INTRODUCTION

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The density of the human populations in large cities is increasing at an alarming rate particularly during the past 150 years Organic wastes (both domestic and industrial) resulting from the above has become a potential problem The sewage and sullage available in over 100 cities and towns of India is estimated at about 800 million gallons per day Natural ecosystems are being used as disposal sites for a wide variety of wastes from human activities The discharge of untreated sewage causes physical, chemical and biological damages to the natural environment It is thought to pose a threat to the health of humans bathing in polluted waters or consuming fish/shellfish grown in polluted waters Thus the problem becomes multidimensional especially when the developing countries are facing water scarcity due to industrialisation and urbanisation. Although a river will recover during the course of the flow due to its natural ability to purify, entry of sewage at several points over short distances, reduces the self-purifying power of the river In order to control eutrophication, epidemics and water scarcity, several types of conventional and non-conventional systems have been established of which the commonly used treatment processes are activated sludge, trickling filter system, oxidation/waste stabilization ponds, aerated lagoons, water hyacinth bed, wetland method, anaerobic fixed bed reactor, upflow anaerobic sludge blanket (UASB), etc (Bucksteg, 1987, Cloris and Araiyo, 1987, Jhingran and Ghosh, 1988, Brix, 1994) The advanced treatment systems for eliminating nitrogen are ion exchange column, stripping of ammonium ion, chemical precipitation and breakpoint chlorination and to remove phosphorus, methods like calcium phosphate crystallisation, magnesium ammonium phosphate precipitation, flocculation and filtration have been designed Besides these, methods like ion exchange column, reverse osmosis, activated carbon and electrolysis are also used to remove constituents of domestic sewage (Vojnaya, 1981) In all processes of sewage treatment, the goal is to produce a final liquid effluent in which the biologically important elements have been restored to the inorganic state Sewage treatment accordingly involves intensive operation of matter under more or less controlled conditions (Stanier *et al*, 1986)

Sewage is well known for its vast array of high concentrations of nutrients necessary for biological systems In recent years, there is a growing awareness, particularly in developing countries to recycle wastes with a view to alleviating the health hazards associated with their insanitary disposal and utilising the same as nutrients for food production through agriculture and aquaculture The so called 'waste' is an important source of fertilization for aquaculture production through augmentation of natural food organisms It is prevalent in China, Indonesia and Vietnam, where waste materials including human excreta, faecally polluted surface waters and conventional sewage are used for fertilising fish ponds (Edwards, 1993) In India, the use of sewage effluents for fish production has gained momentum in recent years because of stringent measures of the Government to enforce the environmental laws to control pollution In view of the demographic scenario, sewage-fed fish farming is an age-old practice in West Bengal and has advanced further in recent years

Aquaculture is a potential system not only from the productive potential point of view but as a method of disposal of community waste without bringing any ecological disorder in the aquatic ecosystem as reported by Kumar *et al* (1996) Naskar *et al* (1986) suggested that the primary effluents can be utilised for successful culture of duckweeds which in turn could be used as fish feed in aquaculture Based on the efficiency of wastewater treatment, aquaculture systems using silver carp and big head carp (Hejkal *et al*, 1983), common carp (Metcalf and Eddy, 1991, Allen and Hepher, 1976) and polyculture of carps (Carpenter *et al*, 1974, Duffer and Harlin, 1979) have been suggested to be viable treatment systems for domestic sewage resulting in a product suitable for animal or human consumption Experiments involved in exotic filter feeding fin fish have been conducted by the Arkansas Game and Fish Commission at Benton, Arkansas, which indicated that this process has a good potential for municipal application achieving a BOD_5 reduction and total suspended solids (Duffer, 1982)

There are several specific references in the literature to the reuse of domestic sewage in aquaculture in Asian countries like China (Kuo, 1980, Zhou, 1986, Wang, 1987), Israel (Watson, 1962, Feinmesser, 1971, Hepher and Schroeder, 1974, Katzenelson *et al*, 1976, Arthur, 1983, Fattal, 1993), Indonesia (Vaas, 1948 and 1957, Djajadiredja *et al*, 1979) and India (Bose, 1944, Chacko and Ganapati, 1949, Saha, 1970, Saigal, 1972, Ghosh *et al*, 1974, Jhingran, 1974, Dehadrai and Ghosh, 1977, Ghosh, 1983 and 1984) According to Kovacs and Olah (1984), several Europian countries including Czechoslovakia, Poland and the Soviet Union have followed the Munich sewage-fed pond system Wood (1986) discussed the feasibility of fish culture in sewage stabilization ponds in South Africa, Balarin (1987) in Malawi and Hodgson (1964) in Mosambique

Aquaculture methods using vascular aquatic plants have the greatest potential as final filtration systems for treating wastewater before discharge into rivers and streams (Duffer, 1982) A large variety of aquatic plants like duckweeds, water hyacinth, Typha, etc are tested for wastewater treatments and they have potentials for water quality improvement (Culley and Epps, 1973, Sutton *et al*, 1980, Dzikiewicz, 1996)

The sewage-fed fish culture is a unique system whereby the nutrients and COD values of water are reduced to safe limits before being discharged into the river, canal as per requirements of the environmental laws The establishment of sewage fisheries for treatment and reuse in aquaculture is an economically feasible means of reducing riverine pollution (Ghosh, 1983) The aquaculture systems are cheaper and simpler alternatives to conventional secondary treatment system (Duffer and Mayer, 1978)

Fish have been assessed for their ability to improve wastewater treatment in stabilization ponds (Hepher and Schroeder, 1974, Buras *et al*, 1987, Backiel, 1990) The limited evidence to date indicates that they do not reduce phytoplankton biomass significantly, a desirable objective as maturation pond effluents contain high concentrations of suspended solids to confirm to effluent standards for secondary treatment (Edwards, 1992) As fish cause a more rapid circulation of nutrients in the pond by mixing the sediments and by accelerating the mineralization of seston (living and non-living floating matter), they may increase the phytoplankton biomass in the pond, which may further be enhanced by grazing on zooplankton which also filters phytoplankton Utilisation of city sewage in fish ponds and the environment supporting healthy growth of fish has been realized (Olah, *et al*, 1986) may further be enhanced by grazing on zooplankton which also filters phytoplankton Utilisation of city sewage in fish ponds and the environment supporting healthy growth of fish has been realized (Olah, *et al* , 1986)

Microorganisms play a major role in the treatment of wastewater The biological treatment systems depend on the effective use of bacteria for breakdown, digestion and stabilization of organic matter and pollutants (Cooke, 1976). As the microorganisms are potent saprophytic decomposers, they help in reducing the concentration of pollutants in sewage (Rai *et al* , 1989) The complex organic and inorganic compounds are degraded and mineralized by a variety of microorganisms, among which bacteria and fungi play a vital role Environmental factors like temperature, pH and nutrient availability influence the types, density, nature and ecology of sewage-inhabiting microbes involved in mineralization and recycling processes

An attempt has been made in this study to assess the treatability performance of duckweeds for wastewater treatment and reuse of the secondary treated effluent for pisciculture, to explore the chemical profiles of sewage with special reference to seasonal variations of different parameters in raw sewage, effluent and in different trophic levels and to establish the interrelationships between biotio and abiotic components The duckweeds (Family Lemnaceae) are small free-floating plants that grow in a wide variety of climates throughout the world Duckweed-aquaculture systems rely upon the existence of a mat of duckweed plants to provide the congenial conditions to treat wastewater During daylight hours, the duckweed mat can be as much as 10°C warmer than the water below The higher temperatures in the mat result in faster reaction rates where BOD, decomposition, nitrification and reproduction of the plant occur more rapidly than normal

All the biological wastewater treatment processes, *i e* trickling filter processes, activated sludge, oxidation ponds, anaerobic digestion, etc operate in the area of mixed bacterial populations under varying environmental conditions While there is a fixed pattern of microbial succession and while the biochemical changes within the wastewater system are related to this microbial pattern, little research has been done to develop sound concepts relating to population dynamics in treatment plant By and large, biologists have looked at the microorganisms present, chemists have analysed the treatment efficiencies, engineers have designed and constructed the treatment facilities, but few people have been concerned about the interrelationships of all these factors. Considering the resource potential of domestic sewage and the gap in the knowledge regarding the microbial activities, the present study proposes a comprehensive microbiological evaluation of sewage treatment through aquacultural practices While considerable work has been done with regard to treatment of wastewater through duckweeds, there is a lack of knowledge on microbial activities in the system The present study on 'Microbial ecology of aquaculture treatment system fed with domestic sewage' involved analysis of the microbial activities in duckweed and fish-based sewage treatment system with reference to the chemical environment

The objectives of the study are

i) To characterise the microbial ecology of duckweed and fish-based treatment system,

ii) To study the bacterial populations associated with organic decomposition of domestic sewage and

iii) To characterise the bacterial flora associated with different media such as water, sludge and fish in treatment ponds

The thesis embodies a brief 'Introduction', 'Review of literature', followed by 'Material and methods' incorporating the details of the design of ASTP, treatment species used and the methods used in collection and analyses of the data Important findings on hydrobiological conditions, sludge and sediment status, plankton and bacterial communities of water and sludge/sediment media along with fish microflora are detailed in 'Results' It is followed by 'Discussion' where present results in the light of earlier observations are discussed Important findings and suggestions for further investigations are presented in 'Summary' and 'Conclusions' The thesis concludes with section 'References' followed during the present study