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Bioremediation of Waste water: In-depth Review on Current Practices and Promising Perspectives

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Abstract

World water resources are available in oceans and seas 97.5%, fresh water resources available is limited to 2.5% which is further contaminated by large range of pollutants such as the effluents from pharmaceutical industries, textile industries, food and dairy industries, mining industries agricultural waste, heavy metals, petroleum hydrocarbons, sewage waste etc. Textile, agricultural and pharmaceutical wastewater contain high concentration of organic matter, microbial toxicity, high salt, and difficult to biodegrade. Heavy metals like uranium, mercury, lead, chromium, copper, iron etc. can cause a major environmental problem due to their toxicity and persistence in nature. To combat, bioremediation is an option that offers the possibility to destroy or render harmless various contaminants using natural biological activity. Further, nanoremediation-nanotechnology that depends on the use of nanomaterials to tackle and address the formidable challenges of 21st century as water pollution crisis. In-silico approach is a computational framework, potential to perform virtual screening of pollutants and helps to fulfill the gaps and address the flaws of convention bioremediation. In this review paper is an attempt to compile the existing information on various treatment technologies viz. Bioremediation, Nanoremediation. Nanotechnology and In-silico approaches for treatment of waste water.

Keywords: Bioremediation; Heavy metals; Nanotechnology; Nano-remediation; Pesticides; Water pollution

Introduction

Due to increased industrialization and population development, environmental conservation and energy security have become major issues for the global economy. Natural resources such as water and fossil fuels have been used to meet human needs. The over exploitation of these resources has put the ecology and ecological sustainability in jeopardy. When used for domestic persistence, industrial processes release toxic gases into the environment and produce polluted water, which is poisonous to the environment receivers. When these toxic compounds accumulate, they have a negative impact on the water ecosystem and raise public health concerns. Water quality monitoring programmes have become more vital in ensuring the public health of water bodies that are vulnerable to pollution. The waste water treatment facility is used to convert unprocessed influents into fairly neutral sewages that can be disposed [1]. After an industry's sanitary needs are met, the water used in various industries in various ways, such as for production, cooling, washing, processing, transporting, and diluting agent, turns into waste water, also known as discharge water, which contains all of the hazardous waste from various industries. To increase water availability and safeguard water resources, wastewater reuse and recycling has become critical. The goal of wastewater treatment is to reduce the concentrations of specified pollutants to safe levels for reuse or discharge into the environment.

The treatment of wastewater involves a combination of biological and physicochemical processes, and the treatment technique chosen is mostly determined by operational costs, the source and quality of influent wastewater, and the effluent's intended reuse [2]. Though predictable methods for treating sewage and other wastewater have been found to be effective in reducing levels of heavy metals, toxic compounds, phosphorous, and nitrogen, these technologies have been found to be ineffective in reducing levels of heavy metals, toxic compounds, phosphorous, and nitrogen, generally requiring more than one step to treat most of the compounds, and not profitable. New machines have recently emerged to improve the effectiveness of target pollutant removal from wastewater. For example, in industrial wastewater treatment, the novel oxidation method offers a compelling option for eliminating non- biodegradable pollutants. Bioremediation is a natural process that uses bacteria, fungus, and plants to reduce, degrade, immobilize, and remove contaminants from water, allowing the contaminated site to be cleaned and returned to a harmless state. Bioremediation is described as a cost-effective and environmentally acceptable process for cleaning up the environment that is gradually becoming the norm. Physical, chemical, and biological bioremediation are examples of diverse forms of bioremediation. Physicochemical procedures like as flocculation, electrocoagulation, active carbon adsorption, and ozone treatments are the most extensively utilized. *Pseudomonas, Bacillus, Achromobacter, Aspergillus,* and *Rhodococcus* are all essential bacteria in bacterial remediation. Phytoremediation is a type of remediation that takes place in the natural environment. This approach is based on plant-pollutant interactions that are chemical, biochemical, microbiological, and biological. Fungal bioremediation is the process of fungi such as *Actinomycetes* and *Aspergillus* spp. degrading pollutants. The breakdown of carbon by *cyanobacterial* bioremediation includes the use of polyethylene. Textile waste water contains a variety of elements that are harmful to the environment, including organic dyes, bright colours, high COD levels, *heavy metals*, *phosphate*, *nitrates*, and *sulphates*. Microalgae can absorb these

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nutrients to help them develop and convert them into useful biofuels like biodiesel. Heavy metals such as *arsenic*, *cadmium*, *fluoride*, *lead*, and *mercury* are among the most common contaminants found in wastewater. The paper industry produces large amounts of waste water with significant levels of phenolic, chlorinated, and lignin-derived pollutants, as well as *sulfonated* contaminants. Metal pollution in aquatic life has been linked to the discharge of industrial wastes and sewage into waterways. They efficiently adhere to clogged particles, gather in the riverbed, and eventually release into the surrounding water, providing a life-threatening threat [3]. Lead in gasoline, acid rain from soil leaching, non-point source runoff, industrial and air pollution, precipitation, processing operations, copper smelting, mining, landfill, and nuclear fuel processing are all human-caused sources of these metals in natural streams (Figure 1). Industrial wastewater has an impact on groundwater quality as well as the ecosystem's flora and fauna. Toxic metals such as cobalt, selenium, zinc, cadmium, copper, vanadium, arsenic, chromium, mercury, nickel, iron, and lead are the most dangerous to humans and should be removed from wastewater to allow value products to be produced. A viable method for restricting the spread of contaminants while lowering toxin levels is essential, given the expanding number of polluted places around the world. One novel treatment technique is for microbes to extract toxins from polluted environments. Biological therapy of waterstuff is the employment of indigenous microbes to alter the organic environment. Bioremediation treatments based on microorganisms are a safe, low-risk, cost-effective, adaptable, and ecologically friendly treatment alternative. Bioremediation is the process of breaking down environmental pollutants into less harmful forms using living organisms, typically bacteria and fungi. Bioremediation enhances radioactive pollution clean-up by converting radioactive wastes into living organisms. Low-harmful versions of contaminants are employed to remove or immobilise contaminants. The processes necessitate the employment of naturally occurring microorganisms those breakdown harmful pollutants and provide food for their growth. As a result, bioremediation can only be successful in conditions where microbial activity is allowed. In this presenting review, we attempt to quick highlights the potentiality of the various treatment technologies of waste water includes natural bioremediation, nanoremediation – nanotechnology and in-silico approaches for cleaning of waste water (Table 1).

Bioremediation of pharmaceutical industry waste water (PIWW)

The waste that pharmaceutical industries produce has hazardous implications on the environment and public health if disposed untreated. Pharmaceutical Industry Wastewater is the product of the drug and formulation development process and its safe disposal upon treatment is very essential. The water discarded from the manufacturing units of pharmaceutical industry wastewater (PIWW). The medication manufacturing process is not keeping up with the treatment alternatives available; in 2008, global phenol production for various industries exceeded 8 million tonnes. As a result, when these substances are ingested or utilised for household purposes, they accumulate to have a negative impact on the water ecology and cause public health issues (Figure 2). Organic biodegradable, organic non-biodegradable, and inorganic compounds, heavy metals, and potential inhibitors are all examples of PIWW that eventually wind up in a water catchment region or groundwater as landfill leachates. The pharmaceutical industry's effluent stream is not consistent because it comprises substances ranging from active biomass and antibiotics to poly aromatic hydrocarbons and phenols, and it contains substances ranging from active biomass and antibiotics to poly aromatic hydrocarbons and phenols. Microplastics were also discovered in the water bodies, which are crucial to this business because polymers such as PVC and others are utilised for packaging. They have gene-altering and endocrine-disrupting impacts on aquatic life and are toxic to other biota. Because of the fragmentation process, they represent an indirect threat to human health. Traditionally, PIWW treatment has

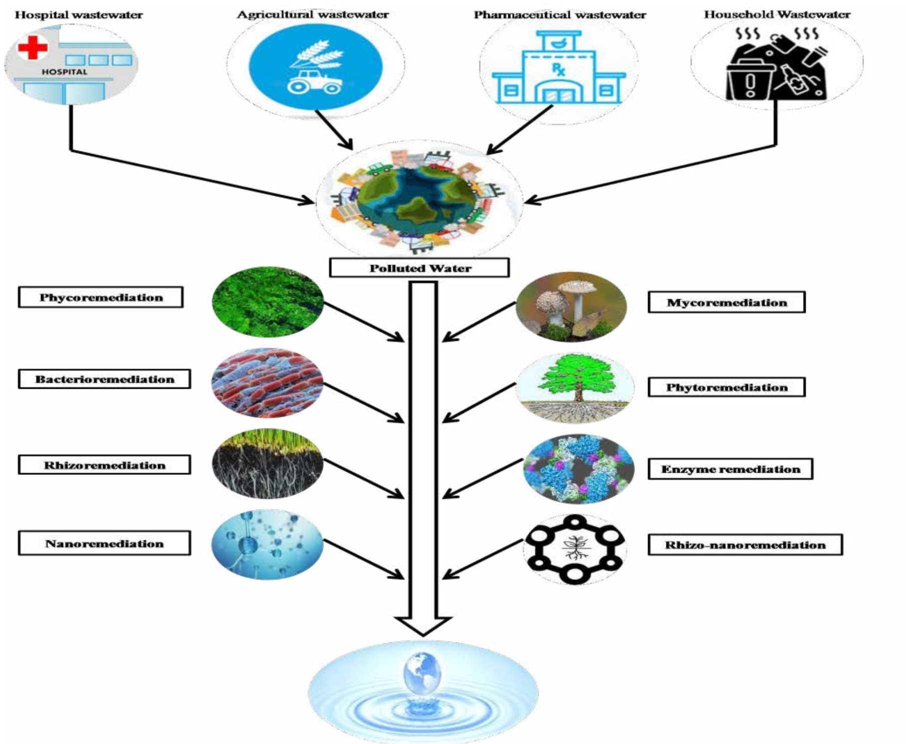

Figure 1: Bioremediation sources of contamination and various remediation techniques.

Table 1: Microorganisms and their genes involved in bioremediation mechanism.

S. No.	Gene name	Accession ID	Microorganism	Function
1	tbmD	Acc. ID 187	Pseudomonas aeruginosa	*Cellular aromatic compound metabolic process. Toluene/ benzene monooxygenase large subunit [28]
		Acc. ID 174	Pseudomonas putida	
		Acc. ID 12176	Pseudomonas oleovorance	
		Acc. ID 71652	Streptomyces koyangensis	
		Acc. ID 13511	Streptomyces Spp	
		Acc. ID 83618	Pseudoxanthomonas	
		Acc. ID 97067	Thelaporaganbajun	
2	tmoA	Acc. ID 12176	Pseudomonas oleovorans	*Cellular mono aromatic metabolic process. toluene monooxygenase large alpha subunit [28]
		Acc. ID 174	Pseudomonas putida	
		Acc. ID 187	Pseudomonas aeruginosa	
		Acc. ID 2490	Ralstoniaeutropha	
		Acc.ID 1020	Deinococcusradiodurans	
		Acc. ID 1642	Dechloromonasaromatica	
3	xylA	Acc. ID 167	Escherichia coli	*Catalytic activity Xylose isomerase activity D- xylose catabolic process.Xylose monooxygenases [28]
		Acc. ID 13526	Enterobacter spp	
		Acc. ID 13508	Pseudomonas spp	
		Acc. ID 14399	Fusarium	
			pseudo-graminarum	
		Acc. ID 104756	candida Africana	
		Acc. ID 13759	symbiodinium spp	
		Acc. ID 76301	Scenedesmus spp	
4	xylE1	Acc. ID 167	Escherichia coli	*Transmembrane transporter activity Catechol extradiol oxygenase. [28]
		Acc. ID 13526	Enterobacter spp	
		Acc. ID 150	Pseudomonas fluorescence	
		Acc. ID 157	Bacillus cerus	
5	bedc1	Acc. ID 13508	Pseudomonas spp	Benzene dioxygenase [29]
		Acc. ID 10703	Burkholderiacepacia	
		Acc. ID 13536	Arthrobacter spp	
		Acc. ID 13525	Rhodococcus spp	
		Acc. ID 943	Brucella melitensis	
		Acc. ID 13685	Stenotrophomonas spp	
		Acc. ID 665	Bacillus subtillis	
		Acc. ID 13719	Ralstonia spp	
			Caldithermus terrae	
6	phaC1	Acc. ID 2490	Cupriavidusneccetor	*Poly hydroxyl butyrate biosynthetic process.Class - II PHA synthase [30]
		Acc. ID 174	Pseudomonas putida	
		Acc. ID 150	Pseudomonas fluorescence	
		Acc. ID 12176	Pseudomonas oleovorans	
		Acc. ID 11181	Haloferaxmediterranei	
		Acc. ID 30999	Pseudomonas corrugata	
		Acc. ID 13759	Symbiodinium spp	
		Acc. ID 12568	Pseudomonas chlorophis	
			Alkanivoraxborkumensis(1655)	
7	alkB1	Acc. ID 1638	Rhodococcuserythropolis	*DNA methylation DNA repair and damage. n-alkane monooxygenase. [31]
		Acc. ID 80095	Trichonephileaclavipes	
		Acc. ID 187	Pseudomonas aeruginosa	
		Acc. ID 11433	Alcanivoraxdieselolei	
		Acc. ID 526	Aspergillus orzae	
		Acc. ID 17303	Wallemiaicthyophaga	
		Acc. ID 92094	Aspergillus latus	
8	todC1	Acc. ID 40688	Cellulomonas hominis	*Aromatic compound catabolism Aromatic dioxygenases large subunit. [28]
		Acc. ID 174	Pseudomonas putida	
		Acc. ID 815	Klebsiella pneumoniae	
		Acc. ID 13536	Arthrobacter siderocapsulatus	
			Ralstoniainsidiosa	
		Acc. ID 45089	Serratia marcescens	
		Acc. ID 1112	Acinetobacter spp	
		Acc. ID 13512	Thauera spp	
		Acc. ID 13688	Enterobacter spp	
		Acc. ID 13526	Raoultella Omithinolytica	
		Acc. ID 15885	Methylibium petrroliphillum	
		Acc. ID 1138		

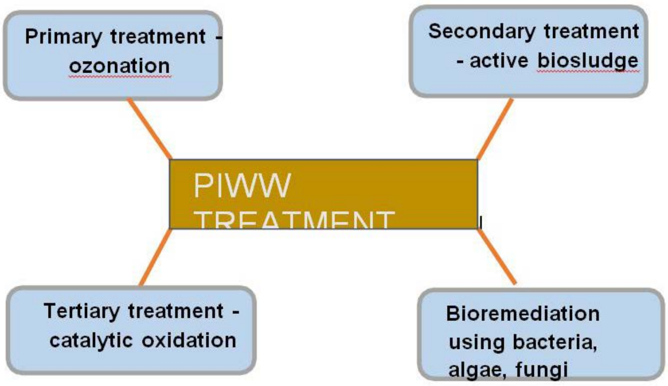

Figure 2: Various classes of pharmaceutical industry wastewater treatment.

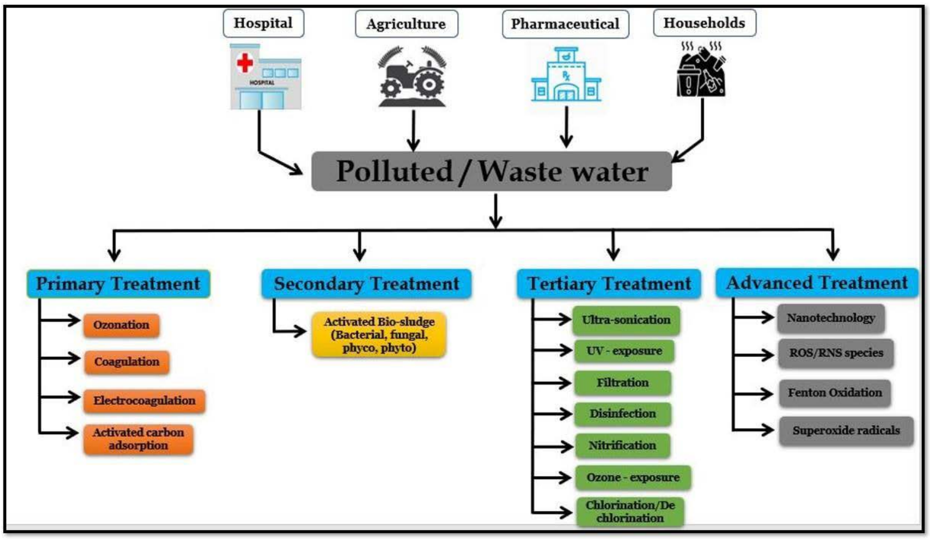

Figure 3: Polluted/waste water different treatment technologies (Primary, secondary, tertiary and advanced).

been divided into three categories: primary, secondary, and tertiary. Bioremediation has emerged as a viable treatment option among. A bioremediation technique tries to treat xenobiotics and plastics by microbial decomposition, resulting in water that is less hazardous and stable than it was before it was polluted. To treat and maintain a consistent level of chemicals in the water ecosystem, bioremediation relies on the action of fungal, bacterial, algal, or plant species, as well as the use of aerobic, anaerobic, or membrane bioreactors. Bacterial bioremediation has been used to clean industrial wastewaters widely. Conducted a study in Tamil Nadu, India, in which they collected samples from nine different pharmaceutical industry sites in the form of MEE Feed water, Condensate Water, Condensate Water Online, Boiler Blow Down Water, Cooling Tower Water, and S.T.P Water, ETP, MEE, and Processed salts, the latter three of which were solid. A bacterial consortium using *Bacillus subtilis, Bacillus megaterium, Pseudomonas fluorescens, Phosphate solubilising bacteria, Pseudomonas putida, Bacillus pumilis, Nitrobacter, Aspergillus niger, Bacillus licheniformis, Nitrosomonas, Rhodococcus* was prepared. Parameters including COD, TSS, TDS, and *Sulphates* were measured before the treatment. The effluents were subsequently treated with the bacterial consortia stated before. When comparing the results before and after the treatment, it was discovered that the levels of sulphates, TDS, and TSS in all samples were significantly decreased (Figure 3). The COD of all the samples, on the other hand, appeared to be quite stable and only showed minor alterations after treatment. The findings show that a diverse bacterial consortium with a variety of strains is excellent at degrading sulphates and TSS but fails to enhance the COD of water. Iinvestigated the biomass and lipid production potential of microalgae *Chlorella sp. SL7A, Chlorococcum sp., SL7B, and Neochloris sp., SK57* cultured in river water contaminated with pharmaceutical effluent. *Neochloris sp. SK57* was shown to be the fastest growing algae in that medium. *Neochloris sp. SK57* (0.52g/l) and *Chlorococcum sp. SL7B* (0.129g/l) produced the highest biomass and lipid yields, with a dry cell weight of lipid of 28 percent. The increased biomass and lipid in this medium could be attributed to organic nutrient assimilation and stress from other components in the river water. Saturated fatty acid production increased in oils of *Neochloris sp. SK57*, as did its solubility in food and fuel applications, according to the fatty acid profile of algal biomass. COD and BOD levels in the river's water were measured before and after algae cultivation. The quality of the river improved after algal cultivation, according to the findings [4]. The breakdown of phenol in pharmaceutical wastewater by monoculture of white-rot fungi was investigated. In synthetic media, the breakdown rate of total phenol was compared in batch flasks by four fungal monocultures of *Trametes versicolor, Phanerochaetechrysosporium, Gloeophyllumtrabeum,* and*Irpexlacteus*. The white-rot fungus *T.versicolor*was shown to be the most effective of the species. Further selection tests of optimal biomass concentration, pH, and temperature were conducted, revealing that the best conditions for degradation are pH 5-6, 25˚C, and 10% biomass inoculum (v/v). With *T.versicolor* species, total phenol was decreased by 93 percent in ideal conditions, with total phenol content decreasing from 42012 mg/l to 291 mg/l in seven days. According to the findings, biological therapy with fungi could be employed as a pre-treatment stage for phenol elimination before polishing wastewater with traditional biological methods.

Bioremediation of wastewater-Textile Dyes

The textile business is a global industry that generates over 1 trillion dollars, accounts for 7% of total world exports, and employs around 35 million people worldwide. Despite its indisputable importance, this industry is one of the most polluting in the world, consuming large amounts of fuel and chemicals. Textile manufacturing uses a lot of water and produces a lot of contaminants, such as dyes, detergents, additives, suspended particles, aldehydes, heavy metals, non-biodegradable waste, and insoluble compounds. Dye production in the world totals more than 7105 tonnes per year. The dyes are organic compounds that are soluble [5], particularly those that are reactive, direct, basic, or acidic. They have a high-water solubility, making it difficult to remove them using traditional procedures. Because of the presence of chromophoric groups in its molecular structures, it has the capacity to transmit colour to a particular substrate. However, auxotrophic groups, which are polar and may bind to polar groups of textile fibres, have the property of attaching colour to the material. Various major environmental agencies, notably the United States Environmental Protection Agency, have classified dyes as harmful pollutants (US EPA). Textile dyes degrade water quality, limit photosynthesis, infiltrate the food chain, inhibit plant growth, offer recalcitrance and bioaccumulation, increase BOD and COD, and may increase toxicity, carcinogenicity, and mutagenicity. The two main types of dye clean-up procedures are physicochemical and biological. Oxidation, flocculation, coagulation, precipitation, irradiation/ ozonation, bleaching, membrane filtration, ion exchange, and adsorption are some of the traditional physicochemical processes employed. In addition to the traditional physicochemical approaches, bioremediation is a viable alternative that has the advantages of cheap operating costs and the generation of non/less harmful products (Figure 4). Several enzymes have also been shown to have high dye degradation ability. Investigated dye-contaminated wastewater and soil samples from a textile plant in Egypt's 10th of Ramadan industrial city, looking for bacteria capable of decolorizing textile dyes. The investigation used the K2RL dyes Acid Red (AR) 151, Orange (Or) II, Sulfur Black (Sb), and Drimarene Blue (Db). *Pseudomonas aeruginosa, Pseudomonas putida,* and *Bacillus cereus* were identified as the most efficient bacterial isolates (high decolorization zone) utilising the Biolog Gen III technology. The ability of isolates to decolorize was investigated, as well as the optimization of physicochemical factors (agitated versus static conditions, pH effect, dye concentration effect, and incubation times). The ability of bacterial isolates to decolorize textile wastewater effluents was also investigated, and the resultant effluent's toxicity was determined using a Microtoxanalyzer 500. The results showed that static incubation conditions resulted in higher depolarization ratios than agitated incubation, that the optimum pH for decolorization was 7.0, that the highest depolarization was observed at a dye concentration of 600 mgL-1 and that as the incubation period was increased, the decolorization ratios gradually increased. Finally, local bacterial isolates were able to decolorize textile wastewater effluents, resulting in a nontoxic final effluent [6].

Bioremediation of wastewater: Pesticides

Pesticide active ingredients are administered to control the occurrence of weeds, insects, fungi, and other undesired species in agricultural and urban environments on an annual basis in the amount of 2.4 million metric tonnes. Chemical pesticides have substantially aided in the development of agricultural yields by controlling pests and diseases, as well as in the management of insect-borne diseases (malaria, dengue fever, encephalitis, filariasis, and others) in the human health sector. These chemicals were thought to be a godsend to agriculture and medical entomology because of their efficacy. Organo-chlorine insecticides are more poisonous to insects and less destructive to non-target organisms, but their longevity in the environment means they can harm a wide range of useful and harmful organisms. As a result, organo-chlorine insecticides have significant ecological consequences in addition to their targeted effects. Microorganisms are involved in many basic ecological processes, such as biogeochemical cycles, decomposition processes, energy transfer through trophic levels, and numerous microbe-microbe, microbe-plant, and microbe-animal interactions, so the interaction [7]. Pesticides have been linked to a variety of illnesses, including cancer, as well as neurological, mental, and reproductive impacts. Pesticide exposure can potentially cause immune system problems in humans. Due to increased pesticide exposure through food and breast milk, immature detoxification pathways, and a longer life expectancy in which to develop diseases with extensive latency periods, children may be more vulnerable to pesticide impacts. Pesticide exposure to aquatic environment organisms, whether direct

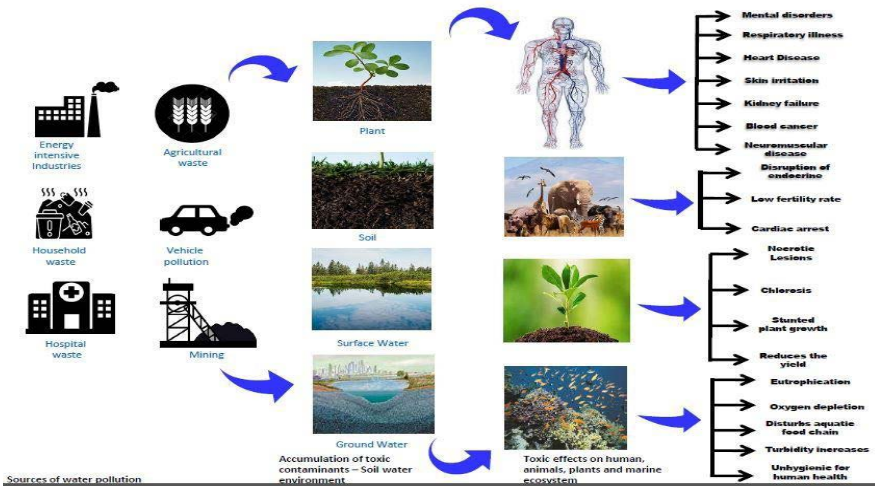

Figure 4: Schematic representation of contaminants and their toxic effect on soil, surface and ground water and human health.

or indirect, can be acute or chronic. Acute effects, such as organism mortality, are frequently identified in toxicity studies during pesticide evaluation. Chronic impacts, such as lower reproduction success, behavioural problems, and changes in community structure, on the other hand, are significantly more difficult to detect and are frequently promoted by long-term pesticide exposure at low concentrations. Isolated and characterised *Arthrobacter sp. AK-YN10*, a bacterium that can breakdown atrazine in 24 hours and convert it to cyanuric acid. *AK-YN10* has also been demonstrated to degrade *simazine, ametron, prometron, ametryn, prometryn, and terbuthylazine*, among other s-triazines. The presence of the trzNeatzBC degrader gene combination in a single plasmid was confirmed by Southern blot analysis. Investigated the ability of a consortium of Microalgae and Cyanobacteria *(Chlorella vulgaris, Scenedesmus quadricuda, and Spirulina platensis)* to remove the organophosphate pesticide malathion as well as the heavy metals cadmium, nickel, and lead from water samples collected from a variety of sources in Egypt, including urban wastewater and agricultural drainage water. The treatment including the microorganismal consortium, malathion, and heavy metals cultivated in water samples collected from agriculture drainage and urban wastewater showed the fastest algal development in this investigation. In this study, microalgae were able to remove malathion from wastewater samples with up to 99 percent efficacy and bioaccumulate nickel with up to 95 percent efficacy. Microalgae were also found to be able to absorb lead and cadmium with up to 89 percent and 88 percent effectiveness, respectively. According to the findings, a consortium of *Chlorella vulgaris, Scenedesmus quadricuda,* and *Spirulina platensis* can effectively remove the insecticide malathion as well as the heavy metals cadmium, lead, and nickel from waste water [8].

Pseudomonas putida strain G3 was identified by as a novel bacterial isolate that can be exploited for the efficient biodegradation of butachlor, a systemic selective herbicide. Butachlor is a persistent pollutant, a probable carcinogen, and a mutagen, according to reports, posing a harm to the environment. After optimising process parameters, batch biodegradation of herbicides at concentrations ranging from 100 to 1000 mg/L by a bacterial strain was investigated. Within 360 hours, the bacterial strain can totally decompose up to 700 mg/L of butachlor. However, increasing the herbicide concentration resulted in a decrease in the microbial strain G3's effectiveness due to substrate inhibition. As a consequence, multiple inhibitory models were fitted to the results obtained during the batch biodegradation investigation in order to identify the bio-kinetic parameters. 2.74 mg/L/h was found to be the maximum estimated specific degradation rate. The microbial cells were immobilised on Ca- alginate beads to improve the bioremediation effectiveness of the bacterial strain in the presence of larger concentrations of the herbicide, and the efficiencies of free and immobilised bacterial cultures were compared. Butachlor biodegradation occurred with intermediate metabolites 2-chloro-N-(2,6-diethylphenyl)-N-hydroxymethylacetamide, 2-chloro-N-(2,6-diethylphenyl) acetamide, and 2,6-diethylaniline, according to the ESI-MS study, and a degradation mechanism has been postulated. The bacterial strain can efficiently digest herbicides like Alachlor and Glyphosate up to 500 mg/L and 1000 mg/L, demonstrating its broad substrate specificity. The research is crucial because it will aid in the development of future bioremediation technologies that will be suitable for the treatment of various herbicides.

Bioremediation of wastewater: Heavy Metals

Heavy metal contamination is also one of today's most serious environmental issues. A wide range of technologies can be used to clean up contaminated locations; however, because metals are immutable and generally immovable, only a few technologies can be used to clean up metal contamination. Heavy metals can be found in both natural and manmade environments, including water, soil, sediments, air, and live creatures. Anthropogenic sources produce pollution that is constantly rising, whereas natural sources are mainly seasonal, weather- dependent, and do not generally produce pollution. Industries, agriculture, and urbanisation are the three main sources of anthropogenic pollution. Tanneries, textiles, metallurgical, galvanising companies, distilleries, and manufacturers producing pesticides, fertilisers, paints, varnishes, and pharmaceuticals are the most polluting industries. The extraction, processing, and use of metals cause direct contamination in the metallurgical industry; however, most sectors pollute indirectly. When fossil fuels are used in boilers, for example, metals present in these fuels are released [9]. Heavy metal toxicity can impair the functions of the lungs, brain, liver, kidneys, blood composition, and other organs, as well as reduce energy levels. Because of their long-term exposure, some metals and their compounds can cause cancer discovered three bacterial strains with high Hg tolerance and reduction capacity from the Yellow River's polluted waters. The mer operon was primarily responsible for reducing Hg2+ in these bacterial strains. When the bacterial strains were mixed in similar quantities, they provided the best treatment effect on Hg-contaminated wastewater. It would take roughly 60 L of the three strains in the same proportion in a cultured solution to treat 1 tonne of wastewater containing 10 mg/L Hg2+ under the bacterial strains' optimal growth conditions. The concentration of Hg2+ in the wastewater might exceed the national standard (Hg2+ 0.05 mg/L) after 48 hours of treatment. Pb2+, Cr6+, As5+, and Cd2+ tolerance and transformational abilities were also found in the bacteria, indicating that they may be used in more complicated heavy metal–polluted situations. Investigated the potential of SCRB 19, a gram-positive, rod-shaped bacteria isolated from chromium-contaminated tannery wastewater at the Kanpur (U.P.) Common Effluent Treatment Plant (CETP). The bacteria were identified as *Microbacterium paraoxydans* based on 16S rRNA gene sequencing. This bacterium has a remarkably high Cr(VI) tolerance (1000 mg/L). At 100, 200, 300, and 500 mg/L of Cr(VI), the Cr(VI) reduction potential of isolated bacterium was investigated, and the results revealed that the bacterium reduced 93.45, 87.28, 72.01, and 39.24 percent of Cr(VI) at their respective concentrations. SEM and EDX research revealed morphological alterations on the bacterial cell exterior as well as intracellular accumulation after Cr(VI) reduction. FTIR spectroscopy was used to test if the Cr (VI) reduced product was attached to membrane functional groups such as amide and carboxyl groups. The presence of probable reduced chromium species is confirmed by the strong peaks found by XRD and XPS investigation. The chromate reductase enzyme activity of *Microbacteriumparaoxydans* SCRB19 was 1.603 0.041 U/mL in a suspended culture. As a result, this strain could be a viable bio-agent for environmentally friendly removal of harmful Cr(VI) from polluted environments (Table 2).

Bioremediation of wastewater: Hydrocarbons and Aromatic compounds

The greatest serious threat to water is petroleum and derivatives. Oil refineries and petrochemical industries produce a lot of trash, which is a big problem for the environment. Water, sediments, aliphatic and aromatic hydrocarbons, resins, asphaltenes, and metals are all found in oil sludge. Because of their toxic character, mutagenesis potential, and carcinogenic tendency, polyaromatic hydrocarbons (PAH) are a major source of worry. Because of the presence of numerous contaminants, sludge treatment in water is quite complicated. Phenolic compounds are hazardous to aquatic life, plants, and a wide range of

Table 2: Microorganisms and their mode of action in bioremediation of various contaminants.

Microorganisms	Contaminants	Mode of action
Pseudomonas putida	Aromatic compound	Degrade toluene and naphthalene from oil and petrol.
Klebsiella pneumoniae	Organic compound	Act on lignin
Bacillus subtilis	Textile dyes	Degrade azo dyes
Enterobacter lignolyticus	Non phenolic compound	Degrade non phenolic aromatic compounds
Bacillus subtilis	Heavy metals	Degrade lead copper and zinc metal ions
Sphingomonas spp.	pesticides	Degrade organophosphorus
Brevudimonas spp.	pesticide	Degrade coroxon and coumaphos
Gamma proteobacteria	hydrocarbon	Degrade marine hydrocarbons
Alcanivoraxborkumensis	Oil spills	Consume hydrocarbon from oil
Deinococcusradiodurans	Heavy metals and aromatic compound	Metabolize mercury and toluene
Dechloromonasaromatica	Aromatic compounds	Oxidize toluene and benzene anaerobically
Methylibiumpetroleiphilum	Petroleum waste	Degrade MTBE (methyl tert butyl ether)
Paracoccusdenitrificans	Nitrate compound	Denitrify ammonia
Bacillus velezensis	Organic matter	Metabolize carbon and nitrogen
Rhodobacter Sphareroides	Ammonium, and anoxigenic compound	Metabolize anoxygenic compound
rhodobacterspaeroides	Aromatic compound	Nitrobenzene degradation
Aspergillus spp.	Phenolic and heavy metals	Consume heavy metals like mercury and chromium and phenolic compounds
Pseudomonas aeruginosa	hydrocarbon	Rhamnolipid production
Bacillus cerus	Heavy metal	Consumption of arsenic
White rot fungi	Organic compound	Metabolism of carbon tetra chloride and dioxin
Pancrochaetechrysosporium	Xenobiotics and	Use PAH as an energy source
	PAH	
Haloferax spp.	Crude oil	Degrade aromatic compounds
Halococcus	hydrocarbon	Grow on pyrene, anthracene and benzene
Cyanobacteria	Heavy metal	Hexavalent chromium degradation
Ralstonia spp	hydrocarbon	BTEX metabolism

other organisms, and they can obstruct biotransformation by serving as substrate inhibitors. As a result, appropriate phenolic chemical elimination is vital to preserve the environment and human health. By bioremediation, microorganisms with the ability to breakdown and break down diverse contaminants by integrating organic molecules into cell biomass and transforming them into other products such as carbon dioxide and water. Hydrocarbon clastic bacteria, which subsist almost entirely on hydrocarbons, are found in aqueous oil degrading microorganisms. Immobilization of HC degrading bacteria and phenol metabolising strains, which enable viability of catalytic activity and tolerance to unfavourable environmental circumstances, can be used to cure oil and aromatic chemical pollution in water. This method reduces the expense of bioremediation while simultaneously preventing the spread and reduction of cells in the environment. Microorganisms such as *Pseudomonas spp, Lysinibacillus spp, Aspergillus spp, Pleurostora, Richarsiae, Cosmospora spp, and Bacillus spp.* are involved in water bioremediation to remove monoaromatic pollutants and oil spills. Saw how effectively local endophytic bacterial strains digested benzene and phenol. Plants watered with oil refinery wastewater yielded seven strains of *Cannabis sativa*, which were successfully identified. For molecular characterization, 16S rRNA gene sequencing was used. When exposed to 250, 500, and 750 mg L1, *Achromobacter sp. (AIEB-7), Pseudomonas sp. (AIEB-4),* and *Alcaligenes sp. (AIEB-6)* biodegraded phenol almost completely; however, when exposed to 1000 mg L1, degradation was only 81 percent, 72 percent, and 69 percent, respectively. *Bacillus sp. (AIEB-1), Enterobacter sp. (AIEB-3), and Acinetobacter sp. (AIEB-2)* degraded benzene substantially at 250, 500, and 750 mg L1. At 1000 mg L1, however, these strains eliminated 80, 72, and 68 percent of benzene, respectively. Modeling degradation rates with first-order kinetics is possible, with rate constant values of 1.86 102 h1 for *Pseudomonas sp. (AIEB-4)* and 1.80 102 h1 for *Bacillus sp. (AIEB-1)*. Investigated the efficiency of certain carriers and immobilisation methods for four cultures of hydrocarbon-degrading bacteria isolated from oil-polluted wastewater using the American Petroleum Institute (API) separators (1, 2, and 4) of the Alexandria Petroleum Company (APC), Alexandria, Egypt. Adsorbing cells on a sponge exhibited the best overall petroleum hydrocarbon removal efficiency for the four cultures when compared to free cells. When comparing individual cultures to a created bacterial consortium, researchers determined that mixed cultures had the highest crude oil degradation percentage (81.70 percent removal efficiency), which was 1.083 times higher than *Bacillus brevis* (75.42 percent). The use of a fixed bed bioreactor for biodegradation of crude oil by bacterial cultures held on sponge cubes revealed that mixed cultures (87.53 percent) had the highest crude oil degradation percentage, followed by individual cultures of *Pseudomonas aeruginosa KH6* (82.97%), providing insight into biodegradation by immobilised bacterial consortia within bioreactors. Mixed culture adsorbed on sponge showed significant degradation in both aliphatic and aromatic 20hydrocarbons, as measured by GC/MS. For an oily wastewater sample, a simulation strategy was used to recommend a combination of bio-stimulation and bio augmentation techniques, which resulted in removal efficiencies of 92.17 percent and 91.30 percent, respectively, in a bioreactor packed with sponge or polyethylene. As a result, the studied strains might be used for industrial effluent treatment and natural polluted region decontamination, and they could be reported in future communication. Created innovative and environmentally friendly bio sorbent-biodegrading biofilms to mend oil-contaminated water. This was accomplished by immobilising hydrocarbon-degrading gammaproteobacteria and actinobacteria on biodegradable oil-adsorbing carriers made of electrospun polylactic acid and polycaprolactone membranes. Bacterial cells demonstrated significant adhesion and growth capacities, according to scanning electron microscopy. Whenthe systems were tested on crude oil and the biodegradation efficiency was assessed using gas chromatography, it was discovered that immobilisation increased hydrocarbon biodegradation by up to 23% compared to free-living bacteria. The resulting biosorbent biodegrading biofilms absorbed 100% of the spilled oil and biodegraded more than 66% in 10 days, with limited cell dispersion in the environment. For aquatic bioremediation, biofilm-mediated bioremediation employing ecologically friendly supports is a low-cost, low-impact, and versatile approach [10].

Bioremediation of sewage waste

Water scarcity has become a serious international issue. Treatment of sewage and reuse of recovered water has become a global. Water demand has risen as a result of expanding population, advanced farming practises, industrialization, urbanisation, and a wide range of water applications. Domestic wastewater treatment has grown into a major aquatic environmental issue affecting people all over the world. Due to a lack of cheaper solutions and the higher cost of treatment plants, municipalities are dumping untreated household wastewater into aquatic bodies such as ponds and lakes. The process of a body of water becoming more nutrient-dense is known as eutrophication. Wastewater treatment plants (WWTPs) treat wastewater using physical, chemical, and biological methods. The potential of microorganisms for the treatment of municipal wastewater was investigated. A total of eight bacterial isolates developed on wastewater agar media in this investigation. *Pseudomonas aeruginosa NS19, Pseudomonas sp. NS20, Planococcuss alinarum NS23, Stenotrophomonas maltophilia NS21, Paenibacillus sp. NW9, Paenibacillus borealis NS3,* and *Aeromonas hydrophilia NS17* were identified as *Bacillus licheniformis B. licheniformis NW16*, with the exception of ammonical nitrogen, exhibited the greatest capacity to reduce all of the parameters evaluated. The most significant reductions in BOD were found in *B. licheniformis NW16* and *Aeromonas hydrophilia NS17* (42.86 percent). In *B. licheniformis NW16* and *Paenibacillus sp. NW9*, COD was reduced by 82.76 percent and 81.61 percent, respectively. Nitrate reductions ranged from 17.36 percent to 63.64 percent in *B. licheniformis NW16*, *P. salinarum NS23*, and *Aeromonas hydrophilia NS17.* Phosphate levels can be reduced by all of the isolates from 17.55 percent to 72.3 percent. *B. licheniformisNW16, Pseudomonas aeruginosa NS19, Pseudomonas sp. NS20, Paenibacillus sp. NW9,* and *Aeromonas hydrophilia NS17* all had lower TSS levels. TDS levels were lowered by 14 percent to 81.4 percent in *B. licheniformis NW16, Pseudomonas aeruginosa NS19, Pseudomonas sp. NS20, S. aeruginosa NS20, S. aeruginosa NS20, S. aeruginosa NS20, S. aeruginosa NS20, S. aeruginosa.*

In-silico approach in bioremediation

The feasibility of in-silico techniques, paired with the computational framework, has been tested using predictive bioremediation aimed at cleaning up contaminants, toxicity evaluation, and potential for the degradation of difficult resistant chemicals. Pollutants from many businesses have posed a threat to the environment and public health. However, clear-cut vital information about biodegradation is sadly absent from the perspective of typical remedial treatments. An alternative technique is required due to a lack of complete knowledge on bio-transformed compounds. In-silico technologies have emerged as alternative bioremediation methods that are now recognized as in-silico approaches (Figure 5). Molecular docking, molecular dynamics simulation, and biodegradation route predictions are all used intensively in predictive biodegradation. Based on the earlier transformation for the reaction, predictive tools look for the most likely degradation route results for degraded compounds. In order to improve polluted site clean-up, bioremediation has several limitations, takes time, and has a limited action range. As a result, major efforts are needed to accelerate the degrading process, improve its efficiency, and adapt it to a wider spectrum of organic pollutants. Genomic, transcriptomics, proteomics, metabolomics, interactomics, fluxomics, and other "omics" technologies may be able to assist in addressing the aforementioned issues. Multipleomics research, rather than single omics techniques, may provide a more comprehensive understanding of microbial metabolic and regulatory processes in bioremediation. Bioinformatics, often known as computational biology, is a new field that solves biological problems by combining biology principles with mathematical, computer, and statistical methods. Such a storage medium is inconvenient for study, despite dedicated databases that include microbial genome sequence data, metabolic pathways, and biomolecular structures. Phylogenetic analysis, molecular phylogeny for the nearest clade, data mining, and system biology are the main fields of bioinformatics that help with bioremediation problems. System biology is commonly used to examine complex interconnected networks at the genetic, cellular, population, community, and ecosystem levels during diverse biological processes. The decolorization of four textile azo dyes, Joyfix Red, Remazol Red, Reactive Red, and Reactive Yellow, was studied. Using 16S rDNA analysis of nineteen soil bacterial isolates, two novel *Lysinibacillus sphaericus* (KF032717) and *Aeromonas hydrophila* (KF032718) strains were found as *Lysinibacillus sphaericus* (KF032717) and *Aeromonas hydrophila* (KF032718). The Schrödinger Suite was used to simulate decolorization percent using laccase and azoreductase enzyme modelling and enzyme dye interaction. Both the cumulative

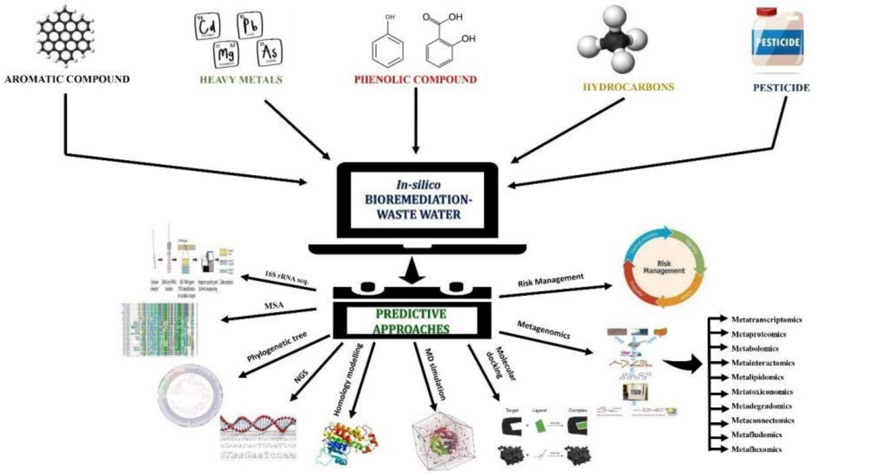

Figure 5: Schematic representation of *In-silico* approach - Predictive bioremediation of waste water contaminants.

Glide score (Dry laboratory) and the decolorization % of the other three dyes based on ultraviolet visible (UV vis) spectroscopy (Wet laboratory) were trustworthy. A high-performance liquid chromatography (HPTLC) elution profile for Joyfix Red biodegradation revealed four peaks at 1.522, 1.800, 3.068 and 3.804 minutes, compared to a single peak at 1.472 minutes for the parent dye. The biotransformation of Joyfix Red was supported by a study using Fourier transform infrared spectroscopy (FT-IR). According to GC–MS investigation, sodium (3E, 5Z)-4-amino-6- hydroxyhexa-13,5-triene-2-sulfonate was produced as an end product during biodegradation. Based on these findings, it can be determined that enzyme and dye interaction studies can aid in analyzing the decolorization efficiency of bacteria and their enzyme, hence enhancing the bioremediation process by eliminating the need for time-consuming wet lab testing. This is the first time a combined in silico and in vitro method for bioremediation of wastewater containing these textile azo dyes has been published, as well as the validation of the process. A study was done to examine the presence of pharmaceuticals, with an emphasis on their metabolites, in raw hospital wastewater using wide-scope screening based on liquid chromatography connected to high resolution mass spectrometry (HWW). A huge, purpose-built database containing over 1000 medications and 250 metabolites is used in the procedure. During a six-month period, raw HWW samples were collected from a hospital in south Brazil on a monthly basis. The accurate mass full-spectrum data provided by quadrupole-time of flight MS enabled the identification of 43 medicines and up to 31 metabolites in the materials under study. A complementary technique based on the parent chemical's and its metabolites' identical fragmentation pathways could be utilized to find four more metabolites not found in the initial database. Nine metabolites derived from four drugs were detected in the raw HWW samples, but their source compounds were not. This study's findings demonstrate the need of screening not only the parent drugs but also their key metabolites. Researchers were also able to assess the environmental fate and effect of pharmaceuticals and metabolites in terms of biodegradability, as well as their potential to become Persistent, Bio accumulative, and Toxic (PBT) compounds and pose a threat to the aquatic environment, using in silico QSAR predictions.

Conclusion

Environmental pollutants waste water from various resources like industrial discharge, household waste, sewage and municipal discharge, hospitals waste, agricultural waste etc. contains pollutants such as heavy metals, pesticides, hydrocarbons, industrial dyes, pharmaceuticals drugs represent overlooked global challenge for sustainable environment. Remediation of toxic compounds can be achieved by emerging technologies i.e., Advanced natural bioremediation use of novel microorganisms, Nanoremediation involves nanomaterial like Carbon Nano Tubes (CNT), Bimetallic nanoparticles, Nanocrystalline zeolites etc. In-silico approach - 16S rRNA sequencing, Next generation sequencing, Phylogenetic analysis, multiple sequences alignment, Molecular docking, Molecular dynamics simulation, Metagenomics etc. Such techniques are cost effective, time saving, eco-friendly and more efficient to enhance the existing conventional bioremediation as an alternative emerging technology for the treatment of waste water to clean up the soil and water environment.

Conflict of Interest

There is no known conflict of interest of any author. The submitted manuscript is used as a base for the master thesis of Hetal Shukla, Saloni Gautam, Himanshu Bapodariya and Mukund B Maliwad at Parul Institute of Applied Sciences and Center of Research for Development, Parul Institute of Medical Sciences & Research, Parul University, Vadodara, Gujarat, India – 391760.

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References

1. Javed F, Aslam M, Rashid N, Shamair Z, Khan AL, et al. (2019) Microalgae -based biofuels, resource recovery and wastewater treatment: a pathway towards sustainable biorefinery. Fuel 255: 115826.
2. Brar A, Kumar M, Vivekanand V, Pareek N (2019) Phycoremediation of textile effluent-contaminated water bodies employing microalgae: nutrient sequestration and biomass production studies. Int J Environ Sci Technol 16(12): 7757-7768.
3. Rashid N, Park WK, Selvaratnam T (2018) Binary culture of microalgae as an integrated approach for enhanced biomass and metabolites productivity, wastewater treatment, and bioflocculation. Chemosphere 194: 67-75.
4. Arif MS, Riaz M, Shahzad SM, Yasmeen T, Buttler A, et al. (2016) Contrasting effects of untreated textile wastewater onto the soil available nitrogen-phosphorus and enzymatic activities in aridisol. Environ Monit Assess 188(2):1-15.
5. Kumar G, Huy M, Bakonyi P, Belafi-Bako K, Kim SH (2018) Evaluation of gradual adaptation of mixed microalgae consortia cultivation using textile wastewater via fed batch operation. Biotechnology Reports 20: e00289.
6. Dhaouefi Z, Toledo-Cervantes A, Ghedira K, Chekir-Ghedira L, Munoz R (2019) Decolorization and phytotoxicity reduction in an innovative anaerobic/aerobic photobioreactor treating textile wastewater. Chemosphere 234:356-364.
7. Phiri O, Mumba P, Moyo BHZ, Kadewa W (2005) Assessment of the impact of industrial effluents on water quality of receiving rivers in urban areas of Malawi. Int J Environ Sci Technol 2(3): 237-244.
8. Kannel PR, Lee S, Lee YS, Kanel SR, Khan SP (2007) Application of water quality indices and dissolved oxygen as indicators for river water classification and urban impact assessment. Environ Monit Assess 132(1): 93-110.
9. Suthar S, Sharma J, Chabukdhara M, Nema AK (2010) Water quality assessment of river Hindon at Ghaziabad, India: impact of industrial and urban wastewater. Environ Monit Assess 165(1): 103-112.
10. Gadipelly C, Perez-Gonzalez A, Yadav GD, Ortiz I, Ibanez R, et al. (2014) Pharmaceutical industry wastewater: review of the technologies for water treatment and reuse. Ind Eng Chem Res 53(29): 11571-11592.