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RESEARCH ARTICLE

BIOREMEDIATION OF POLLUTED KAMLA RIVER WATER BY PHYSICAL, BIOLOGICAL AND ECOLOGICAL PROCESSES

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Abstract

The increasing need for remediation of contaminated sites has led to the development of new technologies that emphasize on the biological detoxification anddestructionofthe(organic)contaminants.Bioremediationisamongthesetechnologiesthatdestroyorrenderharmlessvariouscontaminants,usingthebiologicalactivityofcertainmicroorganisms[1].Needlesstosaythatasbioremediationactuallyreliesonthemicrobialgrowthandactivity,itseffectivenessishighlydependentontheappliedenvironmentalparametersthatinfluencethemicrobialgrowthandthedegradationrate.Bioremediationtechnologiescanbeclassifiedintotwogeneralcategories:exsituandinsitu.Theexsitutechniquesarethosethatrequirethe physical removal of the contaminated material and its transportation to another area for further treatment, for example, by bioreactors, landfarming and composting. The insitute chnologies are those that involve treatment of contaminated material in place, for example, by bioventing, biostimulation and biopiling. Overall, bioremediation isconsideredasaverypromisingtechnologywithgreatpotentialwhendealingwithcertaintypesofcontaminatedsites.Sofar,ithasbeenusedatanincreasingnumberofsitesworldwide,includingEurope,withvaryingsuccess.Theapplicationofbioremediationandphytoremediationofferssignificantbenefitstoenvironmentalpollutionabatementand,moreimportantly,tohumanhealth;however,theriskofadversehealtheffectsmaybepresentduetothevariabilityofcontaminantsandtheirpossiblebiotransformationtowardnotcontrolledmetabolites.Therefore,specificcontrolproceduresshouldalsotakeplace.

Introduction:-

Principles of Bioremediation

Bioremediationistheprocesswherebyemploysthelivingorganisms,mostnotablymicroorganisms,todegradethepollutants(mostlyorganicwastes)andconvertthemintolesstoxicornontoxicform.Thesuitableorganismscanbebacteria,fungiorplants,whichhavethephysiologicalabilitiestodegrade,detoxifyorrenderthecontaminantsharmless.Insomeoccasions,themicroorganismscanbealreadypresentonthesite(indigenousmicroorganisms)orcanbeisolatedfromelsewhereandaddedtothetreatedmaterial,usingbioreactorsasanexample.Bioremediationactuallyreliesonthemicrobialgrowthandactivity,itseffectivenessishighlydependentontheappliedenvironmentalparametersthatinfluencethemicrobialgrowthandthedegradationrate. Overall,bioremediationtechniquedependsonhavingtherightmicroorganismsintherightplaceunderthesuitableenvironmentalconditionsinorderforthedegradationprocesstooccursuccessfully.Thebiologicalprocessesinvolvedinbioremediationt

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echnologycanbeenhancedandfocusedontheremovalofspecifichazardouspollutantsfromsoil,wateroratmosphere.Itcanmineralizewastematerialintowater,carbondioxide,biomassorothernon-hazardousproductsandthusobviatetheneedforfurthertreatment.Bioremediationcantreatawiderangeofcompounds.Apartfromdomesticandfactorieswastesandprocesswaters,suitable(foreachcase)microorganismsmayalsobeappliedforthedegradationofpesticides,industrialchemicals,componentsofcrudeoilandevencompoundsthat,untilrecently,wereregardedasnon-biodegradable,suchaschlorinatedsolvents,chlorofluorocarbonsandothersyntheticorganiccompounds[3].

Sources of River Water Pollution

Uncontrolled, unplanned, rapid and extensive growth of urbanisation and factories activities generate large amounts of solid and liquid waste in town areas. Disposal of untreated solid waste, storm water and agricultural runoff, alongwith town and factories waste water into the Kamla river is the main cause of physical, chemical (nutrients, metals, organic matters, nanomaterials, etc.) and biological (microbial) contamination of river water [1,3]. Sources of these wastes include factory production, sewage, domestic waste, town waste, shopping markets, restaurants, agricultural waste, etc. [4]. In India, about 50% of total human waste is discharged into the rivers and other water bodies without proper treatment [5]. In developing countries, agricultural crop production is practiced on vast land areas in order to meet the food demand of the increasing population. Agrochemicals (fertilizers, pesticides, herbicides, etc.) used in agricultural activities discharge different chemicals, including nutrients (Nitrate and Phosphate), into the river water. These contaminants originate from both point and non-point sources. Stormwater runoff is another major contamination transport route, which brings treated and untreated sewage, industrial waste, petroleum hydro-chemicals and road dust into the river water [6].

Theincreasingneedsforremediationofcontaminatedsitesof Kamlariverhasledtothefocusedonnewtechnologiesorprocessesthatemphasizeonthebiologicaldetoxificationanddestructionofthe(organic)contaminants.Bioremediationisamongthesetechnologiesorprocessesthatdestroyorrenderharmlessvariouscontaminants,usingthephysical,biologicalandecologicalactivitiesofcertainmicroorganisms.Amongthephysicalprocesses,aerationisaneffective,sustainableandpopulartechniquewhichincreasesmicrobialactivityanddegradesorganicpollutants[7].

Methodology:-

Physical Techniques

Mechanical Aeration Processes, Water transfer or Diversion and Dilution, Mechanical Algae Removal, Building Hydraulic Structures, Dredging River Sediment, Riverbank filtration, etc.

Biological & Ecological Techniques

Microbial Bioremediation, Membrane Bioreactor Technology, Ecological Ponds, Ecological Floating Beds, Plant Purification Treatment, Constructed Wetlands, Biofilms, Contact Oxidation etc.

Result and Discussion:-

Physical Techniques

Mechanical Aeration ProcessesAir flow into river water increases microbial diversity and degrades organic compounds in water[7]. This process remove the black colour, odour, COD and BOD of Kamla river water.

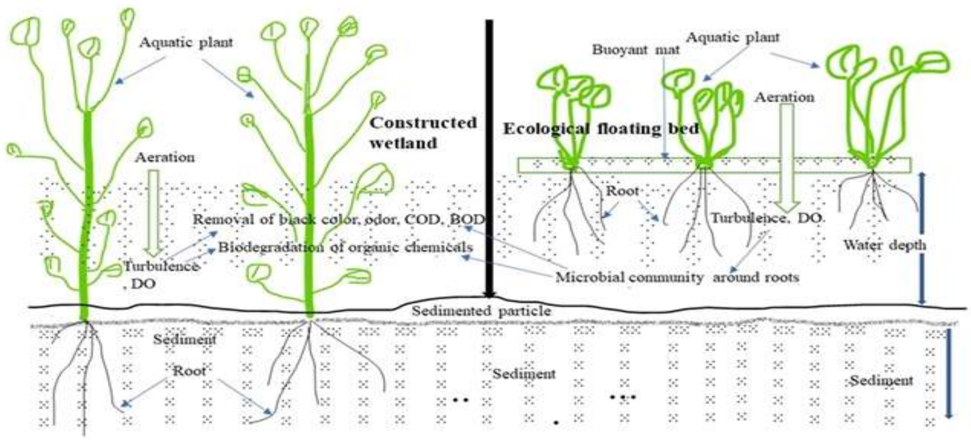

Figure 1:- Schematic diagram of aeration technique in ecological treatment of river water.

Water transfer or Diversion and Dilution

Mixing of clean water with polluted river water and dilution of Pollution[10]. Water transfer provides multiple benefits, such as irrigation, water supply, navigation, flood control, power generation, reducing water crisis, increasing water security, reducing the concentration of nutrients and phytoplankton and improving water quality[10,14]. This method demonstrated the explicit evidence of reduction in the concentrations of NH_4, other N_2containing compounds and COD in Kamla river water.

Mechanical Algae Removal

Removal of algae by mechanical process. It minimizes dissolved inorganic Carbon, pH and DO level of Kamla river water[7].

Building Hydraulic Structures

The construction of hydraulic structures such as irrigation weirs or irrigation infrastructure reduces water flow velocity but increases hydraulic retention time, which facilitate sedimentation, aeration, sunlight irradiation and anaerobic reactions, resulting in improving water quality of river[6,8].

Dredging River Sediment

Removal of polluted sediment those sattled down at bottom are picked out by dredgingmachine. This process is also help in creating waterways, removing trash and debris, reopening channels, reconfiguring waterways, restoring banklines, increasing waterways depth, maintaining ecosystem and more of Kamla river.

Riverbank filtration

Riverbank filtration processes remove organic and inorganic contaminants (COD, NH_4 and NO_3) from river water, particularly when water flows through the river-bed and groundwater aquifer to the pumping wells[9,10,12].

Table 1:- Efficiency, advantages, and disadvantages of different physical/engineering-based treatment methods of river water.

Treatment/ Techniques	Process/ Description	Advantages	Disadvantages
Artificial aeration	Air flow into river water increases microbial diversity and degrades organic compounds in water	Effectively improve water quality, simple and easy to apply, sustainable and widely applicable	Cost intensive during operation and maintenance phase.
Water transfer/diversion	Mixing of clean water with polluted river water and dilution of pollution	Improve river water quality, water supply, river pollution control, promote self-purification process	Potential destruction of ecosystem, cost and labour intensive
Mechanical algae removal	Removal of algae by mechanical process	Improve river water and sediment quality	Cost intensive during operation and maintenance phase
Dredging river sediment	Removal of polluted sediment by dredging machine	Improve sediment and river water environment	Potential increase of pollution, cost intensive mechanical process
Building hydraulic structures	Irrigation weirs or infrastructure built on the river	Improve river water quality for irrigation purposes	Potential destruction of ecosystem health, cost intensive
Riverbank filtration	Flow through riverbed and groundwater aquifer to the pumping wells	Remove organic and inorganic contaminants through natural filtration process	Slow process

Biological & Ecological Techniques

Microbial Bioremediation

The treatment of polluted Kamla river water by application of microbial agents/photosynthetic bacteria and microalgae-bacteria media significantly degrades organic matter and removes COD and BOD (about 70%) and nutrients.

Biofilm Reactors
The treatment system exhibited very high efficiency to remove Ammonia Nitrogen, BOD, TDS and COD from Kamla river water by using biomembrane[15].

Ecological floating bed
Ecological floating beds use ecological processes and the removal mechanisms involve phytoremediation (heavy metal uptake by plants), microbial biodegradation of organic chemicals and removal of N and P by absorption and sedimentation processes[3,5].

Phytoremediation Process
The most widely used aquatic plants for wastewater treatment are reed (Phragmites australis), water hyacinth (Eichhornia crassipes), alligator weed (Alternanthera philoxeroides), water lettuce (Pistia stratiotes), duckweed (Lemna gibba) and canna (Canna indica). These plants exhibited significant capacity to remove nutrients such as total N and P from water bodies[13].

Constructed Wetlands
Constructed floating bed wetland, horizontal subsurface flow constructed wetland and surface flow constructed wetland are effectively removed COD, NH_4, TN (total Nitrogen), TP (total Phosphorus) and Suspended Solids from river water[2,9].

Table 2:- Plant species used in ecological restoration of river ecosystems and remediation of river water.

Techniques	ProcessesorSystems	PlantSpecies
Wetland	Removal of nutrients and organic matter by aquatic plants and aeration	Pontederia cordata
	Constructed wetlands, floating bed systems	Reed (Phragmites communis), E. crassipes (water hyacinth), A. philoxeroides Water lettuce (Pistia stratiotes) Watermilfoil (M. verticillatum), pondweed (Potamogeton spp.), cattail (T. latifolia), duckweed (L. gibba), canna (C. indica)
Hydroponic floating bed	Removal of TN and TP; Water spinach performs better than sticky rice.	Water spinach, sticky rice
Revetment	Ecological revetment plants	Goosegrass, sedges, and water grasses
Floating bed	Removal of BOD, COD, nutrient, metal Multistage floating-bed system Enhanced ecological floating beds Ecological floating bed for removal of nutrients	Polygonum hydropiper bagen, reeds, bulrushes. Macrophytes. Canna indica L., Iris pseudacorus L. Canna indica, Accords calamus, Cyperus alternifolius, Vetiveria zizanioides.
Floating wetland	Endophyte-assisted floating wetlands Floating treatment wetland	Typha domingensis, Leptochloa fusca. Elodea nuttallii Carex spp., Lythrum salicaria.

Conclusion:-
The random disposal of treated and untreated solid and liquid wastes into water pollutes the receiving river water with nutrients, organic chemicals, metals and nanomaterials[15]. The most widely applied physical processes are aeration, water transfer, mechanical algae removal, building hydraulic structures and dredging river sediment.

Aeration is an effective, sustainable and widely applicable technique that plays an important role in increasing the diversity of the microbial community and degrading organic chemicals in river water. Riverbank filtration is a natural, slow and self-sustainable process which removes organic and inorganic contaminants from river water without any adverse effects. The microbial agents, ecological floating beds, constructed wetlands and biofilm reactor techniques use microorganisms and plant-based bioremediation processes to decompose organic chemicals and remove nutrients and metals from river water[13,16]. The hybrid, integrated, sequential and engineering-based floating bed wetlands can demonstrate the maximum water purification efficiency and overcome the drawbacks of single constructed floating beds or wetland. However, All the techniques and processes which have been applied on Kamla river water reduce maximum level of inorganic nutrients, organic chemicals, metals and nanomaterials.

Biofilm reactors are highly efficient at remediating polluted river water through the growth of microbial communities in biofilms. The efficiency and stability of the biofilm-based systems are dependent on water flow velocity, hydraulic loading rate, temperature, components of media and water depth. The gravel contact oxidation method is applicable to shallow creeks, but not to deep river water. The moving bed biofilm reactors show high efficiency in the removal of COD and organic matter. The direct mixing of microbial agents with river water moderately removes NH_3-N, COD and TP, whereas engineering-based applications of microbial agents significantly degrades organic matter and removes COD, BOD and nutrients[1,6,10,12]. However, their application should be monitored cautiously to avoid microbial contamination. Ecological floating bed techniques are more widely applicable for the treatment of river water. Water fluctuation, river waves and inundation do not affect their treatment performances. The appropriate selection of plant species is the key influential parameter for them. Inclusion of high capacity adsorbent materials in the matrix of floating mats enhances their contaminant removal efficiency. The hybrid, integrated, sequential and engineering-based floating bed wetlands can demonstrate the maximum water purification, efficiency and overcome the drawbacks of single constructed floating beds or wetland[2,6,8].

Suitablemicrobialpopulationscandegradeawiderangeofcontaminants,rendering(transforming)ahazardouscompoundto aharmlessone.Eventually,theresiduesofthetreatmentmayincludesimplercompounds,suchascarbondioxideorwaterbutalsocellbiomass[5,7].Therefore,achanceforfuturehazardsinthetreatmentanddisposalofcontaminatedmaterialispractically eliminated.Often,bioremediationcanbeperformedon-site,thusreducingtheassociatedtransportationcostsandliabilitiesandalsothepotentialthreatstohumanhealthandtotheenvironmentduetothetransportationofhazardousmaterials.Inaddition,itisoftenappliedasinsitutechnologyhencethesitedisruptionisminimized,enablingtheabovegroundactivitiestobecontinued[1,9].Needlesstosaythatbioremediationasabiologicalsystemcanoftenbeshowntobelessexpensivethanotherrelevanttreatmenttechnologies,whichcanbeappliedforthesamepurpose.Finally,bioremediationcanbecombinedwithothertechnologiesintoaprocesschain,thusincreasingtheefficiencyofthe wholetreatment.

Moreover,theeffectivenessofbioremediationishighlysusceptibletothemicrobialgrowthandotherenvironmentalparametersofthesite.Finally,bioremediationoftenrequiresmoretimethanothertreatmentoptions,suchasincinerationorexcavationandremovalofsoil[11].

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