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A comprehensive case review on microbial remediation of heavy metals and pesticides in the Yamuna River

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Abstract: Water resources (mainly surface and groundwater) support two-thirds of the global population but have been of great concern in recent years. Most civilizations all around the world evolved on the river's banks. River Yamuna is the major tributary to River Ganga (India's largest river) and one of the major rivers in India. The extreme cause of pollution in rivers is the excessive discharge of domestic waste water from adjacent towns and residents, contributing to about two-thirds of pollution. Agricultural and industrial effluents cause the rest one-third. Organic pollutants can be treated or removed through appropriate sewage water treatment before final discharge into the river. The status of river water is advantageous because it determines the life cycle of animals, plants, and human beings. The direct use of river water for drinking causes severe hazards due to anthropogenic activities causing environmental pollution in rivers. The noxious discharge of toxic industrial waste consisting of heavy metals and pesticides into the water bodies, especially rivers, prevails in water bodies and accumulates through the food chain. Biomagnification of toxic heavy metals and pesticides through the food chain causes severe health hazards to humans and other living creatures. However, extensive farming depends on pesticides, accelerating water and land contamination. Long-duration contact with pesticides can harm living organisms and disrupt the function of different body organs. Various chemical and biological methods are available for reducing the water pollution level. Still, the emergence of an astonishing technology of multi-cultures of aerobic and anaerobic effective and beneficial microorganisms is gaining popularity because of its eco-friendly nature.

Keywords: urbanization; industrialization; biomagnification; multi-cultures; aerobic; anaerobic

Introduction

Today, the cry due to environmental pollution can be heard worldwide. The rapid increase in the pollution level has become a significant threat to the survival of humankind on earth. The ecological balance of nature is being disturbed by humanity for their wealth, comfort, and ego. The tremendous increase in industrial activity and discharge of toxic industrial waste into the environment are serious concerns. The foremost responsibility of every citizen is to maintain ecological balance and environmental purity. Based on the global scenario, according to a WHO report on national baseline data reported through 86 developing countries by the end of 1980, three residents out of four from urban had access to pure water [1]. Almost 80% of all diseases and epidemics can be associated with inadequate water and improper sanitation. Approximately 6 million infants in developing countries die because of diarrheal diseases each year, and more than 400 million citizens suffer from gastroenteritis [1].

According to the Indian National Scenario survey, eight hundred cases out of one lakh annually revealed the incidence of water-borne diseases [2]. Based on the data collected by the Planning Commission, India, water-related or borne diseases incorporated around 80% of the country's health-related problems [3]. By the end of 1980, approximately 59% of the population of India (about 69% rural and 23% urban) did not have an approach to safe and pure drinking water [4]. To assess water quality, it is necessary to examine its physico-chemical and biological parameters and check out the source of pollution, which finally helps in water quality management. Such qualities guide finding out if water is convenient for agricultural, domestic, and industrial purposes. To remediate the waste water, select the most helpful technique, determine the degree of pollution and propose possible solution, ascertain the ability towards natural purification during sewage and industrial discharged into the water system; and check the effect of rainfall on the water quality of water. In the natural

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environment, direct estimation of water pollution levels has been of great interest to scientists, engineers, and environmentalists [5, 6].

Present Scenario of Yamuna River

River Yamuna is the major tributary to River Ganga (India's largest river) and one of the major rivers in India. Both of the rivers cater to the fundamental needs of humankind in the northern state of India. The extreme cause of pollution in rivers is the excessive discharge of domestic waste water from adjacent towns and residents, contributing to about two-thirds of pollution. The rest one-third is caused by agricultural and industrial effluents [7]. Organic pollutants can be treated or removed through appropriate sewage water treatment before final discharge into the river. The status of river water is advantageous because it determines the life cycle of animals, plants, and human beings. The direct use of river water for drinking causes severe hazards due to anthropogenic activities causing environmental pollution in rivers [8]. The regular destruction of wetlands and, more precisely, the constant decline of water quality and standards will result in human health deterioration exclusively for the residents of developing countries, disturbing aquatic life [9].

The physical-chemical and biological parameters of water bodies can be highly changed by various artificial activities like agricultural practices, industrial discharges, and natural dynamics, disturbing the water quantity and quality [10-12]. Chemical alteration of river water quality can be checked by analyzing chemical parameters and biochemical studies. For a healthy river, DO must be a minimum of 5 mg/L and BOD 3 mg/L, which is necessary for the survival of aquatic life. Though, disease-causing microorganisms can be characterized by evaluating the fecal coliform counts, which should be less than 500 per 100 ml of water. River water is divided into five classes [13] (Fig.1).

Pollution of the riverine ecosystem is a burning problem. The release of toxic industrial waste and untreated waste water has severely influenced the quality of the Yamuna River. Approximately every year highest mortality rate of fish is reported due to drastically increased BOD concentration and reducing DO levels. The Centre of Science and Environment said that almost 75-80% of the river pollution results from industrial runoff, raw sewage, religious practices, and domestic garbage is thrown into the river. The discharge of untreated domestic waste water into the river enhances the ammonia level; when the concentration of ammonia reaches 0.4 mg/l or more, the water becomes untreatable; this condition is found in the Yamuna River at Agra and the nearby surrounding region. The extensive use of fertilizers and pesticides for increasing agricultural productivity has also increased pollution in the river [14, 15]. A summary of Yamuna River pollution is presented in table 1

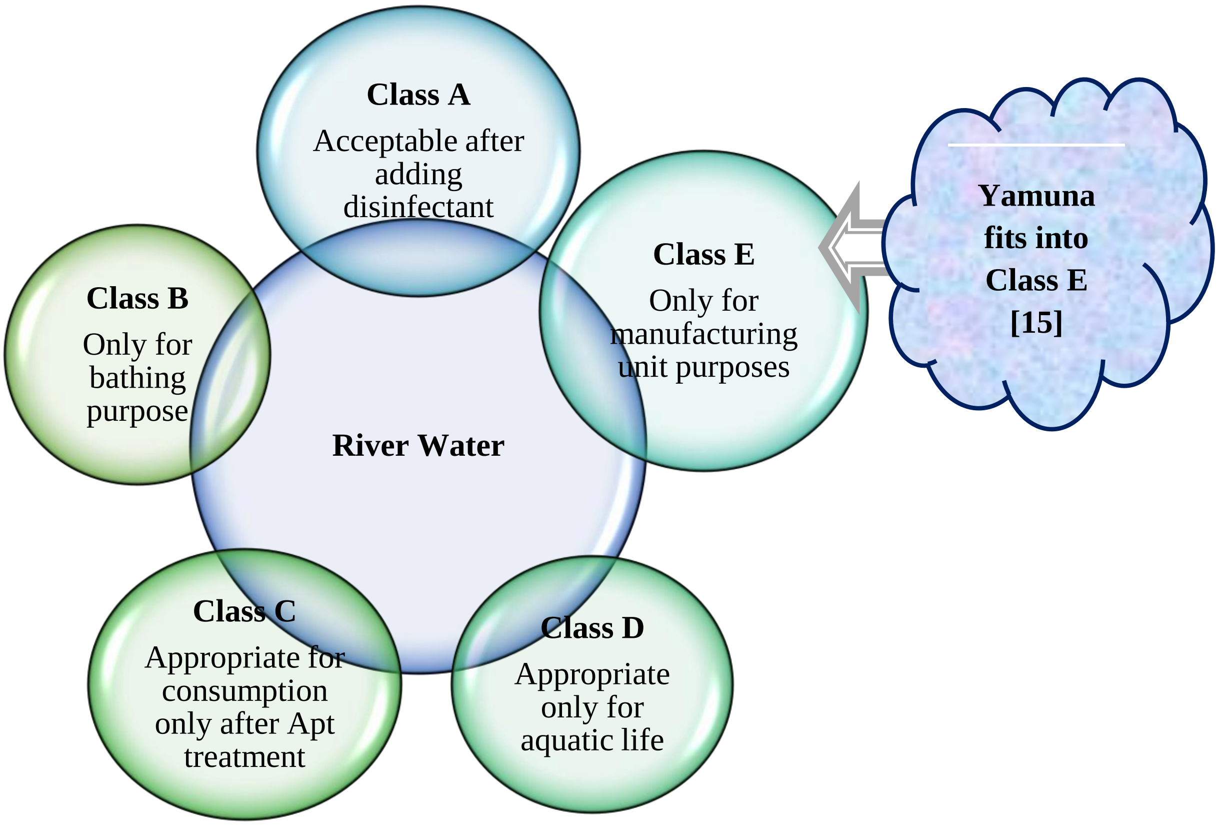

Figure 1. Different classes of river water.

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Table 1. The present condition of the Yamuna River water

Parameter Studied and Calculated Data	Summary	References
• pH (6.2 to 8.5 in summer and 6.5 to 8.0 in winter) • DO (5.5 to 8.2 mg/l in summer and 7.0 to 8.9 in winter) • Alkalinity (156 to 210 mg/l in summer and 230 to 345 mg/l in winter) • Total hardness (156 to 250 ppm in summer and 230 to 345 in winter) • TDS (178 mg/l to 200 mg/l in summer and 210 mg/l to 280 mg/l in winter) • Ca (65 to 88 mg/l in summer and 71 to 79 mg/l in winter) • Na (8 to 22 mg/l in summer and 16 to 49 mg/l in winter) • Cl (9 to 22 mg/l in summer and 28 to 42 mg/l in winter)	➢ Numerous physico-chemical parameters were analyzed from River Yamuna during the summer and winter. ➢ The study was conducted between the Taj Mahal and Kailash Ghat areas, which are most polluted; because of the presence of many ions, chemical, fertilizers, leather, and various industries. ➢ Analytical results revealed that the water quality is more suitable for household purposes during the winter season.	[16]
• pH- 7.3-7.7 • EC- 990 µmhos/cm to 1285 µmhos/cm • TDS- 705 mg/l to 785 mg/l • Total Alkalinity-175 mg/l to 310 mg/l • Turbidity- 9.9 NTU to 33.7 NTU • Total hardness- 252 mg/l to 304 mg/l • Chloride- 180 mg/l to 218 mg/l • Calcium- 72.8 mg/l to 86.4 mg/l • Magnesium- 13.6 mg/l to 24.3 mg/l	➢ Yamuna River water was collected from nine different sites in Agra city. ➢ Most of the parameters were at the pollution level except pH, chloride, and total hardness. ➢ Thus, the river Yamuna of Agra city is highly polluted and unsafe for domestic purposes.	[17]
• pH-6.3-6.5 • TDS-530-1180 mg/l • Hardness-540-680 mg/l • Chlorides- 277.9-49.3 mg/l • BOD- 31-35 mg/l	➢ The report provides an assessment of physico-chemical parameters of different sites of River Yamuna and exit points of tannery and textile industries. ➢ Conventional methods were used for the analysis of water quality parameters. ➢ Hence it can be concluded that all samples were highly polluted and need suitable treatment methods.	[18]
• pH- 7.69-8.38 • Dissolved oxygen- 4.23-8.33 mg/l • Biological oxygen demand- 10.31- 23.83 mg/l • Total coliforms- 57111- 168889/100ml • Faecal coliforms- 20375-56500/100ml	➢ In the Agra region, the quality of Yamuna River water was assessed for domestic uses in terms of spatial deviation in physico-chemical parameters and biological characteristics. ➢ Analysis of principal components was used to determine the possible sources of contamination and to check the spatial variation of Yamuna River water quality. ➢ The findings suggest an urgent efficient management plan to conserve water resources.	[19]
• E.C- 1.29 ms/cm • TDS- 936.25 mg/l • Tubidity- 113.44 NTU • Chlorides- 311 mg/l • COD- 85.95 mg/l	➢ Water quality was determined along with the different sampling sites of river Yamuna. ➢ Correlation matrix analysis shows a strong relationship between analyzed water quality parameters. ➢ A higher value of the water quality parameter indicates that	[20]

	Yamuna River water is not safe for domestic and drinking purposes.	
• pH, DO, BOD, Chloride • W.Q.I have more than 100	➢ Water Quality Index was calculated from different physical and chemical parameters of river water. ➢ Conclusively, the river Yamuna is highly contaminated, and the water is not suitable for irrigation, domestic and drinking purposes without proper treatment.	[21]
• Temperature- 16.5–35.9° C • Conductivity- 0.95 to 2.965 • Turbidity- 11.2-20.6 • pH- 7.25 to 8.10 • DO- 2.5 -5.2 mg/l • Free CO_2- 15.35 to 60.42 mg/1 • Chlorides- 160 mg/l to 280 mg/l • Alkalinity- 160 mg/l to 320 mg/l • Hardness- 300 mg/l to 490 mg/l	➢ During 2014-15 Yamuna River water samples were collected from five different sampling sites in Agra. ➢ pH value shows that River water is alkaline. ➢ TDS and Turbidity values were higher than WHO permissible limits.	[22]

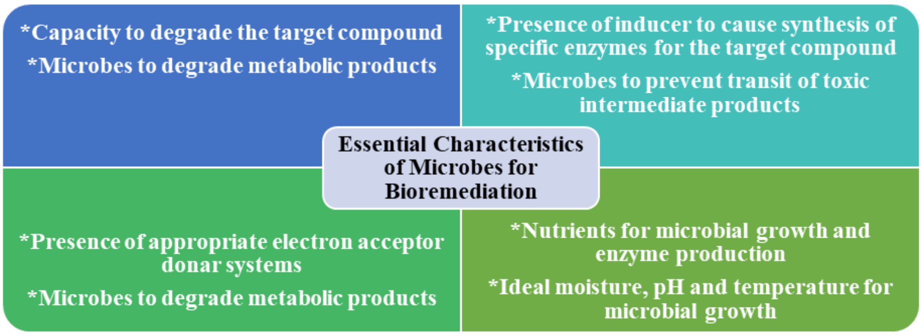

Figure 2. Some essential features of microbes for bioremediation

Bioremediation process

Bioremediation is the manipulation of living systems to bring about desired chemical and physical changes in a confined and regulated matter [23]. Bioremediation is often used to describe various diverse microbial processes in natural ecosystems, such as mineralization, detoxification, co-metabolism, and activation [24]. Bioremediation is one of the most promising techniques due to its safety, economic and environmental features because organic contaminants are transformed and even fully mineralized through this technique [25]. The bioremediation process comprises effective and beneficial microorganisms (figure 2) for degrading and detoxifying harmful contaminants from the polluted environment and has gained widespread attention as a practical biotechnological and microbiological approach to cleaning up the degraded and polluted environment [26]. Bioremediation involves the knowledge of microorganisms that degrades the targeted compound and includes understanding the mechanism and pathways of degradation at molecular and physiological levels [27].

The detoxification process targets the toxic chemicals by alteration, mineralization, or transformation [28]. Bioremediation relies on boosting the growth of microbial consortia or microflora that perform desired activities and are indigenous to the polluted sites [29]. Formulating microbial consortia or bioremediators is done in different ways, i.e., by adding nutrients for promoting growth, adding terminal electron acceptor, and marinating temperature and moisture conditions [30-32].

Physico-chemical parameters for assessment of water quality

The most important compound that significantly impacts life is water [33]. Water quality is determined mainly by natural processes comprising the climatic conditions, lithology of the basins, and anthropogenic and atmospheric inputs [34]. The dissolved solids in natural water mainly include bicarbonates, carbonates, chlorides, phosphates, sulfates, and nitrates of calcium, magnesium, sodium, and potassium with traces of manganese, iron, and other minerals. Water quality management incorporates an assortment of physical, chemical, and biological parameters. The fundamental issue of water quality monitoring is unpredictably connected to analyzing many factors [35], following which different physicochemical parameters are tested regularly for monitoring the quality of water (Table 2).

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Table 2. Parameters Included in Water Quality Assessment

Parameters	Description	Permissible level
pH	➢ pH is imperative in determining the corrosive nature of water. The higher corrosive nature of water is due to its low pH value [36]. ➢ The high pH value accelerates the scale development in the water warming apparatus and decreases potential germicidal chlorine. pH value depends upon different stages of water treatment and water supply like- acid-base neutralization, coagulation, sedimentation, and corrosive control [39]. ➢ As a result of acid rain or discharges, the pH value alters, which consecutively enhances the bacterial degradation, diminishing the DO, and thus BOD requirement exponentially accelerates [40].	6.5-8.5 [37, 38]
Hardness	➢ The hardness of water is not a contamination parameter but rather shows low salinity because of the presence of calcium and magnesium particles expressed as $CaCO_3$ (temporary hardness) generally consolidated with bicarbonates, carbonates, sulfates, chlorides, and other anions of mineral acids (permanent hardness) [41]. ➢ The water containing abundance hardness is not alluring for consumable water as form scales on water warmers and utensils when utilized cooking and consume more detergents or soaps while washing clothes [36, 39]. ➢ Hardness causes various monetary hardships [42].	300 mg/L [37, 38]
Total Dissolved Solids	➢ The measure of dissolved solids is essential in determining the appropriateness for drinking, irrigation, and industrial uses. TDS demonstrate the general nature of the saltiness of water; for instance, a higher concentration will have a salty taste. Dissolved solids are critical for the agriculture system because their progressive accumulation brings about soil salinization, making the agricultural land non-productive [43].	500 mg/L [37]
Alkalinity	➢ The aggregate alkalinity of the reservoir is an impression of its carbonates, hydroxide, and bicarbonates profiles with the possibility of phosphates and silicates adding to it [44]. ➢ A higher value of total alkalinity in the dry season could be because of the higher concentration of carbon dioxide and discharge of bicarbonate particles by sediments. The potential source of alkalinity is weathering of rocks [43].	120 mg/L [38]
Chemical Oxygen Demand	➢ COD is an indicator of organic content of water as the most prevalent substance oxidized by DO in water is a biological element having an origin, i.e., dead and decay wastes animals and plants [36]. ➢ It is an essential parameter of water quality assessment that calculates the oxygen demand of biodegradable and non-biodegradable pollutants [39]. ➢ The extensive COD level connected with pollution could have occurred because of the tremendous rate of organic decomposition emerging from artificial activities on the water shed that produce agricultural and sewage drainage into the reservoir, which harms water quality [41].	10 mg/L [45]
Biological Oxygen Demand	➢ The untreated domestic and municipal waste discharge in the aquatic system expands organic content measures. Hence the microorganisms inhabiting water require more oxygen concentration for its degradation; in this manner, the BOD of water gets raised [36]. ➢ BOD is the measure of the degree of the pollutant in the water body. More BOD means more microorganisms, which means the presence of more organic wastes [42].	5 mgL^{-1} [38]

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Dissolved Oxygen	➢ DO is an essential parameter of water quality, environmental status, efficiency, and strength of water bodies. Its relationship with the water body gives direct and indirect data, e.g., photosynthesis, bacterial activity, stratification and availability of nutrients, etc. [46]. ➢ If there is insufficient oxygen in the water, this may happen to aquatic life- growth retardation, deaths of adults and adolescents, change of species, and failures of larvae/egg to sustain present in the given water body. Excess amounts of DO have been reported during rains could be due to low temperature and expanded water mixing [41]. ➢ The effect of lesser DO amount or anaerobic conditions is reflected in the death of fishes, odors, unbalanced ecosystems, and another aesthetic botheration [35, 47].	5 mgL^{-1} [38]
Calcium and Magnesium	➢ The fundamental sources of calcium present in natural water are different types of rocks, sewage, and industrial effluents. Water with a calcium concentration of ‹10 mg/L is usually oligotrophic, while higher than 25 mg/L is commonly eutrophic [41]. ➢ Hard water plays a crucial role in heart diseases. Higher magnesium makes the water unpleasant and acts as purgative to human beings [39].	Ca (75 mgL^{-1}) Mg (50 mgL^{-1}) [45]
Chloride	➢ Higher chloride concentration in water might be because of pollution from industrial, sewage, domestic, and municipal effluents. Yet, excess chloride imparts a salty taste to water, and individuals who are usual to high chloride are subjected to laxative effects [36].	250 mgL^{-1} [37, 38]

Effect of heavy metals on human health

In recent years, the severe concern worldwide is heavy metal toxicity because these heavy metals cause detrimental effects on all types of living organisms in the ecosystem. Heavy metals are not readily degradable in the biosphere but accumulate in the human and animal bodies at high lethal levels leading to obnoxious effects. The progress in industries and agricultural systems and increased population density have further entangled this situation [48]. The noxious discharge of toxic industrial waste consisting of heavy metals into the water bodies, especially rivers, prevails in water bodies and accumulates through the food chain. Biomagnification of toxic heavy metals through the food chain causes severe health hazards to humans and other living creatures. Heavy metal alters biomolecules' structural and biological functions [49]. Unlike organic pollutants, the natural disintegration process does not eliminate heavy metals. Moreover, they may be enhanced by organisms and reformed into organic complexes, which might be more toxic.

In the aquatic system, metals are introduced due to weathering of rocks and soil from a volcanic eruption and an assortment of human activities, including mining, preparation, and utilization of metals, and metal contaminants containing substances [50]. Heavy metals are essential trace elements for living beings; however, the accumulation of these metals, such as Cd, Zn, Pb, Fe, and Cu, in viable cells poses detrimental effects [51, 52]. Consequently, heavy metal falls into the priority pollutants underwater quality classification. Heavy metals can enter the aquatic system via natural resources like soil erosion and artificial activities such as the discharge of toxic wastes containing heavy metals accomplished through agricultural activities, industries, and household use. However, agricultural activities contribute to the primary source of heavy metal pollution in riverine systems.

Heavy metals incorporated in pesticides and fertilizers are introduced into the aquatic system by settling airborne particles of soil after agricultural cultivation and wastewater [53-56]. Untreated or partially treated heavy metal polluted sewage and toxic effluents cause severe environmental and health hazards when discharged into accepting water bodies. The nature of heavy metals contaminated wastewater on people may be lethal (chronic, sub-chronic, or acute), mutagenic, neurotoxic, teratogenic, or carcinogenic [57]. Despite the fact it is accounted that individual metals show particular signs of toxicity and danger, the signs correlated with lead, mercury, arsenic, cadmium, copper, aluminum, and zinc poisoning are diarrhea, tremor, gastrointestinal disorders, hemoglobinuria, stomatitis causing ataxia, paralysis, depression, vomiting, pneumonia, convulsions and rust-red color of stool when volatile vapors are breathed in [57].

Though heavy metals are natural segments of the earth's crust that can't be degraded, they are just noxious and lethal when they are not synthesized and metabolized by the body and aggregated in its delicate tissue. Table 3 briefly describes the different heavy metals detected in the environment and their hazardous effect on human health.

Table 3. Heavy metals and health effects

Pollutants (Permissible limit) [58]	Sources	Health Effects
Arsenic (0.01 mgL^{-1})	Fungicides Pesticides Metal Smelters	➢ Cancer is related to kidney, lungs, bladder, and skin ailments [59]. ➢ Toxicity (developmental, reproduction, subchronic, genetic, acute) [60]. ➢ Immunotoxicity [61]. ➢ Chronic, cellular and biochemical toxicity [62]. ➢ Extreme concentration of Arsenic can be lethal, as it is known to coagulate protein, form complexes with co-enzymes, and restrict the production of ATP during respiration [63].
Lead (0.01 mg/L)	Batteries Paint Pesticides Glass Industries	➢ Low hemoglobin production, kidney, joints, cardiovascular and respiratory diseases, and lifelong impairment to the peripheral and central nervous systems [64, 65]. ➢ Sensor neural deafness, peripheral neuropathy in children, gastrointestinal damage, developmental delay, cerebral injury in children [66, 67]
Cadmium (0.003 mg/L)	Batteries Electroplating Wielding Pesticides Fertilizers Shield within a nuclear reactor	➢ Bronchitis, renal malfunction, bone damage, osteoporosis, infrequent fractures, high blood pressure, osteomalacia, gastro-intestinal suffering, myocardic injury, cadmium pneumonitis, and lung disease [66]
Chromium (0.05 mgL^{-1})	Electroplating Mineral Mines	➢ Renal, neural, gastrointestinal, hepatic damage, fatigue [66]
Mercury (0.001 mgL^{-1})	Batteries Paper Industries Pesticides	➢ Congenital malformation, gastrointestinal disorders, neurological disorders, central nervous system damage, rapid abortion, acrodynia (pink disease identified by rash and peeling of the hands and feet skin), erethism, stomatitis, gingivitis, protoplasm poisoning [68]
Copper (0.05 mgL^{-1})	Chemical industries Pesticides production Mining	➢ Causes anemia, stomach pain, vomiting, intestinal irritation, diarrhea, infections in the liver and kidney, headache, and nausea in children [69-71].
Zinc (5 mgL^{-1})	Sewage discharge Idol immersion Refineries	➢ Damage to the liver, kidney, nervous membrane, diarrhea, and vomiting [72, 73]. ➢ bloody urine and icterus (yellow mucus membrane) [63, 64]
Nickel (0.02 mgL^{-1})	Electroplating Stainless steel Manufacturing units	➢ Neurotoxic, genotoxic, carcinogenic, nickel dermatitis [66, 74]

Effect of pesticides on human health

The utilization of pesticides is universal in modern agriculture and is vital to increase crop yield and lessen post-harvest misfortunes. However, extensive and extreme utilization of farming pesticides accelerates water and land contamination. Discharge of pesticides originates from both diffuse and point sources. The latter incorporates blending and loading facilities on the field, and leakages and spillages from the filling operation and equipment for spraying and water from cleaning and rinsing may lead to pesticide contamination [75]. Wastewater generated through washing facilities for vegetables and manufacturing plants of pesticides is also a vital source of pollution. Numerous pesticides are recalcitrant compounds and have prevailed in the environment for a long time. Pesticides have been distinguished in surface and groundwater utilized for consumable water supply and have been connected to antagonistic human wellbeing impacts [76].

In India, the distressing level of pesticides has been reported in water, air, soil, biological materials, and food [77]. A few pesticides have been considered lethal [78], cancer-causing, mutagenic and carcinogenic [79]. The most imperative contaminations among the toxicants in India are organochlorine and organophosphorus pesticides. During 2001-2002 the utilization of pesticides was up to 43,580 MT. In the Indian market, among the insecticides, quinalphos, chlorpyriphos, and monocrotophos top the series of organophosphorus insecticides. The assessed utilization of technical grade chlorpyriphos in 2002-2003 was 5000 MT in India [80].

Some determining organochlorine pesticides have been banned for general well-being and horticulture use for the last few years; instead, high concentrations of pesticides and their metabolites have been estimated in water, soil, and sediment samples [81, 82]. Besides, other insecticides like lindane and endosulfan are presently in use worldwide, and their presence in water, air, and soil is an issue of great concern. Diminishing their level in the ecosystem has therefore turned into a vital objective. The utility of pesticides in India started in 1948 when DDT was transported for malaria control and benzene hexachloride (BHC) for beetle control. In 1952, India began pesticide production with a manufacturing plant for BHC and DDT. In 1958, over 5000 metric tons of pesticides were produced in India. Extensive use of agricultural pesticides transmits potential hazards to human beings, specifically by exposure to toxic and poisonous residues in food and indirectly to the ecosystem [83].

Long-duration contact with pesticides can harm living organisms and disrupt the function of different body organs, including endocrine, reproductive, nervous, renal, immune, respiratory, and cardiovascular systems. In such a manner, there is mounting proof of the connection of pesticide exposure with human chronic diseases such as Parkinson's, Cancer, Multiple sclerosis, Alzheimer's, Aging, Diabetes, Cardiovascular and chronic kidney disease [84-86].

WHO has assessed at least 3 million extremes, severe cases of pesticides (suicide agent) hazards, and almost 20,000 unexpected deaths every year, especially in developing countries [87]. One WHO studies revealed that around 3% of agriculture workers suffer from poisoning every year in developing countries, bringing about 25 million occupational poisonings [87].

Human well-being risk is an element of pesticide poisoning and exposure. A more severe hazard is expected to emerge from high vulnerability to a modestly dangerous pesticide than little exposure to highly toxic pesticides. Nonetheless, logical scientific controversy remains on whether dietary exposure to the overall population to residues of pesticides present in drinking water and food comprises a potential risk to human well-being [88]. Table 4 represents the different classes of pesticides and their exposure that cause a potential threat to human health.

Table 4. Different classes of pesticides and their phases of intoxication

Classes	Exposition	Signs and syndromes
Organophosphorus	lungs, skin, conjunctiva, gastrointestinal tract [89]	Excess acetylcholine in the synaptic cleft, Nicotine syndrome, and Muscarinic Syndrome [90].
Carbamates	gastro-intestinal tract, lungs, skin [91]	Abdominal pain, salvation, tearing, sweating, miosis, vomiting, behavioral change, rhinorrhea, diarrhea [92].
Organochlorines	skin, lungs, gastrointestinal tracts [93]	Faintness, malnutrition, headache, vomiting, anxiety, nausea, diarrhea, eczema, muscle fragility, tremors, mental confusion, and convulsion [94].
Pyrethrins and pyrethroids	lungs, skin, gastrointestinal [92]	Erratic movements of limbs, fatigue, spasms, salivation, coordination, tremors, toxic convulsions, and hypersensitivity to stimuli [95].
Triazines	eyes, nose, skin, and gastrointestinal tracts [89]	Cancer-causing and teratogenic evidence, inflammation at the site of contamination [94, 96].
Phenoxy derivatives	lungs and gastrointestinal [97]	Dizziness, renal failures, vomiting, metabolic nausea, expanded aminotransferase, aspartate and lactase, alanine dehydrogenase, and hyperthermia (because of uncoupling of oxidative phosphorylation) [97].
Dipyridal derivatives	eyes, lungs, skin, and gastrointestinal [98, 99]	Dehydration, high oxidative stress causes necrosis in the kidney, liver, lungs, tubules, and gastrointestinal tract [99, 100].
Glycine derivatives	gastro-intestinal and skin [97]	Convulsion, respiratory arrest, coma, disorder of consciousness, and irritation consequent to local contact [96].
Dithiocarbamates	slow absorption by dermal and oral contact [89]	Thyroid problems, cancer-causing and teratogenic [101].

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Microbial remediation of toxic pollutants from different sources of wastewater-physico-chemical parameters

Rapid industrialization and urbanization coupled with a steadily growing population is the primary source for discharge of industrial effluents and untreated sewage water within the water bodies. Lack of awareness, enormous withdrawal, and utilization of river water for various purposes, including domestic, industrial, and irrigation, are considered the main sources of degradation of river water quality [102-105]. The pollution status of any river can be assessed by examining the physicochemical properties of the water bodies. Distinct researchers concerning pollution of river water like Jhelum [106], Krishna, Godavari and Tungabhadra [107], Ganga [108-112], Sutlej [113], Ulhas [114], Narmada [115, 116], Cauvery [117], Godavari [118], Kosi [119], Brahamani [120], Goriganga [121, 122], Yamuna [123-126] have captivated more attention for past several years. Wastewater treatment differs in its quantity, characterizing media, and dilution available. Wastewater could be processed for recycling and disposal through one or more steps. The initial treatment is the primary or preliminary treatment, i.e., physicochemical treatment, but due to the objection properties of effluent, the biological treatment, which is a secondary treatment, is employed. Biological treatment involves the degradation of suspended and dissolved compounds by microorganisms under controlled conditions. The primitive characteristic of biological treatment was to utilize microbial consortiums, including bacteria, fungi, or algae, to convert toxic substances or pollutants [127].

In comparison to chemical/physical methods, biological methods have gained more interest due to their eco-friendliness, low sludge production, and cost-effectiveness [128]. The summary of the degradation of different physicochemical parameters through effective microorganisms is presented in table 5.

Table 5. Role of microorganisms in treatment of degraded quality of physico-chemical parameters

Source of wastewater	Microorganisms	Parameters & percentage degradation	Summary	References
Paper and pulp mill effluent	*Pseudomonas, Alkaligenes, Bacillus pumilus, Bacillus subtilis, Trichoderma reesei*	BOD- 99% COD- 85% (Combination of *Psuedomonas, Alkaligenes, B. subtilis* and *T. reesei*) BOD-92% COD-77% (*P. alcaligenes*)	➢ The shake flask method evaluated the degradation ability of individual microbes and consortium. ➢ *B. pumilus, T. reesei* and *Pseudomonas*, and *Alkaligenes* (monocultures and consortium form) proved maximum treatment efficiency than other isolates.	[129]
Sewage water	*B. pumilus, Brevibacterium* sp., *P. aeruginosa*	COD- 75.5% BOD- 80.8%	➢ Optimization (temperature, agitation, inoculum size) was done to achieve a better result. ➢ The result obtained through this study indicated that microbial consortium in the ratio of 1:2 (effluent: biomass) at 35ºC and 2000 rpm could efficiently reduce the load of pollution of the sewage water. ➢ The formulated bacterial consortium acts in a symbiotic way and effectively degrades toxic compounds from sewage water.	[130]
Textile effluent	*Bacillus* sp., *Pseudomonas* sp., *Aspergillus* sp., *Penicillium* sp.	Color- 50% COD- 75% TS- 90%	➢ The consortium of A1* and A12* were more efficient and effective in reducing all parameters than other combinations *A_1 =*Pseudomonas* sp., *A_{12}= *Aspergillus* sp. & *Pseudomonas* sp.	[131]
Sewage water	*B. megatherium, Nitrobacter* sps., *Nitrosomonas* sps., *P. denitrificans, Chromatium* sps.,	BOD- 56-66%	➢ Bacterial culture-treated water sharply reduced the concentration of BOD in the presence of 0.05-0.5 ppm of microbial culture.	[132]

	B. mucilaginosus, *L. acidophilus*, *Rhodococcus terrae*, *B. licheniformis*, *Thiobacillus ferrooxidans*,		➢ The study concludes that a microbial consortium was more effective in degrading toxic pollutants than single bacterial culture.	
Yamuna River water	*Rhodopseudomonas palustris*, *E. coli*, *Rhodobacter spheroides*, *B. subtilis*, *B. fusiformis*, *B. thurigiensis*, *B. cereus*, *Lactobacillus* sp.	BOD- 79.49%, 77% and 63.2% COD- 85.46%, 94% and 63.2%	➢ The reduction of COD and BOD by *B. subtilis* is highest compared to other bacteria. ➢ Similarly, *B. subtilis* combination with *Lactobacillus* sp. and *B. fusiformis* showed a significant BOD and COD reduction.	[133]
Dairy waste water	*Neisseria* sp., *Citrobacter* sp., *Klebsiella* sp.	COD- 67.1% and 48.3%	➢ Isolation of bacterial isolates was done along with activated sludge; later raw waste was treated through the isolates to check reduction in COD concentration. ➢ *Neisseria* sp. and *Citrobacter* sp. were more effective in decreasing the COD level and helping in bioremediation.	[134]
Pulp and paper mill effluent	*Arthrobacter agilis*, *B. licheniformis*, *B. seohaeanensis*, *Cellulomonas cellasea*, *Aspergillus niger*, *Penicillium* sp.	COD- 90% and BOD-95%	➢ Monocultures of *A. niger*, *B. licheniformis*, *Penicillium* sp *C. cellasea* were outstanding paper and pulp effluent degraders. ➢ The innovative formation LCN (*B. licheniformis* + *C. cellasea* + *A. niger*) is approved, exhibiting the maximum BOD concentration reduction.	[135]
Common effluent treatment plant (CETP)	*Pseudomonas* spp., *Actinomycetes* spp., *Bacillus* spp., *Streptomyces* spp., *Staphylococcus* spp.	BOD-94% and COD- 90%	➢ The microbial consortia constituting five species have the utmost potential in wastewater treatment. ➢ Therefore, microbial species in consortia form can renovate complex wastewater.	[136]
Pulp and paper mill effluent	*Alkaligenes faecalis*, *B. cereus*	COD- 63.2%	➢ The study revealed that maximum reduction of COD was obtained with *B. cereus* at pH 6 and 35ºC after 10 days of incubation. ➢ *Bacillus cereus* was more effective under different optimization conditions (pH, temperature, and nutrient source) than *Alcaligenes faecalis* in COD removal from waste effluent.	[137]
Industrial effluent	*Klebsiella* sp., *E. coli*, *Pseudomonas* sp., *Staphylococcus aureus*	TDS- 53.94%, 55.7% BOD- 90% and 95.4% COD- 91.6% and 87.6%	➢ Biotreated samples (native *E. coli* and non-native *Bacillus* sp.) showed a maximum reduction of contaminants because these microbes use it for their growth and development. ➢ After treatment or degradation of pollutants from wastewater, it could be used for crop cultivation, aquaculture, and irrigation purposes.	[128]

Sewage water	Phototropic bacteria	DO-23% BOD-64% COD-32% Organic Matter-75%	➢ The metabolic rate of microorganisms affects the concentration of BOD, COD, pH, DO, and suspended solids present in water. ➢ Microbial treatments are more eco-friendly, economical, and sustainable than other methods.	[138]
Domestic waste water	*B. subtilis, Nitrosomonas, B. circulans, B. pumilus*	TSS-77%, COD- 66% and BOD-67%	➢ The protocol used in this research is an experimental analysis of a completely randomized design (CRD) containing two factors and repeated three times. The first factor is bacterial consortia type, and the second one is the time period of bioremediation consisting of eight levels. ➢ The study concluded that bacterial consortium effectively biodegradation of domestic wastewater.	[139]
Yamuna River water	*Rhodopseudomonas palustris, E. coli, R. spheroides, B. subtilis, B. cereus, B. thuringiensis, B. fusiformis, Lactobacillus* sp.	COD- 84.1% and BOD-89.2%	➢ Recent research has been planned to evaluate the physicochemical parameter of Yamuna River water of Agra and lower the DO, BOD, COD, pH, hardness, and dissolved solids through bioremediation using a practical bacterial consortium. ➢ The study indicates that effective microbes technology helps lower the concentration of water impurities.	[140]
Dairy effluent	*Lysinibacillus sphaericus* (L2) *P. taiwanensis* (L8) *B. marisflavi* (P11) *P. aeruginosa* (P9)	BOD-88.31% COD- 79.51% TDS- 41.66% Protein-74.44% Lipid- 72.87%	➢ *P. aeruginosa* showed a maximum reduction, followed by *L. sphaericus* ➢ Five different sets of the bacterial consortium were prepared to improve the effectiveness in degradation. ➢ The report revealed that the consortia set of *L. sphaericus*, *P. taiwanensis*, and *P. aeruginosa* dominated with maximum level of degradation compared to other sets of consortia.	[141]
Industrial and municipal wastewater	*B. subtilis, B. cereus, E. coli, S. aureus*	COD- 62.88%, 51.7%, 74.21% BOD- 82.83%, 80.83%, 77.77%	➢ Monocultures of bacteria were used for the treatment of wastewater. ➢ *B. subtilis* showed a maximum reduction of BOD and COD compared to other bacteria.	[142]

Heavy Metals

The release of wastewater consisting of many heavy metals to recipient water bodies has detrimental environmental effects. Accumulation and heavy metals in the environment result from direct or indirect human activities like rapid urbanization, industrialization, and anthropogenic sources [143, 144]. Minimal concentrations of heavy metals are vital as a co-factor of enzymatic reaction; however, an elevated amount of them may bring out severe toxicity to living beings due to restraint of metabolic responses. Microorganism reacts to these heavy metals by a few procedures involving transport across the cell membrane; entrapment in extracellular capsules; biosorption to the cell walls; complexation, precipitation, and oxidation-reduction reactions [145-150].

Microbial metal bioremediation is a productive system because of its minimal cost, immense efficiency, and eco-friendly behavior; furthermore, it brings out the complete or partial biotransformation of wastes to microbial biomass and durable harmless end products [151]. Using organic materials to effectively eradicate heavy metal contaminants from waste water has developed a potential alternative approach to conventional procedures [152]. The summary of the microbes associated with heavy metals detoxification is presented in table 6.

Table 6. Microbes associated with heavy metals remediation from the environment

Heavy Metals	Bacteria	Summary	References
Ag^{+}, Cd^{2+}, Cu^{2+}, La^{3+}	*E. coli* *B. subtilis* *P. aeruginosa* *B. cereus*	Freundlich K constants showed that *E. coli* was most effective at Cd^{2+} removal and *B. subtilis* removed Cu^{2+} From 1mM solution total Ag^{+} removal was approximately 89% while only 27%, 29% and 12% of the total Cu^{2+}, La^{3+} and Cd^{2+} were removed. The affinity series for bacterial sorption of the heavy metals decreased in the order Ag>La>Cu>Cd. Results proved that bacterial cells could bind large amounts of different metals.	[153]
Zn, Cu, Cr, Pb, Ni, Al	*Acidithiobacillus* sp.	Bacterium showed sulfur-oxidizing ability at both neutral and acidic conditions and allowed metal leaching at high (130 g L^{1}) sludge solids concentration.	[154]
Cd	*A. xylosoxidans* *Comamonas testosteroni* *Klebsiella planticola* *P. putida* *S. liquefaciens*	Bacterial isolates could remove Cd from the solution, and the efficacy of cadmium degradation was related to the quantity of synthesized protein in the cell fraction. The plasmid content analysis showed that only two strains of *K. planticola* harbored plasmid.	[155]
Cr, Pb, Cu	*Staphylococcus* sp.	The highest adsorption of $Cr^{6+,}$ Pb^{2+}, Cu^{2+} was found at the initial concentration of 105 mg Cu^{2+} /l, 193.66 Cr^{6+}/l and 100 mg Pb^{2+}/l. under these circumstances the biosorption values were found to be 44.94 mg Cu^{2+} /l, 88.6 mg Cr^{6+}/l and 100 mg Pb^{2+}/l respectively.	[156]
Pb, Cu	*Bacillus* sp.	The maximal removal of the metal ions was determined at pH 5.0 ± 0.1 for Cu(II) and pH 3.0 ± 0.1 for Pb(II) ions. *Bacillus* sp. is the best biosorbent for removing Pb (II) and Cu (II) ions from an aqueous solution.	[157]
Hg, Cr, Ar	*P. aeruginosa* *Bacillus* sp.	Mercury biosorption through monocultures of *Pseudomonas aeruginosa* and *Bacillus subtilis* showed 99.3% and 78.5% mercury removal at pH 5, temperature 32°C, and biomass concentration of 0.5 mg/ml in 50 minutes and 2.5 mg/ml in 60 minutes period of contact time, respectively. Sorption capacity of *Pseudomonas aeruginosa* is maximum in comparison to *Bacillus subtilis* and mixed cultures.	[158]
Ar	*P. aeruginosa* *Bacillus* sp. *Flavobacterium* sp *E. coli* *Klebsiella* sp *Staphylococcus* sp.	Bacterial isolates showed maximum resistance to the heavy metals with minimum inhibitory concentration for heavy metals varying from 100-400 ppm. For the bioremediation of heavy metals degraded ecosystem, bacterial isolates could be exploited biotechnologically.	[159]
Hg, Cd, Cu, Mn	*Streptococcus* sp. *Staphylococcus* sp. *Pseudomonas* sp.	Analysis revealed that *Pseudomonas* sp. is capable of removing Cd, Mn, and Hg much better way than other bacterial isolates, while Copper is evacuated better by *Streptococcus* sp After three days of incubation, maximum heavy metals were uptake by bacterial isolates.	[151]
Cd	*P. aeruginosa*	Mutated and wild-type strains of *Pseudomonas aeruginosa* removed Cd^{2+} at various time intervals (100-300 minutes). From 30mg/L of Cd^{2+} solution, 94.7% of calcium was removed within 1h.	[160]

Mn, Cd, Cr, Cu, Zn, Pb	*Bacillus* sp. *Pseudomonas* sp. *Staphylococcus* sp. *A. niger*	*Pseudomonas* sp. and *Bacillus* sp. reduced Ni by 65% and 48%, while Cu was 68% and 56%, respectively. *A. niger* reduced Zn 58% and Cd 50%, whereas *Staphylococcus* sp. reduced Cu 42%, Cr 45%, and Pb 93%. Maximum reduction of heavy metals was observed by *Pseudomonas* sp. compared to other microbes but *Staphylococcus* sp. reduced Pb up to 93%	[161]
Cr, Cu, Pb	*Staphylococcus* sp. *Streptomyces* sp. *Flavobacterium* sp.	Cr, Cu, and Pb were biosorbed by *Streptomyces* sp and *Staphylococcus* sp., while *Flavobacterium* sp. biosorbed Cu and Cd with very low efficiency. The bioremediation potential of *Streptomyces* sp. was 18%, 72%, and 32.5% for Cu, Cd, and Pb; the potency order was Cr>>Pb>Cu, while *Staphylococcus* sp. reduced Cu, Cd, and Pb metal by 42%, 45% and 82.6% respectively. The weak bioremediation agent was *Flavobacterium* sp., and it decreased the concentration of Cu and Cd metal by 20.3% and 25%, respectively.	[162]
Cu, Cd, Co, Cr	*Enterobacter* sp. (Cu_1) *Enterobacter* sp. (Cu_2) *Stenotrophomonas* sp. (Cd_1) *Providencia* sp. (Cd_2), *Chryseobacterium* sp. (Co_1) *Comamonas* sp. (Co_2) *Ochrobactrum* sp. (Cr) *Delftia* sp. (M_1)	Bacterial strains (*Chryseobacterium* sp., *Enterobacter* sp., *Ochrobactrum* sp., and *Stenotrophomonas* sp.) resisted 275 mg Cu/l, 320 mg Cd/l, 140 mg Co/l, and 29 mg Cr/l. Conclusively, activated sludge with resistant bacteria mixture was more effective than activated sludge alone for heavy metal removal.	[163]
Pb, Zn, Cr	*Bacillus carotarum* *Bacillus cereus* *Bacillus lentus* *Bacillus licheniformis*	The heavy metal tolerance test revealed the highest microbial tolerance to Pb while minimum tolerance to Cr and Zn. Isolated *Bacillus* sp can resist an extensive range of antibiotics and heavy metals.	[164]
Pb	*Enterobacter* sp. *Klebsiella* sp.	Bacterial strains showed an excellent capacity to remove divalent chromium to monovalent lead (non-toxic) at 31°C pH-4 after 48h of incubation. The result indicates that isolated bacterial strains can be effectively employed to remove Pb^{2+} from industrial effluent, constituting maximum concentrations of heavy metals.	[165]
Cu	*Chryseobacterium* sp. (S2) *Stenotrophomonas* sp. (S7) *Enterobacter* sp. (S5)	The concentration of copper and its toxicity effect was measured using a bioluminescent bioreporter and atomic absorption spectrophotometer. The bioluminescence inhibition strain S5 is 91.4%, while strain S7 is 83.3% at 225 mg/l of copper ions, whereas the highest biosorption efficiency for S7 and S3 reached 70.1% and 71%, respectively.	[166]

Pesticides

Pesticides are extensively used in farming and public health for controlling insect vectors and pests responsible for crop diseases and damage. To overcome the problem of agricultural pests, rodents, weeds, and insects, pesticides are used as a powerful weapon. The use of pesticides increases and stabilizes agricultural yield and preserves the nutritional value of food items [167, 168]. However, excessive pesticides use results in their accumulation in agricultural products. Around one-third of the world's total agricultural productivity is lost each year because of pests despite over two million tons of pesticide utilization [169].

In India, agricultural pests cause crop loss of approximately more than Rs 6000 crores annually, of which 33 percent is because of weeds, 26 % to diseases, 20 % to insects, 10 % to birds and rodents, and the rest 11% is due to several other factors [170].

In biological treatment, microorganisms use aerobic respiration to convert organic contaminants to carbon dioxide by transferring electrons and use co-metabolism, where enzymes secreted by microbes help transform contaminants usually exhibited. Numerous studies have shown that various microorganisms can degrade a range of pesticides table 7.

Table 7. Various microorganisms degrading pesticides

Pesticides	Remarks	References
Hexachlorocyclohexane	Anaerobic *Clostridium* sp. degraded technical hexachlorocyclohexane.	[171]
	Under aerobic conditions, *Rhodanobacter lindanclasticus* degraded hexachlorocyclohexane (technical grade)	[172]
	B. circulans and *B. brevis* isolates degraded α and γ isomers at significantly high rates but also degraded thermodynamically stable β and δ isomers at different concentrations.	[173]
	Results revealed that biological growth kinetics of *Pseudomonas aeruginosa* degraded HCH in batch process under aerobic condition	[174]
Diazinon and Parathion	*Flavobacterium* sp. hydrolyzed diazinon to 2-isopropyl-6methyl-4-hydroxy-pyrimidine, which was further converted to carbon dioxide. The bacterium also converted parathion to *p*-nitrophenol.	[175]
Parathion	*P. diminuta* degraded parathion rapidly; cells cultivated for 48 h consisted of 3,400 U of parathion hydrolase activity per liter of broth.	[176]
Carbofuran	*Pseudomonas* and *Flavobacterium* could degrade carbofuran (2, 3-dihydro-2, 2-dimethyl-7-benzofuranyl methylcarbamate) by applying an oxidative pathway.	[177]
2,4 Dichlorophenoxyacetate	*Flavobacterium* sp. can degrade 2, 4-D, 2-chlorobenzoate, and 2-methyl -4- chlorophenoxyacetate, imparting mercury resistance and harbored pRC10 (degradative plasmid).	[178]
Lindane	Investigated the dechlorination of lindane by *P. aeruginosa*	[179]
	B. circulans and *B. brevis* degraded 80% of lindane concentration.	[173]
Atrazine	Bacterial isolate *Rhodococcus* were screened for their efficiency in degrading atrazine (herbicide). *Rhodococcus* that degrades s-ethyl dipropylthiocarbamate (EPTC) can metabolize atrazine.	[180]
	Pseudomonas sp. can metabolize atrazine at high concentrations (>1,000 ppm); hence atrazine was fully mineralized	[181]
Atrazine, Propazine, and Simazine	Under aerobic conditions, *Rhodococcus* strain (B-30) degraded the herbicides-Atrazine, Propazine, and Simazine. Atrazine was degraded promptly, *i.e.*, in 72 hr, around 16 mg L^{-1} was metabolized, and mono and di-N- dealkylated products were formed.	[182]
2,4 Dichlorophenoxyacetate	*P. cepacia* is capable of utilizing 2,4-D and 2-methyl-4-chlorophenoxyacetate as exclusive sources of carbon and energy	[183]
Dichlorodiphenyltrichloroetahne	The study revealed that dichlorodiphenyltrichloroethane seems to be oxidized by a dioxygenase in *Alkaligenes eutrophus*. Such oxidation products are later subjected to ring fission to yield a significant stable intermediate, i.e., 4-chlorobenzoic acid.	[184]
Endosulfan	*P. spinosa*, *P. aeruginosa*, and *B. cepacia* were the most effective degraders of endosulfan as they consumed more than 90% of the broth after 14 days of incubation.	[185]
Chlorpyrifos	*P. aeruginosa* (NCIM 2074) degraded chlorpyrifos at concentrations up to 50 mg/l since higher concentrations inhibit the organism.	[186]
	As assessed by GC-MS, it revealed that chlorpyrifos at 10, 25, and 50 mg/l degraded entirely within 1, 5, and 7 days, respectively. *P. aeruginosa* (NCIM 2074) has been beneficial in degradation of chlorpyrifos at concentrations up to 50 mg/l,	[187]
Dimethoate	Bacterial strains such as *Brevundimonas* sp. showed 96% degradation, *Bacillus* sp. 94%, while *Klebsiella oxytoca* showed 71% degradation of dimethoate pesticides.	[173]

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	Acetonitrile extracts of the bacterial isolates *Bacillus licheniformis* and *P. aeruginosa* were run through thin layer chromatography using two solvent systems: methanol-cyclohexane and hexane-chloroform. The chromatogram showed four different metabolites of dimethoate having different R_f values. Complete disappearance of dimethoate spot shown in *B. licheniformis* strain after three days.	[188]
	An exclusive approach for degradation of dimethoate (organophosphorus pesticides) in liquid media by Effective microorganisms (EM) was studied. The study recommended that microorganisms enriched with the ability to degrade toxic pollutants from the ecosystem are blessings to human beings.	[189]
	The effectiveness of dimethoate degradation was 100%, 96%, 83%, 72%, and 71% for *B. licheniformis, P. aeruginosa, Aeromonas hydrophila, Proteus mirabilis,* and *B. pumilus,* respectively.	[190]
Iprobenphos, Malathion Propenophos, Quinolphos Triazophos, Acetamiprid Carbaryl, Hexaconazole Carbendazim	*Bacillus thuringiensis* (NCIM 2159) and *Proteus* spp. (SUK 7) are found efficient in degradation and assimilation of many of pesticide residues.	[191]
Organophosphate, Quinalphos	The study showed that > 80% of quinalphos was degraded in 17 days by *Bacillus* and *Pseudomonas* spp. No metabolites were observed during the biodegradation process.	[192]
Endosulfan and Endosulfan sulfate	*Bacillus subtilis* (AKPJ04) strain was suitable to degrade endosulfan as well as its equally lethal metabolite endosulfan sulfate to endodiol and endosulfan lactone (non-toxic metabolites) very effectively, i.e., up to 94.2 % within 7 days, estimated quantitatively by gas chromatography-electron capture and qualitatively by thin-layer chromatography detection methods.	[185]

CONCLUSION

Water is a prime resource for numerous human activities. Its quality and quantity are gaining extensive attention worldwide due to massive population growth and increasing social and economic development trends. Rivers are the primary source of water in distinct parts of India. Unfortunately, rivers also become a significant sink of waste that flows into them. River water management is a substantial field of natural resource management, and to be more efficient, it requires public interference through formal institutions and an action plan approach. The direct use of river water for drinking causes severe hazards due to anthropogenic activities causing environmental pollution in rivers. The noxious discharge of toxic industrial waste consisting of heavy metals into the water bodies, especially rivers, prevails in water bodies and accumulates through the food chain. Biomagnification of toxic heavy metals through the food chain causes severe health hazards to humans and other living creatures. Heavy metal alters the structural and biological function of biomolecules. In India, the distressing level of pesticides has been reported in water, air, soil, natural materials, and food. However, extensive and extreme farming pesticides accelerate water and land contamination. Long-duration contact with pesticides can harm living organisms and disrupt the function of different body organs, including endocrine, reproductive, nervous, renal, immune, respiratory, and cardiovascular systems. Various chemical and biological methods are available for reducing the water pollution level. Still, the emergence of an astonishing technology of multicultures of aerobic and anaerobic effective and beneficial microorganisms is gaining popularity because of its eco-friendly nature.

Declarations

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