PROCESSANDPLANTSFORWASTEWATERREMEDIATION:AREVIEW

[1]NIYATI NAIK,

Gandhi Institute of Excellent Technocrats, Bhubaneswar, India

[2]RAHUL KHARSEL,

Capital Engineering College, Bhubaneswar, Odisha, India

ABSTRACT

Increasingurbanization,industrializationandoverpopulationarethefactorsmainlyresponsibleforaddinghazardouscomponentsinwater,whichmainlyconstitutesheavymetalsandchemicalsetc.Waterbodiesarethemaintargetsfor disposing the pollutants directly or indirectly. This is a review paper illustrating the role of plants to assist the treatmentof industrial and residential wastewater. The prevailing purification technologies used to remove the contaminants are toocostlyandsometimesnon-ecofriendlyalso.Therefore,theresearchisorientedtowardslowcostandecofriendlytechnologyfor waste water purification, which will be beneficial for community. The paper discusses the potential of different processandutilizationofterrestrialandaquaticplantsinpurifyingwaterandwastewaterfromdifferentsources.

Keywords:Phytoremediation,Treatmentmethods,Wastewater,Waterpollution,Heavymetals.

INTRODUCTION

Waste-wateristhecombinationofliquidorwater-carriedwastesoriginatinginthesanitaryconveniences of dwellings, commercial or industrial facilities and institutions, in addition to any groundwater, surface water and storm water that may be present. Untreated wastewater generally contains highlevelsoforganicmaterial,numerouspathogenicmicroorganisms,aswellasnutrientsandtoxiccompounds.It thus entails environmental and health hazards and, consequently, must immediately be conveyed awayfromitsgenerationsourcesandtreatedappropriatelybeforefinaldisposal.Theultimategoalofwastewatermanagement is the protection of the environment in a manner commensurate with public health and socio-economicconcerns.Wastewatertreatmentisbecomingevenmorecriticalduetodiminishingwaterresources,increasingwastewaterdisposalcostsandstricterdischargeregulationsthathaveloweredpermissible contaminant levels in waste streams. The municipal sector consumes significant volumes ofwater, and consequently generates considerable amounts of wastewater discharge. The present studycomprises a comprehensive survey of the various methods and technologies currently used in wastewatertreatment. The study also addresses the utilization of some eco-friendly and low cost technologies forsustainable development, with special reference to phytoremediation technology[1]. Studying the economicsofdifferentwastewatertreatmentsisanessentialpre-requisitetotheidentificationofcost-effectivesolutions.

Reviewwork

Boyd[2] gave the method for reducing the pollution of lakes by harvesting of aquatic plants, whichhavewithdrawnnutrientsfromthewater.Theauthorpointsoutthatallaquaticplantscanservethispurposebut small plants, like phytoplankton, or submerged plants are more difficult and expensive to harvest thanthefloatingandemergentvascularplants.Fourspeciesareconsideredsuitable,*Eichhorniacrassipes*(waterhyacinth),*Alternantheraphiloxeroides*,*Justiciaamericana*and*Typhalatifolia*.

AccordingtoBoyd[3,4]waterhyacinth,confinedinbarrierssothatitonlycovers10%ofthepond,andregularlyharvested, canremovesufficientnutrientstoavoidexcessivephytoplanktongrowth.Reviewingtheliterature, he cites three estimates of the amount of nitrogen and phosphorus that water hyacinth could beexpectedtoextractfromnutrient-richwatersundergoodgrowingconditions:(t/ha/year).AveragerratesofNandPremovalovertheentireperiodwere3.4 and0.43kg/ha/day,respectively.

Glass-house and field trials were arranged to measure the uptake of nitrogen and phosphorus bywater hyacinths from water having varying concentrations of N and P by Duniganet al.[5] The N was addedasammoniumchlorideandpotassiumnitrate.TheNandPconcentrationsatthebeginningofthetrialswerearranged to be 50, 100 and 250 ppm. After 21 days, all the ammonium N at the lower and medium levels,andthenitrateNatthelowestlevel,hadbeentakenup.AbouthalfthePateachconcentrationhadalsobeenabsorbed.Inthefieldtrials,thehyacinthsincreasedtherateoflossofammoniumN,butwereineffectiveinremovingnitrateN.TheremovalofPwaslow. The test plants used for the study were *Ceratophyllum*sp., *Cladophora*sp., *Hydrodictyon*sp.,*Aphanizomenon*sp., *Microcystis*sp., *Anabaena* sp., and *Nostoc*sp.[6] Water hyacinth was grown in thelaboratoryinculturesolutionscontainingphosphorusatvaryingconcentrations.ThePconcentrationcriticalformaximumgrowthwas0.1ppm.Belowthislevelgrowthwaslimited,aboveitthehyacinthstookupPinluxuryamountswithoutanyincreaseinyield[7].

Water hyacinth was grown outdoors in concrete tanks containing sewage effluent. Over a period offive weeks the uptake of P was measured as 5.5 mg/g of the dry weight of the plant. The P concentration intheeffluentwas1.4mg/litreatthestartoftheexperimentandwasreducedto0.2mg/litreattheend.Ofthisdecrease70% tookplaceinthefirsttwoweeksand80%bytheendofthreeweeks.Thehyacinthincreasein(dry)weightwasatamaximum duringthefirstweekandtotaled97g/m^2ofwatersurface,whichrepresenteda45%increaseinthedryweightoftheplantsatthestartoftheexperiment[8].TheauthorsconcludedthatthisstudyindicatedthatwaterhyacinthscouldbeusedtoreducePin sewageeffluenttolowlevels.

Wastewater treatment systemsTreatmentsystems

Naturalsystemsforwaste-watertreatmentaredesignedtotakeadvantageofthephysical,chemical[9,10]andbiologicalprocesses[11]thatoccurinthenaturalenvironmentwhenwater,soil,plants,micro-organisms and the atmosphere interact natural treatment systems include land treatment, floating aquaticplants and constructed wetlands. All natural treatment[12] systems are preceded by some form of mechanicalpretreatment for the removal of gross solids. Where sufficient land suitable for the purpose is available,thesesystemscanoftenbethemostcost-effectiveoptionintermsofbothconstructionandoperation.

Landtreatment

Land treatment is the controlled application of waste-water to the land at rates compatible with thenatural physical, chemical and biological processes that occur on and in the soil. The three main types oflandtreatmentsystemsusedareslowrate(SR),overflow(OF)andrapidinfiltration(RI)systems.

Constructedwetlands

Wetlandsareinundatedlandareaswithwaterdepthstypicallylessthan2ft(0.6m)thatsupportsthegrowth of emergent plants such as cattail, bulrush, reeds and sedges. The vegetation provides surfaces forthe attachment of bacteria films, aids in the filtration and adsorption of waste-water constituents, transfersoxygen into the water column and controls the growth of algae by restricting the penetration of sunlight[6]Wetlandsalsocleanthewaterbyfilteringoutsedimentation,decomposingvegetativematterandconvertingchemicals into useable form. The ability of wetlands to recycle nutrients makes them critical in the overallfunctioningofearth.

Floatingaquaticplants

ThissystemissimilartotheFWSsystemexceptthattheplantsusedareofthefloatingtype,suchashyacinthsandduckweeds.Waterdepthsaregreaterthaninthecaseofwetlandsystems,rangingfrom1.6to
6.0 feet (0.5-1.8 m). The floating plants shield the water from sunlight and reduce the growth of algae.Systems of this kind have been effective in reducing BOD, nitrogen, metals and trace organics and inremoving algae from lagoons and stabilization pond effluents. Supplementary aeration has been used withfloatingplantsystemstoincreasetreatmentcapacityandtomaintaintheaerobicconditionsnecessaryforthebiologicalcontrolofmosquitoes.

Useofaquaticplantsforwaterpurification

Several papers did refer to the capacity of water plants to extract plant nutrients from the water inwhichtheygrew.Thereasonwhichhaspromptedthespateofpaperswithinthelasttenyearsonthenutrientextraction possibilities of aquatic plants[14] is the increasing awareness of the problems of water pollution -both fresh and salt water - as a consequence of population growth and industrial development, and thedisposal of human, animal and industrial wastes into inland waters and into the sea. Many examples of thedevastating consequences of the waste water on formerly clean and useful rivers and lakes have arousedpublic and scientific awareness of the need not only to arrest the practice of direct dumping but to try andreverse it by extracting the pollutants. The remarkable ability of aquatic plants, particularly the waterhyacinth[4,5],toextractcompoundsandelementsfromwaterefficientlyhasbecomewellrecognized.

Itisoneoftheearliesttogointothequestionofreducingthepollutionoflakesbytheharvestingofaquatic plants, which have withdrawn nutrients from the water[2]. It is pointed out that all aquatic plants canservethispurposebutsmallplants,likephytoplankton,orsubmergedplantsaremoredifficultandexpensiveto harvest than the floating and emergent vascular plants. Four species are considered suitable: *Eichhorniacrassipes*(waterhyacinth),*Alternantheraphiloxeroides*,*Justiciaamericana*and*Typhalatifolia*(Table1) .Itisstatedthatwaterhyacinthwouldbeideallysuitedfornutrientremovalsystems.Asitfloatsonthesurfaceand is not rooted, harvesting is facilitated. There would be considerable microbial activity beneath thehyacinths and nutrients would be absorbed by these organisms. In addition considerable organic matterwould reach the water by the loss of root fragments and probably have a fairly high biological oxygendemand(BOD)anditmightprovenecessarytouseconventionalsewageholdingpondstoreducetheBODpriort ofinalrelease.

*Alternantheraphiloxeroides*could probably be best harvested by draining the pond and then usingmodified forage harvesting equipment. *Typhalatifolia*as an emergent species could be grown in pondsabout1mdeepsothatthewaterremainsanaerobic,allowingbottomsoilstoremovePfromsolution.Butitwould be better, if space permitted, to grow the plants in water 15–20 cm deep to maximize soil absorptionof P. At a stage when P equilibrium had been reached then the ponds could be dried and used forconventionalcropsuntilthePlevelsarereduced.

Table1:Uptakeofvariouselementsbyselectedaquaticplants

	Aquaticplantspeciesandtheiruptake(kg/ha/year)			
Element	*E.crassipes*	*J.americana*	*A.philoxeroides*	*T.latifolia*
N	1980	2290	1780	2630
P	320	140	200	400
S	250	200	180	250
Ca	750	1020	320	1710
Mg	790	470	320	310
K	3190	3720	3220	4570
Na	260	190	230	730
Fe	19	120	45	23
Mn	300	13	27	79
Zn	4	30	6	6
Cu	1	3	1	7

Ref.FAO CorporateDocument RepositoryProduced by:Fisheries and Aquaculture Department (Handbookofutilizationofaquaticplants)

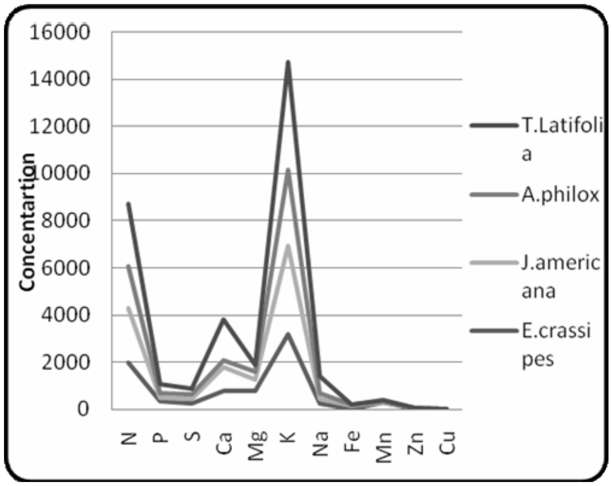

Fig.1:Aquaticplantspeciesandtheirnutrientuptakein Kg/ha/year

Nutrientremovalbyplantswouldbemosteffectivewhenthenutrientisconcentrated.Thisistypicaloftheeffluentsfrom feedlotsofcattle.Ifplantsweregrownonthepondsholdingtheseeffluents,theycouldbe fed to the cattle. This would be ideal because handling and transport of the plants would be kept to aminimum.Nutrientremovalandplantutilizationcouldalsobehandledbythesameorganization.

The paper reviews the potential of aquatic plants[3], for removal of nutrients from polluted water.Wastefeedandtheexcretionsofthefishleadtothedevelopmentofdensebloomsofphytoplankton.Whenthe plankton dies, their decaying residues can result in oxygen depletion and fish kill. Water hyacinth,confined in barriers so that it only covers 10% of the pond and regularly harvested, can remove sufficientnutrientstoavoidexcessivephytoplanktongrowth.

A method of harvesting aquatic weeds emphasizes the usefulness of aquatic plants in purifyingwater[15]Hecommentsthatwaterplantsareoneofthemostefficientwaysofextractingnutrientsfromwater.By releasingoxygentheyalsocontributetowaterclarity.Inthefieldandlaboratoryevaluationsofbioassaysfornitrogenandphosphorus[8]withalgae[6]andaquaticweed[16,17],techniquedescribestheconditionsofsurplus,orlimitingconcentrationsof,nitrogenandphosphorusinalgaeandaquaticplants.Thereportalsodiscussesa simple method for measuring rates of nitrogen fixation by blue-green algae. The test plants used were*Ceratophyllum*sp., *Cladophora*sp., *Hydrodictyon*sp., *Aphanizomenon*sp., *Microcystis*sp., *Anabaena* sp.,and *Nostoc*sp. It is found that aquatic plants which have been recently exposed to a relatively highconcentration of available P could absorb enough to indicate surplus P conditions by their total P content.The comparative study on nutrient content of aquatic plants from different habitats was done. In theexperiment,threeaquaticplantsweregrowninwaterwithdifferentdegreesofpollution,fromrawsewage[18]tounpolluted.Theuptakeofnutrientswasanalyzed."Luxuryconsumption"ofnutrientswasobservedfromwater containing large amounts of N, P and K. The authors conclude, "As the availability of the nutrientchangessodoestheconcentrationofnutrientintheplant."

The relationship of nutrients in water to algae and aquatic plants was observed. Accordingly, "Thegrowth and development of established aquatic plants will depend on the available nutrients in the water,suitableclimaticconditionsandcompetitionwithotherspecies[19].Thevoidcreatedbythedestructionofonetype of biological growth may be filled by another and different type of biological activity". The authorreviews the relationship and importance of aquatic plants to their habitat. Several aquatic plants have beenfoundtoaccumulatearsenictoalevelwellabovethoseassociatedwithtoxicityofthiselement[20].

Theeffectofsewageeffluentongrowthoffiveaquaticspecies[21,22].*Eichhorniacrassipes*,*Alternantheraphiloxeroides*, *Egeriadensa*, *Najasflexilis*and *Potamogetoncrispus*were grown in plasticpoolsinwellwater,withorwithouttheadditionof25%ofsewageeffluent.Ofthefivetestplants, *E.crassipes*showedthemaximumgrowthresponsetothesewageeffluent,with*A.philoxeroides*second.Inwell water alone *A. philoxeroides*was the only plant to survive, indicating its ability to tolerate very lownutrient levels. The water hyacinth dominated others covering 71% of the water surface and removed 6.9 gof N, 2.9 g of P and 8.7 g of K from the sewage pools. *A. philoxeroides*did not gain N and K, instead theplantsreleasedtheseelementstothewater;butthey tookupsomeP(0.15mg).

Experiment[23] on the aquatic plants for the removal of mevinphos (insecticide) from the aquaticenvironment[24,25].Itwasconcludedthatemergentaquaticplantsmaybemoreeffectiveinremovingmevinphos thansubmergedspeciesbecauseof the quantityof watertheytranspire.Theyalso gavesuccessful trials on Water hyacinths and alligator weeds for removal of lead and mercury from pollutedwaters.Followingontheuptakeofnickelandcadmiumbywaterhyacinths[26,27]inthesameseries,theuptakeof lead and mercury was carried out. The work was expanded to include also *Alternantheraphiloxeroides*(alligator weed) which is known to tolerate higher levels of salinity than hyacinths. They also studied theroleofwaterhyacinthforremovalofphenolandphenolicderivatives,frompollutedwaters[7,25].

Similarlyvariousotheraquaticplantssuchas*Alternantheraphiloxeroides*(alligatorweeds),*Sparganiumramosum*, *S. simplex* and *Butomusumbellatus*, *Chara spp*[28]. *Myriophyllumspicatum*, duck-weedetc.wereexperimentedfortheircapacitytoremovenutrientsfromwastewater.

RESULTSANDDISCUSSION

Thereviewpresentedinthispaperrevealsthataquaticplant-basedtreatmentsystemsusingpondsorartificialwetlandsareeffectiveinwaterpollutioncontrol.Aquaticplantsshow promisefortreatingdomesticwastewater,industrialeffluents,andagriculturaldrainagewater.Aquaticplantsarealsobeingconsideredforimprovingwaterqualityoflakesandstreams.Biosorptionisbeingdemonstratedasausefulalternativeto conventional system for the removal of toxic metals from industrial effluents. The development of thebiosorptionprocessesrequiresfurtherinvestigationinthedirectionofmodelingofregenerationofbiosorbent material and testing with industrial effluents. The high nutrient concentrations in water can besubstantiallyreducedbypassageofwaterthroughaquaticvegetation.Theaquaticplantsplayaverycrucialrole in purification of waste water. Nutrient removal is being influenced by temperature, biological activityand flow rate. The slower the flow and the longer the retention time, the greater is the removal. It isconcluded that out of various aquatic plant species *Eichhorniacrassipes*(water hyacinth) can be usefullyemployed to extract nutrients from sewage. It is also proved useful in treating effluents polluted with toxicheavy metals. Duckweeds[27] are being tested as a means of sewage filtration during cold months when waterhyacinth is temporarily inactive. *Typhalatifolia*(Bulrush) is a perennial herbaceous plant which grows intemperate,subtropicalandtropicalareasandshowsthemaximumabsorptionofmetallikeNa.Thusononehand aquatic plants show marked absorption of nutrients like N, P, S, Ca, Mg, etc. and metals like Na, Fe,Mn, Zn, Cu etc.[29] and on the other hand it is also emphasized to simultaneously harvest and remove theaquatic vegetation specially submerged plants from the lagoons otherwise they will die, decay and returntheir contained/absorbed nutrients to the water and thus the level of nutrients in the lake cannot be reducedtoanacceptablelevelandwillfurtherdegradethewaterquality.

REFERENCES

1. J.M.LawrenceandW.W.Mixon,ComparativeNutrientContentofAquaticPlantsfromDifferentHabitats,Proc.Annu.Meet.South.WeedSci.Soc.,**23**,306-310(1970).
2. C.E.Boyd,VascularAquaticPlantsforMineralNutrientRemovalfromPollutedWaters,Econ.Bot., **24**,95-103(1970).
3. C.E.Boyd,UtilizationofAquaticPlants,AquaticVegetationandItsUseandControl,D.S.Mitchell,(Ed.)UNESCO,Paris,(1974)pp.107–14.
4. C.E.Boyd,AccumulationofDryMatter,NitrogenandPhosphorusbyCultivatedWaterHyacinths,Econ.Bot., **30**,51-56 (1976).

5. E.P.Dunigan,R.A.PhelanandZ.H.Shamsuddin,UseofWaterHyacinthstoRemoveNitrogenandPhosphorus fromEutrophicWaters,Hyacinth.ControlJ.,**13**,59–61(1975).
6. W.T.Haller,E.B.KniplingandS.H.West,PhosphorusAbsorptionbyandDistributioninWaterHyacinths,Proc.Soil,Crop,Sci.Soc.Flarida,**30**,64-68(1970).
7. G.P.Fitzgerald,FieldandLaboratoryEvaluationsofBioassaysforNitrogenandPhosphoruswithAlgaeandAquaticWeeds,Limnol.Oceanogr.,**14**,206-212(1996).
8. W.H.OrnesandD.L.Sutton,RemovalofPhosphorusfromStaticSewageEffluentbyWaterHyacinth,HyacinthControlJ.,**13**,56-58**(**1975**)**.
9. C.N.Ibeto,N.F.OparakuandC.G.Okkpara,ComparativeStudyofRenewableEnergyBasedWaterDisinfectionMethodsforDevelopingCountries,J.Environ.Sci.Technol.,**3**,No.4,226-231(2010).
10. K.M.Mackenthun,NutrientsandtheirRelationshiptoWeedandAlgalGrowths,HyacinthControlJ., **9**,58-61(1971).
11. C.G.GoluekeandW.J.Oswald,HarvestingandProcessingSewage-GrownPlanktonicAlgae.J.WaterPollut.ControlFederation,**37**,471-498(1965).
12. S.C.Reed,R.W.CritesandE.J.Middlebrooks,NaturalSystemsforWasteManagementandTreatment,3rdEdn.,McGraw-Hill,NewYork(1988).
13. E.ScarsbrookandD.E.Davis,TheEffectofSewageEffluentonGrowthofFiveAquaticSpecies,Proc.Annu.Meet.WeedSci.Soc.,**23**,305-305(1970).
14. S. A. Abbasi, Aquatic Plant Based Water Treatment Systems in Asia, Aquatic Plants for WaterTreatmentandResourceRecovery,K.R.Reddy(Ed.),MagnoliaPublishersInc.,Orlando,FL.,USA,(1987).
15. C.B.Bryant,YouNeedWeeds.Proc.Annu.Meet.South,WeedSci.Soc.,**23**,301-305**(**1970**)**.
16. A.Fekete,D.RiemerandH.L.Motto,ABioassayUsingCommonDuckweedtoEvaluatetheReleaseofAvailablePhosphorusfromPondSediments.J.Aquat.PlantManage,**14**,19-25**(**1975**)**.
17. G. Durai and M. Rajasimman, Biological Treatment of Tannery Wastewater-A Review. J. Environ.Sci.Technol.,**4**,1-17**(**2011**)**.
18. H. H. Rogers and D. E. Davis, Nutrient Absorption from Sewage Effluent by Aquatic Weeds, Proc.Annu.Meet.South.WeedSci.Soc.,**24**,352-352**(**1971**)**.
19. P. F. Reay, The Accumulation of Arsenic from Arsenic-Rich Natural Waters by Aquatic Weeds, J.Appl.Ecol.,**9**,557-565(1972).
20. U.S.AgencyforInternationalDevelopment,EconomicDamageCausedbyAquaticWeeds,NationalTechnicalInformationService,PB-206–905,Washington,D.C.,(1971).
21. E. Scarsbrook and D. E. Davis, Effect of Sewage Effluent on Growth of Five Vascular AquaticSpecies,HyacinthControlJ., **9**,26-30(1971).
22. Metcalf and Eddy Inc., Wastewater Engineering Treatment Disposal and Reuse., 3rd Edn., McGrawHillBookCo.,NewYork,ISBN:0070416907,**(**1991**)**.
23. B. C. Wolverton and D. D. Harrison, Aquatic Plants for Removal of Mevinphos from the AquaticEnvironment.J.Miss.Acad.Sci.,**19**,84-88(1975).
24. V. Ramachandran, T. Ramaprabhu and P. V. G. K. Reddy, Eradication and Utilization of WaterHyacinth,Curr.Sci.,**40**,367-368(1971).
25. B. C. Wolverton, A. Water Hyacinth for Removal of Phenols from Polluted Waters, NASA Tech.Memo.,(TM-X-72722),18p,IssuedalsoinSci.Tech.AerospaceRep,**13(7)**,79(1975).