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REVIEW ARTICLE

NANOPHARMACEUTICALS AND BIOREMEDIATION

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ABSTRACT

Usefulness of nanotechnology is exploring for producing safer and appealing pharmaceuticals. Those devising with said technology has specific surface chemistries and properties, for achieving wished novel physicochemical properties. These being manufactured nanomaterials presented as nanopharmaceuticals bearing dissenting biological and chemical properties comparing their macro form. Comparing natural nanomaterials, manufactured nanomaterials may act differently conferring potential and novel benefits and concurrently may peril. Their dispersion and shading into environment from the composite material may or may not associate with aging and degradation. Major concern bobbing up from their dispersal and shading is fate and ecological consequences and pollution of aquatic system. This may be periling diverse aspects of human life and environment, and causing ecotoxicological effects periling environment and ecology. Diverse remediation process adopting for nullifying ecotoxicological effects of nanomaterials in aquatic system. However, biological systems are receiving attentions for remediating it and process is terming 'bioremediation'. This process be exploiting to adsorb or sequester pollutants and to remove them. Bioremediation process is considering as novel, improved and efficient methods for degrading and sequestering pollutants of water, seeded nanomaterials. Available literatures are unable to provide insight on nanopharmaceuticals and their bioremediation. In this regard, information collected and presented as a handy reference. This insight features on bioremediation of nanopharmaceuticals and has applicability in nullifying their ecotoxicological effects.

Key Words: bioremediation, ecotoxicological, effects, nanomaterials, nanopharmaceuticals, nanotechnology.

INTRODUCTION

Global technological competition and breakthroughs driven by science and engineering had been resulting amalgamation of features of nature and science at nanoscale. This is bearing foundation of new knowledge, innovation, and integration of technology. It stemming in production of nanomaterials, the novel materials and devices whose properties never envisioned before. Nanomaterials are devising with nanotechnology have potential in rendering products with novel properties in diverse domain [1-4].

Usefulness of nanotechnology is exploring for producing safer and appealing pharmaceuticals, safe and more nutritious and appealing foods, and for protecting or remediating environment. In remediation of environment is through pollution prevention, treatment, and cleanup; combating long-term problems at hazardous waste sites; and replacing current practices for site remediation [1-4].

Nanotechnology-based products are marketing as electronic items, stain-resistant clothing, self-cleaning glass, paints, sports equipment, biotechnology products, nanopharmaceuticals, transparent sunscreens, and so on. Introduction potentially of nanomaterial bearing products is broadening gradually and having expectation for enhanced importance in near future [1-4].

Nanopharmaceuticals are the manufactured nanomaterials designed with specific surface properties and chemistries for achieving wished novel physicochemical properties. These confer potential and novel benefits concurrently may peril, as these may act differently, comparing natural materials. Possible benefits over possible risks of them remain unclear. These may have differing biological and chemical properties comparing their macro form. Thus may be periling so many aspects of human life and environment and their consequences on human and environmental health became a concerns. Bearing of ecotoxicological properties and poorly understood potential risks might escort unintended consequences like irreversible damage [1-5].

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Questions/concerns on the safety issues of nanopharmaceuticals include their fate in human, their fate and ecological consequences, and so on. Major concern bobbing out is ecological consequences followed to their dispersion and shading into environment from the composite material may or may not associate with aging and degradation. These upon dispersion and shading into aquatic system pollute it [1-4].

Ecotoxicological effects of dispersed and seeded nanomaterials from composite nanopharmaceuticals periling environment and ecology. Reports on ecotoxicological effects are available while concerns intensifying possible impact on plants, animals, microorganisms, and ecosystems [6-12].

Nowadays, diverse remediation process adopting for nullifying ecotoxicological effects of nanomaterials. Amongst them biological systems are receiving attentions for remediating aquatic system. Use of biological system in remediation process of environment is termed as 'bioremediation' [13].

Bioremediation process be exploiting to adsorb or sequester pollutants and to remove them from water. It is considering as novel, improved and efficient methods of water purification be using for degrading organic pollutants of water [13].

Present work is insights bioremediation of nanopharmaceuticals. Laid information has applicability in complying issues adjoining use of nanotechnology and pollution abatement of nanopharmaceuticals.

NANOPHARMACEUTICALS AND NANOTECHNOLOGY

A material may have diverse optical, electrical, magnetic, mechanical and chemical properties at assorted size scales. Over past two decades, this desperate concept is stemming scientists and engineers in mastering the intricacies at nanoscale level. Manipulation of structures at the atomic level is developing newer technical methods for more precise and controlled production of novel materials and devices. These be terming as nanomaterials are devising with the nanotechnology. 'Nanotechnology' is the understanding and control of matter at dimensions between approximately 1 and 100 nanometres, where unique phenomena enable novel applications [1-4].

Integration of nanotechnology and pharmaceuticals synergizes effect of pharmaceutical mothering nanopharmaceuticals. The effort is to abreast improving performance of medications, cosmetics, delivery systems, and diagnostics. Improving performance is abreast in increasing efficacy, tolerability, specificity, stability, patient compliance, therapeutic index, and so on. In addition, is in nullifying toxicities and improving marketability [1-4].

Enormous potential of nanotechnology bobbing up in devising nanopharmaceuticals is under extensive study. Pharmaceuticals containing nanomaterials presented as nanodosage form, nanotherapeutics, and nanodevices. These having potential in revolutionising offering of device for drug targeting or site-specific controlled delivery, and presenting of differential device-activity in dissimilar physiological environments, under direction of an external operator or physician. In addition, efforts is presenting them as disinfectants, cosmetics, and biosensor or bio-tracer based diagnostic agent for detecting toxins, pathogens, volatile compounds, and organic components of body fluids; and for monitoring diseases [1-4].

Semi-biological nanodevices may be offering versatile therapeutic services demonstrating unitary biochemical activities. Nanodevices amalgamating imaging and therapeutic function can provide therapeutic intervention concurrent with prognostic information [1-4].

Nanovesicles may be vesicular systems encapsulates drug in a cavity of polymeric membrane. Polymeric nanodevices with diverse functionality were being designing. Vesicular nanodevices have poor kinetic stability comparing nanoparticles [1-4].

Nanodevice systems are designing with diverse functionality. Type of process or technique and materials is bearing for wished physicochemical properties and wished therapeutic objective. Biodegradable and non-biodegradable polymers of natural or synthetic origin is using for devising them [1-4].

Adsorbing or grafting of molecules on surface of nanodevice modifies its surface property modifying interaction with intestinal mucosa. Ligand molecule like glycoproteins, antibodies or peptides confers targeting while hydrophilic molecules like polyethylene glycol improve transcytosis. Adsorbing, grafting, or coating of them with mucoadhesives improves gastric retention time [3, 4, 14-18].

BEHAVIOUR OF NANOPHARMACEUTICALS

Nanopharmaceuticals devised with specific surface properties and chemistries that were not likely to be observable with natural nanomaterials. Consensus on them is the engineered nanomaterials contained in it may act differently comparing natural one [1-6].

Entry of nanopharmaceutical in human body is through gastrointestinal (GI) -tract, skin and or lungs. Concern on their safety was rising with similar properties as comparable with pathogenic particles [12, 19, 20]. Evidence exhibiting uptake and internalization of them by diverse type of mammalian cells, and their ability to cross the cell membrane are available [21-23]. They were more likely to penetrate the skin unpredictably to significant extent [24].

Factors playing majorly in bearing of toxicity by nanopharmaceuticals are size dependency for their uptake, increased concentration and exposure time, and large surface area [25-28]. In addition, their inhalation at elevated concentrations may cause inflammatory reactions in lungs and adverse effects in the nervous and cardiovascular systems [24].

Nanomaterials cause oxidative stress in the liver, harm the brain associated with higher Blood Brain Barrier permeability, and activate blood platelets leading to clot formation [24]. Ferric oxide nanoparticles upon inhalation

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may uptake by cells causing oxidative stress response at much higher level [29]. While it upon internalization by cells leading to cell death and may persist in biological systems leading to potentially long-term effects. Possible long-term effects may due to mutagenic influence on organisms through DNA damage, lipid peroxidation, and *in vivo* oxidative protein damage [30, 31]. Internalization of dispersed C60 fullerenes results morphological changes in the vascular endothelial cells while at elevated concentrations could induce lethal effects and cytotoxic [32, 33].

Fate of nanomaterials in human was chiefly unknown [34]. Amongst, paracellular or transcellular route, transport for particles across the epithelium of GI-tract, transcytosis involved in the uptake of them. Transcytosis is dependent on physicochemical properties of nanomaterials, physiology of the GI-tract, and animal model used for study [35]. In addition, some aspects of GI environment and abrupt change in pH from stomach to intestine, disease state of the gut, and presence of other macromolecules in food may affect uptake of nanomaterials or possible toxicity [24].

Dispersal and shading potential of nanopharmaceuticals depends on its dissolution potential. Said potential is influencing by not only properties of dissolution media but also quality and quantity, size or surface area, surface energy, surface morphology, and aggregation of nanopharmaceuticals. The characteristics of exposed environment, and the biochemical, physiological, and behavioural traits of the exposed organism and adsorbing species determines their biological and ecological fate and effects [36-38].

Environmental fate of seeded nanomaterials depends on their potentiality for aggregation-segregation and adsorption-desorption occurring during interaction among themselves and or with natural nanomaterials or macromaterials [39-41]. Their aggregation potential in natural systems depends upon their particle size and physical processes like Brownian diffusion, fluid motion, and gravity. This potential also determines efficiency of their removal from environment [42].

The surface charge of nanomaterials plays dominantly in their adsorption processes that consequently modifies their nature [43-45]. Their mobility can be modifying with coating and environmental conditions. Environmental conditions like composition of groundwater and hydrologic conditions responsible for facilitation or inhibition of contaminant transport bears for increasing/decreasing toxicity of transported contaminants [14-18, 46-50].

Proponents of nanotechnology and nanopharmaceuticals were reviewing concerns along with difficulties referring reliability on assessing potential utility and safety prior to their continuances. However, proponents on promising beneficial properties could hostile governments, damage ecology and environment leading to wreak havoc, and are becoming a hot topic [12, 51-53].

ECOTOXICOLOGY OF ENGINEERED NANOMATERIALS

Nanomaterials seeded from nanopharmaceuticals may accumulate in the environment can scupper negatively affecting stability of many aquatic ecosystems. In addition, can be peril human health and the environment. Human activities, use, industrial discharges, domestic effluents, and improper waste disposal practices are seeding nanomaterials from composite nanopharmaceuticals [1-4].

Seeded nanomaterials pollute the aquatic ecosystems and may be persistent. Persistency processes involves processes of their adsorption, desorption, immobilization and accumulation, and transformation and activation. Persistency can made them available to benthic organisms as well as organisms in the water column [54]. Their persistence can scupper health and safety of human and wildlife [55-57].

Reports on ecotoxicological effects of manufactured nanomaterials were available [7]. In addition, lab-scale report on uptake of some manufactured materials by fish, *Daphnia magna*, copepods, and other organisms were available. Raising peril being on reactivity of nanomaterials might affecting plants, animals, microorganisms, and ecosystems making up the basis of food chains [8-12]. Some nanomaterial scupper humans and or environment may have damaging potentiality. Knowledge on impact of nanomaterials in the environment and on human health was still scarce [7, 56-58].

Nanopharmaceuticals high in lipids serve as the base of both pelagic and benthic food chains are categorised as persistent organic pollutants (POPs). POPs peril if persistent and enter the food chain may be carcinogenic. These pollutants may be classing as polycyclic aromatic hydrocarbons (PAHs), short and long chain alkanes, and Polychlorinated biphenyls (PCBs) [56-59].

Shorter and longer chain alkanes (< C10 and C20–C40 respectively) and PAHs are difficult to degrade [60]. Phenanthrene (PHE) and fluoranthene (FLA) highly toxic pollutant belongs to PAHs [61]. Nonchlorinated aliphatic and aromatic hydrocarbons are hydrophobic and pass very slowly to the aqueous phase liquid where microorganisms are active and use them as carbon source [62]. The asphaltenes most complex hydrocarbons contain nitrogen, sulphur and oxygen, are very resistant to microbial degradation [63, 64].

PCBs a worst pollutant is toxic and carcinogenic, widely distributed and slowly biodegraded in the environment. Their degradation is complex as many are of different forms. Some of monohydroxylated PCBs are potent endocrine disrupters. Whilst some metabolites of PCBs having a hydroxy group at meta or para position reported to be involved in developmental neurotoxicity [54, 65, 66].

Studies emphasizing peril of nanomaterials on health and environment, and assessing their life cycle were very infancy. Lack of data on said issue is detracting consensus. Their damaging potentiality may inaccessible due to lack of knowledge on dosage and follow-up of traditional risk analysis models. However, their unique physicochemical property complicates environmental risk assessment [67, 68].

Size-dependent adsorption reactivity of crystalline iron-oxide nanomaterials is responsible for conveying adsorbed pollutants like copper, mercury, and silver. Consequently is eliciting toxicity on algae, fungi, flowering plants, and phytoplankton [69].

BIOREMEDIATION

Bioremediation is a waste management technique involving use of organisms in removal or neutralization of pollutants from a contaminated site. Alternately is a 'treatment that uses naturally occurring organisms to break down hazardous substances into less toxic or non toxic substances'[70, 71].

The technologies of bioremediation can generally be classifying as *in-situ* or *ex-situ*. *In-situ* technology involves on-site treatment of pollutants, while *ex-situ* involves their removal from the site followed by off-site treatment [70, 71].

Process of bioremediation may occur on its own calling natural attenuation or intrinsic bioremediation. Alternately may only effectively is occurring through addition of fertilizers, oxygen, etc. Added materials encourage growth of the pollution-eating microbes within the medium terming as biostimulation [70, 72].

Worldwide the trees, grasses, herbs, and associated fungi and microorganisms have being using increasingly for remediating polluted sites. Phytoplankton critically controls the fate of POPs in the water column as are high in lipids and serve as the base of both the pelagic and benthic food chains [59, 73]. In some cases these uses to detoxify organic compounds [71].

Bioremediation using plants is 'Phytoremediation' and that using fungi is 'Mycoremediation'. Phytoremediation 'on the brink of commercialization' is proposing often for bioaccumulation of metals. In Europe its market potential is still emerging and increasing rapidly while in United States the revenues progressing [74-80]. Mycoremediation follows decomposition of pollutant is performing by the mycelium of fungi. Mycelium reduces toxins *in-situ* by stimulating microbial and enzyme activity. Some fungi are hyperaccumulators, capable of absorbing and concentrating heavy metals in their fruit bodies. Microbial consortium exploited for degrading PAHs [71, 81].

Oyster mushrooms reduce PAHs to non-toxic components in the mycelial-inoculated plots. Wood-decay fungi are more effective in degrading aromatic pollutants, as well as chlorinated compounds, components of certain persistent pesticides.

The algae is exploring in controlling and biomonitoring of organic pollutants in aquatic ecosystems. Green algae are investigating for bioaccumulation/biodegradation of organic xenobiotics [72, 82]. The algae are effective in hyperaccumulation of heavy metals as well as degradation of xenobiotics [83]. Application of benthic microalgae in restoration of organic-polluted aquatic environment (sediments) is in primary stage [84].

Higher plants and bacteria are exploiting for bioextraction and bioremediation of heavy metals and organic pollutants [76-79, 85, 86]. Bacteria, fungi, algae producing enzymes are capable of degrading harmful organic compounds by attacking and utilising them. They are effective in remediating pollutants of hydrocarbon unless polluted medium contains limiting nutrients like nitrate, phosphate, and microelements [73, 87].

Some microorganisms can be degrading PCBs aerobically or anaerobically under diverse conditions [88-91]. Dioxygenases aerobically degrade lower chlorinated PCBs via co-metabolism resulting complete mineralization through ring cleavage [92]. However, orthochlorinated PCBs inhibit and inactivate dehydroxybiphenyl oxygenase, a key enzyme in the degradation pathway [93].

Brown algae *Caepidium antarcticum* and *Desmarestia* sp. having ability to associate their exudates with PCBs [94]. Uptake of PCBs congener 2,2',6,6'-tetrachlorobiphenyl, lipid assimilation, by *Stephanodiscus minutulus* (a phytoplankton) significantly altered by nutrient availability which subsequently affects transfer to *Daphnia pulicaria* (a zooplankton) [59]. Exudates from brown algae *Ascophyllum nodosum* and *Fucus* sp. are able in incorporating organic compounds like amino acids, sugars and fatty acids in their lipid stores [95].

Some microalgae producing enzymes are capable of degrading harmful organic compounds transforming them into low toxic one [87]. Benthic microalgae can remediate organically enriched sediments [84]. *Scenedesmus obliquus* GH2 (a microalgae) is used to construct an artificial microalgal-bacterial consortium [96]. This isolated microbial consortium upon mixing with asphaltenes fastens and improve oxygen consumption degrading crude oil and asphaltenes [97]. In addition, this in different amendments enhances significantly degradation efficiency of both aliphatic and aromatic hydrocarbons of crude oil. Another consortium of pre-isolated oil-degrading bacteria in association with three species of plants effectively remediates hydrocarbon [98].

Several microorganisms can metabolise the nonchlorinated aliphatic and aromatic hydrocarbons as sources of carbon, but due to their hydrophobicity they pass very slowly to the aqueous phase liquid where microorganisms are active [62]. Marine organisms including phytoplankton can uptake and accumulate several chlorinated hydrocarbons [99]. Consensus is that in bioremediation of organic contaminants such as PAHs oxygen plays key role and can proceed under aerobic and anaerobic conditions [100, 101].

Two algal species, *Nitzschia* sp. and *Skeletonema costatum*, accumulates and biodegrades two typical PAHs, PHE and FLA [102]. Accumulation and degradation abilities of *Nitzschia* sp. is more to *S. costatum*. Degradation of FLA by these species was slower making it more recalcitrant PAH compound. Removal efficiency of PHE-FLA mixture by these species is comparable or more comparing that of PHE or FLA alone [101-103].

An algal-bacterial consortium, *Chlorella sorokiniana* and *Pseudomonas migulae* (a PHE-degrading strain), degrades PHE under photosynthetic conditions without needing external supply of oxygen [103]. This suggests microalgae releases biosurfactants that could further enhance degradation of PHE. *Burkholderia cocovenenas* can degrade PHE liquid culture at pH values ranging between 5.5 and 7.5 [102, 104].

During biodegradation of PAHs, phenolics, and organic solvents by acclimatized bacteria requires O_2 could supplied by microalgae [105]. The bacteria after up taking PAHs gets activated in aerobic metabolism by insertion of two oxygen atoms supplied by green algae to produce either cis-dihydrodiols or phenols [106].

Nine cyanobacteria, five green algae, two diatoms, and one each of red alga and brown alga could oxidize naphthalene under photoautotrophic conditions. An algae *Agmenellum quudruplicatum,* strain PR-6 oxidises naphthalene to l-naphthol [107]. This suggests ability to oxidize naphthalene is widely distributed amongst the algae [107, 108].

Once in the aquatic environment, antimicrobials have potential inducing adverse effects on ecosystem health [109]. Organochlorine pesticides are lipophilic and persistent is accumulating along the food chain. These are ubiquitous environmental pollutants in the global ecosystem [110, 111]. In developing countries, pesticides causes up to one million intoxication cases and up to 20.000 deaths per year [102].

Phytoremediation of pesticides using transgenic plants is emergent nowadays [113]. Aquatic plants, *Leman minor*, *Elodea canadensis* and *Cabomba aquatic* can remove and assimilate three pesticides copper sulphate, flazasulfuron and dimethomorph. Their uptake capacity is of follow order *Lemna minor* > *Elodea Canadensis* > *Cabomba aquatic* [114]. *Scenedesmus quadricauda* is more effective in the removal of dimethomorph and pyrimethanil and isoproturon [115].

The green alga *Chlamydomonas reinhardtii* have great ability to accumulate and degrade fluroxypyr [116]. and prometryne [82]. Another green algae *Monoraphidium braunii* is considering as promising species for bioremediating aquatic bisphenol [117]. In addition, freshwater microalgae convert bisphenol A into its mono-glucoside [118].

The marine diatom *Amphora coffeaeformis* consumes mesotrione resulting increase in its cellular density [119]. Algae of *Chlorococcum* sp. and *Scenedesmus* sp. degrade α-endosulfan to endosulfan sulfate and endosulfan ether. The first is major metabolite and latter a minor metabolite [120].

Freshwater systems located in urban or agricultural areas exposes microalgae to a multitude of toxicologically different pesticides [121]. This could hypothesize in the appearance of resistant mutants. Thus will simultaneously determine arose of new morphological populations driven by algaecide-resistant clones [122].

BIOREMEDIATION BY GENETIC ENGINEERING

Nowadays genetic engineering had been using for improving bioremediation of heavy metals and organic pollutants. Expression of metal-binding proteins or peptides in plants and microorganisms enhances heavy metal accumulation and/or tolerance. Said ability of expression has great potential in removing heavy metals from contaminated aquatic ecosystems [123-126]. In this regard, the plants either with bacterial or animal xenobiotic degrading genes has been successfully tried a transgenic approach of engineering [83]. Genetic engineering can be creating genetically modified organism, potentially degrading diverse POPs and removing diverse toxic compounds [125-127].

Transgenic plants and associated bacteria constitute a new generation of genetically modified organisms for bioremediation. These transgenic organisms are developing to degrade or modify POPs [125-132]. Transgenic algae and microorganisms mutated with bioluminescence genes could be using in biomonitoring of organic and inorganic pollution [133, 134]. Expression of the catabolic genes of PCB-degrading microorganisms is a key factor for biodegradation of PCBs [135]. Transgenic plants expressing the bacterial xenobiotic degradation genes combine the advantages of both the systems. Firstly, more ability of biodegradation by bacteria secondly is high biomass and stability of plants for having an ideal system for *in situ* bioremediation of contaminants [86, 136].

Transgenic Chlamydomonas cells express metallothionin, a metal binding protein. These cells grow at normal rates in the presence of lethal concentrations of cadmium accumulating five-fold more cadmium comparing wild type cells [137]. Mixotrophy in cyanobacteria and microalgae can provide many competitive advantages over bacteria and fungi in degrading POPs.

Bioremediation of pharmaceuticals, pesticides, and petrochemicals also done with gomeya/cow dung [138]. Bioremediation of industrial pharmaceutical drugs had also been devised [139].

DEALING WITH THE UNCERTAINTY AND PERIL OF NANOTECHNOLOOGY

Introduction and continuances of nanopahrmaceuticals requires reviewing of its proponents. Their potential risks understood poorly. Underestimations of this might escort to unintended consequences like irreversible damage [5, 12, 51-53].

However, advocated promising beneficial effect of nanopahrmaceuticals could hostile governments or angry individual and damage humans and environment leading to wreak havoc and become a hot topic presently. Unavailability of data relating toxicity, exposure, and life cycle of their applications regulatory decisions were in a state of ambiguity. This level of uncertainty may be resulting in either forgoing benefits of nanopharmaceuticals bearing from too much regulation or scupper damages bearing from relaxed regulation [1, 12, 51-53].

Contradictory reports highlighting toxicology, gaps in research, and possible testing strategies for nanomaterials were publishing. Contradicting opinions bearing with scarce scientific evidence based harmful/hazardous effects is the elimination for need to regulate these by regulatory bodies and industry, and adoption of more proactive risk management strategies advocating by non-government organizations [1, 58].

Several government and non-government organizations had identified health risks and potential environmental consequences, and the importance for assessing it. Environmental consequences determine hazardous effects, fate and transport, and bioaccumulation of released/dispersed nanomaterials [1, 20].

Comparing other pharmaceuticals, nanopharmaceuticals have differing material, size, surface, and shape. Therefore, general claims cannot be making on associated health and other risks. Consequently, suggestions had been making to assess their risk and toxicity on case-by-case basis [1-4].

Many factors can be influencing the bioremediation of PAHs includes temperature, oxygene, pH, seeding potential and ecotoxicity. Temperature considerably affects ability of the *in situ* microorganisms to degrade them. In most situations, contaminated sites will not be at the optimum temperature for bioremediation throughout the seasons of year [100]. The solubility of PAHs increases with an increase in temperature. Their degradation potentiality is dependent on availability of optimum pH of contaminated sites [140].

Combination of microbiological and ecological knowledge, and biochemical mechanisms are the essential elements for successful *in situ* and *ex situ* bioremediation using transgenic bacteria and microalgae [141, 142]. Molecular methods and metabolic and genomic information will help in identification and selection of mixotrophic species of cyanobacteria and microalgae with capabilities to degrade organic pollutants. In addition, also this will help in monitoring efficiency of bioremediation [142].

CONCLUSION

Scientists working in the field of nanopharmaceuticals were more optimistic with their potential benefits while least concerned about risks periling to environment and public. Group of experts expecting these will be providing novelty in the treatment of human diseases whilst others were more concerned for environmental contamination and new health problems. Their application bears a high level of terror and suspect, was likely to turn into controversial topic. None redressing the issues with respect to public expectation may lead to a social amplification process.

Application of bioremediation in biomoniroring and restoration of aquatic systems favour the phytoextraction and biodegradation of many nanopharmaceuticals (pollutants). However, there still some persistent pollutants, from nanopharmaceuticals, difficult to remediate. The genetic engineering can solve this problem.

Transgenic bioremediation process may offering a promising tool to improve the absorption and bioremediation of many of said pollutants will increase phytoplankton tolerance to these pollutants. In addition, it is necessary to study and control temperature, pH, nutrient availability of aquatic ecosystems and other environmental parameters for increasing absorption, accumulation and biodegradation of diverse category of said pollutants. In fact, these parameters accelerate bioremediation process and reduce the time of decontamination of an aquatic ecosystem.

Discussed field will provide opportunities for integrating science and technology with social science and humanities. Whilst professionals may be updating on pros and cons by a well-developed educational mechanisms is through intelligent database. Governmental and non-governmental system must carefully redress health and the environmental consequences, necessary for delivering wished benefit combating hostilely attitude of public.

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