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Aqua Plant -Based Sewage Treatment Plants: Review

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ABSTRACT
These studies present a general perspective of the field with most known examples from common literature, emphasizing a practical point of view in this technologically oriented topic. Conventional wastewater treatment plants as major contributors to greenhouse gases. Duckweed, Algae and Fish culture based wastewater treatment also releases CO^2 but the algae consume more CO^2 while growing than that is being released by the plant, this makes the entire system carbon negative .Algae-based wastewater treatment technology is suited for tropical countries where the temperature is warmer and sunlight is optimum. Environmental factors play a major role in algae cultivation. Maintenance of optimum temperature and lighting in algae ponds are difficult. Apart from these environmental factors, there are a number of biological problems and operational problems can arise in the mass cultivation of microalgae using wastewater. These include contamination and grazing. Control measures for avoiding contamination by bacteria and other algal species are sterilization and ultra-filtration of the culture medium.
Key word - Algae, Aquaculture, Domestic Sewage, Economics Treatment

I. INTRODUCTION

The practical use of wastewaters of various types of aquaculture is a subject of increasing interest. Wastewater aquaculture has the multiple benefit of producing potentially valuable materials while re-using resources and treating wastes, resulting in overall greater protection of the environment at lower cost. Proper design of an aquaculture farm is required for efficient use of the resources available in the sewage water. By the proper design only, we can use more effectively and more efficiently the available water resources and the land area. In India a lot of fish farms are running by using sewage water but there is no proper designed sewage-fed aquaculture farm, in the laterite soil zone, is available. This study was formulated to make a proper design of an aquaculture farm by using sewage water in laterite soil zone. There is a tremendous need to develop reliable technologies for the treatment of domestic wastewater in developing countries. Such treatment systems must fulfill many requirements, such as simple design, use of non-sophisticated equipment, high treatment efficiency, and low operating and capital costs. In addition, consonant with population growth and increase in urbanization, the cost and availability of land is becoming a limiting factor, and ‘‘footprint size’’ is increasingly becoming important in the choice of a treatment system (Ghosh *et al*., 1995).

Health issues and waste-fed aquaculture

Based on recommendations by WHO (1989) and bacterial quality standards and threshold concentrations for fish muscle, Pullin *et al*., (1992) published guidelines for domestic wastewater reuse in aquaculture:

- a minimum retention time of 8-10 days for raw sewage;
- a tentative maximum critical density of 105 total bacteria/ml in wastewater-fed fish pond water;
- absence of viable trematode eggs in fish ponds;
- suspension of wastewater loading for 2 weeks prior to fish harvest;
- holding fish for a few hours to facilitate evacuation of gut contents;
- < 50 total bacteria /g of fish muscle and no *Salmonella*;
- good hygiene in handling and processing, including evisceration, washing and cooking well; and
- use as high-protein animal feed if direct consumption of fish is socially unacceptable.

Anecdotal evidence does not indicate significantly increased risk to public health from consumption of fish raised in most reuse systems but scientifically based data are almost entirely lacking to support such a contention. It was recognized at the outset (WHO, 1989) that public health standards should be based on epidemiological rather than microbiological guidelines *i.e.*, on actual rather than on potential risk, and this has been detailed by Strauss (1996). There is evidence from India (Pal and Das Gupta, 1992) and Egypt (Easa *et al.*, 1995) that the microbiological quality of fish cultured in wastewater-fed ponds is better than that of freshwater fish from many other water bodies and surface waters which have been polluted unintentionally. It can be argued that it is safer to consume fish cultured in a well managed and monitored, wastewater-fed system than to rely on wild fish caught from increasingly polluted and unregulated surface waters.

II. MATERIAL AND METHODOLOGY

Wastewater treatment using ponds can be an economical way of treatment which produces effluent that is highly purified. The number and the type of ponds used are the determining factors as to the degree of treatment that is provided. Another name for wastewater treatment ponds is waste stabilization pond.Stabilization ponds because these ponds help to stabilize the wastewater before it is passed on to receiving water. They can also be referred to as oxidation ponds or sewage lagoons. The waste stabilization pond is a biological treatment process, where bacteria use organic matter in the wastewater as food. The three types of bacteria at work in most ponds are the aerobic, anaerobic, and the facultative bacteria. Because of unpleasant conditions associated with the anaerobic decomposition, plant operators must make sure that there is enough dissolved oxygen (D.O.) in the pond to make sure that it will be the aerobic and facultative bacteria that will be predominant, rather than having anaerobic decomposition take place.The biological treatment is made by means of solar energy and thus cost savings are achieved compared to systems that use more costly energy sources.

Serious interests in natural methods for wastewater treatment have reemerged. The using of aquaculture systems as engineered systems in wastewater (domestic and industrial) treatment and recycling has increased enormously over the past few years, they are designed to achieve specific wastewater treatment and can simultaneously solve the environmental and sanitary problems and may also be economically efficient (Bastian and Reed, 1979; O'Brien, 1981; Oron et al., 1985; Hussein et al., 2004; Deng et al., 2006). Wastewater has been also used in a variety of aquaculture operations around the world for the production of fish or other biomass. Usually the production of biomass was a primary goal with marginal concern for wastewater renovation (Reed, 1987). The intensive growth and consequent harvesting of the algal biomass as a method for removing wastewater borne nutrients was first suggested and studied by Bogan et al. (1960). It was further investigated by Oswald and Golueke (1966) who proposed the removal of algae growth potential from wastewater by high-rate algal treatment. concerning the removal of industrial nitrogenous wastes with high-rate algal ponds concluded that a multi-stage algal system is required for exerting the full removal potential of nitrogen by algal biomass incorporation followed by algal harvesting.Aquatic treatment systems consist of one or more shallow ponds in which one or more species of water tolerant vascular plants such as water hyacinths or duckweed are grown (Tchobanoglous, 1987). Water hyacinth systems are capable of removing high levels of BOD, suspended solids (SS), nitrogen and refractory trace organic matter (Orth and Sapkota, 1988) while phosphorus removal seldom exceeds 50–70% in wastewater, as it is mainly limited to the plant uptake (Dinges, 1976; Bastian and Reed, 1979). A system consisting of a pond covered with duckweed mat seems to be able to purify the wastewater jointly with bacteria. The bacterial decomposition causes anaerobiosis in the water. It is maintained by the duckweed mat as it prevents reaeration. It has been shown that duckweed species such as Spirodela and Lemna even reduce the oxygen content of water (Culley and Epps, 1973) but this anaerobiosis dose not seem to affect the plants. The main minerals C, N and P in turn will be converted into protein by duckweed, also, it has the ability to remove the organic materials because of their ability to use simple organic compounds directly and assimilate them as carbohydrates and various amino acids (Hillman, 1976). In aquatic systems used for municipal wastewater the carbonaceous biochemical oxygen demand (BOD) and the suspended solids (SS) are removed principally by bacterial metabolism and physical sedimentation. In systems used to treat BOD and SS, the aquatic plants themselves bring about very little actual treatments of wastewater (Tchobanoglous, 1987). Many investigations have been conducted and concern the distribution and species composition of fresh water algal communities in different water supplies in Egypt in response to the impact of some environmental stresses (Abdel-Raouf et al., 2003). The polluted rivers, lakes and seas, were aesthetically displeasing also by Man which importantly was a public health hazard, since they harboured human pathogens and increased the risk of spreading excreta-related diseases through the water-borne route. In order to prevent such problems, the sewage treatment systems were designed. Through most of human history, agriculture has been in effect a major form of biological water treatments through its use of the potential pollutants of human and animal wastes to support plant growth. Municipal sewage, for example sometimes after treatment is applied as a source of nutrients over land occupied by natural vegetation or various crops (Hunt and Lee, 1976; Wood-Well, 1977). Such wastes are still important in world agriculture, especially where commercial fertilizers are not readily available (Tourbier and Pierson, 1979).

Microalgae for wastewater treatment

The history of the commercial use of algal cultures spans about 75 years with application to wastewater treatment and mass production of different strains such as Chlorella and Dunaliella. Currently significant interest is developed in some advanced world nations such as Australia, USA, Thailand, Taiwan and Mexico (Borowitzka and Borowitzka, 1988, 1989a,b; Moreno et al., 1990; Wong and Chan, 1990; Renaud et al., 1994). These are due to the understanding of the biologists in these nations for the biology and ecology of large scale algal cultures, as well as in the engineering of large-scale culture systems and algal harvesting methods, all of which are important to the design and operation of high rate algal cultures to produce high-value products, such as Pharmaceuticals and genetically engineered products (Javanmardian and Palsson, 1991). These include antibacterial, antiviral, antitumers/anticancer, antihistamine and many other biologically valuable products (Starr et al., 1962; Borowitzka, 1991; Ibraheem, 1995; Haroun et al., 1995).Bio-treatment with microalgae is particularly attractive because of their photosynthetic capabilities, converting solar energy into useful biomasses and incorporating nutrients such as nitrogen and phosphorus causing eutrophication (De la Nou¨ e and De Pauw, 1988). This fascinating idea launched some fifty-five years ago in the U.S. by Oswald and Gotaas (1957) has since been intensively tested in many countries (Goldman, 1979; Shelef and Soeder, 1980; De Pauw and Van Vaerenbergh, 1983). Palmer (1974) surveyed microalgal genera from a wide distribution of waste stabilization ponds. In order of abundance, and frequency of occurrence the algae found were Chlorella, Ankistrodesmus, Scenedesmus, Euglena, Chlamydomonas, Oscillatoria, Micractinium and Golenkinia. A survey of algal taxa in six-lagoon systems in Central Asia was completed by Erganshev and Tajiev (1986). Their analysis of long term data revealed that the Chlorophyta was dominant both in variety and quantity followed by Cyanophyta, Bascillariophyta and Euglenophyta. Palmer (1969) listed the algae in the order of their tolerance to organic pollutants as reported by 165 authors. The list was compiled for 60 genera and 80 species. The most tolerant eight genera were found to be Euglena, Oscillatoria, Chlamydomonas, Scenedesmus, Chlorella, Nitzschia, Navicula and Stigeoclonium. More than 1000 algal taxa have been reported one or more times as pollution tolerant which include 240 genera, 725 species and 125 varieties and forms. The most tolerant genera include eight green algae, five blue-greens, six flagellates and six diatoms. Since the land-space requirements of microalgal wastewater treatment systems are substantial (De Pauw and Van Vaerenbergh, 1983), efforts are being made to develop wastewater treatment systems based on the use of hyperconcentrated algal cultures. This proved to be highly efficient in removing N and P within very short periods of times, e.g. less than 1 h(Lavoie and De la Nou¨ e, 1985). The algal systems can treat human sewage (Shelef et al., 1980; Mohamed, 1994; Ibraheem, 1998), livestock wastes (Lincoln and Hill, 1980), agro-industrial wastes (Zaid-Iso,1990;Ma et al.,1990; Phang, 1990, 1991) and industrial wastes (Kaplan et al., 1988). Also, microalgal systems for the treatment of other wastes such as piggery effluent (De Pauw et al., 1980; Martin et al., 1985a,b and Pouliot et al., 1986), the effluent from food processing factories (Rodrigues and Oliveira,1987) and other agricultural wastes (Phang and Ong,1988) have been studied. Also, algae based system for the removal of toxic minerals such as lead, cadmium, mercury, scandium, tin, arsenic and bromine are also being developed (Soeder et al., 1978; Kaplan et al., 1988; Gerhardt et al., 1991; Hammouda et al., 1995; Cai-XiaoHua et al., 1995). The technology and biotechnology of microalgal mass culture have been much discussed (Burlew, 1953; Barclay and Mc-Intosh, 1986; Richmond, 1986; Lembi and Waaland, 1988; Stadler et al., 1988 and Cresswell et al., 1989). Algal systems have traditionally been employed as a tertiary process(Lavoie and De la Nou¨ e, 1985; Martin et al., 1985a; Oswald, 1988b). They have been proposed as a potential secondary treatment system (Tam and Wong, 1989). Tertiary treatment process removes all organic ions. It can be accomplished biologically or chemically. The biological tertiary treatment appears to perform well compared to the chemical processes which are in general too costly to be implemented in most places and which may lead to secondary pollution. However, each additional treatment step in a wastewater system greatly increases the total cost. The relative cost of treatment doubles for each additional step following primary treatment (Oswald, 1988b). A complete tertiary process aimed at removing ammonia, nitrate and phosphate will thus be about four times more expensive than primary treatment. Microalgal cultures offer an elegant solution to tertiary and quinary treatments due to the ability of microalgae to use inorganic nitrogen and phosphorus for their growth (Richmond, 1986; Oswald, 1988b,c; Garbisu et al., 1991, 1993; Tam and Wong, 1995). And also, their capacity to remove heavy metals (Rai et al., 1981), as well as some toxic organic compounds (Redalje et al., 1989), therefore, does not lead to secondary pollution. Amongst beneficial characteristics they produce oxygen, have a disinfecting effect due to increase in pH during photosynthesis (Mara and Pearson, 1986; De la Nou¨ e and De Pauw, 1988). Algae can be used in wastewater treatment for a range of purposes, some of which are used for the removal of coliform bacteria, reduction of both chemical and biochemical oxygen demand, removal of N and/or P, and also for the removal of heavy metals.

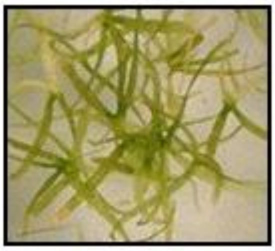
Performance Of Common Duckweed Species On Different Types Of Wastewater

Duckweeds belong to the fastest-growing angiosperm plants on earth (Hillman and Culley, 1978). Maximum growth rates of Lemnaceae are species- and clone-spe- cific. Maximum relative growth rates (RGR) of 0.73 to 0.79 d^{-1} were measured in lesser duckweed (*Lemna aequinoctialis*Welw.) and Indian duckweed [*Wolffiami- croscopica* (Griffith) Kurz], which correspond to dou- bling times between 20 and 24 h. Lowest maximal growth rates are observed in submerged species (Lan- dolt and Kandeler, 1987). For comparison, RGR values of angiosperm herbaceous plants range between 0.031 and 0.365 d^{-1} (Lambers and Poorter, 1992), whereas algae grow at rates between 0.26 and 2.84 d^{-1} (Nielsen and Sand-Jensen, 1990). The growth of common duckweed species, including fat duckweed (*Lemna gibba* L.), common duckweed (*Lemna minor* L.), star duckweed (*Lemna trisulca* L.), great duckweed [*Spirodela polyrhiza* (L.) Schleiden], and spotless watermeal [*Wolffia arrhiza* (L.) Horkel ex C.F.H. Wimmer], on different types of wastewater (300–442 mg L^{-1} chemical oxygen demand [COD], 14–52 mg Kjeldahl nitrogen L^{-1}, and 7–9 mg total P L^{-1}) compared with a standard mineral growth medium (1/10 Huttner) was considerably different. All species yielded less on the two artificial wastewaters (sucrose, propionic acid, acetate, and milk powder) on the mineral medium, whereas the submerged species (star duckweed) The smallest species (spotless watermeal) performed to highly variably (low *r*2). Only great duckweed and fat duckweed performed equally well on domestic sewage compared with the mineral medium (Vermaat and Hanif, 1998). The latter species has been selected frebling quently for trials on wastewater, but no reference gives explicit reasons for this selection (Sutton and Ornes,1975; Oron et al., 1987; Boniardi et al., 1994).

Spirodela

Lemna

Wolffia



Wolffiella

Model of wastewater treatment

The model of the proposed sewage treatment aquaculture farm is shown in Figure 1

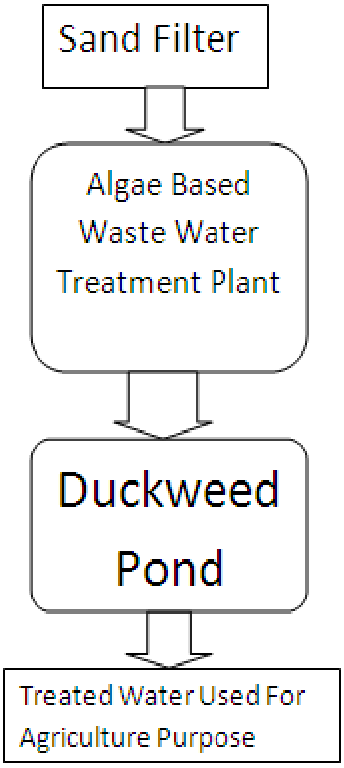


Figure-1. Model of the proposed wastewater treatment for aquaculture purpose.

III. CONCLUSION

Although duckweed pond technology is known to be a robust option and involves low operating cost, not much work has been carried out on it in India. Very limited references are available and that too of small sized or pilot sized plants. However, based on the available information the following can be concluded about this technology option :

- Duckweed ponds have the same or even better performance efficiency with regard to the BOD and nutrient removal.
- They can operate in conjunction with waste stabilisation ponds and/or maturation ponds to achieve complete and high degree of treatment in terms of BOD, SS and faecal coliform.
- Indian warm climatic conditions are favourable for rapid growth of duckweed which serves as a source of protein in fish and cattle feed thereby leading to tangible resource recovery from wastewater treatment
- They can serve as centres of job creation for community based organisations who can be involved in sustainable aquaculture production activities
- Unlike WSPs, more care and skill is required in their operation and maintenance as the weed needs to be harvested regularly and to be fed to the fishes or processed as animal feed
- Care is required in maintaining a thick layer of the weed to prevent growth of other competing aquatic plants such as blue green algae, etc.

- Furthermore, elaborate arrangement of floating barriers is required to break the wave or wind action and to prevent drifting of the duckweed mass
- As in case of WSP, the only drawback of this technology option is its large land requirement which may be difficult to obtain in large urban centers.

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