CONCLUSIONS

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The microbial communities serve as ready indices of aquatic environmental conditions providing for corrective and ameliorative measures These assume great significance in view of the fact that biological sewage treatment systems are largely dependent upon them for organic decomposition and nutrient cycling The basic mechanism employed by the duckweeds in sewage treatment system is the role of nutrient absorption of those of nitrogen, phosphorus, carbon, etc from wastewater These in their ionic forms along with pathogens concentrated on the leaf and root surfaces are inevitably removed permanently from domestic sewage as the plants are harvested The following conclusions are drawn from the present study on the Aquaculture Sewage Treatment Plant (ASTP), Matagajpur, Cuttack, Orissa, India spanning over a period of 18 months during November, 1995-April, 1997

* The tertiary treatment performance of the Aquaculture-based sewage treatment system was equal or even superior to that of conventional wastewater treatment systems The duckweed and fish-based sewage treatment system showed the potential of turning wastewater into usable water by removing nutrients, organic load, algae and bacteria including pathogens, by as much as 99% The system was distinctly different from other wastewater treatment measures, in that it produced valuable protein-rich fish biomass as a byproduct

* The analyses of bacterial regimes in ASTP, Matagajpur, Cuttack, showed that the heterotrophs are the predominant groups over-riding the autotrophs The total coliform bacterial populations were higher than faecal coliforms followed by faecal streptococci, which indicated recent pollution due to human excreta The counts of faecal coliforms and faecal streptococci were found to be more than *Salmonella* counts The occurence of faecal coliforms, faecal streptococci and *Salmonella* at the outlet were negligible Proportion of *Nitrosomonas* (NI) populations was more than *Nitrobacter* (NII) populations in water and sludge media Higher populations of denitrifying bacteria in sludge than water showed vigorous bacterial nitrate reduction (denitrification) in anaerobic environment The

proportion of aerobic cellulolytic bacteria was less in comparison to amylolytic bacteria in the whole treatment system

* Dynamics of pollution indicator bacteria and pathogenic bacteria like total and faecal coliforms (*Escherichia coli*, *Enterobacter* spp , *Klebsiella* spp , *Citrobacter* spp , *Proteus* spp and *Clostridium* spp), *Salmonella* spp , faecal streptococci (*Streptococcus faecalis*, *Streptococcus faecium*), etc in ASTP showed high densities at raw sewage, which were found to be reduced by one log unit through aquaculture-based treatment system at outlet A higher level of reduction of enteric pathogenic bacterial populations was studied in duckweed ponds than fish ponds They did not persist through the whole process or even the length of the sewerage system, caused not only by reduced nutrient levels but possibly also autolysis of bacteria, protozoan feeding and other physico-chemical factors which exercise a bactericidal effect

* Bacteria, particularly the gram negative ones, constituted the major component of treatment system, which were responsible for the oxidation of organic matter and nutrient transformations Identified bacterial genera from aquaculture-based treatment plant were mainly *Pseudomonas* spp , *Enterobacter* spp , *Escherichia coli*, *Salmonella* spp , *Flavobacterium* spp , *Proteus* spp , *Bacillus* spp , *Lactobacillus* spp , *Klebsiella* spp , *Clostridium* spp , *Arthobacter* spp , *Micrococcus* spp , *Staphylococcus* spp , *Streptococcus* spp , *Achromobacter* spp , *Azotobacter* spp , *Nitrosomonas* spp and *Nitrobacter* spp Among heterotrophic bacterial populations, 75-80% of the bacteria were found to be *Pseudomonas* spp , *Bacillus* spp , *Flavobacterium* spp and *Proteus* spp

* The observed levels of cellulolytic and amylolytic bacterial populations in aquaculture-based treatment system indicated effective degradation of complex organic components into simple substances through the action of extracellular enzymes

* As regards the reduction in bacterial populations, it was significant in cases of aerobic heterotrophic bacteria and pathogens like total coliforms, faecal coliforms, faecal streptococci and *Salmonella* Bacteria involved in nitrogen cycle, *i e*

nitrogen-fixers, nitrifiers-I, nitrifiers-II and denitrifiers showed a decreasing trend through duckweed ponds and fish ponds While amylolytic bacteria and cellulolytic bacteria were in higher ranges in raw sewage, perceptible decrease could be observed through the aquaculture-based treatment system The populations of inorganic phosphorus-solubilising bacteria could also be reduced under controlled conditions created through duckweeds

* The treatment was found to be effective as it resulted in favourable pH and dissolved oxygen contents in the effluents Further, considerable reduction in total alkalinity, total hardness, nutrients like NH_4^+-N, NO_2^--N, NO_3^--N and $PO_4^{\equiv}$-P as well as organic load (BOD_5 and COD) and dissolved organic matter could be seen in the water emerging out of duckweed culture complex The variations in the above parameters between different duckweed ponds and fish ponds as well as periods were found to be significant ($p<0$ 01) The reduction levels of ammonium-nitrogen, nitrite-nitrogen and nitrate-nitrogen were upto 96%, 91 78% and 94 92% respectively, and that of phosphate-phosphorus was upto 94 5% The ranges of percentage reduction of BOD_5 from source to fish pond, fish pond to outlet and source to outlet were 47 88-73 17%, 0-30 98% and 48 05-81 69%, respectively Similarly, the ranges of percentage reductions of COD from source to fish pond, fish pond to outlet and source to outlet were 32 63-72 06%, 0-37 50% and 16 07-84 50%, respectively Moderate ranges of plankton (403-33,276/l) and low species diversity were seen in the ASTP

* Treating an average flow of one million litre per day of Cuttack city sewage, the 0 56 ha plant produced a final treated effluent meeting the quality requirements mandated in the Indian standards The primary effluent and final effluent data of the sewage treatment system for the Aquaculture-based Sewage Treatment Plant at Cuttack showed the unique ability of duckweeds to absorb and reduce the nutrient levels, inhibit algal growth, reduce bacterial populations and in effect treat the domestic sewage

* Substantial contributions of fish ponds to the whole treatment system were by utilising the remaining nutrients in the secondary treated sewage serving as

polishing pond It also provided a balanced system with both algae and detritus contributing to the food chains of fish species in the pond

* Studying the different aspects of hydrobiology and microbial ecology of the Aquaculture-based Sewage Treatment Plant (ASTP), Matagajpur, Cuttack, India and elaborating the treatment efficiencies, the investigation defined the structure and function of the treatment system and conclusively proved that the aquaculture-based treatment system is an effective system and duckweed and fish played an important role during treatment.

* Based on the results of the study, the following suggestions are made for further investigations in this area

  - Nitrification and denitrification rates in water and sludge level of duckweed pond complex and fish pond
  - Characterisation of bacterial populations accumulated on the leaf and root surfaces of duckweed
  - Quantification of organic decomposition in duckweed pond complex and fish ponds in comparison to other sewage treatment systems
  - Intensities of autotrophy and heterotrophy in sewage-fed fish pond systems.
  - Treatment efficacies of different duckweed species
  - Accumulation of heavy metals in plant species
  - Interactions between algae and macrophytes in sewage-based system
  - Nutrient budgets of the aquaculture-based sewage treatment system
  - Multilocational evaluation of ASTP under different agro-climatical conditions