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Microbial Remediation of Physico-Chemical parameters, Heavy Metals and Pesticides: A Review

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Abstract

Water (Blue Gold) one of the most treasured natural resources is responsible for life on earth by contribution, development and growth of human civilization. Most of the civilization all around the world evolved on the rivers banks. Unplanned urbanization, indiscriminate industrialization, rapidly increasing population along rivers and their catchment area have caused tremendous loss and stress on water quality and their resources. The noxious discharge of toxic industrial waste consisting heavy metals into the water bodies specially river, prevail in water bodies and through the food chain get accumulated. Biomagnification of toxic heavy metals through the food chain causes severe health hazards to humans and other living creatures. However extensive and extreme utilization of farming pesticides accelerate contamination of water and land. Long duration contact to pesticides can harm the living organisms and can disrupt the function of different body organs. Various chemical and biological methods are available for reducing the water pollution level but the emergence of an astonishing technology of multicultures of aerobic and anaerobic effective and beneficial microorganism is gaining a lot of popularity because of its eco-friendly nature.

Keywords: Intra and Interspecific population, coral vine, Eudrilus eugeniae, Eisenia fetida, Waste utilization

Keywords: Blue Gold; Urbanization; Industrialization; Biomagnification; Multicultures; Aerobic; Anaerobic

Introduction

In present day the cry due to environmental pollution can be heard from all around the world. The rapid increase in the pollution level has now become a major threat to the survival of mankind on Earth. The ecological balance of nature is being disturbed by the mankind for their wealth, comfort and ego but now nature itself has started disturbing the nature's balance. The tremendous increase in industrial activity and discharge of toxic industrial waste into the environment is an issue of serious concern. The foremost responsibility of every citizen is to maintain ecological balance and environmental purity.Based on global scenario, according to a report of WHO 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. Almost 80% of all diseases and epidemics can be associated to 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 According to the survey of Indian National Scenario, eight hundred cases out of one lakh annually revealed incidence of water borne diseases based on the data collected by Indian Planning Commission, water related or borne diseases incorporated around 80% of country's health related problem. By the end of 1980, approximately 59% of the population of India (around 69% rural and 23% urban) did not have approach to safe and pure drinking water. To assess the quality of water it is necessary to examine its physico-chemical and biological parameters and to check out the source of pollution, which finally helps in water quality management, such qualities guide to find out in case water is convenient for agricultural, domestic, industrial purpose and if it is not; select the most useful technique, determine the degree of pollution and propose a possible solution, ascertain the ability towards natural purification during sewage and industrial discharged into the water system; and to check the effect of rainfall on water quality of water. In natural environment primary estimation of water pollution level has been of great interest to the scientists, engineers and environmentalists (Agrawal and Shrivastva 1984, APHA, 1998).

Description

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 the fundamental needs of mankind in northern state of India. The extreme cause of pollution in rivers are excessive discharge of domestic waste water from adjacent towns and residents contributing about two-third load of pollution and the rest one third is caused by agricultural and industrial effluents. Organic pollutants can be treated or removed through appropriate treatment of sewage water 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. At present, the direct use of river water for the purpose of drinking causes severe hazards due to anthropogenic activities causing environmental pollution in rivers.

Degradation because of pollution has considerably reduced the ability of wetlands to provide adequate amount and also the water fulfilling the minimal standards. The regular destruction of wetland and more precisely the constant decline of water quality and standards will result in human health deterioration exclusively for the residents of developing countries

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which will also disturb the aquatic life.

The physical chemical and biological parameters of water bodies can be extremely changed by various man-made activities like agricultural practices, industrial discharges and natural dynamics which consequently disturbing the water quantity and quality. Chemical alteration of river water quality can be check out by the analysis of chemical parameters and biochemical studies. For a healthy river it is essential that DO should be minimum 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 faecal coliform counts which should be less than 500 per 100 ml of water. According to water quality the river water is divided into five classes pollution of riverine ecosystem is a burning problem. Various social, Non-Government Organizations (NGO's) and prominent persons have shown concern for pollution in Yamuna river water of Agra, which is clear by perusing following news articles- (Table-1, Figure-1 & 2).

S. No.	Title	Publisher	Published Date and Year
1.	Yamuna Pollution problem beyond redemption: Central Water Commission	The Times of India	February, 07, 2015
2.	Activists protest against Yamuna Pollution	The Times of India	March, 26, 2015
3.	Yamuna Pollution Threatens Taj: Parliamentary Panel	The Times of India	July, 26, 2015
4.	Only biodegradable idols to be immersed in Yamuna	The Indian Express	September, 17, 2015
5.	Eco-Activists urge government to save Yamuna River	The Times of India	September, 19, 2015
6.	Uttar Pradesh told to clean up Yamuna	The Hindu	November, 18, 2015
7.	Activists row boat in dry Yamuna River	The Economic Times	December, 04, 2015
8.	Slight change in Yamuna level, low Demand Save Cities	The Times of India	January, 19, 2016
9.	NGT asks about pollutants dumped into Yamuna from Agra	The Hindu	January, 20, 2016
10.	NGT issues bailable warrant against Yamuna Polluter	The Times of India	February, 23, 2016
11.	Squatters on Yamuna Flood Plain: NGT asks Agra authorities to file action taken report	The Times of India	July, 09, 2016
12.	UP making millions from Taj Mahal yet unable to protect it: NGT	The Times of India	August, 5, 2016
13.	No action on NGT plan for Yamuna	The Times of India	August, 09, 2016
14.	Work on Rs 40 cr clean Yamuna project starts at Mathura	The Times of India	August, 17, 2016
15.	63% of sewage flows into rivers untreated everyday: Central Pollution Control Board	The Times of India	September, 27, 2016

Table 1: News Paper Articles related to Yamuna River Pollution

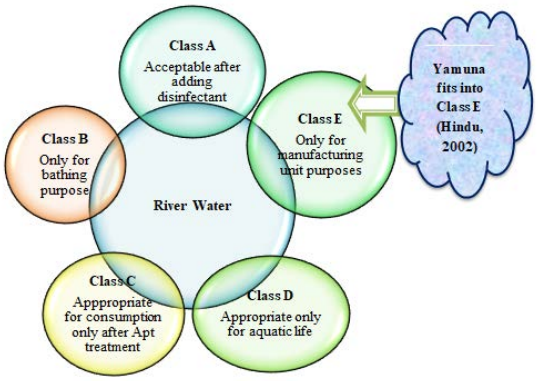

Figure 1: Different classes of River water

Figure 2: Various news paper articles related to Yamuna River Pollution

Bioremediation process

Bioremediation is one of the most promising techniques due to its safety, economical and environmental features because organic contaminants are transformed and even fully mineralized through this technique. Bioremediation process comprises the use of effective and beneficial microorganisms for degrading and detoxifying harmful contaminants from polluted environment has gained a widespread attention as an effective biotechnological and microbiological approach to clean up the degraded and polluted environment (Khan and Anjaneyulu, 2005). Bioremediation not only involves the knowledge of microorganism which degrades the targeted compound but also includes the understanding of mechanism and pathways of degradation both at molecular and physiological levels.

Effect of Heavy Metals on Human Health

During recent years, the serious concern all over the world is heavy metal toxicity because these heavy metal cause detrimental effects on all types of living organisms in the ecosystem. Heavy metals are not easily degradable in the biosphere but accumulate in the human and animal bodies at high lethal levels leading to obnoxious effects. The progresses in industries and agricultural system and increased population density have further entangled this situation. The noxious discharge of toxic industrial waste consisting heavy metals into the water bodies specially river, prevail in water bodies and through the food chain get accumulated. 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. Now a days the contamination of riverine framework by heavy metals has pulled the attention of the scientific researchers. Unlike organic pollutants and natural process of disintegration do not eliminate heavy metals. Moreover, they may be

enhanced by organisms and can be reformed to organic complexes, which might be more toxic in nature.

In aquatic system metals are introduced as a consequence of weathering of rocks and soil, from volcanic eruption and from an assortment of mankind activities including mining, preparation and utilization of metals and additionally metal contaminants containing substances.

Heavy metals are essential trace elements for living beings however accumulation of these metals such as Cd, Zn, Pb, Fe and Cu in viable cells pose detrimental effects. Consequently heavy metal falls into the category of priority pollutants under water quality classification. Heavy metal can enter aquatic system via. natural resources like soil erosion and man-made activities such as discharge of toxic wastes containing heavy metals accomplished through agricultural activities, industries and household use, though agricultural activities contributes the primary source of heavy metal pollution in riverine systems.

Heavy metals incorporated in pesticides and fertilizers introduced into aquatic system through settlement of airborne particles of soil after agricultural cultivation and waste water. Untreated or partially treated heavy metal polluted waste water, Toxic effluents causes severe environmental and health hazards when discharged into accepting water bodies.

Nature of heavy metals contaminated waste water on people may be lethal (chronic, sub-chronic or acute), mutagenic, neurotoxic, teratogenic or carcinogenic. In spite of the fact it is accounted that individual metals show particular sign of toxicity and danger, the signs correlated with lead, mercury, arsenic, cadmium, copper, aluminum and zinc poisoning are diarrhea, tremor, gastrointestinal disorders, hemoglobinuria and stomatitis causing ataxia, paralysis, depression, vomiting, pneumonia, convulsions and rust-red color of stool when volatile vapors are breathed.

Though heavy metals are natural segments of the earth crust that can't be degradable they are just noxious and lethal when they are not synthesized and metabolized by the body and when aggregated in the delicate tissue of the body.

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 accelerate contamination of water and land. Discharge of pesticides originate from both diffuse and point sources. The latter incorporate 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 of the equipment may led to pesticides contamination. Waste water generated through washing facilities of vegetables and manufacturing plants of pesticides are also vital point source of pollution. Numerous pesticides are recalcitrant compounds and prevail in environment for a long period of time. Pesticides have been distinguished in surface and ground water utilized for consumable water supply and been connected to antagonistic human wellbeing impacts.

In India distressing level of pesticides has been reported in water, air, soil along within biological materials and food. A few pesticides have been accounted to be lethal, cancer causing, mutagenic and carcinogenic. The most imperative contaminations among the toxicants in India are organochlorine and organophosphorus pesticides. During 2001-2002 the utilization of pesticides was 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.

Some determined organochlorine pesticide have been banned for general well-being and horticulture use since last few years, instead of this high concentration of pesticides and its metabolites have been estimated in water, soil and sediment samples. Beside other insecticides like lindane and endosulfan are at present in use throughout the world and their presence in water, air and soil is an issue of incredible concern. Diminishing their level in the ecosystem has therefore turned into a vital objective. 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 manufacturing plant for BHC and DDT.

During 1958, over 5000 metric tons of pesticides were produced in India. Extensive use of agricultural pesticides transmit it potential hazards to human being and specifically by exposure to toxic and noxious residues in food and indirectly to the ecosystem.

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

WHO has assessed that there are at least 3 million intense serious cases of pesticides (suicide agent) hazards and almost 20,000 unexpected deaths every year, especially in developing countries. One of the WHO study revealed that in developing countries around 3% of agriculture workers suffers from poisoning incident every year, bringing about 25 million occupational poisoning.

Human well-being risk is an element of pesticide poisoning and exposure, a more serious hazard is expected to emerge from high vulnerability to a modestly dangerous pesticide than from slight exposure to extremely toxic pesticides. Nonetheless, whether dietary exposure to the overall population to residues of pesticides present in drinking water and food comprises of potential risk to human well-being is still the subject of logical scientific controversy.

Microbial Remediation of Toxic Pollutants from different sources of waste water-Physico-chemical Parameters

Rapid industrialization and urbanization coupled with 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 moreover considered as main sources for degradation of river water quality.The pollution status of any river can be assessed by examining the physico-chemical properties of the water bodies. Distinct researchers in relation to pollution of river water like Jhelum, Krishna, Godavari and Tungbhdra, Gangaand Sharma and Sharma, 2015) have captivated more attention for several past years. The treatment of waste water differs with its quantity, character the way of receiving media and dilution available. Waste water consistently could be processed for recycling and disposal through one or more steps. The initial treatment is the primary or preliminary treatment i.e. physico-chemical treatment but due to the objection properties of effluent, the biological treatment which is secondary treatment is employed. Biological treatment involves the degradation of both suspended and dissolved components through microorganism under controlled conditions. The primitive characteristic of biological treatment is the utilization of microbial consortium including bacteria fungi or algae for the conversion of toxic substances or pollutants.

Heavy Metals

The release of waste water consisting huge amount of heavy metals to recipient water bodies have detrimental environmental effects. Accumulation and occurrence of heavy metals in the environment is a consequence of direct or indirect human activities like rapid urbanization, industrialization and anthropogenic sources (EPA 2000, Hussein et al. 2005, Gardea et al. 2005). Minimal concentrations of heavy metals are vital as co-factor of enzymatic reaction; however 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.

Microbial metal bioremediation is a productive system because of its minimal cost, immense efficiency, eco-friendly behavior furthermore it brings out the complete or partial biotransformation of wastes to microbial biomass and durable harmless end products. The utilization of organic materials for effective eradication of heavy metal contaminant from waste water has developed as a potential alternative approach to conventional procedure.

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 preserve the nutritional value of food items.

However, excessive usage of pesticides results into their accumulation in the agricultural products. Around one-third of the total world agricultural productivity is lost each year because of pest inspite of over two million tons of pesticides utilization.

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

In biological treatment, microorganisms used aerobic respiration to convert organic contaminants to carbon-dioxide by transferring electrons and also uses co-metabolism where enzymes secreted by microbes helps in transformation of contaminants which normally exhibits biodegradation. Numerous studies have shown that various microorganisms are able to degrade a range of pesticides (Table 2).

Pesticides	Remarks	Citation
HCH	Anaerobic Clostridium sp. degraded technical HCH.	Mac Rae et al., (1969)
Diazinon and Parathion	Flavobacterium sp.hydrolyzed diazinon to 2¬-isopropyl¬-6-methyl¬-4¬hydroxy¬-pyrimidine which was further converted to carbon dioxide. Bacterium also converted parathion to p¬-nitrophenol.	Sethunathan and Yoshida (1973)
Parathion	Pseudomonas diminuta degraded parathion rapidly, cells cultivated for 48 h consisted 3,400 U of parathion hydrolase activity per liter of broth.	Serdar et al., (1982)
Carbofuran	Pseudomonas and Flavobacterium were able to degrade carbofuran (2, 3-dihydro-2,2-dimethyl-7-benzofuranyl methylcarbamate) by applying oxidative pathway.	Chaudhry and Ali (1988)
2,4 Dichlorophenoxyacetate	Pseudomonas and Flavobacterium were able to degrade carbofuran (2, 3-dihydro-2,2-dimethyl-7-benzofuranyl methylcarbamate) by applying oxidative pathway.	Chaudhry and Huang (1988)
Lindane	Investigated the dechlorination of lindane by Pseudomonas aeruginosa	Sahu et al., (1992)
Atrazine	Bacterial isolate Rhodococcus were screened for their efficiency to degrade atrazine (herbicide). Rhodococci that degrades s-¬ethyl dipropylthiocarbamate (EPTC) can metabolize atrazine.	Behki et al., (1993)
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 h around 16 mg L-1 was metabolized and mono and di-N- dealkylated products were formed.	Behki and Khan (1994)
2,4 Dichlorophenoxyacetate	Pseudomonas cepacia capable of utilizing 2,4-D and 2-methyl-4 chlorophenoxyacetate as exclusive sources of carbon and energy	Bhat et al., (1994)
DDT	Study revealed that DDT seems to be oxidized by a dioxygenase inAlkaligenes eutrophus and the products of such type of oxidation later subjected to ring fission to ultimately yield a major stable intermediate i.e. 4-chlorobenzoic acid.	Nadeau et al., (1994)
Atrazine	Pseudomonas sp. able of metabolize atrazine at high concentrations (>1,000 ppm) hence atrazine was fully mineralized	Mandelbuam et al., (1995)
HCH	Under aerobic conditions Rhodanobacter lindanclasticus degraded HCH (technical grade)	Nalin et al., (1999)
Lindane	Bacillus circulans and Bacillus brevis degraded 80% of lindane concentration.	Gupta et al., (2000)

HCH	Bacillus circulans and Bacillus brevis isolates degraded α and γ isomers at significantly high rates but also degraded thermodynamically stable β and δ isomers at different concentrations.	Gupta et al., (2000)
Dimethoate	Bacterial strains such as Brevundimonas sp. showed 96% degradation, Bacillus sp. 94% while Klebsiella oxytoca showed 71% degradation of dimethoate pesticides.	Deshpande, (2002)
Endosulfan	Pseudomonas spinosa, P. aeruginosa, and Burkholderia cepacia, were the most effective degraders of endosulfan as they consumed more than 90% of amount in the broth after 14 days of incubation.	Hussain et al., (2007)
HCH	Results revealed that biological growth kinetics of Pseudomonas aeruginosa degraded HCH in batch process under aerobic condition	Lodha et al.,(2007)
Dimethoate	Acetonitrile extracts of the bacterial isolates Bacillus licheniformis and Pseudomonas aeruginosa were run through Thin layer chromatography using two solvent systems: methanol-cyclohexane and hexane-chloroform. Chromatogram showed the presence of four different metabolites of dimethoate having different Rf values. Complete disappearance of dimethoate spot shown in Bacillus licheniformis strain after three days.	Debmandal et al., (2008)
Chlorpyrifos	Pseudomonas aeruginosa (NCIM 2074) degraded chlorpyrifos at concentrations up to 50 mg/l since the organism is inhibited by higher concentrations	Fulekar and Geetha (2008)
Chlorpyrifos	As assessed by GC-MS, revealed that chlorpyrifos at 10, 25, 50 mg/l degraded completely within 1, 5 and 7 days, respectively. Pseudomonas aeruginosa (NCIM 2074) has been beneficialin degradation of chlorpyrifos at concentrations upto 50 mg/l,	Fulekar and Geetha (2008)
Dimethoate	An exclusive approach for degradation of dimethoate (organophosphorus pesticides) in liquid media by Effective microorganisms (EM) was studied. Study recommended that microorganisms enriched with the ability to degrade toxic pollutants from ecosystem are blessings to human beings.	Megeed and Nakieb (2008)
Dimethoate	The effectiveness of dimethoate degradation were 100%, 96%, 83%, 72% and 71%, for Bacillus licheniformis, Pseudomonas aeruginosa, Aeromonas hydrophila, Proteus mirabilis and Bacillus pumilus respectively.	Debmandal et al., (2011)
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.	Sabale et al., (2012)
Organophosphate, Quinalphos	Study showed that > 80% of quinalphos was degraded in 17 days by Bacillus and Pseudomonas spp. No metabolites were observed during biodegradation process.	Dhanjal et al. (2014)
Endosulfan and Endosulfan sulfate	Bacillus subtilis (AKPJ04) strainwas 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, estimatedquantitatively by gas chromatography-electron capture and qualitatively by thin layer chromatography detection methods.	Kumar et al., (2014)

Table 2: Biodegradation of Pesticides

Water is a prime resource for numerous human activities and its quality and quantity are gaining extensive attention throughout the world due to massive population growth and increasing trends of social, economic development. Rivers are the primary source of water in distinct parts of India. Unfortunately, rivers also becoming a major sink of wastes that flow into them. River water management is significant field of natural resource management and in order to be more efficient it requires public interference through proper institution and an action plan approach. At present, the direct use of river water for the purpose of drinking causes severe hazards due to anthropogenic activities causing environmental pollution in rivers. The noxious discharge of toxic industrial waste consisting heavy metals into the water bodies specially river, prevail in water bodies and through the food chain get accumulated. 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 distressing level of pesticides has

been reported in water, air, soil along within biological materials and food. However extensive and extreme utilization of farming pesticides accelerate contamination of water and land. Long duration contact to pesticides can harm the living organisms and can 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 but the emergence of an astonishing technology of multicultures of aerobic and anaerobic effective and beneficial microorganism is gaining a lot of popularity because of its eco-friendly nature.

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Conflicts of Interest

The authors have no conflicts of interest.

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