, and perchloroethylene are examples of toxic and cancer-causing substances that are frequently employed in cleaning,textile and oil extraction industries [135]. Toxic and carcinogenic compounds, such as chloroform, hexane and perchloroethylene, are commonly used in the cleaning, textile and oil extraction industries [135]. Nano-sized micro emulsions can be used as receptors to extract specific molecules at the nanoscale level. For example, the use of nanotechnology in the synthesis of micro emulsions for the separation of organic matter and the cleaning of textiles [8]. Researchers have synthesized micro emulsions that reduce the surface tension of organic matter,

making it easier to separate oil from seawater [136]. Micro emulsions are also able to clean textiles from oil, so that microemulsions are very competitive with conventional cleaning compounds [137].

9. Role of nanomaterial in the environment

Two primary environmental domains can be distinguished by the application of nanotechnology:

Area of nanotechnology-based environmental pollution monitoring: Continuous monitoring of environmental pollution is one of the most crucial and fundamental requirements for the control of environmental pollution. data on the types, amounts, and distribution patterns of pollution in each location will be gathered, and a suitable response plan will be developed as a result. In order to reduce pollution, environmental organizations have established rules and regulations for food and industry. Maintaining continuous control over sources of pollution is a challenging, intricate, and time-consuming undertaking.

These days, point-by-point, inexpensive monitoring of the target areas' contamination status is achievable because to nanosensors. These pollutants, which have detrimental short- and long-term consequences on the ecosystem and human health, include soil, water, and air pollution. Because of their extensive range, contaminants are extremely difficult to remove from the environment. On the other side, it is crucial to remove contamination at its source and from its sources. Numerous techniques have been employed in numerous nations to lessen environmental contamination of the air, water, and soil. By using nanotechnology, it is feasible to limit soil pollutants, treat industrial and urban effluents in the best way possible to prevent water pollution, and reduce various air pollutants in cities and factories to a manageable level.

10. Conclusion

Nanotechnology is the study of arranging atoms to create new materials and molecular structures. The various subfields and sciences that make up nanotechnology are mostly based on the applications of these products in various fields of study.The energy and electrical industries can greatly benefit from chemistry and chemical process nanotechnology. Carbon nanotubes may selectively absorb particular gases from a stream that contains a mixture of gases. Several industrial uses for nanotubes exist, such as the elimination of hazardous gases and pollutants from the environment. Carbon nanotubes can be used to build and improve the performance of molecular gas sensors. Thus far, it has been demonstrated that nanotube sensors may be used to detect a wide range of gases, including CO, NO_2, NH_3, and so on. One effective way to store hydrogen is by using carbon nanotubes. In reality, these tubes are tiny carbon tubes with a finite diameter that are used to store hydrogen in the tiny cavities both within and on the tubes. Apart from the hydrogen storage capabilities of nanotubes, fuel cells can be employed within the structure to enhance its efficiency. Because nanofiltration can function at low pressures, it is a membrane method that is more cost-effective than RO. The topic of nanotechnology can be used to analyze the production and application of NF and RO membranes. Because the cavities' effective dimensions-that is, their sizes-are nanoscale in both processes and because the mechanisms for separation are the same in both process.

11. References

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