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Review on current world water resources scenario and water treatment technologies and techniques

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Abstract
This review mainly aimed to review researchers' outlook on water resources and development of water and waste water treatment level and its main challenges for further researching to find last long solution as far as water resources concerns. This also includes author practical experiences and to identify the significance of nanotechnology for today's water treatment related problem. Supply of clean and affordable water with ever growing demands, with all climatic threats and current population growth is among the grand challenges of this century to meet human need. Most of developing countries enforced to use unconventional water sources as a result of fresh water supplies are getting depleted. This resulted that on average daily about 5000-to-6000 children are die diarrhea which is water related & incoming couple of decades more than 1 billion people in the world will face problem in safe water access though current water supplies will be decreasing by one-third. Therefore, advancement in water treatment which is applicable in all condition for all nations, reliable, efficient, economical, safe and easy is needed to address water and its derivative problems. Applying and developing new Nanomaterials for water and wastewater treatment is the only promising technologies and techniques for current scenarios and future outlooks. However, in synthesizing and application of Nanomaterials; environmental fate, protection of water treatment system against potential chemical and biological terrorist acts, some modification of currently used Nanomaterials for more selectivity and reactivity with selected materials are equally important. Among recent synthesis methods in Nanomaterials; Green synthesis is the most eco-friendly approach which has to be practiced by the researchers in the world. The advancement in Nano scales suggesting that, many of the current rigorous problems involving in safe water access will be resolved or greatly diminished with the application of Nanotechnology.

Keywords: Water Treatment, Nanotechnology, Nanomaterials, Green Synthesis.

Introduction

Water Resources, Water treatment and its challenges

Water demand is raising entire the globe, though fresh water resources are depleting due to some of natural and anthropogenic activities which is resulting prolonged drought, increasing population, climate change threats and coupled with strict water quality standards have been introduced (Lee and Schwab, 2005) [11]. Most of developing countries enforced to use unconventional water sources as a result of fresh water supplies are getting depleted. Our water management systems (treatment system, distribution systems and wastewater disposable trends) which highly centralized seem no longer (sustainable) for the nations (Weber, 2002) [41]. Thus we need the development of our water treatment to support our nation alive. The impacts of some resources have integral of all aspects on human life. Among such resources water will take the major place. It is not affecting only on human health, availability of food resources, energy and economy of the nations but also it has extended impact on environmental security, socio-economic, sanitation, politics and many other related impacts will be (Mara, 2003) [6]. Indeed, supply of fresh water is very essential for the safety of nations in general for children specifically (Theron and Cloete, 2002) [17]. However research shows that around 10-20 Million people die each year by waterborne and also nonfatal infection killing more than 200 million people every years (Leonard, 2003) [33]. On average daily about 5000-to-6000 children dies diarrhea which is water related (Ashbolt, 2004) [31]. Currently more than 0.78 billion people entire the world have no access for safe water and caused major health problems (WHO and UNICEF, 2013) [42]. This also projected that in coming couple of decades more than 1 billion people in the world will face problem in safe

water access while current water supplies will be decreasing by one-third. Whereas, the only accessible fresh water will be 0.5% of 1.4billion KM^3 of world's water resources in which is further more poorly distributed across the globe (Dessouky and Ettouney, 2002) [14]. Additionally, there is very limited possibility to boost supply of fresh water with today competing demands, current per capital consumption growth trend, water related tribulations due climatic threats and population growth (Osmarty, 2000) [2]. UN's projection shows that, world population will increase by 2.9 billion as of now and 2050 (Rockstrom; 2003) [16]. Among many others for depletion of fresh water are over consumption and exploitation of water resources for industrial application, currently modified agricultural purposes, wasteful domestic uses and so forth around the globe.

The pollution in our water sources such as on surface water and ground water sources due to anthropogenic activities is also an other causes for the depletion of fresh water from sources. Salty water intrusion, erosion, sanitation, contamination by microbes, our daily detergents, modern pesticides and fertilizers, chemicals, heavy-metals and so forth are entering to our water sources and resulting depletion aquifers around the globe and they are polluting (Ritter, 2002) [22].

In another ways there is an introduction of newly emerging micro-contaminants such as endocrine disrupting compounds/EDCs in a polluted water and wastewater is today's main challenges for existing conventional water and wastewater treatment ineffectiveness to fulfill environmental standards. This will show us our conventional water and wastewater treatment techniques, treatment materials and technologies such as Reverse Osmosis/RO, activated sludge treatment, oxidation, membranes, Nanofiltrations/NF cannot be effectual to maintain our water resources due to its more complex and complicated quality of water sources which is comprise of personal care chemicals, pharmaceutical products, surfactants, additives and other many chemicals purported. Since our conventional water and wastewater treatment system are inadequate for the removals of today water pollutant. Thus, it is the right time to keep on researching for new water purification technologies in order to properly addressing water and its derivative problems. New outlook for water treatment technologies which can be applicable in all condition for all nations, reliable, efficient, economical, safe and easy is very essentials in entire the globe. Even though dilution of domestic or industrial effluent may reduce the load of pollutants downstream, however much of them can escape from conventional water treatment because there are newly emerging pollutants having sizes of micro and nano-grams per liter (Verstraeten, Heberer, Vogel, Speth, Zuehlke, and Duennbier, 2003) [28].

Water treatment system such as biological sludge and trickling filters are ineffective in order to remove a wide range of newly emerging contaminant there by these compounds stay soluble in the discharged effluent (Servos, Bennie, Burnison, 2005) [27]. Various studies prove that the removals of EDCs and other pharmaceutical by physicochemical treatment such as coagulation flocculation, lime softening become ineffective (Petrovic, Diaz, Ventura, and Barcelo, 2003) [26] while chlorination, providing residual protection against regeneration of pathogens (Szewzyk, Szewzyk, Manz, and Schleifer, 2000) [36], but it is resulting undesirable odors and tastes (Suffet, J. Ho, Chou, Khiari and Mallevialle, 1995) [15].

Even though ionization considered good as alternatives, it fails due to its expansiveness and short lifetime. As far as micro-pollutants of today concerns; even some of advanced treatment methods like ultraviolet (UV) photolysis and ion exchange are not feasible alternatives (Adams, Wang, Loftin, and Meyer, 2002) [3]. In another way, some of membrane processes such as microfiltration, ultra filtration, Nano filtration, reverse osmosis in which high pressure driven filtration processes are recently considered as new and highly effective processes for the removals of huge amounts of organic micro-pollutants (Bodzek, Dudziak and Luks-Betlej, 2004) [24]. This membrane technique in water and wastewater treatment is cost effective and also technically practicable as compared to traditional treatment systems to meet high environmental standards (Owen, Bandi, Howell and Churchouse, 1995) [12]. While Nanofiltrations and Reverse Osmosis have been proved as quite effective filtration technologies in order to remove micro pollutants (Yoon, Westerhoff, Snyder and Wert, 2006) [44]. Even though Nano-filtration based membrane processes are very effective for the removals of highly loads of micro-pollutants, there is high demand for advanced materials and treatment techniques for newly emerging micro-pollutants in order to address the main challenges of the century which is providing safe and fresh water in adequate qualities and quantities (Bolong, Ismail, Salim and Matsuura, 2009) [30]. Therefore, our conventional treatment systems have to be upgraded by developing materials and techniques in which it has more features such as more efficient, reliable and less cost. Here, one among the most recent and promise for the future has to be considered most effective in solving water problems especially for the enhancement of water supply in both qualities and quantities which is Nanotechnology (Bottero, Rose and Wiesner, 2006) [19]. Carbon-nanotubes/CNTs and Dendrimers are most important example among the contribution of Nanomaterials for more efficient treatment processes of advanced treatment systems (Obare and Meyer, 2004) [34]. To ensure/address multiple problems of our today water resources and environmental stabilities Nanotechnology has several aspects to be considered.

All the reviews showing that, safe drinking water both in quality and quantity are among rigorous problem as of today. These problems becoming more and more severe in developing countries like Ethiopia and India in which 80 % of diseases is caused by contaminated drinking water (WHO, 1996) [43]. In another ways, our world is facing redoubtable challenges in meeting ever rising demands for clean water compounded with depletion of available freshwater supplies, population growth and growing trend of per capital water consumption (US EPA, 1999) [40]. As far as water treatment concern, numerous techniques are available with the application of chemical and physical agent such as using chlorine and its derivatives, low frequency ultrasonic irradiation, UV, Reverse Osmosis, activated carbon, ion exchange, distillation, ionization, and many others can be considered and also halogens such as chlorine (Cl) and bromine (Br) are widely known and used as antibacterial agents. But direct uses of halogens as bactericides' have many problems due to their toxic properties and vapor pressure in their pure form (Droste, 1997 and Gupta, Behari and Kesari; 2006) [10, 13].

One of the Common cation; which affecting animals and human health is NH4+. The removal of this cation is very important especially in drinking water to control oxygen

depletion and algal bloom and its toxicity to most of fish (Jung, Chung, Shin and Son, 2004) [21]. This can be substitute by biologically acceptable cations such as Na^{+}, K^{+} or Ca^{2+} in zeolite. There are number of investigation in the past few decades have made to use synthetics and natural zeolites, polymer films and metal ion Ag^{+}, Cu^{++}, Zn^{++}, Hg^{++}, Ti^{+++}, Ni^{++}, Co^{++} as anti-bacterial in water disinfection (Chohan, Suparna and Scozzafava, 2004) [4]. Research is underway to use advance nanotechnology in water purification for safe drinking water. This technology is that of deliberate manipulation of matter in nano scales which is less than 100nm at least in one direction. It is promising in creating new advanced materials and devices with the advantage of unique phenomena realized at those length scales, this is because of their high reactivity introduced by large surface to volume ratio. Today, these nanoparticles (NPs) are anticipated to play leading role in water purification (Dhermendra, Tiwari, Behari and Prasenjit, Sen, 2008) [8]. Even though the knowledge about the environmental fate, toxicity and transport of nanomaterials is still in infancy, no doubt at all that Nanotechnology is by far better than any other techniques used in water treatment system (Colvin, 2003) [5]. The advancement in nano-scales suggesting that, many of the current rigorous problems involving in water quality will be resolved or greatly diminished with the application of Nano-Absorbent, nanostructured catalytic membranes, bioactive nano-particles, nano-catalysts, flake, granules, magnetic nano-particles, nanotubes, submicron, nano-powders, nano-metal particles, supra-molecular assemblies with length scale of 9-10 nm including colloidal clusters have micro molecules as significant impacts in water quality of natural environments (Mamadou and Savage, 2005) [29]. Nanotechnology will uses for detection of pesticides, biological matters and chemical substances (Cadmium, Copper, Lead, Mercury, Nickel and Zinc) also nutrients (Phosphate, Ammonia, Nitrite, Nitrate), Algae, Bacteria, viruses, Parasites, Cyanide organics, antibiotics and Biological agents are used for different purpose even for some terrorism acts (Nair and Pradeep, 2004) [32]. Now a day, newly emerging crucial problem in protection of water treatment system against potential chemical and biological terrorist acts in water resources planning (US EPA, 1999) [40].

Review Results

Nanotechnology and water purification

In its broad senses nanotechnology is manipulation of matter having size ranging from 1-to-100nm at least in either of the dimensions while Nanomaterials are the particles (crystalline or amorphous) of organic or inorganic materials having size of ranging from 1-to-100 nm (Edelstein, 1999) [1]. There are number of ways to classify nanomaterials for instance according to (Zhang and Lagall, 1997) [45] can be classified into (two major groups) nanostructure materials which is condensed bulk materials that are made of grains in which grain sizes is in the nanometer sizes and the other class is called nanophase/nanoparticle materials which are dispersive nanoparticle. Today's research showing us there is high demand for miniaturization of our devices for most efficient in to nano-sized with enhanced their ultimate performance. This is mainly important for the achievement in specific functionality and selectivity. This will be achieved through the technology of design, fabrication and application of nanomaterials based on fundamental physical properties and materials dimensions. This technology also promises the possibility of creating nanostructures of metastable phases with non-conventional properties such as magnetism and super-conductivities, also more and more miniaturization present and future instrument, new sensors, and machineries of wider application which can create significant difference for the world. Very recently Nanotechnology has get ever growing demand in Environmental application such as for the removals of toxic chemicals in human body, in water purification, in environmental monitoring and others. It is seen that properties of these miniaturized particles are quite sensitive to their sizes (Weertman, 1996) [18]. The twenty-first century highly demands the new technology in order to miniaturization of devices in to nanometers sizes with their performance superior and in this regard "Nanotechnology" will be considered as next revolution entire the globe (Thomas, Varghese & Balakrishna; 2012) [35]. There are plentiful Nanomaterials naturally, as alike as organisms operating basically at nano-scale levels. Expertise of Nanotechnology mostly wills to produce and utilize both novel nanomaterials and natural nanomaterials in huge quantities and in more controlled and consistent size ranges. Even though numerous techniques are used in fabrication of different nanomaterials, they can be generalized in two main categories based on our starting point of production. One of the mainly known is that the production of nanoparticle from larger structures in the approaching ways called Top-to-Down approaches with the application of considerably ultrafine grinders, lasers and vaporization followed by cooling. while the second type is "Bottom-to-Up" approaches which is generally preferred by nanotechnologists' to synthesize nanostructures by forming new arrangement of molecules to form other complex structures with new and useful characteristics.

Commonly used NPs in water treatment

The exploration of NPs is underway and also plenty of research work is needed. As far as recent research shows that there are four major classes of Nano-scale materials which have been evaluated as most functional materials for enhancement of water quality (Dhermendra and Tiwari, 2008) [8]. They are Dendrimers, Metals, Zeolites and carbonaceous. These four classes of nanoparticles are recently get particular attractive for separation of pollutant and reactive media in water purification areas. In characterization process of the interaction of those nanoparticles with bacterial contaminant caused by Atomic-Force-microscopy (AFM), Transmission-Electron-Microscopy (TEM) and Laser-Confocal-Microscopy is indicating significant changes of integrating cell membranes in which resulted bacteria has been killed in most cases (Dhermendra and Tiwar, 2008) [8].

Synthesis of Nanoparticle

There are number of chemical and physical methods/processes widely used in order to synthesize nanoparticle. However, all of these production methods are not cost effective, they are labor intensive and toxic to human, environment and other organism (John & Fendler, 1998) [20]. Therefore, it is clear that high need for other alternative method in order to synthesize NP's which most efficient, environmentally sound, inexpensive and easy, not time consuming and high possibilities for mass production. Our recent development is questioning and enforcing the researcher to take care of environmental safety in their innovation. Thereby the advancement of green chemistry is evolving and growing faster than ever. Therefore, in

synthesizing nanoparticle the methods has got attraction by many researchers. Researcher, entire the globe in the areas of nanotechnology considering highly factor such as efficiency of NP's, environmentally soundness of the methods, cost effective materials, easiness of the process, needed time to produce, possibilities for mass production in synthesis of nanoparticle are attractive platform. In consideration of those factor uses of organism/biological substance has got attention. Today's wider application of metal NP's is based on their number of unique properties which distinguish form their bulk types (Zhang, Gu, Chan, Wang, Langer, Farokhzad, 2008) [46]. The following figure will show the two main categories of nanoparticle synthesis by "Bottom-to-Up" approaches.

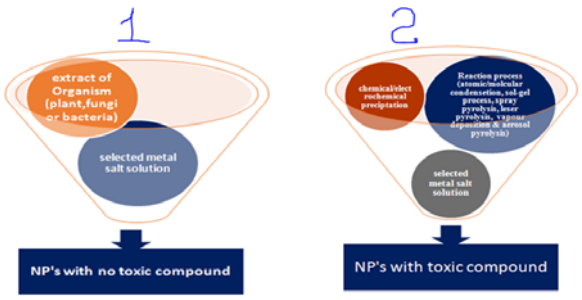

Fig 1: (1) Synthesis of Metal Nanoparticle by Green Methods, **(2)**Synthesis of Metal Nanoparticle by other than Green Methods (Sources: a part of principal author's practical work experiences in 2015)

Conclusion

All reviewed research shows that, the impact of water resource is exerting pressure in all direction to all nations' entire the globe and becoming world most competitive resource in many parts of the world. In many researches this impact is increasing drastically with increasing natural and anthropogenic climatic threats such as introduction of new emerging pollutant, population growth, prolonged drought, climate changes and many others.

In the other way, our conventional water and wastewater treatment system are inadequate for the removals of today water pollutant coupled with increasing demand and strict water quality standards. Thus, it is the right time to develop new water treatment technologies and techniques to address water and its derivative problems. More and more new research outlook is highly needed. Water treatment technologies which can be applicable in all condition for all nation, reliable, efficient, economical, safe and easy is very essentials in anywhere in the world specifically for developing countries and it is grand challenges for the researcher of this century. Accordingly, Nanotechnology have got particular attractive with the nanomaterials having distinctive biological, physical as well as chemical properties/characteristics as a result of large surface areas, manageable size, shapes and dimensions for water and wastewater application in the process like membrane separation, adsorption in selective and effective removal of pollutants, disinfection process of pathogens.

All the reviewed literatures are showing that application and developing nanomaterials for water and wastewater treatment is the only promising technologies and techniques as far as current development of water treatment fields and future research concerns.

Even though application of nanomaterials is considered as promising materials for current and future, this field is needs intensive research works. Specially, environmental fate with the application of nanomaterials, protection of water treatment system against potential chemical and biological terrorist acts, some modification of currently used nanomaterials for more selectivity and reactivity of selected materials and others are big questions/homework for the researchers.

There are many optional ways in preparation of nanomaterials such as physical, chemical and biological or green synthesis methods are mainly known. But researchers have to alerted in exploiting resources for nanomaterials synthesis in order to make it most competent and environmentally friend approaches. Among recent synthesis methods in nanomaterials; Green synthesis is the most eco-friendly approach which has to be practiced by the researchers in the world. The advancement in nanoscales suggesting that, many of the current rigorous problems involving in water quality will be resolved or greatly diminished with the application of Nanotechnology.

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