Water Hyacinth in Sewage Discharge Ponds: Innovative Ways for Water Purification and Environmental Management

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Introduction

Ancient Tamil kings of Cheran, Cholan and Pandian kingdoms were well known for adopting *good agricultural and water management practices* by promoting creation of ponds and lakes in order to store the runoff during rainy seasons, and use this excess water during summer times for domestic and irrigation purposes. They knew the fact that storing water in ponds and lakes was important for promoting ground water recharge. One of the kings of the Chola kingdom – Karikalan – has constructed ¨*Kallanai*"(meaning dam made up of stones) for storing water. To date this dam remains the oldest dam in the world, and it is still under function to serve the needs of the local people. Also, it was a practice in the construction of a Hindu temple to have its own shrine, drawing water from the nearby river. All the rivers were considered holy, and their virginity was maintained by avoiding contamination. People were using separate tanks for drinking water, irrigation, and animal needs. But, as time run, the need to store excess water was slowly forgotten, and the following generations have started contaminating the water resources by the advancement of science and technology. The water scarcity, reducing amount of uncontaminated water,

increasing demand on the water resources, and the need to survive the socio-economic pressure have all contributed to the *rediscovery* of those ancient practices.

Coimbatore district located in the southern state of India, Tamil Nadu, is well-known world-wide for its textile and engineering sector products. This is the one of the fastest growing cities of India. Also, it is one of the worst cities afflicted by heavily depleting ground water resources. Thus, recently enormous effort has been put on de-silting the ponds in Coimbatore district in order to save the runoff to enhance local ground water recharge. Most of these tanks and ponds invariably receives untreated sewage, and it has remained unavoidable by the local authorities to subject these water bodies from such awkward utilization due to growing urban demands, and absence of man-made *wetland treatment systems*. The worst thing is that these tanks also receive untreated and partially treated effluent from local industries engaged in electroplating process. Thus, the tanks in Coimbatore are contaminated with sewage as well as heavy metals. Utilizing this potential water bodies, water hyacinth has grown enormously, which largely prefers nutrient-rich places for its sustenance. Growth of water hyacinth colonies in ponds have resulted in the following major problems:

1) development and sustenance of eutrophic condition, preventing the growth of other plants like algae, and faunal assemblages;
2) blockage of water flow, resulting in stagnation;
3) stinging smell in the surrounding areas due to the consumption of water column oxygen by the degrading organic matter, and emission of hydrogen sulphide;
4) growth of anaerobic organisms in the water column and sediment, which are mostly disease causing to the human kind.

Thus, there is a need to assess the available alternatives in the context of existing socio-economic constraints, and suggest suitable remedial measures.

Here an assumption is made that, the sewage discharge into the existing tanks is unavoidable and, available financial resources are limited so that cost-effective methods should be found for necessary remedial measures. One more constraint is that, the suggestion, if implemented, should provide a permanent solution, so that the efforts put up towards cleaning up of the water resources are not wasted. Thus, this article examines various aspects of the current problems facing the water bodies in Coimbatore district, and suggests some of the best remedial measures that could be adopted.

Origin of the problem

The sewage water normally contains large quantities of domestic waste mixed with some amount of industrial effluents. Apart from other constituents, the domestic wastes invariably contain large quantities of phosphate,. While major nutrients for the growth of the plants are nitrate and phosphate, the nitrate requirement of water-living plants is mainly met by nitrogen fixing bacterias, which takes up necessary nitrogen from the atmosphere and convert it into nitrate. Hence, the supply of nitrate is limited only by the ability of the bacteria to fix nitrogen under the given environment. Thus, normally in terrestrial wetland systems, availability of nitrogen is not the limiting factor. However, phosphorus has to be supplied only through weathering of rocks, over flow of fertilized lands

during rainy season, domestic wastes and sewage. Thus, phosphorus always remains as a vital "*limiting nutrient*" for terrestrial plant growth.

Why water hyacinth grows well in sewage discharge ponds? What are its consequences?

The water needs and growth rate of water hyacinth are higher. Therefore, the rate of supply of nutrients for its growth should also remain high. The sewage water provides such a conducive environment for copious supply of nutrients for its sustained growth and survival. Hence, generally, wherever we see untreated sewage discharge, we can also see colonies of water hyacinth – while the contrary may not be true always.

The growth of water hyacinth results in the following:

1) Growth of water hyacinth prevents formation of waves and currents in the water bodies. Absorption of thermal energy into the pond system is also kept minimal due to the surface covering water bodies by heavily grown water hyacinth. Thus, mixing in the water column is minimal, which promotes stratification.
2) Stratification prevents replenishment of water column with oxygen. Though the surface layers of the water column could be able to absorb little amount of oxygen through diffusion, the the lower layers are severely depleted of oxygen.
3) Due to stratification and continued utilization of dissolved oxygen by the degrading organic matter in the upper water column, the bottom water becomes anoxic.
4) Water column becomes anoxic, resulting in the development of unfavorable condition for the growth and sustenance of fish and other biota.

5) In addition, under anoxic condition, iron-manganese oxides in the sediments are dissolved and, dissolved iron and manganese are released across the sediment-water interface into the water column.
6) Since iron-manganese oxides are the effective scavengers for phosphate (and other many trace elements as well), their dissolution invariably results in the release of phosphate (and other trace elements too) to the water column.
7) The phosphate reaches the top layer of water column through diffusion, augmenting to the supply of nutrients to the upper water column for further growth of water hyacinth.
8) Thus, a *positive feed-back* is set, which finally leads to eutrophication in the water column. Thus, phosphorus plays a crucial role in the growth of water hyacinth, maintenance of eutrophication, and evolution of conditions unsuitable for the growth of fish.

How to tackle the problem?

Addressing the issues related to the growth of water hyacinth is a complicated problem. It requires a clear understanding of the local environmental conditions, which leads to their growth. In order to prevent the growth of water hyacinth, the sewage must be treated before its discharge into the ponds. The sewage

treatment procedures can be broadly classified into three main categories: 1) chemical treatment, 2) biological treatment, 3) a combination of both of these two.

Current practice

Presently, chemical treatment is widely used. Initially the sewage water is treated to settle down organic wastes. If desired, the organic waste is converted into organic manure. Otherwise, the settled down organic matter disposed off. The supernatant water is then treated with flocculants (such as, alum) to remove contaminants in the form of colloids. Then, the water is treated with aerators for reducing biological oxygen demand (BOD) and to increase dissolved oxygen. Finally, the treated water is discharged into the ponds. Normally, it may be necessary to use aerators in the ponds itself in order to keep down the biological oxygen demand (BOD). Under well aerated water column and, in the absence of necessary nutrients, growth of water hyacinth is largely controlled. In this method, the initial investment is more and operating costs are higher due to the need for continuous supply of electricity for running the pumps.

Some weed controlling chemicals are also used to control the growth of water hyacinth, but they are found to be futile, if sewage water supply to the pond continues. Recently there has been growing interest to use *anaerobic reactors*[1,2,3]. Though, in the following suggested remedial plan, anaerobic reactor is utilized, it also includes some other methods which makes it an unique, low investment, and cost-effective sewage water treatment plan.

Suggested remedial measures, and the action plan

For sustainable and energy efficient methods of treating sewage water, we have to depend on *biological treatment*. This is because the biological system, composed of several group of microorganisms, has the ability to break down highly complex organic molecules. In addition, biological methods are *energy*

efficient due to the effective utilization of *enzymes* (biological catalysts) for carrying out biochemical reactions. Bearing in mind that, the treatment procedure should require minimum amount of investment and it should remain a cost-effective mechanism, the following methodology is suggested. Considering the fact that nature is the best teacher, we have to learn from it the best treatment procedure for the sewage treatment. We observe that, by nature water hyacinth grows well in sewage water. This means that under the given environmental conditions, only water hyacinth has the ability to effectively utilize and recycle nutrients in sewage. Thus, the best treatment procedure is to grow water hyacinth – but in a controlled and systematic fashion so as to achieve the desired result. Based on this conception, a brief outline of sewage treatment procedure is given below.

Action step-1: In the first stage of treatment, the sewage water is let into a special tank, where water hyacinth is grown regularly – periodic removal of water hyacinth may be necessary for effective treatment and removal of pollutants (nutrients and trace elements) in the sewage water.

Advantages:

a) Due to the growth of water hyacinth, excess nutrients in the water column are removed.

b) Heavy metals in the sewage water is also taken up by water hyacinth. This is most essential aspect of sewage water treatment, which requires no chemicals or, electrical energy.

c) Heavy metals cause many health hazards to human kind such as cancer, kidney disorder, hypertension, hormone imbalance (which has severe consequence on human reproductive mechanism), nervous disorder, etc. Under conventional treatment procedure, organic manure is produced before removing heavy metals. Thus, the organic manure contains high levels of heavy metals, which will get into farming fields. During plant growth, these heavy metals might reach vegetables, fruits etc., and from there, finally get into our body through food web.

d) Instead, if we choose not to convert sewage waste into organic manure, then the heavy metals in the sewage water will get into the tank, from where it reaches the ground water aquifer through percolation.

e) By growing water hyacinth, two problems are solved in a single step: 1) excess nutrients such as phosphorus and nitrate are removed; 2) toxic heavy metals are also removed from entering the ecosystem.

Action step-2: In the second stage, the water is let into a closed anaerobic reactor, where organic wastes in the water are anaerobically digested by bacteria and methane is produced.

Advantages:

a) The sewage water invariably contains large quantities of organic matter (both dissolved and particulate). While large quantities of sewage water is treated, it is beneficial to convert these organic wastes into biogas, which can be used for producing heat energy or, electricity. While aerobic processes consume large amount of electricity for operating aerators, and produces large quantities of sludge, the electric energy needs to operate anaerobic reactor are much less.

b) Further, the methane gas produced from anaerobic reactor can be utilized as a raw material in the synthesis of various chemical compounds or, used for on-site electricity generation. This generated electric power can be utilized for operating the sewage treatment plant, lighting around the tank, etc.

c) The excess electricity, if any, can be sold at a price to industries or, utilized by municipality itself for operating public utilities or, can be given to free of cost to the poor people living in the surrounding areas to promote their livelihood.

Action step-3: In the third stage, the outlet water from the anaerobic reactor is let out into the pond after aeration.

Advantages:

The water coming out of anaerobic reactor is highly deficient of dissolved oxygen. Thus, aeration of outlet water is essential. It enables growth of aerobic micro-organisms in the water, which will consume low-molecular organic substrate produced in the anaerobic reactor. As a result, there is an effective utilization of organic substrates in sewage, resulting in the establishment of a healthy ecosystem in the pond. There is no need for this aeration process to be extensive, since in the next treatment step utilization of natural organisms to oxygenate the water column is made use of. Thus, the electricity need of the sewage treatment plant can be brought down drastically. Further, the electricity required to aerate the water can be obtained from the bio-gas plant.

Action step-4: Application of iron salts to the tank for increasing water column dissolved oxygen by promoting the growth of fresh water algae.

Advantages:

The water discharged from the anaerobic reactor will have very low levels of dissolved oxygen even after initial aerator treatment. In order to promote the

growth of aerobic microbials, and other associated flora and fauna, the dissolved oxygen content of the water column has to be increased. This can be done by promoting growth of natural biota, such as algae, which increases the water column productivity and dissolved oxygen through photosynthesis. This reduces the electricity required for operating aerators in the ponds.

(a)Application of iron salt is a one-time process, and costs very less. Since algae require only very less quantities of iron, the one-time requirement for iron is also limited. Further, iron is not toxic to any organism. Application of iron prevents development of anaerobic condition in two ways:

i. Dissolved iron in the water column photochemically oxidizes dissolved organic matter, thereby reducing the development of anaerobic condition.
ii. Even if anoxic condition develops, then iron get dissolved from the sediments. The dissolved iron reaches the upper layers through diffusion. There it promotes growth of algae, which restores oxic condition in the water column.
iii. Thus, there is a *natural switch,* which always keeps the water column under oxic conditions. In this way, the need for regular aeration becomes totally unnecessary. Hence, the maintenance cost is also brought down.

Need for alternatives, and development of strategies

This gives you a brief idea about how to effectively utilize water hyacinth for treating sewage fed ponds. This strategy can be tested in a small-scale, where water quality parameters should me measured at each level of treatment. After this feasibility study, assessment of suitability of this method for large-scale implementation should be made with a clear understanding of the physical, chemical and biological processes involved.

The following parameters should be considered for utilizing water hyacinth in the treatment of sewage-fed ponds:

a) Detailed analysis of the prevailing environmental conditions in each pond;
b) Insight into the water column characteristics and chemical reactions;
c) Material transport across sediment-water interface, and its influence on water quality;
d) Effect of proposed treatment on water quality;
e) Response of the biological system to the adopted treatment procedure; and,
f) Seasonal variation in water column and sediment characteristics.

The detailed study of each pond must include:

1) Mathematical modeling of *nutrient cycle* (nitrate and phosphate) in the water column, and *fate of pollutants (heavy metals)* has to be undertaken in order to have a clear plan for implementation of sewage treatment plan.
2) Estimation of *sustainable load* is necessary to estimate the quantity of treated sewage, that can be safely let into the pond without degrading its environmental conditions.

The results of this detailed analysis might be useful in drafting a suitable treatment plan for each pond. This is because each pond may require different treatment procedures, depending on its local environmental conditions as well as the response of the system to the adopted treatment procedure. Thus,

development of alternative plans may become necessary as the program progresses.

Uses of water hyacinth:

Water hyacinth grown in sewage treatment plants can be used for various purposes. Scientific research initiated by the ZERI Foundation demonstrated that dried water hyacinth is the best substrate for farming mushrooms. In addition, it could also be utilized for various purposes[4] viz., 1) as feed supplement of livestock, 2) raising earth warms that constitute an excellent chicken feed, 3) paper production, 4) biogas and electricity generation, whereby dependence on wood fuel is reduced and forests are preserved, and, 5) for the manufacture of value-added products like baskets, domestic furniture, *etc.*

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