Pre-Feasibility of Duckweed-Based Wastewater Treatment and Resource Recovery in Bangladesh

Main Report

by Huub J. Gijzen and M. Ikramullah

Commissioned by
The World Bank, Washington D.C.

IHE DELFT
International Institute for Infrastructural, Hydraulic and Environmental Engineering

PRISM Bangladesh

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IHE, Delft, The Netherlands

and

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PREFACE

This report describes the results of a pre-feasibility study, commissioned by the World Bank and executed by IHE, Delft, The Netherlands and PRISM, Bangladesh. The study forms part of the preparations for the proposed School and Community Sanitation Project. The study aimed at the selection of five potential sites with large quantities of wastewater, and the preparation of pre-feasibility reports for cost effective duckweed-based treatment of the waste, combined with safe aquaculture to generate (partial) cost recovery

The Main Report is organized in 8 chapters. After presenting background information on the assignment (chapter 1) and on the country (chapter 2), chapter 3 provides an overview of the state of the art of duckweed-based wastewater treatment Chapter 4 presents a detailed financial analysis of the Kumudini Hospital duckweed based wastewater and aquaculture system operated by PRISM over the past 6 years. A similar economic assessment is made for a selected village project on duckweed based sanitation and aquaculture as well. Chapters 5 and 6 describe the project sites selection, and pre-feasibility analyses of five selected sites. Although the main focus here is on the financial feasibility, also other feasibility criteria are considered and discussed, including socio-economic, state of preparedness, technical and logistic aspects Project preparation and possible public health risks are covered in chapters 7 and 8, respectively. In the back of the report, a list of references used in the text is presented

The process of site selection and the development of the pre-feasibility analyses was based on the results of a Socio-economic Survey and an Environmental Audit in selected areas For ease of reading and data analysis, the detailed results of the baseline survey and environmental audit are not presented in the main report, but these are attached as separate appendices. Appendix I, II and III show the results of the Rapid Appraisal, Socio-economic Survey and Environmental Audit, respectively.

Valuable inputs were obtained from DPHE and World Bank/UNDP office in Dhaka Mr A K. Ibrahim, Executive Engineer Design Division, was seconded by DPHE to the project team, to take part in the socio-economic survey. His assistance is gratefully acknowledged. The project team also wishes to thank Mr Babar Kabir, Dr Tanveer Ahsan, Mr. Harun Rashid (WB/UNDP Dhaka), Mrs Kirsten Homman, Mr Robert Robelus, Mr. Christopher Bosch (WB Washington), Mr Shafique (DPHE) and Mr. Sidique (LGED) for their valuable comments, advice and support.

Delft, The Netherlands, 24 December 1999

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EXECUTIVE SUMMARY

1. *Assignment*

1.1 This report presents the findings of a pre-feasibility study, commissioned by the World Bank and executed by IHE, Delft, The Netherlands and PRISM, Bangladesh. The study forms a part of the preparations for the proposed School and Community Sanitation Project (SCSP) in Bangladesh. The purpose of this study is to evaluate the pre-feasibility of duckweed based wastewater treatment combined with safe aquaculture to generate (partial) cost recovery. For this purpose, pre-feasibility reports for five selected project sites were prepared.

2. *Background*

2 1 Bangladesh is amongst the most densely populated and poorest countries with a population density of over 800 per km^2 and a per capita annual income of about US$ 260 (1996) This, combined with a population growth of about 1.8%, generates a rapidly increasing pressure on the national economy, the environment, including the country's natural resources (water and land), and on the general well being of the people.

2.2 Poor health and malnutrition form a wide spread problem in Bangladesh The most prevalent health problems are diarrhea, parasitic and respiratory infections, which all can be clearly related to environmental factors. About 80% of all reported illness cases are either water born or water related The above health problems are worsened by chronic malnutrition of the population (about 60% of the population has a daily food intake of 2100 calories or lower).

2.3 The above situation calls for urgent action to prevent further deterioration of the environment, especially of the water quality. The uncontrolled discharge of domestic and industrial wastewater has put the important functions of open water bodies for bathing, washing, water supply, irrigation and aquaculture under serious pressure Bangladesh, therefore, needs to make urgent investments for improvement of the currently poor infrastructure for wastewater collection, transport and treatment

3. *Duckweed based wastewater treatment*

3 1 In order to address the problems described above, various options need to be considered The 'no sanitation' option will put a very high price on the public health and environmental condition in Bangladesh and is not considered sustainable. 'Conventional wastewater treatment', on the other hand, is an option that is far beyond the financial capacity of a poor country like Bangladesh and, therefore, not considered realistic. The combination of low cost treatment methods, with strategies for recovery of valuable energy, nutrients and water could prove to be a more feasible option.

3.2 Duckweed based wastewater treatment combined with applications of the high quality duckweed biomass in aquaculture could be an attractive and appropriate mechanism of generating incentives for wastewater treatment. The main objective of a duckweed based system is to recover a substantial part of the wastewater treatment costs by converting the nutrients present in wastewater into fish protein, and eventually to realize full cost recovery via payment of fees by water users The income generating component of this treatment concept provides an attractive opportunity for privatization of wastewater treatment

3.3 The favorable characteristics of duckweed have attracted interest world-wide from both scientists, NGO's and commercial companies. The commercial initiatives so far are related to the application of duckweed ponds for treatment of domestic wastewater (Lemna corporation, U.S.A.) More recently (1999) Greengold Corporation (U.S.A.) was established with the objective to sell/lease duckweed based pig manure treatment systems. The concept developed by Greengold Corporation proposes the recycling of nutrients in the manure via feeding of duckweed to the pigs In Bangladesh, PRISM, a local NGO, has developed and applied a duckweed based stabilization pond system in combination with duckweed fed aquaculture.

4. *Mirzapur demonstration facility*

4.1 Since 1993 PRISM has operated a 270 m^3/d (3500 capita) duckweed based wastewater treatment system at the premises of Kumudini Hospital Complex (KHC) in Mirzapur The daily duckweed harvest from the ponds is fed to adjacent polyculture fish ponds and the monthly harvest is sold, partly to KHC (as per contractual agreement) and partly into the local market (wholesale). The financial evaluation of the combined wastewater-aquaculture system shows a net annual profit in the 4th and 5th year of about US$ 2000 per ha of total land area used for treatment and fish ponds. The IRR of the system is calculated at 25%.

4.2 The fact that the system has been able to continue operation for such a long time without receiving external support provides evidence that this indeed is a profitable undertaking. The positive financial performance of the KHC system was achieved under rather favorable conditions and institutional arrangements. These positive conditions may not be met in other project locations, and therefore the results can not be extrapolated for application elsewhere The experience at KHC demonstrates, however, that the combination of wastewater treatment and aquaculture offers a good potential to recover a substantial part of the costs of wastewater treatment This is a major improvement compared to conventional treatment (high cost and no cost recovery from system operation), and it forms the basis for further demonstration projects to be developed

4 3 The excellent facilities available at the KHC site should be used for the implementation of well defined research and optimization studies. The current infrastructure available at the KHC site provides good possibilities for further upgrading to a research and demonstration facility to support further initiatives and projects in duckweed based wastewater treatment in Bangladesh and the wider

region. The consultants propose to consider the development of KHC site to a 'Duckweed Demonstration & Research Station' as a component under the SCSP

5. *Project sites*

5 1 During this study, 14 potential project sites were identified via a Rapid Appraisal, for the implementation of a Socio-economic Survey and an Environmental Audit. The methodology for the selection of five project sites for pre-feasibility analyses includes the following steps, with corresponding objectives:

- Rapid appraisal To identify 14 potential sites in 7 areas (thanas) of 5 districts for the implementation of a detailed socio-economic survey and environmental audit.

- Socio-economic survey To collect important socio-economic information from identified project sites, to be used in the further selection of 5 project sites and for pre-feasibility assessment.

- Environmental audit. Same objective as for socio-economic survey, and to evaluate the quality of selected water bodies and quantity of waste production in each site

- Selection of 5 sites· To select from the 14 surveyed and audited sites 5 sites which show the highest potential for duckweed-based wastewater treatment and aquaculture

- Pre-feasibility analyses. To prepare pre-feasibility reports for the 5 selected sites

5 2 The results of the Socio-economic Survey and the Environmental Audit for the 14 sites were checked against a set of defined selection criteria. On the basis of the score and practical considerations the following five project sites were selected for pre-feasibility analyses:

- Ispahani and Arseen canal (IAC-14): IAC-14 is located in Narayanganj District, Thana Bandar, Union Pouroshava Bandar, in the Ekrampur and Kadamrasul localities on the south-west side of Bandar Pouroshava headquarter.

- Isdair Basti canal (IBC-13) Idair Basti canal is located in Narayanganj, Thana Narayanganj Sadar, Union Fatullah Pouroshava, 1 5 km north of Narayanganj District Headquarters

- Savar Dairy Farm and BLRI Complex (BLRI-05) The site is located in Dhaka District, Thana Savar, Union Pathalia, on the Dhaka Aricha road, 40 km from Dhaka city

- CPP outlet to garinda beel (CPP-19): This site is located in Tangail District, Thana Tangail Sadar, union Garinda, in the eastern part of Tangail Sadar town.

- Saidpur PSVA Vagar (SPV-22) The site is located in Nilphamari District, Thana Saidpur Sadar, Union Kerdal, four km north of Saidpur District Headquarter.

6. *Pre-feasibility analyses*

6.1 A pre-feasibility study for each of the five selected project sites was conducted, providing information on site location/description, socio-economic and environmental audit findings, duckweed based wastewater system design, assumptions, financial analyses, overall pre-feasibility analyses and state of preparedness. Except for the IBC site, in the four other sites the sources of wastewater were mainly from domestic origin (households), municipality (e.g. bazaar), and educational institutes. The IBC site also receives industrial wastewater from textile industries. For the five sites the following treatment capacity has been considered, based on the wastewater flow:

- BLRI-05 1500 m^3/d treatment capacity
- SPV and CPP· 1000 m^3/d treatment capacity
- IAC and IBC: 500 m^3/d treatment capacity

6.2 Duckweed fed aquaculture has been recommended for all five sites with the aim to combine the cost intensive treatment with resource recovery and income generation. In addition, for BLRI site, application of duckweed feed for animal and poultry raising has been proposed.

6 3 The wastewater and aquaculture systems proposed for the five sites all show a positive overall financial performance, since the revenues from the aquaculture component exceed by far the cost of the treatment component. The combination of the two system components is attractive, also from the point of view of aquaculture, since the system guarantees a stable and continuous supply of high quality fish feed (high quality fish feed is extremely scarce in Bangladesh and supply is unstable). Depending on the site situation and capacity of the system, the Internal Rate of Return (IRR) ranges from 17% to 22%. These results indicate that for the five sites, duckweed based treatment and aquaculture is viable and potentially profitable. It is therefore strongly recommended to develop demonstration projects in the five selected sites

7. *Sensitivity analyses*

7 1 The assumptions and conditions for the calculation of the financial performance of the systems in the five project sites are outlined in par. 6.1 and in Annex 9 A number of parameters were derived from the experience of PRISM at the KHC site, and a sensitivity analyses was done to check the effect of changing a number of key parameters such as fish yield, fish price, land lease costs, and cost of supplementary fish feed The results of this analysis show that the financial performance is strongly affected by fish yield and fish price (break-even at 63% of baseline value), whereas fish feed price and land lease cost appear to have less impact (break-even at 10 times the baseline value for land lease cost)

8. *Project preparation*

8 1 Chapter 7 of the report discuses the state of preparedness of the five project sites, the country capacity to execute the proposed demonstration projects, the institutional arrangements, system monitoring and evaluation, and research and development aspects

8.2 In order to define the possible institutional arrangements for the effective implementation and operation of duckweed based wastewater treatment and aquaculture, the following functions were considered: ownership, technical assistance, financial sustainability, and public sector involvement The consultants propose that the system operation and maintenance in the five project sites should be delegated to a private enterprise. Depending on the local situation, the enterprise may consist of a group of shareholders, farmers (land owners), private investors or an NGO. The conditions with respect to wastewater rights, possible lease of infrastructure, payment of a fee for wastewater treatment, etc. need to be worked out in a detailed contractual agreement between the Municipality/DPHE and the enterprise

8 3 Separate monitoring and evaluation formats are proposed for a) the M&E of the financial performance of the system, b) the M&E for economical assessment, and c) the M&E of public health aspects With respect to the monitoring of public health aspects a 6 months detailed sampling and analyses program is proposed prior to project initiation in order to evaluate the water bodies and wastewater for the presence of macro-pollutants (BOD, TSS, nutrients, pathogens) and micro-pollutants (pesticides, metals, Arsenic) Especially the possible presence and behavior of micro-pollutants and pathogens deserves attention, since these compounds may be accumulated in the duckweed-fish-human food chain The proposed monitoring scheme should be continued during the first 12 months after starting the wastewater treatment and aquaculture system, in order to cover the possible effect of seasonal differences.

9. *Public health aspects*

9 1 Preliminary analyses of pathogens in wastewater, duckweed and fish in the KHC system suggest that pathogen transfer from duckweed to fish and subsequently to human consumers is not likely The numbers of pathogens transferred to fish ponds seems to be in the same range as for non-wastewater grown duckweed (natural contamination) Analyses of water samples taken from ponds in the five project sites demonstrated that the present situation is much more alarming, since none of the ponds evaluated met the requirements for restricted irrigation (fecal coliforms ranged between 10^3 and 87×10^5/100ml). Since most of these water bodies were used for washing and bathing by surrounding communities, the public health risk associated with the day to day use of these ponds seems more urgent than the possible transfer of pathogens via duckweed.

9.2 Preliminary analyses of few water samples in the five project sites suggest that Arsenic is not present in high concentrations. For all samples analyzed, values were well below the standard for irrigation. Nevertheless it is recommended that detailed sampling and analyzes of arsenic should be done as part of project preparation

10. *Final assessment and recommendation*

10 1 The financial evaluation of the KHC system operated by PRISM suggests that this is the first system that is able to generate a net profit from the treatment of wastewater This is possible because the cost intensive treatment is combined with revenue generating aquaculture The scope for privatized wastewater treatment via duckweed ponds combined with aquaculture seems bright also in other locations in Bangladesh, and therefore serious efforts should be undertaken to develop demonstration level projects under different scenarios. Inclusion of a duckweed component in the proposed SCSP would be justified since this will not only help to improve the sanitation and economic situation in the project sites, but it would also provide a good basis to incorporate environmental thinking into the educational process.

10 2 To support the effective development and monitoring of the new technology, the consultants suggest that sufficient attention is given to both training and research. Both goals will be satisfied by upgrading the current demonstration facility for duckweed based wastewater treatment at KHC and BLRI into 'Duckweed Research and Demonstration Centers'.

10 3 The consultants recommend that a workshop is organized, where the findings of the pre-feasibility study and the orientation of the proposed demonstration projects will be discussed with all stakeholders before project appraisal.

1. INTRODUCTION

Wastewater treatment in combination with possible re-use scenarios for nutrients, energy and water provides attractive options for environmental and water resources management. At the same time such re-use oriented treatment systems can yield considerable by-products in the form of crops, fish or livestock. These by-products provide important incentives, to make the overall treatment economically attractive, which is necessary for countries with low GNP if these are expected to adopt wastewater treatment technologies within the next decades. A one-sided focus on wastewater treatment and environmental protection will not be economically feasible for most countries in the world. There exists therefore a real danger, that, in the absence of cost-effective wastewater treatment technology, environmental degradation, including surface and groundwater contamination will continue at ever increasing rates in most of the developing world.

The emphasis in this report is on duckweed based wastewater treatment and aquaculture as an attractive low-cost option for wastewater treatment and resource recovery The collection and transport of wastewater form part of a complete water supply and sanitation scheme, but this component is not included in the pre-feasibility study. The total cost of water supply, and wastewater collection, transport and treatment need to be recovered from the water users (households, industries etc), if these water services are meant to be sustainable. This report evaluates the possibility of a duckweed based wastewater treatment and aquaculture system to recover at least part of the treatment costs.

PRISM, an NGO in Bangladesh has successfully applied duckweed based wastewater treatment and aquaculture at the Kumudini Hospital Complex (KHC) in Mirzapur and in village projects for a period of almost 10 years now (since 1989) In 1993, a full-scale continuous flow duckweed based treatment system was constructed at the KHC site. The duckweed pond system treats about 270 m^3 wastewater per day, while the daily duckweed harvest is fed to fish ponds. Both duckweed and fish production has shown steady increases over the years. The duckweed wastewater treatment and aquaculture system at KHC in Mirzapur probably represents the first wastewater treatment system that derives a net profit from the treatment process The fact that the system has been able to continue operation for such a long time without external support provides evidence that this indeed is a profitable undertaking. Except for some initial estimates performed by the Duckweed Research Project (1996/1997, funded by The Netherlands Government), it is not known what the financial performance of this demonstration scale treatment facility is Therefore, an analysis was made of the financial performance of the KHC treatment system and of a village based duckweed project, as part of the present assignment (Chapter 4).

The main objective of the present study was to perform a pre-feasibility study for 5 selected sites, of cost effective duckweed based wastewater treatment technology with a view to:

- improve surface water quality
- improve the local health and environmental conditions

- convert waste into an economic asset by using duckweed in safe aquaculture or other animal feed applications
- create rural employment, and
- to explore the potential of public private partnership in innovative wastewater treatment and integrated aquaculture enterprises

The detailed terms of reference of this study is presented in Annex 1. The study was executed by IHE, The Netherlands, and PRISM, Bangladesh, who formed a team composed of

Dr Huub J Gijzen	IHE, Team Leader
Mr. M. Ikramullah	Coordinator PRISM team
Dr. M. Khondker	Environmental audit expert
Mr. H. Rashid	Socio-economist
Mr. A.K.M.Ibrahim	Executive Engineer Design Division, DPHE
Mr. K.M. Alahuddin	Coordinator field survey team

6 experienced extension staff from PRISM assisted in the field survey

The main report was prepared by Prof. Gijzen and Mr. Ikramullah The study was implemented in the period October 1998 to April 1999 (6 months). The methodology consisted of a series of well planned steps, including a) rapid appraisal, b) selection of 14 sites with high potential, and c) selection and further study of 5 sites with highest potential (chapter 5). For these 5 sites pre-feasibility level reports were prepared (chapter 6)

The World Bank Dhaka office in collaboration with GOB (DPHE, LGD) is preparing a School and Community Sanitation Project (SCSP) and is interested to consider the scope of duckweed based wastewater treatment and aquaculture as a component in the project preparation. Besides a possible role in the SCSP, the consultants suggest that also other possibilities could be explored to set up demonstration projects of duckweed based wastewater treatment and aquaculture, especially where positive impacts on environment and/or local economy may be expected.

Besides direct benefits on improved water quality and aquaculture products, duckweed-based wastewater treatment technology is also expected to deliver additional (secondary) benefits, which may improve the feasibility and acceptability of the technology These benefits will be discussed briefly in chapter 3.
A list of people and organizations contacted during the assignment is attached in Annex 2

2. BACKGROUND AND COUNTRY SPECIFIC INFORMATION

2.1 Socio-economic context

Bangladesh is amongst the most densely populated and poorest countries with a population density of over 800 persons per km^2 and a per capita annual income of about US $ 260 (1996) This, combined with a population growth of about 1.8 %, generates a rapidly increasing pressure on the national economy, the environment, including the country's natural resources (water, land), and on the general well-being of the people in the country.

The female population seems to be particularly under pressure. This is expressed in the following statistics

- Women comprise less than half of the total population (48.7%; this is usually the opposite in other countries);
- the enrollment rate in primary schools for girls is almost 10% lower than for boys;
- literacy rates for Women (22%) are much lower than for men (44%);
- food calories intake for women is about 30% lower than for men;
- the proportion of female headed households, usually the most disadvantaged socio-economic group is rather high (15-25%).

Public expenditure by GOB on education, in percentage of GNP, amounts to 2.3% The primary enrollment rate in 1996 was estimated at 62% (66% for boys, 58% for girls). Total adult literacy rate is only 38% (1995). Bangladesh has undertaken great efforts to increase enrollment in primary education since 1980, and, more recently, in secondary education, especially for girls The quality of education and low learning achievements, however, require further attention.

The high population density puts a high pressure on the land. Almost all available agricultural land is under cultivation, while still some 65% of the rural population is functionally landless. The farming system is dominated by small producers, applying an integrated production pattern, which yields crops, vegetables, fruits, poultry, and fish for both home consumption and market. Paddy is the most important crop, while jute and wheat rank next. Fish is in fact the main source of animal protein in the diet of the Bangladesh population. Another result of the pressure on land is that large areas of forest have been cleared for food production, and this has resulted in a gradual degradation of the soil and hydrological system.

Poor health and malnutrition form a wide spread problem in Bangladesh. The most prevalent health problems are diarrhea, parasitic and respiratory infections, which all are clearly associated with environmental factors. 80% of all reported illness cases are either water borne or water related. Gastrointestinal and diarrheal infections annually causes death of about 0.36 million children under the age of 5 (1996), resulting in a mortality rate of 184 per 1000 births. These figures represent one of the highest infant mortality rates in the world.

The above health problems are worsened by chronic malnutrition of the population. About 60% of the total population has a daily food intake of less than 2100 calories, while some 35% consumes less than 1800 calories. Malnutrition seems to be most severe in June and in the period September-October. The second period corresponds with the end of the rainy season and therefore is accompanied also with a high rate of infections by water borne pathogens.

The above statistics provide an indication of the severe development problems faced by the rural population in Bangladesh, particularly the socially and economically most disadvantaged groups, such as female headed households, and the landless. In this context the approach to look at waste and wastewater as a resource may not be surprising. It is therefore expected that duckweed based wastewater treatment with combined aquaculture could be readily adopted by the local population, with positive impacts on sanitation, health and nutritional condition.

2.2 Environmental sanitation situation

World wide the total amount of wastewater treated is estimated to be only a small fraction of the total volume produced. This situation can be explained by the substantial costs associated with the collection and treatment of both domestic and industrial wastewater. Although developed industrialized countries may have the economical capacity to deal with these and other environmental problems via high-tech approaches, such as activated sludge and tertiary treatment, these technologies are simply not within the economical reach of developing nations (Box 1). Most developing countries have recently defined legislation regarding effluent standards, while they are currently looking into ways of enforcing this legislation.

Box 1. Cost of wastewater collection and treatment

According to World Bank, up to 3% of a country's GNP can be realistically spent on environmental protection (including wastewater treatment). Grau (1994) and Gijzen (1997) estimated the period of time needed to meet EU effluent standards by a number of low GNP countries, assuming that 1.5% of the GNP could be invested in sewers and treatment facilities. As can be seen from the table, this period exceeds, by far, the economic life time of the treatment plant (20-30 years) and in many cases even that of sewers (about 50-60 years), and therefore the implementation becomes unrealistic.

Estimated periods needed to meet EU effleunt standards at an investment level of 1.5% of the GNP of various countries

Country	Population Million	GNP/capita US$/cap.	Cost to meet EU standards[1)] US$/cap.	Period needed at 1.5% GNP Year
Bulgaria	8.5	2210	3755	113
Egypt	60	1030	4000	259
India	935	335	3750	746
Kenya	29.2	290	4500	1034
Mexico	92.1	2705	3750	92
Poland	38.3	1700	1230	48
Romania	23.2	1640	1422	58

The biggest challenge ahead, however, will be to develop reliable and appropriate treatment options for wastewater that are within the economic and technical capabilities of developing nations. The combination of low cost treatment methods with strategies for recovery of energy, nutrients and water could prove to be a feasible option for many countries.

World-wide attention for water supply and sanitation was increased when the UN General Assembly launched the Water Decade (1980-1990), with the ambitious goal to ensure safe drinking water for all towards the end of that decade. This initiative was taken in recognition of the fact that a good public health situation and reliable environmental sanitation form prerequisites for economic development and welfare in any society. Similar to many other countries, these ambitious goals were not met in Bangladesh. For the 10 years period between 1980 and 1990, GOB aimed to achieve a water supply coverage of 77 and 58% of the urban and rural population, respectively. For the sanitation coverage the goals were set at 50 and 13%, respectively. Despite concentrated efforts, at the end of the water decade the sanitation coverage realized was only 27 and 6%, respectively. The percentage of the population with safe access to water is currently estimated at 95%. The term 'safe', however, should be reconsidered with the recent discovery of wide-spread arsenic (As) contamination in part of the ground water sources tapped for water supply.

A major constraint for the further development of rural sanitation is the high cost involved with the construction of sanitary pit latrines. At the same time there is a lack of social and financial motivation to invest in sanitation facilities. Also in urbanized areas the sanitation situation is often poorly developed Only Dhaka and Chittagong have a sewer facility, whereas treatment of sewage is only applied for part of the wastewater in Dhaka (Pagla). Other cities, growth centers and district towns have a 20-60% sanitation coverage. Some recent improvements were achieved in a number of towns included in the '18 Towns water supply and sanitation and drainage project' (1978 - 1999).

The non covered part of the community causes indiscriminate disposal of fecal matter and sewage into the environment. This situation seriously endangers the important functions of the numerous open water bodies (ponds) for bathing, washing, water supply, irrigation and fishing As a results most open water bodies in Bangladesh are currently highly contaminated with pathogens, BOD and nutrients. The increased industrial activities, both in the urban as well as in the rural areas is another cause of serious concern. Almost all industries discharge their waste (solid and liquid) without any form of (pre-)treatment in the immediate environment. No information is available about the fate of waste components. The nutrients present in both industrial and domestic wastewater causes excess growth of water weeds, which can be observed on most open water bodies in Bangladesh

Current GOB investments in the sector are mainly aimed at water supply. The recent recognition of the scope of the Arsenic problem is claiming urgent attention from both GOB and multi-lateral and bi-lateral agencies in the sector Most sanitary infrastructure projects in towns and urbanized areas have and will continue to cover only drainage, sewerage and on site sanitation Comprehensive solutions including full wastewater collection and treatment are not considered feasible within the economic context of Bangladesh (see Box 1). As a result, the sanitation problems will remain of gigantic proportions for many years to come, resulting in further deterioration of surface water quality. Decentralized low cost wastewater treatment with resource recovery should therefore be considered

2.3 The fisheries sector

In Bangladesh fish forms an integral part of the diet and accounts for over 70% of the animal protein intake of the population. Fish is second only to rice in the diet of the poor Annual average consumption of fish amounts to some 7.5 kg/capita. The per capita consumption, however, ranges from 4 4 kg for the lowest income groups to 22 1 kg for the highest income groups.

The fisheries sector of Bangladesh accounts for about 3 5% of the GDP and for more than 11 % of the export earnings, while it provides employment for over 1 5 million people Fishing is practiced in the Bay of Bengal, rivers, floodplains and ponds Inland fisheries is practiced throughout the country and accounts for about

72% of the total fish production Roughly 95% of all fish production is consumed domestically. Due to high demand, market prices of fish have increased rapidly over the past years, at a rate (16%/y) which is substantially higher than that of rice price increases (10%/y). The increased demands for fish were traditionally met through greater harvest from the sea and inland waters, but over recent years the catch has leveled off, and in the case of inland fisheries, even declined. Explanations for this decline include, among others, infrastructure flood control works, poor management practices of water bodies, over-fishing, and high level of contamination of ponds by agriculture (pesticides), domestic and industrial activities (BOD). The indiscriminate discharge of wastes into ponds results in sharp decreases of the oxygen balance of these aquatic systems Low oxygen levels are probably an important limiting factor in inland fish production at the moment Considering the ever increasing demand for fish protein on the domestic market, and the importance of fish in the Bangladeshi diet, effective strategies need to be defined urgently to increase annual fish production in a sustainable way. The marine fisheries shows little scope for further growth since current exploitation is practiced at, or beyond, maximum sustainability levels. There is however, substantial scope for the expansion of inland fish production. Current fish yields, especially in pond fishing, are low, but can be increased considerably.

The World Bank estimated that, via effective rehabilitation of ponds and introduction of aquaculture technology, the productivity of inland ponds can be doubled from the 1987/1988 level of 150,000 mt to more than 300,000 mt/y in the year 2010.

Satellite surveys of Bangladesh show that there are over 2 million ponds of variable size throughout the country. With an estimated average size of 0 10 ha, this yields some 200,000 ha of potential fish production area. However, only less than half of this area is cultured Most ponds have multiple functions (washing, bathing, sanitation, irrigation, livestock watering, etc.) and are not suitable for fish production. These ponds would require physical improvements in order to increase fish production, but multiple pond ownership and lack of credit form major constraints. Besides, pond owners experience serious production constraints, such as limited knowledge of aquaculture, lack of quality and quantity of stocking material and fish feed, frequent occurrence of fish epidemic disease, and loss of crops due to floods, drought or oxygen depletion of the water.

The potential of controlled aquaculture practices has been demonstrated in Mymensingh, where yields of a polyculture of carps in rural ponds have reached production levels of 5000 kg/ha.y. These yields were possible because high quality fish feeds, such as oil cake and wheat bran were fed The plans to intensify aquaculture in Bangladesh will result in increased demands for low cost, locally available fish feeds. In this respect the experience by PRISM shows that high quality fish feed in the form of duckweed can be produced from wastewater. At the KHC in Mirzapur, PRISM has realized sustainable fish yields of about 12 to 15 mt/ha.y of carp polyculture over a period of about 10 years, applying a duckweed based diet. The importance of duckweed as a fish feed is gaining recognition. This is reflected both in publications by experts from many parts of the world, but also by practices in villages in Bangladesh where duckweed is being collected from the natural environment and fed to fish ponds

Table 1 Overview of ongoing projects in Water Supply and Sanitation in Bangladesh

Project name	Budget	Duration	Donor
	Lakh Taka		
Water supply, sanitation & drainage in 18 towns	17,425	1978-99	NEDA
Water Supply for Rajshahi city	2000	1995-98	GOB
Water supply and sanitation in 9 towns	17,520	1996-99	ADB
Water supply in 23 towns	4,677	1994-2000	GOB
Water supply in Rangamati towns	279	1994-2000	GOB
Water supply in (rural) coastal areas	3,886	1998-2000	ADB
Rural water supply (GOB-4)	63,084	1995-2002	GOB
Rural sanitation	19,960	1996-2001	GOB
Water supply, sanitation and drainage project (municipalities, thana and growth centers)	15,247	1996-2005	DANIDA
Rural sanitation, health water supply	21,747	1996-2000	UNICEF
Environmental sanitation, Health & water supply in slums and urban fringes	3,420	1997-2001	UNICEF
Water supply and sanitation for Gopalganj, Tungipara,Kotanpara, & 2 other thana towns	3,471	1996-2002	GOB
Regeneration of well and water supply system in urban areas	2,235	1997-2001	GOB
Piped water supply for Kuchua, Matlab etc.	1,625	1997-2001	GOB
Bangladesh As mitigation water supply	17,893	1998-2001	IDA
Interim water supply scheme for Khulna town	840	1993-1997	GOB
Expediting and improvement of water and sanitation in Hill Tracts District	18,300	1997-2003	GOB
Water supply export processing zone, Mongla port	6,300	1998-2003	GOB
DWASA, Dhaka	40,000		WB
Technical assistance projects			
Social mobilization for sanitation	1,946	1993-1998	UNICEF
Study in As affected areas	179	1996-1999	UNICEF
Ground water investigation for As contamination	365	1998-2001	DFID
Other projects (under preparation)			
Municipal services project 16 towns	70,000		WB
WS&S partnership Rajshahi			SDC

2.4 The livestock sector

The livestock sector provides an estimated 6.5% of the total GDP and forms an important factor in the rural economy and nutrition. Livestock by-products, such as hides, are also an important factor in the national economy, since this provides an estimated 7-8% of all export earnings.

Rural families usually keep small animals such as chicken, ducks and the typical black Bengal goat. Cattle is kept by only few families in each village. These animals provide essential nutrients to the local population in the form of eggs, milk and meat. Livestock is particularly crucial in providing food and income to landless and marginal farmers. Livestock also provides food security in times of massive crop damage due to drought, flood or other natural disasters

Livestock in Bangladesh is suffering from chronic malnutrition, leading to relatively low production yields for milk, eggs and meat Most livestock is fed only low quality roughage, including rice straw and weeds (including water hyacinth). There are almost no grazing lands for cattle, while the specific cultivation of fodder crops is hardly practiced in Bangladesh. Feed shortages have been identified as the main limiting factor, hindering the further expansion of livestock productivity in Bangladesh. Any expansion of livestock production would be of direct and great benefit to the rural economy and nutritional status, particularly for the poor and women. Increases in the availability of feeds for poultry or goats would have the biggest impact, since these are the animals typically kept by these groups.

Publications from different sources and few preliminary trials with livestock, chicken and duck in Bangladesh, suggest that duckweed could be an attractive feed component for these animals. In addition to duckweed based aquaculture, therefore also the role of duckweed as a livestock feed should be studied further.

2.5 Investments in the above sectors

The sectors described in previous paragraphs have received substantial attention over the past two decades, both from the side of GOB as well as from bi-lateral and multilateral agencies. The World Bank has been involved in these sectors via a number of donation and investment projects Table 1 presents an overview of the most important projects which are currently under implementation in Bangladesh in the field of water supply and sanitation

3. STATE OF THE ART OF DUCKWEED TECHNOLOGY

3.1 What is duckweed?

Duckweed are small floating aquatic plants, which readily grow on the surface of contaminated or nutrient containing fresh and brackish water bodies. The plant belongs to the family *Lemnaceae*, consisting of four genera (*Lemna, Spirodela, Wolffia,* and *Wolffiella*) with at least 37 species identified so far. The size of duckweed ranges from sub-microscopical for *Wolffiella* to up to 20 mm for *Spirodela.* Duckweed has been reported from a wide range of different ecosystems and climatic conditions all over the world, including cold temperate regions, tropical environment, high altitudes (Lake Titikaka, Peru), freshwater and brackish water Optimal growth conditions seem to include: (sub-)tropical temperature, relatively high nutrient levels (especially N and P), stagnant water conditions, long light periods at medium light intensity and the absence of algae and other aquatic weeds.

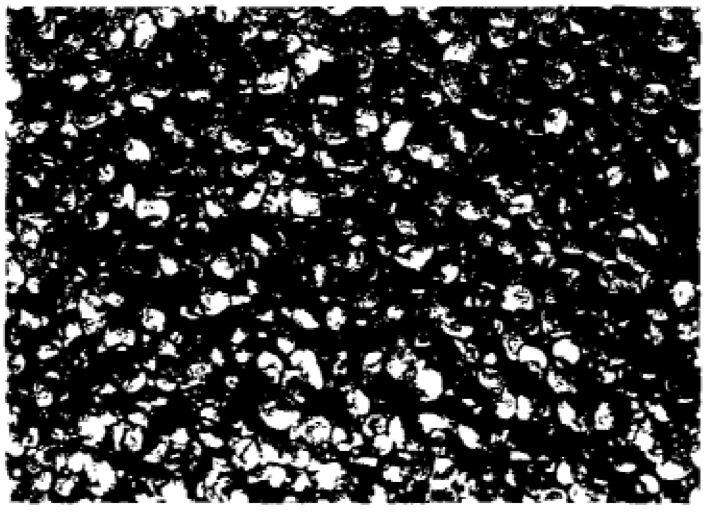

Fig. 1 *Spirodela polyrrhiza* growing on wastewater in a duckweed pond.

Compared to other plants, duckweed has an extremely low fiber content (about 5-9%), because the plant does not require structural tissue to support leaves and stems. Therefore almost all tissue is photosynthetically active. The high specific metabolic activity is reflected in the extremely high production rate of duckweed. Under optimal growth conditions biomass duplication times of less than 1 day have been reported (Leng *et al.*, 1995), which makes it one of the fastest growing plants known so far.

Duckweed has a number of unique characteristics, which makes it attractive as a fish and animal feed, such as its:

- high growth rate and short biomass duplication time;
- high nutrient uptake capacity;
- ability to grow under a wide range of climatic and environmental conditions;
- high protein content of 30 to 40%;
- duckweed can be easily harvested form pond systems, and
- duckweed is readily consumed by a wide variety of herbivorous fish;
- the plant contains essential vitamins and micro-nutrients.

Interestingly, the potential per ha protein production rate for duckweed is about 10 times higher than that of high quality protein crops such as Soy bean. For a more detailed description of the plant ecology, physiology and composition the reader is referred to recent reviews on this subject by Gijzen and Khondker (1996) and by Landolt and Kandler (1987).

The above characteristics have generated world-wide interest in two major application areas for duckweed:

a) The use of duckweed for the effective treatment of wastewater
b) The use of duckweed as a valuable feed or feed supplement for the cultivation of fish, poultry and/or livestock.

The most interesting application may be derived form the combination of wastewater treatment and subsequent use of duckweed as an animal feed. Investigations in the above mentioned application areas are ongoing in a number of countries at the moment. The following paragraph will outline briefly the state of the art of duckweed based wastewater treatment and application as animal feed.

3.2 Duckweed activities world-wide

Commercial initiatives

The favorable characteristics of duckweed have attracted interest world-wide from both scientists, NGO's and commercial companies. The commercial initiatives so far are related to the application of duckweed for wastewater treatment only. In the United States duckweed based wastewater treatment has been introduced mainly for small and medium sized communities. Lemna Corporation is a successful company in the USA, marketing duckweed based wastewater treatment technology not only for the national market but also in Europe and China (see box 2). The objective of these treatment plants is to meet effluent standard requirements through nutrient removal and BOD reduction. The duckweed produced, however, is not used for animal feeding. In this case duckweed is considered as a catalyst in the treatment process, while excess production will be kept to a minimum.

Box 2 Lemna Corporation

Lemna Corporation in the USA has been involved since several years in the development and introduction of full scale duckweed based wastewater treatment plants. The company is divided into two branches, Lemna USA, which takes care of the national market, and Lemna International Inc., which caters for the international market.Lemna USA has targeted communities of less than 20,000 inhabitants to treat both domestic and industrial wastewater. Recently Lemna Corp. has started investigating the possibility to develop duckweed based treatment systems for larger communities as well. Up to 1996 Lemna International had sold 19 duckweed treatment plants in Poland, with 5 more under planning. At that time Lemna Int was installing a system with an estimated cost of $ 50 million in Siberia, whereas a $ 30 million agreement was signed with China (Anonymous, 1996). Up to 1996, Lemna Corp had installed more than 60 treatment systems in the USA and over 125 systems world wide.

For more information: http//www.
email: sales@lemna.com

More recently, another company, Green Gold Int., has been established. This company considers the recycling of animal waste in addition to domestic wastewater treatment (see box 3). Greengold applies the cultivation of duckweed for further processing into a protein-rich animal feed meal. Also in The Netherlands some preliminary trials are ongoing with respect to duckweed growth on pig manure. In these trials, the duckweed produced is used to grow Tilapea (see Box 4).

Box 3. The Green Gold Corporation

The Green Gold Corporation is a subsidiary company of Bionet Technologies, a biotechnology company with headquarters in Jupiter, Florida, USA. In North Carolina, USA, the company is introducing a newly developed duckweed production system, refered to as the Helical Production Unit. The unit consists of a circular shallow pond, covered with duckweed, which treats swine manure. About 20 of such units, with a total surface area of approximately 20 ha can handle the waste flow from about 3000 pigs. Each unit (1 ha) produces about 24 tons of dried duckweed (10% moisture) per season. GreenGold is proposing contracts to the pig and poultry farmers, which specify that the farmers will buy the protein meal produced on site by Green Gold. Recently the company submitted a proposal to the City of Cancun in Mexico for the installation of the patented HPY system for the treatment of the city's wastewater
For more information:http://www.bionettech.com/greengold
skıllı ntrnet.net

India

Besides the above commercial initiatives, there are also a number of important research & development

activities going on by research groups and NGOs. In India Shullabh International, a local NGO is involved in a number of duckweed projects. A demonstration project was started in 1995 in Wazirabad (Northern part of New Delhi), where the Delhi Water Supply and Sewage Disposal Undertaking is operating 17 sewage fed oxidation ponds (500 x 200ft each). Shulabh has converted 2 of these ponds into duckweed systems, whereas another 2 ponds are used for fish cultivation. Via the project Shulabh intends to assess the economic feasibility of duckweed based sewage treatment and aquaculture. Shulabh is also involved in duckweed based village sanitation projects in Orrisa
(DANIDA funding) and in Haryana (funded by the Ministry of rural Areas and Employment).

Box 4. Bogey Venlo Ltd.

Bogey Venlo in The Netherlands has been experimenting with small scale duckweed wastewater treatment plants, using pig manure as an influent. The duckweed is fed to Tilapia and preliminary results show considerable savings on the use of commercial feed pellets. At the same time the system provides costs savings on the treatment side.
The company is currently considering the production of duckweed as a new 'vegetable' by using inorganic growth media.

Further information: Bogey, Box 3006, Venlo, NL. Tel. 31-77-3510088

Thailand
The Asia Institute of Technology (AIT) in Bangkok has been involved in duckweed research for more than 15 years. Initial activities started already in 1981 via funding from ODA. Later on Duckweed research continued under the project 'Resource recovery and health aspects of sanitation', funded by the European Union (1984-1987). The main objective was to study the use of septage in aquaculture. Studies were undertaken to compare fish yields in ponds directly fed with septage with fish ponds where septage grown duckweed was used. Fish yields increased from 3.7 t/ha.y to about 6.7 t/ha.y when duckweed was used (Edwards *et al.*, 1990). The authors, however, pointed out that the duckweed option required a total surface area which was larger than the direct septage fed option. This may be partly explained by the poor duckweed yields in these experiments.

Taiwan
Written information about duckweed cultivation and feed applications in Taiwan are scarce. Chen (1976) reports that *Lemna* and *Wolffia* are cultivated together and are used directly as a green fodder for fish. The shallow ponds have an area of between 0.1 and 0.5 ha and are fertilized by fecal polluted surface water. Although there were originally some 100 ha available in the city of Tainan in 1985, this area has now been significantly reduced due to urbanization.

China
Contrary to the above example of Taiwan, in China about 20 ha of duckweed were reportedly installed at the expense of rice cultivation (Edwards, 1990). China has a long tradition in re-use and recycling of nutrients and waste streams, often by means of integrated systems. The use of macrophytes and other green fodder for fish production is practiced widely. Edwards (1987) reported that various species of duckweed are cultivated in shallow ponds fertilized with manure and the plant biomass is used as a feed for grass carp fry and fingerlings in nurseries. At the smallest size, the fry are fed with *Wolffia*. In the provinces Kiangsi and Chekiang,

Wolffia is cultivated on a seasonal basis (April to September) with an extrapolated annual yield of 14 t dry matter/ha

Vietnam

Duckweed trials in Vietnam are undertaken by a group at the University of Agriculture and Agroforestry, Ho Chi Minh (Dr Preston), as a component in their work on 'integrated farming systems for sustainable use of renewable natural resources'. The group has experimented with the use of biogas reactor effluent as a growth medium for duckweed. Anaerobic digestion of waste materials prior to nutrient recovery by duckweed may have a number of advantages for the efficiency and economy of the overall system (Gijzen, 1996) The biogas digester was charged with pig manure The optimal N-level for duckweed production was between 40-60 mg/l, yielding about 100 g/m^2 d of duckweed with a crude protein content of 35% The research was done in 10 m^2 pilot scale ponds.

Israel

Substantial research results on duckweed growth and wastewater treatment have been produced by Oron and co-workers in Israel. Most studies were performed at a small scale, using 30 liter containers, and may therefore not be directly extrapolated to full scale performance.

The Netherlands

In The Netherlands, The International Institute for Hydraulic, Infrastructural and Environmental Engineering (IHE) has been involved in duckweed research for about 5 years now. Although previous research at IHE was mainly concerned with laboratory scale trials, recently a number of Ph D. studies were started, using pilot scale systems (surface area of between 10 and 40 m^2) In a joint cooperation between IHE and PRISM, a study was performed on the full scale duckweed based treatment system at KHC in Bangladesh (Alaerts *et al.*, 1996). The Ph D. projects are carried out in a 'sandwich construction' in different countries (Ghana, Palestine, Colombia, Egypt, Yemen) under different climatic conditions and using quite different wastewater composition. One of the studies is focused on the die off mechanisms of pathogens in duckweed based treatment systems. It is expected that substantial research data will be produced from these studies in the coming years.

Other countries

In addition to the above countries, and Bangladesh (discussed below), full scale duckweed based wastewater treatment and research is practiced in a number of other countries Morocco has applied duckweed based wastewater treatment for domestic sewage, but re-use of duckweed does not seem to be an option considering cultural and religious characteristics In Egypt research and pilot scale testing of duckweed based wastewater treatment and aquaculture has recently started in close cooperation with IHE, The Netherlands. Similar projects are developed by IHE in Palestine, Ghana, Yemen, and Colombia. In Colombia pilot scale treatment facilities have recently been installed in a cooperation with the Universidad del Valle and a regional water authority Aquavalle. Besides, an NGO called CIPAV is active in Colombia in testing duckweed growth on effluent of biogas plants treating pig manure. Feeding trials of duckweed for pig and fish are also executed by CIPAV. In Zimbabwe recently a 2.5 year project was undertaken with

NORAD funding, on duckweed pond system performance. Several pilot and small (full) scale systems are now in operation.

Bangladesh
In Bangladesh duckweed technology development and application was first introduced by the NGO PRISM. Since 1989 PRISM has been continuously involved in duckweed based wastewater treatment, both in centralized systems as well as in small scale village settings In 1993 a full-scale system for wastewater treatment was installed at the KHC site The main objectives are to generate:

- low cost wastewater treatment (KHC)
- improved sanitation (village projects)
- resource recovery (aquaculture)
- economic viability, and
- improvement of rural employment and nutritional status

A more detailed description of PRISM's activities at KHC in Mirzapur is presented in chapter 4 Besides the activities in Mirzapur (Tangail), PRISM has developed duckweed based projects (demonstration farms) also in Manikganj (Shibaloy) and Khulna districts A number of duckweed village projects were developed in close association with these demonstration farms

The Fisheries Research Institute (FRI) in Mymensingh and the Bangladesh Livestock Research Institute (BLRI) in Savar, have been involved in research on duckweed feed applications for fish production and livestock and poultry feeding The BLRI is still actively involved in research in this area, and has recently set up a large scale duckweed pond fed with urine and wastewater coming from the cattle stables Besides these institutes, research activities have also been developed by Dhaka University (mainly by Botany and Zoology Departments), ICDDRB (pathogen testing), Bangladesh Center for Scientific and Industrial Research (BCSIR), and Bangladesh University of Agriculture (BUA)

3.3 Role of duckweed in sanitation projects in Bangladesh

Role of duckweed in sanitation projects
Duckweed based wastewater treatment ponds are essentially also waste stabilization ponds They differ, however, from waste stabilization ponds as follows

- rather than encouraging algae production, duckweed ponds seek to prevent the occurrence of algae;
- duckweed ponds actively remove nutrients from the wastewater and incorporate these into high quality plant protein that has great potential for reuse as an animal feed,
- because of this effective resource recovery, the duckweed treatment system seems economically more attractive as compared to conventional stabilization ponds

The duckweed concept can basically be applied in two ways for wastewater treatment and sanitation:

a) In case there exists an effective collection of wastewater, a large scale system may be operated as a continuous flow waste stabilization pond There are a number of projects ongoing at the moment (Towns projects) as described in paragraph 2.5, which will improve wastewater collection in a number of rural towns in the coming years. Duckweed technology could be linked up with the collection system to achieve effective and low cost treatment of wastewater before discharge into the environment.

b) In areas where wastewater is not collected, duckweed technology may contribute to an improved and safer sanitation situation, especially in rural areas. In this case, the construction and use of latrines around designated duckweed ponds is stimulated, while duckweed harvested from the pond will be used in fish production. This option has already been successfully applied by PRISM in a considerable number of village projects.

The application of duckweed in the two concepts mentioned above is expected to generate a number of positive effects:

- Duckweed based treatment contributes to surface water quality improvement, due to removal of BOD, nutrients, VSS, pathogens and turbidity;
- the system provides incentives to install and optimally use sanitary latrines (concept b),
- it will contribute to an improved sanitation and health condition due to reduction of indiscriminate discharge of pathogens and other contaminants into the environment,
- duckweed provides urgently needed high quality animal feed;
- duckweed systems provide direct economical benefits from fish sales (or other animals) and other by-products (vegetables, fruits);
- a good functioning system may substantially improve the nutritional, economic and employment situation of the local population in the immediate surrounding,
- a duckweed system will reduce possible bad odors which usually are produced from wastewater contaminated water bodies;
- a duckweed system will cause a reduction of mosquito breeding sites, because water surface area is covered by duckweed,
- duckweed can be grown in uncultivated marginal lands as long as year round water retention and flood prevention is ensured;
- duckweed systems are flexible and can be set up both as small scale decentralized systems, as well as large scale systems

Considering these positive effects, it is clear that duckweed holds great potential in wastewater and sanitation projects if combined with duckweed feed applications in aquaculture. In this respect it is recommended that GOB in consultation with relevant donors considers the option to include a duckweed treatment component in new projects, or possibly also in ongoing projects, in the field of wastewater treatment and sanitation. For instance duckweed technology could easily be linked up with the 18 towns project, since under this project the effective channeling of waste and wastewater already has been realized The same holds for other water supply and sanitation initiatives. Also the pond system constructed in Pagla, where part of the wastewater from Dhaka city is treated could be considered for conversion into a duckweed based system. Currently the system's effective functioning is hindered by the excessive amounts of algae that are produced and leave the system with the effluent.

UNDP, under its 'sustainable environment management program' (total budget TRAC commitment $ 26,466,000), has proposed a 'Community based urban wastewater treatment system' (component no.333), for $801,000, to be implemented by PRISM. This system will use duckweed ponds combined with aquaculture to generate a net revenue from the treatment process.

Another anticipated role of duckweed based wastewater treatment initiatives relates to the Arsenic problem in the water supply sector. It is likely that the arsenic contamination of groundwater in some areas may be so severe that these areas will have to increasingly depend on surface water for their water supply. In many areas in Bangladesh, however, surface water quality has deteriorated over the years due to uncontrolled discharge of domestic and industrial effluents. Duckweed based wastewater treatment technologies will contribute to improve surface water quality, making these water resources more attractive for future water supply.

Role of duckweed in the SCSP

DFID/UNICEF is preparing a school sanitation project, aiming at better water supply and sanitation facilities for primary schools (about 4.5 million British pounds). World Bank is currently preparing a project with a wider approach (SCSP), which includes also secondary schools and communities. The proposed School and Community Sanitation Project (SCSP) evolved from the subdivision of the former Bangladesh National Environment Project into different stand alone projects The project also intends to improve the quality of the surface water through duckweed based wastewater treatment in selected sites on a demonstration scale. Inclusion of a duckweed component in these projects could generate an effective (partial) cost recovery mechanism. The income produced via duckweed based aquaculture together with other secondary benefits (chapter 3) could be an important incentive, which could stimulate good operation and maintenance of the water supply and sanitation infrastructure.

The project will result in a reduction of ongoing fecal contamination of surface water through provision of (public) latrines. Part of the strategy in the implementation of the above objectives will be to create transparent and financially sustainable mechanisms for the delivery of water and sanitation facilities and to improve DPHE's capacity to manage such demand-driven programs.

Primary schools in Bangladesh have an estimated average number of students of about 300/school. For secondary schools student numbers are substantially higher. Only few of these schools are residential schools, and therefore most of the sanitary waste produced will be urine. The total expected volume of sanitary waste produced by a single (primary) school, may not be sufficiently large to justify a duckweed demonstration project. Therefore the consultants feel that the sanitation efforts related to (primary) schools need to be linked up with similar efforts for the immediate community. This will generate enough waste to warrant a productive duckweed based treatment and aquaculture system to be developed.

4. MIRZAPUR DEMONSTRATION FACILITY AND VILLAGE PROJECTS

4.1 Brief description of facilities and arrangement

Facilities

PRISM, a non governmental organization (NGO) in Bangladesh has undertaken an elaborate program to develop and test duckweed based wastewater treatment systems integrated with aquaculture. Besides, PRISM has developed a large number of village duckweed-based sanitation projects, which stimulate the installation and use of latrines, connected to duckweed ponds. Also here the harvested duckweed is used for fish cultivation.

In 1993 PRISM started the full-scale duckweed wastewater treatment system near the KHC in Mirzapur. The wastewater from the hospital, girls and nursing school and staff residences is connected to the system and the effluent quality of the treatment pond shows consistent good treatment efficiency. The facility at KHC also includes duckweed production from inorganic fertilizer, and both sources of duckweed are fed to carp polyculture ponds. The duckweed facility at KHC is operated as a full scale wastewater treatment and aquaculture system, but it also assumes an important demonstration and training function. PRISM has so far developed three of such demonstration centers in different parts of the country. This paragraph will deal only with the wastewater treatment facility at KHC.

Fig. 2 Plug flow duckweed based waste- water treatment system operated by PRISM, in Mirzapur, Bangladesh

The KHC duckweed facility of PRISM consists of one 0.7 ha plug flow lagoon fed with a mixture of hospital, school and domestic wastewater, 66 hydroponic duckweed ponds 0.1 to 0.5 ha) fed with inorganic fertilizer, and 17 fish ponds (0.2 – 2.2 ha). The plug flow wastewater pond is preceded by an anaerobic pond of 0.2 ha with a hydraulic retention time (HRT) of about 2 to 4 days. HRT in the plug flow pond was estimated to be about 21 to 23 days at an average influent volume of 270 m^3/d The wastewater is coming directly from the hospital complex and is produced by some 2500 people (1200 girls in boarding school, 700 patients, 275 nurse students and 325 staff and families) The per capita production of wastewater appears to be close to 100 l/d.

Figure 2 shows a segment of the plug flow wastewater treatment pond, covered with a dense layer of duckweed The duckweed harvested from the 0 7 ha wastewater treatment pond is fed daily to three 0.2 ha fish ponds located next to the treatment pond (see Fig.3). A more detailed description of the KHC duckweed wastewater system is attached in Annex 3.

Arrangements
Fish production by PRISM uses a polyculture of rohu, mrigal, catla, silver carp, grass carp, and common carp. Tilapia was not stocked, but it enters the ponds via contamination and contributes to about 40% of the total fish production. Fish are sold to fish mongers at the farmgate at an average price of Tk. 60/kg, while about 40% of the production is sold to KHC at subsidized prices of Tk. 37/kg. The wholesale price of 60 Tk is low compared to the current retail price of fish in Bangladesh, which is between 80 to 150 Tk/kg (see par. 6.1)

Sewer extension from the KHC complex to the duckweed-based wastewater treatment system was realized by Kumudini Hospital some 15 years ago, at no cost to the duckweed system. The sewer pipeline (9 inch RCC) channels the wastewater over a distance of 1500 m to a fallow land which is property of KHC. At this point the wastewater was discharged into the adjacent river, without prior treatment. When PRISM started the duckweed based treatment and aquaculture system in 1993, it invested an additional Tk 250,000 for earth work, duckweed pond construction, inlet/outlet system, water supply pump and equipment

An agreement for the duration of 12 years was signed between KHC and PRISM stipulating that

- PRISM has unrestricted access to and use of the KHC farmland and wastewater plant site
- PRISM will make all required investments for development and O&M of the duckweed treatment cum aquaculture project.
- PRISM will pay all utility and electricity costs, which are billed by KHC every months.
- In return PRISM will pay 10% of its annual audited revenue to KHC for rental and overhead for the use of land and infrastructure facilities at KHC.
- In addition, PRISM will offer a 40% rebate on the (wholesale) price of fish and other farm products (fruits).

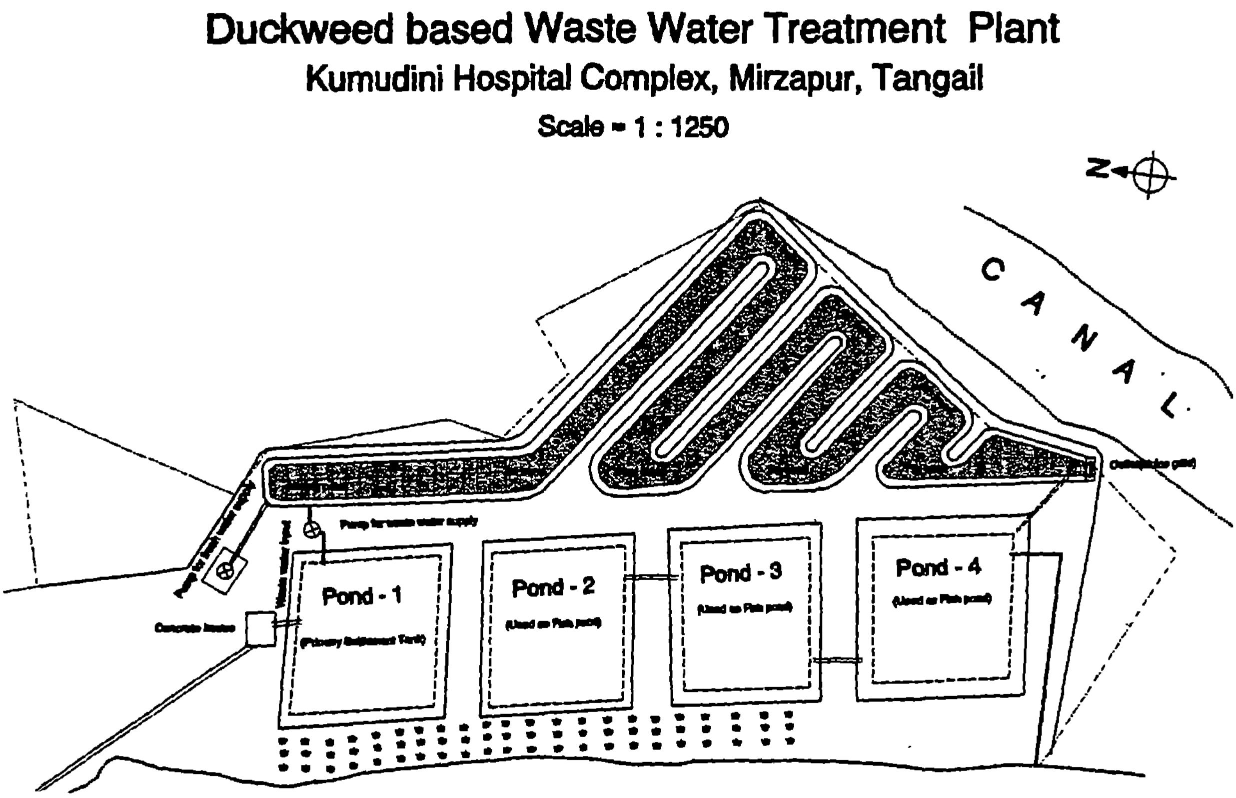

Fig 3. Schematic diagram of the KHC wastewater and aquaculture system

4.2 Validation of past experience

With the operation of the KHC duckweed based wastewater treatment and aquaculture system, PRISM has accumulated now almost 7 years of continuous operational experience. Over the years, the performance of the system in terms of treatment efficiency, duckweed production and fish yields improved steadily The wastewater treatment efficiency, as judged from the considerable set of data collected by PRISM over the years, is excellent, with average removal efficiencies for BOD, N and P, and fecal coliform, of 90-97%, 74-77%, and 99.9% respectively. Figure 4 provides a visual impression of the water quality of samples from different locations in the plug flow system

The effluent from the system is re-used for topping of the 0.6 ha adjacent fish ponds The quality of the effluent (<100 FC/100ml) is such that it could be applied in any form of irrigation. The effluent is also suitable for re-use in aquaculture (WHO guideline for aquaculture is 1000 FC/100 ml). In fact, a high treatment efficiency was already observed at about 60% of the length of the plug flow pond, which suggests that the system is over-dimensioned. Further studies are suggested to optimize pond design and operation

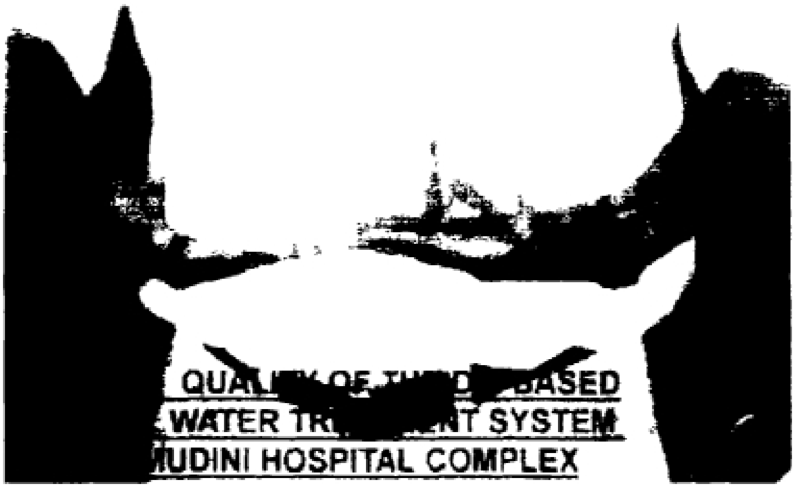

Fig. 4. Visual impression of water quality of samples taken from different locations from the pond, including influent (far left), and effluent (far right).

Under the above conditions the wastewater treatment system yielded an average amount of duckweed between 220 to 400 mt fresh weight (7.8% dry weight) per ha per year (about 17 to 31 t dry weight/ha.y). Fish production from the system was in the range of 10 to 15 t/ha.y

Sometimes doubts were raised by experts with respect to the high duckweed and fish yields obtained in the system. Under the Duckweed Research Project (1996/1997), a detailed validation of the operation, analyses and data processing of the KHC duckweed facility was performed (Duckweed Research Project, doc.2, Scientific and Technical validation of PRISM duckweed activities). The validation document indicates that:

- Duckweed yields are realistic. The per ha per year production is similar to that reported in literature by other authors. The conditions in KHC are almost ideal for duckweed production, because there is a continuous supply of nutrients, an ideal temperature and humidity, and good solar radiation almost all year through;
- Fish production was relatively high due to two factors: a) continuous harvesting, and b) combined feeding of duckweed with supplementary fish feeds (oil cake and wheat bran);
- Detailed material balances were made to calculate feed conversion ratio (FCR), N. P conversion, confirming that reported yields indeed were valid.
- The audited records of prism were checked and found correct, and these confirm that the reported duckweed and fish yields at KHC site indeed have been realized.

For more detailed information, the reader is referred to the validation reports produced by The Duckweed Research Project (reports no.2 and no.3). The treatment efficiency of the duckweed pond was validated by Alaerts *et al.* (1996).

4.3 Financial evaluation of the KHC system

Under the Duckweed Research Project, the financial performance of the KHC system was assessed. The report entitled 'Economic feasibility of duckweed based fish production: a few case studies' (Duckweed Research Project, report no.8), concludes that the per ha gross margin of the system amounted to 220,000Tk in 1995 and 290,000 TK in 1996. The report further states that "Accrual of such high level of gross margin from duckweed based aquaculture was possible due to high yields of fish". The calculations in the above report show that a number of cost factors were not taken into account, while yields were expressed per area of water surface only. Therefore the calculated results seem too positive. Financial evaluations should be based on the actual area requirement, including the land surrounding the water bodies. Below a more realistic calculation of the financial performance of the system is presented.

The results for the last 5 years of operation are summarized in Table 2. The details for the calculation of the above results are presented in Annex 4.

Table 2. Summary of audited accounts KHC duckweed-based wastewater treatment system and aquaculture (amounts in Taka; 1US$ = 48 Tk, 1999)

	1993	1994	1995	1996	1997	5 year average
Recurring operational cost	264,516	277,908	292,249	306,768	327,106	293,709
Total income from sales	157,378	288,200	355,109	451,431	475,382	345,500
Operating profit	-55,707	63,100	117,287	200,810	206,725	106,443
Net profit before taxes	-107,138	10,292	62,860	144,663	148,276	51,791

Note: 1993 was the system construction and start-up period

In the fourth and fifth year of operation the system generates a net profit of almost US$ 2,000 per ha/y. For comparison, the maximum net profit for rice production in Bangladesh can be estimated at 1000 to 1400 $/ha.y.

The internal rate of return (IRR) and other financial ratios for the KHC wastewater treatment system were calculated, assuming realistic investments were made for land cost, construction and operational costs. Table 3 presents an overview of various financial ratios for the system.

Table 3. Financial ratios for the KHC duckweed-based wastewater treatment and aquaculture system

Financial ratio	1993	1994	1995	1996	1997
Gross profit to sales ratio (%)	(51 3)	13.2	26.0	38.9	38.2
Net profit to sales ratio (%)	(69.7)	(1.8)	13.3	28.6	27.9
Return on initial equity (%)	63.0	115.3	142	180	190
Return on investment (%)	17.3	31.7	39.0	49.7	52.3
Debt-equity ratio					32 : 68
Debt-service coverage (times)	NA	1.74	3.66	6 51	6.46
IRR (%)					25.9
Break even operation cap. (%)			67.7	43.3	

The above financial analyses show that the KHC duckweed-based treatment and aquaculture system is a profitable undertaking. The results demonstrate that it is feasible to develop a wastewater treatment system, which not only facilitates cost recovery, but also derives a net profit from the treatment process. These results are very stimulating and form the basis of further demonstration projects to be developed.

It is important, however, to note that the positive financial performance of the KHC wastewater treatment and aquaculture system, were achieved under rather favorable conditions as indicated below

- No major costs for wastewater collection and channeling were incurred, since these investments were already done by KHC earlier
- Capital investments were made available by PRISM under rather favorable terms (PRISM used Tk 250,000 from its own capital and is recovering this via the system's operating profit).
- A substantial portion of the fish produced is bought by KHC, which reduces costs for distribution and marketing
- Both partners (KHC and PRISM) have obvious interests in the effective operation of the system KHC is interested in the effective treatment and proper disposal of its wastewater. PRISM on the other hand, is interested in the effective operation of the system since it uses the system for demonstration purposes, while generating good financial returns

It is not likely that all these positive conditions will be met in other project locations, and therefore the financial performance of the KHC system should not be extrapolated directly for application elsewhere. In the absence of other full-scale examples, however, the KHC experience needs to be considered, while sensitivity analyses can provide information on the effect of changes in important system parameters (see par. 6.3). The financial data of the KHC system indicate that the combination of wastewater treatment and aquaculture has a good potential to recover a major part of the cost of wastewater treatment

4.4. Financial performance of individual components of the system

The KHC system for duckweed based wastewater treatment and aquaculture consists of two components that operate rather independently from each other The duckweed based wastewater treatment system, however, provides important feed inputs to the fish ponds in the form of duckweed biomass. This is important in recognition of the fact that most resources in Bangladesh are under serious pressure This is certainly true for animal and fish feed, which form one of the main limiting factors preventing substantial increases of national fish and livestock production Since conventional fish feeds are scarce and (consequently) prices are high (commercial carp feed is currently valued at 13 Tk/kg; rice bran Tk 9/kg; oil cake Tk 6-8/kg), the use of alternative sources of fish feed derived from wastewater becomes attractive. Although there are good reasons to combine the financial performance data for the wastewater treatment and the aquaculture component, Table 4 provides an estimate of the relative financial performance of the individual system entities

The financial evaluation presented in Table 4 indicates that wastewater treatment via duckweed based ponds is not profitable as a separate activity (meets 68% of the O&M cost) This is not surprising and it may not be expected from a wastewater treatment system The performance of this system component may be further increased if farmers are willing to use and pay for the treated effluent and if producers of wastewater are charged for the treatment. Eventually, the aim should be to recover the Tk –54360 annual treatment costs from the water consumers, but because of the special arrangements made between PRISM and KHC, this is currently not considered The aquaculture component of course is highly profitable. A similar profit might not be obtained if duckweed would not be available, because of high cost and limited availability of high quality fish feed The financial performance of the integrated system is lower than that of the aquaculture component independently, but additional incentives of the combined system need to be taken into consideration when assessing the overall economic feasibility.

Table 4. Estimated annual cost and revenue for individual components and integrated wastewater cum aquaculture system at KHC.

	DW-based WWT	Aquaculture	Integrated system
Costs			
Tot ann.op costs	130000	109000	239000
Cost of duckweed[1)]		100000	100000
Administration costs	29000	25600	54000
Revenues			
Fish sale		301260	301260
Agric.prod./fruits[2)]		39600	39600
Wastewater treatment[3)]			
Sludge and effluent	4640		4640
Duckweed	100000		100000
Operational profit (Tk)	-25360	131860	106500
Net profit before tax	-54360	106260	51900

[1)] Duckweed production was estimated at 30 t dw/ha y, 047 ha productive area, 0.5 Tk/kg fresh weight (duckweed is sold at minimum 0 5 Tk/kg in Bangladesh, which is about 7 Tk/kg dry weight)

[2)] Agriculture products are basically grown as co-crops on duckweed pond embankments for wind protection and shading of the duckweed.

[3)] Currently the producers of wastewater are not charged for wastewater treatment

For a good understanding of the potential of the combined duckweed based wastewater treatment and aquaculture system, it is important to consider also other invaluable benefits that influence the overall economic feasibility, such as reliable and constant supply of fish feed, positive effects of duckweed on fish pond water quality and fish yield, community sanitation improvement, increased food production, surface water quality improvement, public health impacts and employment generation. A detailed analysis of these benefits goes beyond the scope of the present study, but it is recommended to consider this in a separate follow up study before SCS-project implementation Such study should try to assess whether the above benefits produce sufficient incentives to accept the lower financial performance of the combined (integrated) system. In a real scale treatment facility, on the other hand, the objective should be to recover the negative financial performance of this system component from the 'polluters' (i e. community institution, and/or industries)

4.5 Financial evaluation of village projects

In addition to analyzing the financial performance of the well controlled treatment facility at KHC, also a village project was evaluated. PRISM has developed 143 village projects, all under realistic field conditions and owned and operated by the local farmers. The villagers are organized in small enterprises, with a total participation of over 1000 villagers in the 143 projects at the moment. In the villages there is no collection of wastewater and therefore latrines were constructed around selected ponds for duckweed production. Duckweed based fish production is practiced in separate fishponds

The village projects have a dual goal:

a) to stimulate aquaculture using fallow resources and duckweed feed, and
b) to stimulate latrine construction and use to support continuous duckweed production.

The emphasis in the village projects has been on objective a) and therefore, village projects should not be considered as effective sanitation programs. As a side effect, however, these projects have locally contributed to improved sanitation for individual households surrounding the duckweed ponds.

Table 5 Summary of important impacts of the PRISM village projects as judged by the UNCDF evaluation mission, June 1998 (values represent the sum of 143 projects)

Project performance indicators	Results
• Direct employment generated	1150 persons
• Land brought under production	93 ha
• Increased income from fish sales per year	Tk 17,427,500 ($371000)
• Increased income per share holder/year	Tk26,400 ($ 562)
• Increased food availability - Fish - Agroproducts	 1138 MT 515 MT
• Sanitation improvement - Latrines installed - Sanitation awareness built	 838 815 households

In June 1998, the performance of the village projects was evaluated by UNCDF (Annex 5). The most important results of the projects are summarized in Table 5 The village projects have generated better sanitation facilities for selected households in the village and have improved water quality of main water bodies in the immediate surroundings, because of reduced waste inputs into these ponds.

Some enterprises were more successful than others and some showed a negative economic performance as a result of poor management practices and other factors. Quite a number of enterprises, however, are successful and make an annual net profit from their duckweed-based aquaculture activities The UNCDF report provides valuable information on 'lessons learned' and conditions affecting the performance of village projects

For the purpose of demonstrating feasibility it was decided to select an average village project which was making a net profit. This is justified, since this is a reflection of the potential financial scope of village based sanitation and aquaculture projects Keeping this in mind, the village enterprise 'Ufulki Matsha Khamar' was selected for further financial evaluation. The project is organized in the form of a company, owned by 8 villagers. The duckweed production is based on a number of community latrine connections that are installed around the duckweed ponds The financial performance of the village project is summarized in Tables 6 and 7 Further details are presented in Annex 6.

Table 6. Audited accounts for Ufulki Matsha Khamar village project (in Taka)

	95/96	96/97	97/98	3 years average
Recurring operational cost	153,400	97,806	95,645	115,617
Total income from sales	147,210	151,100	148,000	148,770
Operating profit	25,060	80,500	80,900	62,153
Net profit before taxes	-6,190	53,294	52,355	33,153

The results show that the village operated duckweed based system is generating an interesting net profit. Important financial ratios for the village sanitation project are presented in Table 7

The village project concept is still relatively new and therefore performance may be further improved in terms of management and operation, generating even better financial returns.

Table 7. Financial ratios for the Ufulki Matsha Khamar project

Financial ratio	1995/96	1996/97	1997/98
Gross profit to sales ratio (%)	17 0	53.3	54.7
Net profit to sales ratio (%)	(4.2)	35.3	35 4
Return on initial equity (%)	25.3	81.3	81 7
Return on investment (%)	7.0	22 6	22.7
Debt-equity ratio			72 28
Debt-service coverage (times)	0 90	1.99	1.96
Break even operation capacity (%)		53 3%	
IRR (%)			20.7

The information in this paragraph indicates that there exists a very good scope for the development of duckweed based aquaculture companies, which, as a side effect, generate improved sanitation conditions for participating households

4.6 Upgrading of KHC Facilities for demonstration and research

Using the facilities at KHC, PRISM has over the years undertaken an impressive demonstration study on duckweed-based wastewater treatment and aquaculture, with numerous parameters which have been monitored in a standardized and disciplined way. The excellent infrastructure available should be exploited for the implementation of well defined research and optimization studies. The current infrastructure available at KHC provides excellent possibilities for further upgrading to a research and demonstration facility to support further initiatives (projects) in duckweed based wastewater treatment in Bangladesh and the wider region Once upgraded, the KHC demonstration facility could provide a major support function to new projects via training, demonstration, analyses and monitoring, and for applied research. In order to assume these functions, the facilities require upgrading and a laboratory for analyses of routine monitoring parameters and research should be established Equipment for specialized analyses, such as for example amino acid composition or pesticides, should not be installed in the laboratory Such specialized analyses can be out-contracted to laboratories elsewhere in the country.

Annex 7 provides a short description of proposed facilities and costs involved for the upgrading of the present center to a 'Duckweed Demonstration & Research Station'. The source of financing for the upgrading of the laboratory needs further consideration In case a bi-lateral agency is interested to support this component of a larger duckweed based wastewater treatment effort, arrangements could be made directly with KHC and PRISM. In case the laboratory will be upgraded as part of a (WB) credit to GOB, clear inter-institutional arrangements need to be made between DPHE and KHC/PRISM One of the options is that KHC/PRISM takes up the loan, while a service contract with DPHE will be signed. The institutional arrangements need to be worked out further during project preparation

5. PROJECT SITES

5.1 Selection of project sites

The TOR defines that 10 sites should be selected with large volumes of wastewater, in different environmental settings, and with good potential for developing demonstration scale duckweed-based wastewater treatment technology linked with safe aquaculture From these 10 sites a further selection of 5 sites should be made for the development of prefeasibility level reports In the present study actually 14 sites were identified for socio-economic survey and environmental audit, after which finally the 5 most potential sites were selected.

The methodology to select finally 5 sites for prefeasibility analyses included the following steps, with corresponding objectives:

- Rapid appraisal: To identify 14 potential sites in 7 areas (thanas) of 5 districts for the implementation of a detailed socio-economic survey and environmental audit.

- Socio-economic survey To collect important socio-economic information from identified project sites, to be used in the further selection of 5 project sites and for pre-feasibility assessment

- Environmental audit: Same objective as for socio-economic survey, and to get an impression of the quality of selected water bodies in each site.

- Selection of 5 sites. To select from the 14 surveyed and audited sites the 5 sites which show the highest potential for duckweed-based wastewater treatment and aquaculture

- Prefeasibility analyses. To prepare pre-feasibility reports for the 5 selected sites

The process for site selection and pre-feasibility analyses of 5 selected sites is summarized in Table 8. The criteria used in the different selection steps are presented in Annex 8

Table 8. Project area and site selection process

election process steps	Criteria / Indicator	Activities / Methodology
1. Selection of 5 districts representing different micro-environments. **2.** Selection of 7 potential thanas in 5 districts	Applied General selection criteria A.	· Publication of BBS (Bangladesh Bureau of Statistics), reports & literature. · Data collection from Thana statistics office, Thana level Departmental offices & BBS. · Visit & consultation with Thana statistic offices, Agriculture offices, Thana administrative officers, PSVA officers & Departmental staff
3. Identification & field assessment of 93 potential project sites in 7 Thanas	Applied general selection criteria A + indicators B	Thana visits & Rapid Appraisal at field level by surveyors & consultant team. Based on results of Rapid Appraisal findings, consultant's selection confirmation of 6 thanas. Identification & field visit of 93 potential sites in 7 thanas during Rapid Appraisal. · Collection of field data based on 25 indicators Selecting 23 sites with minimum score of 75 · Selection14 sites meeting all site selection criteria.
4. Selection of 14 potential sites in 6 Thanas	Applied primary selection criteria C.	Conducting Socio-economic Survey of 14 sites using household, Industrial & school questionnaires. a Adjacent community 699 household survey b. Survey of 34 Industries at sites c Survey of 57 schools at sites. d Survey of 18 Hat/Bazaar at sites. Environmental audit & field water quality data collection & measurement. · Processing & analysis of data · Preparation of Socio-economic survey report. · Preparation of Environment audit report

5. Final selection of 5 highest potential sites for Duckweed based waster water treatment system installation **6.** site pre-feasibility report preparation	Final selection criteria D.	· Selection of 5 sites with highest potential based on all the criteria and survey findings. · Preparation of pre-feasibility for 5 sites using findings of socio-economic survey & environment audit

Criteria A = General selection criteria
Criteria B = General selection criteria + Indicator
Criteria C = Primary selection criteria
Criteria D = Final selection criteria

An important selection criterium for the final selection of 5 sites with highest potential was the existence of waste collection and transport infrastructure This reduces the need for project investments to be channeled to expensive drain or sewer construction (see par. 6.1).

5.2 Socio-economic Survey and Environmental Audit

Five districts and seven thanas were selected by the consultants on the basis of a set of general selection criteria as defined in Annex 8. The identified potential areas were surveyed using a questionnaire for rapid appraisal. Via the rapid appraisal 14 sites were selected for further studies The results of the rapid appraisal are presented in Appendix I

Table 9. List of selected 14 sites for the pre-feasibility studies.

No.	Name of Site	Village	Union / Ward	Thana	District	Score (%)	SC
1	Savar Unv College Complex (SUC- 01	Shaopara	Savar PSVA	Savar	Dhaka	8	4
2	Savar Dairy Farm & BLRI Complex (BLRI – 05)	Savar	Savar	Savar	Dhaka	7	5
3	Kona Bari Dusta Shisu Kallyan Rehabilitation complex (KBD-07	Kona Bari	Kona Bari	Gazipur Sada	Gazipur	7	4
4	Baniarchala Orphanage (BO-08	Baniarchala	Mirzapur	Gazipur Sada	Gazipur	8	4
5	Earshad Nagar Basti (ENB-09)	Tongi	Tongi PSVA	Gazipur Sada	Gazipur	7	5
6	Zalpar & Zeem's Khal (Paekpara) (ZZK-10	Deobhog	Deobhog	N ganj Sadar	Narayangan	7	4
7	Isdair Basti Canal - (IBC-13)	Isdair	Fatullah	N ganj Sadar	Narayangan	8	5
8	Ispahani & Arseen Canal (IAC-14	Kadamrasul PSVA	Kadamrasul PSVA	Bandar	Narayangan	7	4
9	TNO office & School Complex (TOS-15	Kalagasia	Kolagasia	Bandar	Narayangan	7	4
10	Korotia College Complex - (KCC-16)	Korotia	Korotia	Tangail Sada	Tangail	7	3

11	Kumudını Gırls College Comple (KGC-17	Tangaıl PSV	Tangaıl PSV	Tangaıl Sada	Tangaı	7	4
12	CPP outlet to Garında beel - (CPP-19)	Garında	Garında	Tangaıl Sada	Tangaıl	7	5
13	Saıdpur PSVA Vagar- (SPV-22)	Kundol	PSVA	Saıdpur	Nılphamar	8	4
14	Nıamatpur Zora Pukur- (NZP-23)	Nıamatpur Munsıpara	PSVA	Saıdpur	Nılphamar	7	3

[1)]Surveyers Comment

The 14 sites selected via the rapid appraisal were re-visited with specific questionnaıres for the socio-economic survey and environmental audit As part of the environmental audıt also the quality of a number of selected water bodies and waste streams were assessed via sampling and analysis. The results of the socıo-economic survey and environmental audit were checked agaınst a set of defined selectıon critena (Annex 8). The outcome of this exercise ıs summarızed in Table 9.

5.3 Selection of five project sites

On the basıs of score and practıcal consıderatıons (see Table 10), five project locations were selected for pre-feasibility analyses. Some sites wıth high score percentage were not selected, because of practical reasons, such as complex ownership of land and water bodies, land availability, or difficult access to the site These consıderations are discussed ın Appendix II. A brief description of the 5 sıtes ıs presented in par. 6 For further details on these sites, the reader ıs referred to Part II and to the Appendices II and III.

Table 10 Proposed five sites for pre-feasibility analyses.

#	Name of site	Code	Status & Score%	Remarks
1	Ispahanı & Arseen Canal	IAC - 14	Suıtable (76%)	Domestıc waste water (WW) from household, school, market and paurosova (PSVA) areas, Ispahanı slum ıs avaılable almost throughout the year ın a zıgzag channel wıth the facılıty to release excess or treated water ın the Shıtalakha rıver WW treatment facılıty , Duckweed (DW) based pıscıculture avaılable, Socıal acceptance good, lagoon and fish pond can be leased from Dept of food Exıstıng local fish culture group can be ınvolved ın the project
2	Isdaır Bastı Canal	IBC - 13	Suıtable (85%)	Domestıc WW, WW treatment facılıty, DW based pıscıculture facılıty avaılable Health and sanıtatıon condıtıon of the slum dwellıng population ımproved Group approach for the project ımplementatıon wıll be effectıve Improved latrıne system can be ıntroduced Dıversıfied DW based productıon system can be ıntegrated
3	Savar Daıry farm & BLRI complex & JU	BLRI - 05	Suıtable (79%)	WW from lıvestock farm and educatıon Instıtute could be ıntroduced ın a sıngle system DW productıon lagoon retentıon tank, analytıcal laboratory, enough space and communıcatıon for demonstratıon purpose ıs excellent

				Partly collection system for WW should be developed
4	CPP outlet to Garinda Beel	CPP - 19	Suitable (76%)	Domestic WW from PSVA areas through well-built channel system is available Partly channel system and treatment system need to be developed Health and sanitation condition of the peri-urban city dwellers will be improved Kumudini Girl's College (KGC) can be integrated with CPP as diversified source of DW production and Duckweed based pisciculture
5	Saidpur PSVA Vagar	SPV – 22	Suitable (80%)	Partial wastewater collection system exists Partly channel system and treatment system need to be developed Health and sanitation condition of the people of the project areas will be improved

6. PRE-FEASIBILITY OF FIVE PROJECT SITES

6.1 Assumptions and conditions

The pre-feasibility analyses for duckweed based wastewater treatment and aquaculture in five selected project sites is presented in par. 6.2. This analysis addresses both financial, technical, social and environmental aspects. For the financial calculations, a number of assumptions had to be made. In the absence of other full-scale systems, some assumptions were derived from the experiences of PRISM with the KHC treatment system. The KHC system is operated under rather favorable conditions, and therefore performance in other locations may be less optimal A preliminary sensitivity analysis for some crucial parameters, affecting overall financial performance of the system is therefore presented in par. 6.3. These parameters include fish price, fish yield, price of fish feed, and land lease costs (par. 6 3).

This paragraph describes some of the conditions and assumptions used in the pre-feasibility analyses. The detailed financial assumptions used for calculations are presented in Annex 9.

Wastewater collection and transport
The cost of wastewater collection and transport (sewer) is usually much higher than that of the final treatment itself. The sewer infrastructure forms a major cost component of a complete domestic water service scheme, which includes water supply, wastewater collection, wastewater transport, wastewater treatment and final discharge In Bangladesh only Dhaka and Chittagong are sewered, while currently low cost drains are constructed in a number of towns via bi-lateral and multi-lateral projects (see par 2.2). The construction and sustainable operation of sewers and drains in Bangladesh will only be achieved if the government can realize substantial cost recovery from the communities, institutions and industries, which use water. Similar cost recovery mechanisms need to be developed for wastewater treatment as well. The valorization of components in the wastewater (nutrients to fish) could be an attractive additional option to recover part of the overall system costs

It is important to note that the feasibility analyses presented in par 6.2 did not include investments for sewer infrastructure, but rather has focussed on improved collection and the treatment process itself. The assumption is that wastewater collection and transport infrastructure need to be installed anyway, under whatever option. Since this infrastructure will not be immediately available, an important criterium in the site selection was the existence of waste collection infrastructure (though often informal via natural drains). For the five sites identified, duckweed based wastewater treatment systems are proposed at the final wastewater disposal (outfall) sites. The scale of the proposed systems is limited and therefore only a portion of the total waste accumulated and produced at the sites will be connected to the duckweed system. For each site, therefore, limited investments have been indicated for improvement of the existing system for collection of wastewater and connection to the treatment facility.

Most of the sites only have domestic wastewater mixed with municipal waste. For sites where industrial wastewater is combined with the main flow of wastewater, detailed analyses of the main contaminants will have to be performed. In case toxic compounds are detected, separation and pre-treatment measures at source need to be defined in close consultation with the involved industries. Costs arising from separation of waste streams are not taken into account in the current financial calculations of the system costs.

GOB legislation and wastewater treatment charges
As indicated above, wastewater collection, transport and treatment should be considered in combination with the overall water services to households, industries and institutions It is GOB policy to recover costs for sewerage and wastewater treatment from water users. In the cities where piped water supply and sewer infrastructure exists, a municipality tax is being levied from households. Besides large scale 'illegal connections', many households do not have a holding number and therefore are not charged, resulting in a poor overall cost recovery.

Where no sewer infrastructure is available, the situation is even worse and much more complicated Industries and households extract water from wells and discharge the wastewater in the open in an uncontrolled manner. Recent legislation has categorized industry according to their manufacturing process and waste discharge. Also an environmental assessment program has been instituted for new industries, requiring GOB approval Nevertheless, implementation is slow and enforcement is poor The willingness of households and industries to pay for wastewater treatment should be evaluated by providing transparent information on costs versus benefits of treatment. A WTP assessment has not been undertaken for the five selected sites as part of the present study This should be done via a separate assignment as part of further project preparations

Land lease
The rapid appraisal revealed that land costs in the thanas surveyed ranges from 0 1 to 40 million Taka per ha. The costs at the higher end represents prime building area, while the lower end is representative of marginal land. One of the criteria for the selection of project sites was easy access to marginal land near the present wastewater disposal site The sites selected for pre-feasibility analyses are all located at the final disposal points and surrounding land area therefore has currently little value. This is not true for BLRI, but this institute has offered part of their own land for system development The estimated land lease cost of Tk 12,000 per ha

per year therefore seems realistic for all five sites. The main contribution by the project participating community and institutions is land, and therefore, exact land cost for each site need to be evaluated as part of project preparation

Fish prices and fish market

For the financial calculations presented in par. 6.2, the wholesale price for fish was assumed to be Tk. 50/kg This is Tk 10/kg lower as compared to the current (1999) wholesale price for fish sold at the KHC system. The actual market price of fish will depend on a number of factors including fish species (Rohu and common carp is high priced, while silver carp is low priced), fish size (bigger fish fetches a higher price per kg), and consumer perception (wastewater derived fish may fetch lower price, although we have no indication for this). The retail sale price of fish in Bangladesh is minimum Tk 80/kg to Tk 150/kg, even at village level. Only very small mixed type of local fish fetches a lower retail price of between Tk. 60 and 80 per kg. Prices of essential food items as printed in the daily newspaper on regular basis also indicate similar price levels for fish. Wholesale price of fish appears to be about 30% below the indicated retail price level. The average price assumed for calculations takes all this into consideration and seems to be a rather conservative estimate of actual price levels for fish in Bangladesh Besides, fish prices in Bangladesh have increased sharply over the past years at a rate of 6-10% per year. In par. 6 3 sensitivity analyses are presented for variations of fish price levels

The development of duckweed based wastewater treatment and aquaculture projects will, if successful, eventually lead to local increases in fish production. In a stable and saturated market this may cause fish prices to drop, and therefore would negatively affect the financial performance of the duckweed-aquaculture system The market in Bangladesh, however, is far from stable. Analysis of trends in the fish market shows huge annual deficits in fish production, and current production only satisfies a fraction of the domestic demand. It is therefore anticipated that the projected increases in fish production will be readily absorbed by the market, without causing distortions of the fish market Attention to prevalent fish market and fish prices should be given during project preparation and project implementation.

Cost of fish feed

The supply of good quality fish feed in Bangladesh is unreliable and prices vary widely depending on season and availability. Oil cake and (wheat/rice) bran are used mainly by the poultry and animal raising sector Rice bran is therefore hardly available in the market and prices go up to 9 Tk/kg. The price of oil cake ranges between 6 to 8 Tk/kg depending on availability and season. High quality commercial carp feed costs about 13 Tk/kg The duckweed based wastewater treatment system provides important feed inputs to the fish ponds in the form of duckweed biomass. In some regions in Bangladesh duckweed is recognized as a valuable fish feed and is harvested from natural water bodies and sold in local markets for at least 0.5 Tk/kg fresh weight (7-9 Tk/kg dry weight).

Fish yields

The experiences over 10 years at the KHC system have shown that fish yields as high as 15 tons per hectare per year can be obtained Nevertheless, the yield has not been so high during the first years of operation and apparently there has been a 'learning experience' to achieve high yields in the range of 12 to 15 t/ha.y The experience by PRISM should be made available to the demonstration projects, and therefore we consider a fish yield of 12 t/ha y feasible. Nevertheless, in par. 6.3 we have projected the effect of lower fish yields on financial performance

Financial performance of integrated system versus system components
For reasons explained in chapter 4, the financial performance of the combined duckweed based wastewater treatment and aquaculture system was analyzed Calculation of the performance of individual system components shows that the wastewater treatment system will make a net loss, while the aquaculture component produces substantial profits. The combination of both system components, however, yields a net profit. Eventually, the wastewater treatment component will have to reach a break even situation via charges to wastewater producing households and industries. This would make the combined system as attractive as a stand alone aquaculture enterprise The main justification for combining the two system components is based on the best resource recovery option and on acute shortage of alternative fish feeds (see chapter 4).

Interest rates
In the pre-feasibility assessment we have considered interest rates of 7% for fixed capital and 9 5% for system operation and maintenance working capital The fixed capital rates have been proposed based on Libor rate of international borrowing. It is not realistic to use commercial interest rates offered by national banks for infrastructure development projects. The rate applied for working capital is similar to the commercial agricultural credit rate in Bangladesh.

6.2 Pre-feasibility analyses of five selected project sites

6.2.1 *Bangladesh Livestock Research Institute (BLRI)*

Site identification and description
Bangladesh Livestock Research Institute (BLRI) is the national research institute for livestock and poultry development. The institute has a 200 ha farm with good infrastructure, research facility, laboratory and scientific personnel residing in the institute premises. The institute conducts action research and operates a trial cattle and poultry farm Adjacent to BLRI on the western border is the Jahangir Nagar residential university (6000 students), on the southern side Savar diary farm, and on the north - eastern side the villages of Panchutia, and Chhiata representing typical rural area. The institute has a residential staff population of 300 The adjacent community of residential Jahangir Nagar University, Savar Diary Farm and the villages presents a potential good site for duckweed based wastewater treatment system and utilization of system by- products. BLRI is located on the Dhaka-Aricha Road 40 km away from Dhaka City and represents a peri-urban location adjacent to Savar Pauroshava (PSVA). The detailed site map in Annex 10 indicates the surrounding environment, location of human habitat, schools, water sources, industries, roads, and important wastewater collection system. In the initial evaluation of site selection criteria, BLRI achieved a score of 80% for the 25 indicators used Potential availability of land is good though the land prices are relatively high.

Socio-economic survey

Savar Thana is located in the north of Dhaka district and represents a micro eco-system with high dry land, broken grounds and red clay soil. The Thana is generally flood free and primarily consist of rural farmland with low percentage of built-up area. The Thana has a large number of industries and business establishments and practices modern farming. The general infrastructure like telephone, electricity, water supply is fairly developed with good communication links The net cropping area is estimated at 46,000 acres, forest area is 2600 acres and cultivable land is 24700 acres The Thana has an estimated population of 55000 cattle and 5000 goats and about 4000000 poultry birds Savar Thana operates 800 small and medium chicken farms 5 beef fattening and 40 milk production units of varying sizes The Thana has about 1200 ponds with a total area of 435 acre but fishery is practiced only in 56% of the pond There are 912 derelict ponds available presently lying pre-dominantly fallow Savar Thana has an estimated 20000 sanitary latrines with 45% population sanitation coverage. 35% of total employment is in industry, 20% in business, 20 % in services and 20% in agriculture.

Savar is composed of 15 unions, 386 villages and has a population of 387000 and an average household size of 5 6 members. 71% of the population is literate, 27% of the adult population is employed, 12% unemployed 35% are students and 24% housewives. The major occupation at 12% was services followed by 6% in business and 4% in agriculture only. Average land holding per household was found to be 71.5 decimal and the major portion is under cropping. One third of the households/family owned cattle and a similar percent owned chicken, 25% use the animal waste as fuel and 35% are using it as fertilizer. Straw, green grass, rice bran, wheat bran and oil cake were the major animal feeds used but these were available only in limited quantity Ownership by household of ponds and ditches was only 10 % and 8 % respectively. Almost no formal fish farming is practiced. 60% of the households had an annual income in the range of Tk. 41,000 to 100,000. 21% followed in the range of 21000 to 40000 and 16% above Tk 100000.

Water supply situation of the Savar area is very good with 98 % coverage. The attitude of the community at Savar regarding solid waste and wastewater management was found to be excellent A summary of the socio-economic survey findings is presented in Annex 11.

Environmental audit

General The environmental audit for the site was conducted at BLRI complex, Jahangirnagar University, Savar dairy farm & adjacent Panchutia / Chhiata village communities. The waste and wastewater in the area primarily consist of cattle and dairy farm waste, domestic wastewater and partly institutional (University) wastewater The quantity of wastewater generated is large due to high water consumption. The wastewater is primarily organic in nature. Both solid waste and wastewater in the area are partly collected as there is a formal collection system available and wastewater is used both for Duckweed production and aquaculture by BLRI. BLRI is operating a demonstration duckweed based wastewater treatment system and conducted a series of duckweed feeding trials for fish, cattle, duck and chicken Further improving wastewater collection potential is good, especially from the two cattle and dairy farm sources. The BLRI site sanitary latrine coverage and water supply coverage is high and residential domestic wastewater is mostly connected to septic tank. The wastewater quantity estimation was based on population and wastewater generated by the farms. The site has a number of water bodies very suitable for aquaculture. People interviewed showed high awareness on environmental problems and are keen to participate in waste and wastewater management. Infrastructure facilities like land, electricity, water supply, quality laboratory facilities and animal/aquaculture facilities etc are existing. The site could be effectively utilized as a main research and demonstration center for the project.

Estimate & Measurements of wastewater at site. The primary sources of wastewater at BLRI are cattle and dairy farm, educational institution sewage and domestic wastewater. The type of wastewater is assessed as organic and agriculture in nature. The type wise quantity, percentage composition of wastewater and their sources at BLRI site is estimated as shown below from the qualitative and quantitative data collected during environmental audit (Annex 12, 13 and 14).

- Wastewater volume accumulated in derelict water bodies at sites = 4200 M^3
- Total wastewater generated around site (2 Km^2) = 3100 M^3/day

Source	***Quantity estimation***	***Percentage***
Domestic wastewater from population	51442 Tr./day	2 %
Sanitation/sewage wastewater by Schools & Institutions	1,000,000 Lt /day	48 5 %
Wastewater by cattle/dairy farms	1,000,000 Lt /day	48 5 %
Wastewater from Hat/Bazaar	20,000 Lt./day	1 %

Availability of domestic wastewater was observed as one of the highest amongst the 14 sites surveyed/audited. A concrete collection system for wastewater exists in all the institutions adjacent to the site, except the villages where wastewater is disposed in the derelict ponds and surrounding area. The large volume of institutional wastewater is connected to a septic tank and treated.

Measurements of water quality and assessment through observations were made in the derelict water bodies at the site. The water quality measurements indicated high BOD and suspended solids Absence of any industry close to the site suggests that contamination from chemical and toxic waste is negligible Duckweed was observed to grow in BLRI system in abundance and sustained year round high yield indicating adequate availability of basic nutrients. The water quality measurements and observations for the site are presented below.

water quality measurements			**E. Audit observations**	
Locations	BLRI	U Pond	Location	BLRI/JU
PH	5 22	6 0	Turbidity	Medium
BOD	240 mg/l	10 mg/l	Organic content	High
TSS	1584 mg/l	6 mg/l	Fecal contamination	Medium
TDS	900 mg/l	650 mg/l	Waste input	Medium
DO	1 mg/l	2 mg/l	Smell	Moderate
N Tot	89 6 mg/l	8 4 mg/l	Wastewater color	Black
P Tot	4 7 mg/l	5.3 mg/l	Level of Arsenic count	Very Low
Fecal coliform/100 ml	0 85 x 10^5 cfu	0 03 x 10^5 cfu		
Total coliform/100 ml	3 10 x 10^5 cfu	0 62 x 10^5 cfu		

The domestic and residential wastewater is collected and treated in septic tanks. Animal wastewater from the cattle farms are partially collected and the rest utilized in the surrounding agriculture land or over flows in the adjacent derelict water bodies.

Wastewater treatment facility Proposed. The BLRI site represents an ideal situation for duckweed based wastewater treatment system and aquaculture application from the point of view of availability, composition and collection of wastewater Because of plenty of land availability, excellent infrastructure and high potential of resource reuse for aquaculture and animal production at BLRI site, excellent opportunities exist to establish a commercial scale duckweed wastewater treatment system. The present system at BLRI could be expanded to develop a scaled up duckweed based wastewater treatment system for demonstration and research. The design parameters were selected for a system representing 1.5 millions liter/day capacity:

- Total system treatment capacity = 1 5 million liter/day
- Organic & domestic waste of high BOD = 130-500 mg/L
- Land required for DW system construction = 2 5 hector
- Wastewater collection system = 50 % existing, (50% to be constructed and septage to be collected from staff household/residents)
- Cattle & Poultry population = 2200 + 6000
- Population/household connected = 2000

Type of Treatment facilities proposed consists of secondary earthen lagoons/plug flow system with primary anaerobic/oxidation clay lined pond & continuous flow through. Biogas plants are also proposed as pre-treatment of wastewater collected from animal farm. Effluent water reuse has been considered for agriculture irrigation and aquaculture. Duckweed produced from the wastewater treatment will primarily be used as fish feed for pisciculture and as ingredient for poultry and animal production trials. The design assumptions and specifications for the wastewater treatment system at BLRI is shown in Annex 15.

Resource recovery systems. Considering the availability of aquaculture and animal farm facilities at BLRI site the following options for reuse of duckweed and treated effluent are proposed. The treatment system output is estimated at (a) duckweed production = 30,000 Kg/Yr. (dry weight) and (b) Treated effluent 1,000,000 Liter/day (c) Composted sludge fertilizer = 15,000 Kg/year.

- Duckweed fed Pisciculture in 2 75 ha. water bodies - existing (use 75 % of Duckweed)
- Animal & poultry production trials - existing (use 25% of Duckweed)
- Agriculture land for co-cropping = 1 ha
- Treated effluent used for agriculture irrigation and aquaculture
- Sludge composted & treated as agriculture fertilizer - sludge drying bed and composting facility to be developed

Wastewater treatment system construction cost

Referring to the financial assumption for the duckweed based wastewater treatment system construction as shown in Annex 9 and applying the design criteria and parameters mentioned in the foregoing paragraph the construction cost of proposed duckweed based wastewater system was estimated as follows.

I. Estimates of system construction cost

a) Collection improvement and pre-treatment = Tk. 350,000.-

b) Primary treatment/settlement tank = Tk. 265,000 -
c) Secondary plug flow pond = Tk.1,588,000.-
d) Equipment, machinery and supplies = Tk. 655,000 -
e) Design construction supervision and start up = Tk 400,100 -
Total system construction and installation costs **= Tk.3,258,100.-**

II. Annual Operation and maintenance cost

a) Salary & wages = Tk. 162,000 -
b) Field supplies = Tk 302,500 -
c) Repair and maintenance = Tk. 60,000.-
d) Fuel & utilities = Tk 50,000.-
e) Land lease cost (@ Tk 12,000/ha/Yr) = Tk 60,000.-
f) Travel and transport = Tk 10,000.-
g) Management Overhead and TA = Tk 64,400.-
Total operation and maintenance cost per year **= Tk. 708,900.-**

III. Projection of Sale revenue from Aquaculture/production(5th year)
(Annual duckweed production = 30,000 kg dry weight/ha)

a) Revenue from fish sale = 2.75 ha x 12 tons x Tk. 50,000 = Tk.1,650,000.-
b) Agriculture Co-crop sale = Duckweed co crops + trial livestock = Tk. 100,000.-
c) Miscellaneous sale = Tk. 22,000.-
Total revenue earned from project operation **= Tk.1,772,000.-**

IV. System depreciation (15 years @ 6.6%) **= Tk. 211,500.**
V. Debt-servicing (interest on fixed and working capital) **= Tk. 162,100.-**
VI. Financial Analysis

- Project earning forecast (in Taka)

Year	Year 1	Year 2	Year 3	Year 4	Year 5
Utilization rate	75%	80%	85%	90%	100%
I) Sale revenue	1329000	1417600	1506200	1594800	1772000
ii) Direct operation cost	531675	567120	602565	638010	708900
iii) Depreciation	211500	211500	211500	211500	211500
iv) Debt-servicing (interest)	153250	155020	156790	158560	162100
v) Operating profit	797325	850480	903635	956790	1063100
Vi) Net profit before tax	432575	483960	535345	586730	689500

- IRR (Internal Rate of Return) = 21.9%
  NPV 20% 256326
  NPV 25% (371053)

- Break-even Analysis
  a) Sales Revenue (based on 5th year of operation) = Tk 1,772,000.-
  b) Total production, administrative, selling and financial expenses = Tk. 1,082,500.-

- Break-even sales in Taka = (Fixed cost /PV ratio) = Taka 886670 = 50% of utilized capacity

Financial ratios:

Gross profit to sale %	60%
Net profit to sale %	39%
Return on investment	54%
Debt service coverage (Times)	2.85
IRR	21.9%

Overall feasibility analyses

Analysis aspects	*Score*	*Remarks*
1 Primary & secondary site selection criteria	79 %	Found very suitable site using 25 indicators meeting most of the critical selection criteria
2 Socio-economic survey results	97 %	Savar represent typical peri-urban condition and BLRI a national research & training institute Population consists of higher educated & income group The majority of the Socio-economic indicators are positive and favorable
3 Environmental audit survey results	75 %	Availability and collection of wastewater (organic and domestic) at site is high Represents a distinct microenvironment Potential for treatment & reuse of wastewater very high
4 Overall assessment based on the findings of the Socio-economic survey & EA	97 %	Obtained highest score for the overall assessment amongst the 14 sites Refer to Annex-XXIII
5 Participation of the Institutions	Excellent	The Institute (BLRI) is very interested to participate in all respect and have demonstrated active interest in the project development process Potential linkage with local Govt , MOFL, Administration and other GOB organizations considered high
6 Logistic & facility availability	100 %	Excellent accessibility being located on the main Dhaka-Aricha high way- close to GOB administrative center Electricity, water supply, laboratory facilities, internal roads, physical facilities excellent & reliable
7 Land availability & opportunity cost	Excellent	The BLRI itself owns 500 acre of farmland, adjacent JU has 800 acres & Savar dairy farm has 700 acres Aquaculture resources are available (presently under utilized) Though located next to the Savar PSVA considering the future continuation of the research cattle/dairy farms only a fraction of the land has potential commercial application thus opportunity cost of land is considered low at BLRI site
8 Assessment of potential impacts	80 %	High in terms of demonstration, technology dissemination, research and national capacity building Resource recovery potentials very high could be developed as a commercial business Excellent Community participation in wastewater management and considerable environmental sanitation impacts Spin off and replication in surrounding areas expected
9 Public health consideration		System proposed in a distinct defined area & for Organic/animal farm wastewater poses minimum exposures threat to the community or the workers The system will further improve collection/treatment & prevent dispersal of wastewater in BLRI campus Positive improvement of water quality in the surrounding water bodies
10 Financial feasibility	IRR 22%	Financial performance ratios satisfactory Has excellent potential for commercial scale operation producing protein, employment & income for the community
11 State of preparedness	Excellent	BLRI management is keen on participating as an active partner in the project & offers their existing facilities for the same Experimental scale duckweed wastewater treatment system, aquaculture ponds, waste collection system already exists at site and can be immediately used for project implementation
12 Investment required to install system	Viable	Cost estimates indicate investment requirements are within viable range BLRI is in agreement to make investment in terms of land, physical facilities and production systems Cost saving due to existing pilot treatment facilities

Institutional arrangements

Institutional arrangements proposed for the BLRI site for ownership, technical assistance, operation/maintenance and implementation of the wastewater treatment including adjacent community involvement are as follows:

- *Project implementation agency* will be responsible for design and development of the final wastewater system to be constructed at BLRI through their technical assistance and extension services. Supervision of construction and installation of the systems and training would also be provided by the implementation agency. Co-ordination among all involved agencies and communities including information exchange and monitoring would be the task of the implementation agency.
- *BLRI and adjacent community:* BLRI would be the owner of the Duckweed wastewater treatment system. They will be responsible for sustained operation and maintenance of the system and for commercial success of the project. BLRI will be responsible for conducting action research on potential Duckweed technology application and develop replicable production models for the farmers of the country. They will also act as the service center for information dissemination, training and technical assistance to the community and at the same time act as the focal point for the GOB and administrative agencies for Duckweed based wastewater system.
- *Funding agency:* The funding agency for the project would be responsible for providing the necessary inputs for the project according to a project agreement signed with GOB agencies. External technical assistance to the project if needed will also be ensured by the funding agency. Project development & final agreement with the GOB will be their responsibility.
- *GOB:* The Ministry of Environment & Forest (MOEF), ERD, Ministry of Local Govt will be the executing Ministry, approving Ministry and line Ministry respectively for the project responsible for project approval, inter agency co-ordination & progressing activities of the entire project The departments of public health engineering (DPHE), Department of LGED, local municipality authorities & administration would participate in the planning, information sharing & training component of the project.

Potential impacts

- Considerable impact on community sanitation, health, environment, nutritional status and economy is expected. Total revenue generated from the BLRI duckweed based wastewater treatment system per anum is estimated at Taka 1 6 million.
- BLRI staff and neighboring user community members will be trained and full time employed in community managed wastewater treatment system established servicing the BLRI farm and user population of 2000. The quantity of wastewater treated per day is 1.5 million liters which is converted in to high protein duckweed biomass for animal protein production.
- Biogas is collected from pre-treatment of wastewater and will be used for the farm energy requirement and sediment sludge from the primary settlement tank will be composted and used as agriculture manure.

- High demonstration impacts and wide scale dissemination of information on duckweed technology The site could serve as a service center/support center for potential wastewater resource recovery application in the region.
- Intensification of agriculture production and land use

Conclusions

- BLRI site was found highly suitable for proposed duckweed based wastewater treatment and aquaculture application.
- Overall scoring in the socio-economic survey and environmental audit was high indicating excellent success potentials.
- The project is found to be financially viable and potentially.
- Overall project impacts are judged as very desirable and makes positive contribution in improving community nutrition, employment, income, public health, research and development in resource recovery aspects of the project.
- High demonstration and dissemination prospects.
- The proposed Partners and owner of the system confirmed their substantial contribution and is in immediate state of readiness for project implementation.
- The Wastewater project proposed is recommended for commercial scale investment

6.2.2 *Compartmentalization Pilot Project (CPP)*

Site identification and description

The compartmentalization Pilot Project received bilateral assistance under the flood protection plan to improve drainage of the eastern part of Tangail Sadar/town. Dry season flow of CPP canal indicates that the canal was primarily constructed for improving the general drainage of surface water from the low lying area of the municipality implying that during the monsoon flow volume would increase substantially The canal is three Km. long of which 1.7 Km. (upper region) is concrete and at the outfall to Garinda beel 1.2 km. is earthen canal. The pucca canal is 2m x 2m x 2m in dimension capable of carrying a large volume (6.04 m^3/s) of water The earthen portion of 1.2 Km of the canal widens up to 8 m and becomes shallower with solid waste siltation Wastewater and surface water from the adjacent household communities, municipality ward 1, ward 2 industries and schools are falling into the CPP canal and is finally dispersed in the Garinda beel area. Partly wastewater from households and institutions are also connected to the main canal through concrete pipes and open earthen collection drains. The surrounding area is a typical peri urban/town settlement with high density of population, business establishment and educational institutions The communities of the Tangail Sadar Thana directly served by the proposed system are Bishwas betka, Purba Adalat para, Shibnath para. The map in Annex 10 indicates the communities, schools, water bodies and lay out of the CPP canal

Socio-economic survey

The Socio-economic survey around the CPP canal was conducted for 50 households, 5 educational institutes, 1 industry and 1 hat/bazaar adjacent to the canal and estimated area of 2 Km^2 was covered for the survey The density of population for the site was found to be 1345/Km^2 and the average family size slightly higher at 6.1 members/household. Literacy rate at 76 % was also high compared to other site surveyed. Employment situation was similar to most urban areas with 13% employed in service, 7 % in business, 4 % farmer, 23 % students, 24% housewives and 14 % unemployed Majority (65%) of the housing was tin shed, pucca and semi-pucca construction. 99% of household owned land and average land holding was 109 decimal of which 23 dec. is used as homestead and 76 dec. as cropping land. 56% of the land is assessed as medium low to low land subjected to flooding and 43% land falls into high or medium high category. Main crop grown in the area is paddy followed by potato, jute, oil-seed and pulses. Very few households owned cattle, chicken or duck. Only 7% of households own ponds and ditches and practice natural fish culture Majority (32%) of the household's income is assessed in the range of Tk. 41,000 to 100,000 followed by the income range of 21000 to 40000 (13%) and the rest is below 20,000. 42% of the households took loans for business purpose, the majority from moneylenders (47%) and the rest from commercial Banks (44%) The general state of development and infrastructure status of site is considered very high for electric supply, natural gas, energy, communication and roads. The water supply and sanitation situation of the Tangail Sadar was found to be good with 98% latrine coverage and 94% tube well water supply and 4% of the households was connected to water taps. The majority of latrines were pit latrines (42%) and sanitary latrines (40%). Only 10% of the latrines were open type. Women participation in economic and household decision was also found to be high at 70%. Community response regarding waste and wastewater management was assessed as very good

Environmental audit

General. The environmental audit at the site was conducted for the communities and institutions adjacent to the canal and villages on the embankment of Garinda beel, around CPP fall out area. The waste and wastewater around the site primarily consist of domestic and human excreta from latrines directly connected to the canal. Wastewater input to the CPP canal from other sources like schools, industry and livestock is considered low. Overall availability of wastewater at the site was judged moderate as a formal collection system connecting the community is not developed. The wastewater is primarily organic and represents typical community waste. General cleanliness of the surveyed area was found high to medium and the majority of the waste sources were channeled or washed into adjacent river/canal (64%) and derelict ponds (36%) The quantity of wastewater generated by household was estimated at 220 l/hh/d, which is higher, compared to other sites surveyed because of high water supply coverage. Similarly estimation of solid waste generates by household was quite high at 5 58 Kg/HH/day which is mostly organic in nature. Due to high coverage of sanitation and water supply in the community the potential collection improvement and eventual treatment is considered excellent Presently negative impact of waste and wastewater in the area is perceived by the population.

Estimate & Measurements wastewater at site. The primary sources of wastewater at CPP are from the community household, municipality area and agricultural activities. The type of wastewater is assessed as organic and domestic in nature. The type wise quantity, percentage of composition and sources of wastewater at CPP site is estimated as shown below from the qualitative and quantitative data collected during environmental audit (Annex 12, 13, 14)

- Wastewater volume accumulated in derelict water bodies at sites = 5700 M^3
- Total wastewater generated around site (2 Km^2) = 103,000 l/d.

Source	*Quantity estimation*	*Percentage*
Domestic wastewater from population	98,300 Lt /day	95 %
Sanitation/sewage wastewater by Schools & Institutions	500 Lt /day	1 %
Wastewater from industries	3100 Lt /day	3 %
Wastewater from Hat/Bazaar	1000 Lt /day	1 %

Overall Availability of domestic wastewater is adequate. Wastewater is collected in CPP canal through some concrete and earthen drains from the adjacent community and institutions. The municipality has further plans of installing a collection system for the pauroshova wards and connecting it to CPP drains. The scope for improvement of collection and separation of waste streams is considered excellent. Thereby addressing the community and household environmental sanitation problem at this site.

Water quality measurement and assessment through observations was made for the CPP canal. Similarly selected water bodies were measured in which wastewater is channeled and accumulating The water quality measurements in general indicated medium BOD and total suspended solids. However, total dissolved solids and nutrients was found to be the highest amongst all the 14 sites audited indicating heavy contamination from fecal matter and organic waste. Presence of small number of industry in the vicinity of the site also suggests that contamination from industrial waste, chemicals and toxic waste is negligible. The number of educational institutes (5) close to the site is quite high and potential for collection of their wastewater and linking it to the treatment system is considered very good.

Water quality measurements			**E. Audit observations**	
Locations	tarting Point o PP canal	iddle Point o PP canal	Location	CPP canal
pH	5 9	6	Turbidity	Medium
BOD	46 0 mg/l	10 0 mg/l	Organic content	Medium
TSS	42 mg/l	410 mg/l	Fecal contamination	Low
TDS	900 mg/l	540 mg/l	Waste input	Low
DO	1 mg/l	2 mg/l	Smell	Moderate
N Tot	64 4 mg/l	28 mg/l	Wastewater color	Green
P Tot	4 2 mg/l	1 8 mg/l	Level of Arsenic	Very Low
Fecal coliform /100 ml	9 50 x 10^5 cfu	0 62 x 10^5 cfu		
Total coliform /100 ml	32 5 x 10^5 cfu	4 2 x 10^5 cfu		

During both the environmental audit and Socio-economic survey it was confirmed that wastewater in the area is scattered and is primarily channeled to surrounding drains and derelict water bodies. The state of overall wastewater collection is assessed as very low. Waste flows are not controlled, some wastewater is reused in agriculture and aquaculture

<u>Wastewater treatment facility Proposed</u> The CPP site represents a very good situation for duckweed based waster water treatment system and aquaculture in view of the domestic and organic composition of the wastewater At this site the

potential for addressing community environmental sanitation problems through duckweed technology is judged very high. Adequate land availability, good infrastructure and high potential of community household participation and eventual resource recovery make this site very attractive. Formalizing the casual community latrines connected to the CPP and improving management of domestic wastewater could generate substantial community sanitation improvement with high impacts For this site improvement of collection system, reduction of waste dispersal in the environment and improvement of sanitary latrine coverage will be the primary objective. The design parameters for the proposed duckweed wastewater system selected is 1 million liter/day flow capacity and primarily for treating domestic wastewater

- Total system treatment capacity = 1 million liter/day (1000M^3/day)
- Organic & domestic waste of high BOD = 200-350 mg/l
- Land required for system construction = 2 0 ha
- Wastewater collection system = 50% existing, (70 % to be constructed)
- Improve latrine connection = 1000 Household
- population/household connected or served = 3000

Type of Treatment facilities proposed consists of secondary earthen lagoons/plug flow system with primary anaerobic clay lined pond and continuous flow through. Biogas plant is also proposed as pre-treatment of wastewater collected from household latrines. Effluent water reuse has been considered for agriculture irrigation and aquaculture. Duckweed produced from the wastewater treatment will primarily be used as fish feed for pisciculture and as feed ingredient for poultry, duck, and domestic animal.

Resource Recovery systems. In General Tangail PSVA area livestock and poultry raising is found to be negligible and therefore not considered. The Garinda beel area supports a rural community, which is engaged in casual fishing from the beel. There is a modern fish farm at the edge of the town adjacent to the CPP outlet, which offers the opportunity for collaboration The proposed treatment system output is estimated at (a) duckweed production = 20,000 Kg/Yr. (dry weight) and (b) Treated effluent 600,000 l/day (c) Composted sludge fertilizer = 10,000 Kg/year.

- Duckweed fed Pisciculture in 2 ha water bodies - existing (use 80 % of Duckweed)
- Animal & poultry feed ingredient (use 20% of Duckweed)
- Agriculture land for co-cropping = 0.5 ha
- Treated effluent used for agriculture irrigation and aquaculture
- Sludge composted & treated as agriculture fertilizer - sludge drying bed and composting facility

Wastewater treatment construction cost

Referring to the financial assumption for the duckweed based wastewater treatment system construction (Annex 9) and applying the design criteria and parameters mentioned in the foregoing paragraph the construction cost of proposed duckweed based wastewater system is estimated as under:

I. Estimates of system construction cost **= Tk.2,381,700.-**
II. Annual Operation and maintenance cost **= Tk. 566,700.-**

III. Projection of Sale revenue from Aquaculture/production(5th year)
(Annual duckweed production = 30,000 kg dry weight/ha)

Total revenue earned from project operation	**= Tk.1,294,000.-**
IV. *System depreciation* (15 years @ 6.6%)	**= Tk. 158,800.-**
V. Debt servicing (interest on fixed and working capital)	**= Tk. 121,000.-**

VI. *Financial Analysis*

- **Project earning forecast (in Taka)**

Year	Year 1	Year 2	Year 3	Year 4	Year 5
Utilization rate	75%	80%	85%	90%	100%
i) Sale revenue	970500	1035200	1099900	1164600	1294000
ii) Direct operation cost	425025	453360	481695	510030	566700
iii) Depreciation	158800	158800	158800	158800	158800
iv) Debt-servicing (interest)	113900	115320	116740	118160	121000
v) Operating profit	545475	581840	618205	654570	727300
Vi) Net profit before tax	272775	307720	342665	377610	447500

- IRR Analysis

NPV 15% 546897
NPV 20% (35553)
IRR (Internal Rate of Return) = 19.6%

- Break-even Analysis

A Sales Revenue (based on 5th year of operation) = Tk 1,294,000
B. Total production, administrative, selling and financial expenses = Tk 786,500

Break-even sales in Taka = (Fixed cost /PV ratio) = Tk.700,395.- = 54% of utilized capacity

- Financial ratios:

Gross profit to sale %	56%
Net profit to sale %	35%
Return on investment	54%
Debt service coverage (Times)	2 6
IRR	19 6%

Overall Feasibility analysis

Analysis aspects	*Score*	*Remarks*
1 Primary & secondary site selection criteria	76 %	Found a suitable site using 25 indicators meeting most of the critical selection criteria
2 Socio-economic survey results	77 %	Represents typical peri-urban condition and has high density of population The average family size and the rate of literacy are high Majority of the household is in middle income group and has some annual surplus income Refer to Annex - XI Socio-economic survey
3 Environmental audit survey results	70 %	Waste and wastewater primarily consists of domestic waste and human excreta At site availability of wastewater is high but collection of wastewater is medium Improvement of wastewater collection system needed under the project Potential for treatment & reuse of wastewater is considered high
4 Overall assessment		Obtained highest score for the overall assessment amongst the 14

on the findings of socio-economic & EA survey	80 %	sites surveyed. Reference Annex-XXIII
5 Participation of the community	Excellent	The community is very interested to participate in duckweed based wastewater treatment system Tangail Pauroshava will contribute land and participate in the management of the system
6 Logistic & facility availability	100 %	Excellent accessibility, located on the Dhaka-Bhuapur high way next to an internal pucca feeder road to the site Electricity, water supply, internal roads & physical facilities excellent & reliable
7 Land availability & opportunity cost	Excellent	The CPP site is located in low land area of Garinda beel where wastewater is at present dispersed over a large area The Garinda beel is khaas land and belongs to the government. Being marginal and used as waste disposal land, the opportunity cost of land is considered low Tangail PSVA has expressed willingness to provide land proposed for wastewater treatment system construction
8 Assessment of potential impacts	80 %	High in terms of demonstration, technology dissemination Resource recovery potential is also high could be developed as a commercial business Community environmental sanitation impacts are considerable Demonstrate enormous potential for increased protein production, employment generation & income for the community
9 Public health consideration	Safe	System being proposed in a isolated discreet area and for domestic/sanitary wastewater poses minimum public health threat to the community The system will improve collection/treatment & prevent indiscriminate dispersal of wastewater in the communities next to CPP canal. Positive effect on improved water quality in the surrounding water bodies and Beel area
10 Financial feasibility	RR -20%	Financial performance ratios satisfactory Has excellent potential for commercial scale operation producing protein, employment & income for the community
11 State of preparedness	Excellent	Tangail PSVA management is keen on participating as an active partner in the project CPP out fall is at present lying fallow as such could be acquired for the project at an early date
12 Investment required to install system	Viable	Cost estimates indicate investment requirements are within viable range Tangail PSVA in agreement to make investment in terms of land, physical facilities and production systems

Institutional arrangements

The stakeholders are the Tangail Paorashova authorities, community adjacent to the CPP site, DPHE, LGE and the Local District administration. GOB agencies directly linked are MOE, ERD and MOLG. Appropriate collaborative and participatory institutional arrangements will be developed between the above project stakeholders and related agencies during project preparation.

Potential project impacts

- Considerable impact on community sanitation, health, environment, nutritional status and economy. Total revenue generated from the community & Tangail PSVA area duckweed based wastewater treatment system per anum is estimated at Taka 1.3 million.
- Tangail PSVA staff and user community members will be trained and full time employed in community managed wastewater treatment system established for servicing the user population of 10,000. The quantity of wastewater treated per day is 1.0 million liters, which will produce high protein duckweed biomass for fish/animal protein production.

- Biogas collected from pre-treatment of wastewater and used for the community energy requirement and sediment sludge from the primary settlement tank will be composted and used as agriculture manure.
- High demonstration impacts for the community & wide dissemination of DW technology.
- Community environmental sanitation improved and indiscriminate dispersal of wastewater reduced having important public health impacts

Conclusions

- CPP site seems very suitable for proposed duckweed based wastewater treatment and aquaculture application.
- Overall scoring in socio-economic survey and environmental audit is high indicating good success potentials.
- The project is found to be financially viable, potentially profitable and contributing additional benefits to the owner community
- Overall project impacts are judged as desirable and makes positive contribution in improving community nutrition, employment, income, public health and environmental sanitation aspects.
- The proposed partners and owner of the system agree to make their contribution and are ready for final negotiation.
- The wastewater project proposed at CPP site is recommended for investment

6.2.3 *Saidpur Paurashava Vagar (SPV)*

Site identification **and description**

Saidpur Pauroshava Vagar is located four Kilometers away north of Saidpur District HQ next to a Large water body/beel area, which is used as the dumping ground for the Pauroshava waste Saidpur district was a part of old greater Rangpur district and is the central railway repair maintenance workshop facility for northern Bengal Hence it has a large community of railway officials and workers residing in that area. The site is located at the edge of the railway staff colony and a sweeper's colony who in the old days provided sanitation services to the railway establishments as most of the Latrine facilities were then bucket based The Vagar or the waste dumping area belongs to the Pauroshava and is around two hectares in size and adjacent to the site is a large derelict water body or beel. The site is connected by Pauroshava Pucca road running on the two sides. The SPV site has an earthen canal collecting wastewater from the adjacent community of sweeper colony, railway staff colony and part of the pauroshsva ward 6 population. It has good infrastructure, electricity, roads and communication links. Saidpur Pauroshava is located on the south of the site, Bothlagari union on the north, Sarba Mangala canal on the east and Kharkhari River on the west. The adjacent community of Sweeper colony and Railway staff quarter's presents a potential good site for duckweed based wastewater treatment system installation and utilization of system by- products. The detailed site map attached (Annex 10) indicates the surrounding environment, location of human habitat, schools, water sources, industries, roads, and important wastewater collection system closest to the site.

Socio-economic survey

The Socio-economic survey was conducted for 50 households randomly selected in the vicinity of SPV site covering approximately 2 Km^2. The Socio-economic survey concentrated primarily on the sweepers colony and the railway staff colony next to the site. The average family size of the community was found 6 52 members/household, of which 36% was male and 34% female and 30% children 60 % of the population was literate out of which 59% had formal school/ higher education. 16% of the adult population is employed, 28% unemployed 26% are students and 17% housewives. The major occupation at 9% was business followed by 5% in service and 2% in agriculture only. 65% of the households owned pucca & tin shed roofed housing and the rest is Kaccha house. Average land holding per household was found to be 46.1 decimals and the major portion is under cropping Paddy was the main crop grown, followed by jute, oil seed, and potato respectively. One third of the households owned cattle and a similar percent owned chicken primarily raised for home consumption. Ownership of ponds and ditches by household was only 16 % Water bodies bottom soil condition is judged as primarily sandy loam. Hundred percent of these ponds are used for natural fish culture and domestic activities. Almost no formal fish farming is practiced. Ulceration was found as a major fish disease prevalent. 60% of the households had an annual income in the range of Tk 41,000 to 100,000. 23% followed in the range of 21000 to 40000 and 13% above Tk.100000 The household income range indicated that the majority of the population is middle income groups. 76%

Water supply and sanitation situation of the SPV area is good with 93 % potable water coverage and similarly 95% households had sanitary and pit latrine coverage. The attitude of the community at Saidpur Pauroshava regarding waste and wastewater management was found to be poor with little awareness on the associated problems.

Environmental audit

General. The environmental audit of the site was conducted at SPV for the immediate communities within 2-Km^2 area. The waste and wastewater in the area primarily consist of domestic, municipal and Agriculture waste and partly educational institutions wastewater. The quantity of wastewater generated is large due to a high density of populations and households The wastewater is primarily organic and agriculture in nature. Both solid waste and wastewater in the area are partly collected in the canals and water bodies as most wastewater is channeled to a central pond or water body The potential to further improve wastewater collection under the project is good, especially from the two adjacent colonies. The SPV site sanitary latrine coverage and water supply coverage is high and residential domestic generated wastewater are mostly connected to a nearby pond or central dispersal site The wastewater quantity estimation was based on population and wastewater generated by the communities and schools. The SPV site has a settlement of sweepers or professional sanitary workers by caste that are grossly unemployed due to the changing service demand in the sector. They are very keen to participate in waste management and resource recovery from the system This aspect is considered an important plus factor for this site. The site has a number of water bodies very suitable for aquaculture A large percentage of the population is highly educated and associated with technical services being the railway maintenance center for the country. Infrastructure facilities like land, electricity, water supply and aquaculture facilities etc are adequately existing.

Estimate and Measurements wastewater at site The primary sources of wastewater at SPV are community households, municipality, agriculture and educational institution sewage and domestic wastewater The type of wastewater is assessed as organic and agriculture in nature (see Table below). For more information see Annex 12, 13 and 14

- Wastewater volume accumulated in derelict water bodies at sites = 4440 M^3
- Total wastewater generated around site (2 Km^2) = 306 M^3/day

Source	***Quantity estimation***	***Percentage***
Domestic wastewater from population	98,300 L/day	32%
Sanitation/sewage wastewater by Schools & Institutions	5000 L/day	2 %
Industries	0	0
Wastewater from Hat/Bazaar	203,000 L/day	66 %

Overall availability of wastewater per day at this site was observed as fairly good. A natural canal and earthen channel collection system for wastewater exist adjacent to the site The wastewater from communities at a distance is mostly disposed in the derelict ponds and surrounding area. The large volume of wastewater generated by the two large Haat/Bazaar is eventually collected in the water body close to the Vagar area.

Measurements of water quality and assessment through observations were made in the Pauroshava drain and Vagar derelict water. The water quality measurements indicated one of the highest BOD and suspended solids among the 14 sites surveyed. Absence of any industry close to the site suggests that contamination from chemical and toxic waste is negligible. Duckweed growth was observed in the surrounding water bodies at a moderate scale The water quality measurements and observations for the site are as follows.

Water quality measurements			**Audit observations**	
Locations	*Drain*	*Vagar*	*Location*	*Drain / Vagar*
PH	7 1	7 7	Turbidity	High
BOD	125 mg/l	150mg/l	Organic content	High
TSS	164 mg/l	184 mg/l	Fecal contamination	High
TDS	950 mg/l	900 mg/l	Waste input	High
DO	1 mg/l	3 mg/l	Smell	High
N Tot	75 6 mg/l	78 4mg/l	Wastewater color	Black Green
P Tot	32 3mg/l	32 2 mg/l	Level of Arsenic count	Very Low
Fecal coliform /100 ml	24 x 10^5 cfu	37 x 10^5 cfu		
Total coliform /100 ml	33 x 10^5 cfu	43 x 10^5 cfu		

The domestic and residential wastewater are collected in drains and surrounding water bodies through natural dispersal. In general waste and wastewater in the area are scattered and both collection and reuse low. Waste and wastewater from the Saidpur SPVA area is partly collected and dumped in the Vagar.

Wastewater treatment facility Proposed. The SPV site represents a good situation for duckweed based wastewater treatment system and aquaculture application from the point of view of availability, composition and collection of wastewater at the Vagar Because of adequate land availability, good infrastructure and high potential of resource reuse for aquaculture at SPV site, excellent opportunities exist to establish a commercial scale duckweed wastewater treatment system. The present Waste collection site i.e the Vagar could be formalized and collection expanded to develop a scaled up duckweed based wastewater treatment system for demonstration to the Pauroshava. The design parameters for a system representing 1-million liter/day are as follows

- Total system treatment capacity = 1 0 million liter/day (1000 M^3/day)
- Organic & domestic waste of high BOD = 200-500 mg/L
- Land required for system construction = 1 5 hectare
- Improved latrine connection = 1000 nos
- Wastewater collection system = 70 % existing,
  (30 % to be constructed, septage to be collected from staff residents)
- Population/household connected = 5000

Type of Treatment facilities proposed consists of secondary earthen lagoons/plug flow system with primary anaerobic/oxidation clay lined pond & continuous flow through Biogas plants are also proposed as pre-treatment of wastewater collected from sweeper colony Effluent water reuse has been considered for agriculture irrigation and aquaculture Duckweed produced from the wastewater treatment will primarily be used as fish feed for pisciculture and as ingredient for poultry and animal feed on limited scale. The detailed specifications and design parameters are attached as Annex 15.

Resource recovery systems Considering the availability of aquaculture facilities at SPV site the following reuse of duckweed and treated effluent is proposed. The treatment system output is estimated at (a) duckweed production = 20,000 Kg/Yr (dry weight) and (b) Treated effluent 600,000 Liter/day (c) Composted sludge fertilizer = 10,000 Kg/year.

- Duckweed fed Pisciculture in 2 ha water bodies - existing (use 85 % of Duckweed)
- Animal & poultry production trials - existing (use 15% of Duckweed)
- Agriculture land for co-cropping = 0 5 ha
- Treated effluent used for agriculture irrigation and aquaculture
- Sludge composted & treated as agriculture fertilizer - sludge drying bed and composting facility developed

Wastewater treatment system construction cost

Referring to the financial assumption for the duckweed based wastewater treatment system construction (Annex 9) and applying the design criteria and parameters mentioned in the foregoing paragraph the construction cost for the proposed duckweed based wastewater system is estimated. Contribution by SPV will consist of primarily providing land and system operation management. The final system design and accurate estimations will be provided during project preparation.

I. Estimates of system construction cost = **Tk.2,381,700.-**
II. Annual Operation and maintenance cost = **Tk. 566,700.-**

III. Projection of Sale revenue from Aquaculture/production (5^{th} year)
(Annual duckweed production = 30,000 kg dry weight/ha) = **Tk.1,294,000.-**
IV. System depreciation (15 years @ 6.6%) = **Tk. 158,800.-**
V. Debt servicing (interest on fixed and working capital) = **Tk. 121,000.-**
VI. Financial Analysis

- Project earning forecast (in Taka)

Year	Year 1	Year 2	Year 3	Year 4	Year 5
Utilization rate	75%	80%	85%	90%	100%
i) Sale revenue	970500	1035200	1099900	1164600	1294000
ii) Direct operation cost	425025	453360	481695	510030	566700
iii) Depreciation	158800	158800	158800	158800	158800
iv) Debt-servicing (interest)	113900	115320	116740	118160	121000
v) Operating profit	545475	581840	618205	654570	727300
Vi) Net profit before tax	272775	307720	342665	377610	447500

- IRR Analysis
  NPV 15% 546897
  NPV 20% (35553)
  IRR (Internal Rate of Return) = 19.6%

- Break-even Analysis
  A Sales Revenue (based on 5^{th} year of operation) = Tk 1,294,000
  B. Total production, administrative, selling and financial expenses = Tk. 786,500

Break-even sales in Taka = Tk.700,395 - = 54% of utilized capacity

- Financial ratios:

Gross profit to sale %	56%
Net profit to sale %	35%
Return on investment	54%
Debt service coverage (Times)	2.6
IRR	19.6%

Overall feasibility analysis

Analysis aspects	***Score***	***Remarks***
1 Primary & secondary site selection criteria	80 %	Found very suitable site using 25 indicators meeting most of the critical selection criteria
2 Socio-economic survey results	77 %	Represent typical peri-urban condition being at the edge of Saidpur Pauroshava and adjacent to rural villages Linkage with Railway authorities and Saidpur municipality drainage development offers interesting institutional opportunities Population consists of higher educated & middle-income group
3 Environmental audit survey results	83 %	Availability and collection of wastewater (organic and domestic) at site is high Represents a distinct microenvironment Potential for treatment & reuse of wastewater is also very high Community sanitation improvement demonstration potential very good
4 Overall assessment		Obtained highest score in the overall assessment Reference

based on the findings of the Socio-economic & EA	80 %	Annex-XXIII
5 Participation of the Institutions	Excellent	The Municipality authorities are very interested to participate and have demonstrated active interest in the project development process Potential linkage with local Govt , Administration and other GOB organizations considerable
6 Logistic & facility availability	100 %	Excellent accessibility being located on the main Rangpur-Dinazpur high way- close to GOB administrative center Electricity, water supply, laboratory facilities, internal roads & physical facilities excellent & reliable.
7 Land availability & opportunity cost	Good	The SPV site is located in a two ha waste dump area and next to a 1 km^2 Beel adjacent to the out skirt villages, affected by the wastewater dispersed in the area At present 80 % of the beel area is under perennial water where natural fish is growing and the shallow edge of the beel is used for paddy cultivation exposing the population directly to wastewater The beel area is Khaas land and belongs to the Government The opportunity cost of land is considered low at SPV site
8 Assessment of potential impacts	80 %	High in terms of demonstration, technology dissemination improved community sanitation and national capacity building Resource recovery potentials very high could be developed as a commercial business Community participation in waste management will also be high Community environmental sanitation impacts considerable Good potential for increased protein production, employment generation & income for the community Spin off and replication in the area expected
9 Public health consideration	Safe	System proposed in a distinct isolated area and utilizing already contaminated waterbody pose minimum threat to the community or the workers The system will further improve collection /treatment & prevent indiscriminate dispersal of wastewater in SPV area Positive effect on water quality improvement in the surrounding water bodies used by households for domestic purposes
10 Financial feasibility	IRR-20%	Financial performance ratios satisfactory Has excellent potential for commercial scale operation producing protein, employment & income for the community
11 State of preparedness	Very good	Pauroshava and Railway management is keen on participating as an active partner in the project & offers their existing facilities for the same Duckweed wastewater treatment land, aquaculture ponds, partial waste collection system already exist at site and can be improved/expanded
12 Investment required to install system	Viable	Cost estimates indicate investment requirements are within viable range SPV authority is in agreement to make investment in terms of land physical facilities and production systems Cost saving due to drain collection facilities existing

Institutional arrangements

Institutional arrangement proposed for the SPV site for ownership, technical assistance, system operation/maintenance and project implementation for wastewater treatment including adjacent community involvement will be similar to the proposed in the previous sites. The stakeholders are the Saidpur Paorashova authorities, Bangladesh railways, community adjacent to the SPV site, DPHE, LGE and the Local District administration. GOB agencies directly linked are MOE, ERD and MOLG.

Potential project impacts

- Considerable impact on community sanitation, health, environment, nutritional status and economy. Total revenue generated from the SPV duckweed based wastewater treatment system per anum is estimated at 1.3 million Taka
- SPV and neighboring user community members will be trained and full-time employed in community managed wastewater treatment system established servicing the SPV site and user population of 5000. The quantity of wastewater treated per day is 1 million liters which is converted in to high protein duckweed biomass for animal protein production.
- Biogas collected from pre-treatment of wastewater and used for the farm energy requirement and sediment sludge from the primary settlement tank will be composted and used as agriculture manure.
- High demonstration impact for the country and wide-scale dissemination of information on Duckweed technology.
- Intensification of agriculture production & land use

Conclusion

- SPV site was judged very suitable for proposed duckweed based wastewater treatment and aquaculture application.
- Overall scoring in Socio-economic survey and environmental audit is high, indicating good success potentials.
- The project is found to be financially viable, potentially profitable and contributing additional benefits to the owner community.
- Overall project impacts are judged as very desirable and makes positive contribution in improving community nutrition, employment, income, public health and environmental sanitation aspects.
- The proposed partners and owner of the system agree to make their contributions.

6.2.4 Isdair Basti Canal (IBC)

Site identification and description

Isdair Basti Canal is located 1 5 Kilometers away on the north of narayanganj District HQ near a large earthen canal around which a slum settlement called Isdair basti has developed The canal serves as the main wastewater collection system for the entire area of 2 Km^2 ultimately falling into a larger Shastapur canal system in front of narayanganj sadar Thana complex. Recently the connection to the main canal has been cut off at three fourth lengths. A borrow pit of large size is also running parallel to the Narayanganj by-pass road close to the site which can be utilized as a part of the proposed system The canal is owned by the Rifle club and the department of Roads & Highway is the owner of the burrow pit Adjacent to the site large lagoons suitable for aquaculture exists owned by the Railways. Two Government colleges namely Narayanganj Govt Women college and Tolaram Govt, college are situated within 200 to 300 meters of the site The education institutions are extremely worried and concerned with the overall wastewater dispersal and sanitation problems of the area communication to the site by river, road and Railways is excellent. The site is located at the edge of the main railway station in the narayanganj sadar and Fatullah union The site is bounded by Chashara ward on the south, Shastapur locality on the north, Chashara ward on the east and Fatullah Bazaar area on the west. The adjacent community of Isdair basti (slum), Isdair schools and Isdair Bazaar are to be served by the proposed IBC system. This site is the only site selected where a number of textile industries are present and their wastewater is being dispersed in the surrounding areas aggravating the situation. Duckweed based wastewater treatment system at this site could demonstrate partly treating selected stream from such textile industry. The detailed site map attached (Annex 10) indicates the surrounding environment, location of human habitat, schools, water sources, industries, roads, and important wastewater collection system closest to the site

Narayanganj Sadar Thana is located south of Dhaka on the confluence of Shitalakha and Buriganga rivers. Narayanganj represent a micro eco-system with low lying river washed land, high annual precipitation and extensively built up area with high density of all types of industries. The Thana has a large number of industries and business establishments and only few practices traditional farming. The general infrastructure like telephone, electricity, water supply is fairly developed with good communication links. Narayanganj consists of 10 unions, 8 wards, 74 mohallas, 40 villages and has a population of 725,000 and an average household size of 6.52 members The entire Thana is highly built up and little agriculture land is available. Numerous ponds, water bodies and ditches are scattered through out the entire Thana Majority of these water bodies is highly loaded with waste and is contaminated to a high degree. The population extensively uses water bodies for domestic purposes, traditional fish culture, and industrial purposes. In the initial evaluation of site selection criteria, IBC site achieved a score of 85% for the 25 indicators used. Potential availability of land around the site is good though the land price is comparatively higher. The participation of Narayanganj TNO/Pauroshava, Isdair community and educational institutions and their contribution to the proposed management of the wastewater treatment is considered high.

Socio-economic survey

The Socio-economic survey was conducted for 50 households randomly selected in the vicinity of IBC site covering approximately 2 Km^2. The Socio-economic survey concentrated primarily on the Isdair Basti canal area, Uttar Chashara ward, adjacent private worker housing colonies and Shastapur Ward communities next to the site. The average family size of the community was found 5 44 members in each household, of which 38% was male and 36% female and 26% children. 59% of the population was literate out of which 57% had formal schooling/ higher education. 22% of the adult population is unemployed, 19% employed 20% are students and 23% housewives. The major occupation at 10% was business followed by 8% in service and 0 4% in agriculture only 54% of the households owned pucca & tin shed roofed housing and the rest is Kaccha house. Average land holding per household was found to be 34 decimals and the major portion is under homestead and one third in ponds and ditches. Wheat was the main crop grown, followed by paddy, oil seed, and potato respectively. 16% households/family owned cattle and 30% raised chicken primarily for home consumption.

Ownership by household of ponds and ditches was 14% Water bodies bottom soil condition is judged as primarily sandy loam. Hundred percent of these ponds are used for natural fish culture and domestic activities. Almost no formal fish farming is practiced. Ulceration was found as a major fish disease prevalent. 42% of the households had an annual income in the range of Tk 41,000 to 100,000. 30%

followed in the range of 21000 to 40000 and 16% above Tk 100000. The household income range indicated that the majority of the population is middle income groups. Water supply and sanitation situation of the IBC area is good with 94% potable water coverage and similarly 98% households had sanitary and pit latrine coverage. The attitude of the community at Isdair community regarding waste and wastewater management was found to be poor with little awareness of the associated problems People's knowledge on duckweed and its application was found very high and 93% household uses naturally grown duckweed as fish feed and 34% as poultry feed. Extensive prevalence of duckweed in the area water bodies was observed.

Environmental audit

General. The environmental audit for the IBC site was conducted for the immediate communities within 2-km2 area The waste and wastewater in the area primarily consist of industrial, domestic, municipality and partly educational institution wastewater. The quantity of waste generated is large due to very high density of populations and households The wastewater is primarily mixed type Both solid waste and wastewater in the area are partly collected in the canals and water bodies as most wastewater are channeled to a central pond or water stream. Further improving wastewater collection potential under the project is good, especially from the two adjacent colonies. The IBC site sanitary latrine coverage and water supply coverage is high and residential domestic generated wastewater is mostly connected to nearby canals or central dispersal site. The wastewater quantity estimation was based on population and wastewater generated by the Industries, communities and schools. Prevalence of many industries around the site dictates that the wastewater streams need to be carefully analyzed before fixing the final system design criteria. This aspect is considered an important design factor for this site The site has a number of water bodies belonging to Central Supply Depot (CSD) very suitable for aquaculture. Infrastructure facilities like land, electricity, water supply and aquaculture facilities etc. are excellent and existing at the site. General cleanliness of the area was found very poor suggesting highly scattered state of waste and wastewater in the environment further confirmed by observation

Estimate & Measurements of wastewater at site The primary sources of wastewater at IBC site are industries, community households, Municipality, and educational institution discharges, sewage and domestic wastewater. The industrial discharges need to be carefully studied to decide separation and pre-treatment requirements before addressing the treatment problem The type of wastewater is assessed as mixed with chemical, industrial raw material, organic and domestic waste inputs. The type wise quantity, percentage composition of wastewater and their sources at IBC site is estimated as shown below form the qualitative and quantitative data collected during environmental audit

Overall Availability of mixed wastewater per day at this site was observed as good. Natural canal and earthen channel collection system for wastewater exist adjacent to the site, except the communities at a distance where wastewater is mostly disposed in the derelict ponds and surrounding area. The large volume of wastewater generated by the industries are not directly connected but eventually enter the water bodies This has to be further analyzed to decide the final system design parameters. Prevalence of duckweed in the surrounding natural systems was found very good

- Wastewater volume accumulated in derelict water bodies at site = 2700 M^3
- Total wastewater generated around site (2 Km^2) = 680,000 L/day

Source	***Quantity estimation***	***Percentage***
Domestic wastewater from population	47,600 Lt./day	7%
Sanitation/sewage wastewater by Schools & Institutions	7,000 Lt./day	1%
Industries	525,000 lt./day	77%
Wastewater from Hat/Bazaar	100,000 Lt./day	15 %

Measurements of water quality and assessment through observations were made in the Isdair Basti canal and Railway canal at site where the wastewater is accumulated. The water quality measurements indicated high BOD dissolved solid and suspended solids. The water quality measurements and observations for the site are as under

Water quality measurements			*E. Audit observations*	
Locations	Isdair Canal	ailway Canal	Location	Isdair canal
PH	7 6	6 7	Turbidity	High
BOD	15 mg/l	32 mg/l	Organic content	Medium
TSS	104 mg/l	122 mg/l	Fecal contamination	High
TDS	820 mg/l	1300mg/l	Waste input	High
DO	4 mg/l	1 mg/l	Smell	Medium
N Tot	24 1 mg/l	29 7 mg/l	Wastewater color	Black
P Tot	3 9 mg/l	3 9 mg/l	Level of Arsenic count	Very Low
Fecal coliform /100 ml	0 4 x 10^5 cfu	2 8 x 10^5 cfu		
Total coliform /100 ml	1 3 x 10^5 cfu	6 0 x 10^5 cfu		

Wastewater from the industry, Bazaar, domestic and residential sources are collected in canals and surrounding water bodies through natural dispersal In general waste and wastewater in the area are highly scattered and both collection and reuse is assessed as low. Waste and wastewater from the Isdair Basti area is partly collected and connected to the canals.

Wastewater treatment facility Proposed The IBC site will specially deal textile industry wastewater, a growing problem for entire Bangladesh, and specially provide for waste stream separation, pre-treatment and close performance monitoring activities There is adequate land availability, good infrastructure and high potential for resource reuse in aquaculture at IBC site. Excellent opportunities exist to establish a small-scale duckweed wastewater treatment system. The present Waste collection site i e the Isdair canal / railway canal could be formalized and collection expanded to develop a scaled up duckweed based wastewater treatment system for demonstration to the Narayanganj Pauroshava. The design parameters were selected for a system of 0.5 million l/day capacity and primarily for treating wastewater from domestic and municipality sources and partly textile industry

- Total system treatment capacity = 0 5 million liter/day (500 M^3/day)
- Organic & domestic waste of moderate BOD = 150-350 mg/L

- Land required for system construction = 1 25 hectare
- Wastewater collection system = 30 % existing,
  (60 % to be constructed, septage to be collected from schools, latrine installed for residents).
- Population/household connected = 3000

Type of Treatment facilities proposed consists of secondary earthen lagoons/plug flow system with primary anaerobic/oxidation clay lined pond & continuous flow through At IBC site separation, pre-treatment and quality monitoring for industrial stream of wastewater is proposed. Biogas plant is also proposed as pre-treatment of wastewater collected from Isdair slum.

Resource Recovery systems. Considering the availability of aquaculture facilities at IBC site the following reuse of duckweed and treated effluent is proposed. The treatment system output is estimated at (a) duckweed production = 10,000 Kg/Yr. (dry weight) and (b) Treated effluent 300,000 Liter/day (c) Composted sludge fertilizer = 5,000 Kg/year

- Duckweed fed Pisciculture in 1 25 ha water bodies - existing (use 85 % of Duckweed)
- Animal & poultry feed trials - existing (use 15% of Duckweed)
- Agriculture land for co-cropping = 0 25 ha
- Treated effluent used for agriculture irrigation and aquaculture
- Sludge composted & treated as agriculture fertilizer - sludge drying bed and composting facility developed

Wastewater treatment construction costs

Referring to the financial assumptions for the duckweed based wastewater treatment system construction (Annex 9) and applying the design criteria and parameters mentioned in the foregoing paragraph the construction cost of proposed duckweed based wastewater system is estimated as under. The contribution by IBC to the cost of system construction will be primarily in terms of land and system operation management. Additional cost may be incurred at the collection and pre-treatment stage of the system

I. Estimates of system construction cost **= Tk.1,534,000.-**
II. Annual Operation and maintenance cost **= Tk. 397,400.-**
III. Projection of Sale revenue from Aquaculture/production (5th year)
(Annual duckweed production = 30,000 kg dry weight/ha)
Total revenue earned from project operation **= Tk.816,000.-**
IV. System depreciation (15 years @ 6.6%) **= Tk. 102,300.-**
V. Debt-servicing (interest on fixed and working capital) **= Tk. 78,900.-**
VI. Financial Analysis

- Project earning forecast (in Taka)

Year	Year 1	Year 2	Year 3	Year 4	Year 5
Utilization rate	75%	80%	85%	90%	100%
i) Sale revenue	612000	652800	693600	734400	816000
ii) Direct operation cost	298050	317920	337790	357660	397400
iii) Depreciation	102300	102300	102300	102300	102300
iv) Debt-servicing (interest)	73925	74920	75915	76910	78900
v) Operating profit	313950	334880	355810	376740	418600
vi) Net profit before tax	137725	157660	177595	197530	237400

- IRR analysis
  NPV 15% 114477
  NPV 20% (224247)
  IRR (Internal Rate of Return) = 16.5%

- Break-even Analysis

Sales Revenue (based on 5th year of operation) = Tk. 816,000
Total production, administrative, selling and financial expenses = Tk 578,000
Break-even sales in Taka = Tk. 496,432.- = 61% of utilized capacity

- Financial ratios.

Gross profit to sale %	51%
Net profit to sale %	29%
Return on investment	53%
Debt service coverage (Times)	2.31
IRR	16 5%

Overall feasibility analysis

Analysis aspects	*Score*	*Remarks*
1 Primary & secondary site selection criteria	80 %	Found good site suitability using 25 indicators meeting most of th critical selection criteria
2 Socio-economic survey results	85 %	Represent typical peri-urban condition being at the edge of Fatullah Pauroshava and adjacent to rural villages Linkage with Pauroshava authorities and Narayanganj municipality offers a good opportunity Population consists of educated & middle-income group Reference Annex - XI Socio-economic survey
3 Environmental audit survey results	80 %	Availability and collection of wastewater (industrial, organic and domestic) at site is high Represents a distinct microenvironment Potential for treatment & reuse of wastewater is also very high Education institute sanitation improvement demonstration potential very good
4 Overall assessment based on the findings of the Socio-economic & EA	76 %	Obtained high score in the overall assessment Reference Annex-XXIII
5 Participation of the organization/Institution	xcellent	The Isdair basti community, Schools around site and Municipality authorities are very interested to participate in all respect and have demonstrated active interest in the project development process Potential linkage with local Govt , Administration and other GOB organizations considered very high
6 Logistic & facility availability	100 %	Excellent accessibility, located on the main Dhaka-Narayanganj high way- close to GOB administrative center. Electricity, water supply, internal roads & physical facilities excellent & reliable
7 Land availability & opportunity cost	ood	The IBC site is located in a three hectares waste Slum settlement and next to large water bodies belonging to railways and adjacent to the Fatullah Pauroshava HQs The canals and water bodies belong to the govt agencies Large Aquaculture resources are available around site (presently under utilized) Though located next to the Narayanganj PSVA considering marginal status of land and public property little future potential use for commercial application The opportunity cost of land is considered low at site
8 Assessment of potential	80 %	High in terms of demonstration, technology dissemination improved community sanitation and national capacity building Resource recovery potentials high could be developed as a

impacts		commercial business Community environmental sanitation impacts considerable High potentials for increased protein production, employment generation & income for the slum community Spin off and replication in Pauroshava areas expected.
9 Public health consideration	Safe	System being proposed in a close proximity to the Slum settlement poses limited contact and effluent reuse risks But at present the entire community is constantly exposed to and surrounded by widely dispersed wastewater Instances of households using the canal water for domestic purposes have been observed Any treatment in comparison will minimize the risk to the community and it's members. Positive effect on water quality improvement in the surrounding water bodies used by households for domestic purposes will be achieved
10 Financial feasibility	IRR-17%	Financial performance ratios satisfactory Has good potential for small -scale commercial operation producing protein, employment & income for the community
11 State of preparedness	Very good	Pauroshava and community management is keen on participating as an active partner in the project & offers their existing facilities for the same Duckweed wastewater treatment land, aquaculture ponds, partial waste collection system already exist at site and can be improved/expanded
12 Investment required to install system	Viable	Cost estimates indicate investment requirements are within viable range IBC authorities in agreement to make investment in terms of land, physical facilities and production systems Cost saving due to drain and collection facilities existing

Institutional arrangement

Institutional arrangement proposed for the IBC site for ownership, technical assistance, system operation/maintenance and project implementation for wastewater treatment including adjacent community involvement will be similar to that proposed for other project sites. The stakeholders are the Bandar Paorashova authorities, IBC community adjacent to the site, DPHE, LGE and the Local District administration GOB agencies directly linked are MOE, ERD and MOLG

Potential Project impacts

- Considerable impact on community sanitation, health, environment, nutritional status and economy. Total revenue generated from the IBC duckweed based wastewater treatment system per anum is estimated at 0 8 million Taka
- IBC site and neighboring user community members will be trained and full time employed in community managed wastewater treatment. The quantity of wastewater treated per day is 0.5 million liters which is converted in to high quality protein
- Biogas collected from pre-treatment of wastewater and used for the farm energy requirement and sediment sludge from the primary settlement tank will be composted and used as agriculture manure.
- High demonstration impact for the country.

Conclusions

- IBC site was found suitable for proposed duckweed based wastewater treatment and aquaculture application.
- Overall scoring in socio-economic survey and environmental audit is high, indicating good success potential

- The project is found to be financially viable, potentially profitable and contributing additional benefits to the owner community.
- Overall project impacts are judged as desirable and make positive contributions in improving community nutrition, employment, income, public health and environmental sanitation aspects
- The proposed partners and owner of the system agree to make their contribution.

6.2.5 Ispahani and Arseen Canal (IAC)

Site identification and description

Ispahani Arseen Canal site is located in the Ekrampur and Kadamrasul localities on the southwest side of Bandar Pauroshava headquarter half a Km away Two large natural earthen canal systems, namely Arseen and Ispahani (CSD) canal, are flowing through this area fall in to the Shitalakkha River on the west. The Arseen and Ispahani canal combined is 500m long and approximately 12m wide where community wastewater run off and surface water are being drained Another Burrow Pit 2 km. long and 20m wide runs parallel to the Bandar Pauroshava road. The Burrow Pit has year round water and the surrounding community wastewater is channeled all along its length through various drains. Mainly jute factory workers and other industry workers are settled in this area concentrated in Ispahani colony, sweeper colony, CSD colony and the Ispahani/Ekrampur Bazaar area In general the area is moderately high and prone to only high flood. The IAC site is situated adjacent to the Bandar Pauroshava road on the eastern side and Ispahani Bazaar road on the north side The site is within the Bandar Pauroshava but on the embankment of the Shitalakkha River representing a typical growth center The density of population in the area is very high and basic amenities like housing, water supply and sanitation facilities are poor in quality. The location of the wastewater treatment site is proposed near the Central supply depot (CSD, Food department) on the Ispahani canal The CSD owns large number of fishponds and land They have expressed their willingness to participate in installation of the duckweed based wastewater treatment system Adjacent to the site is a poultry farm with 1000 birds willing to participate in the management of the treatment system. The Ispahani Bazaar committee was consulted who also expressed their keenness in project participation. Reference is made to the attached map indicating the communities, schools, water bodies and lay out of the CPP canal (Annex 10).

Socio-economic survey

The Socio-economic survey around IAC site was conducted for 50 households, 5 educational institutes, 1 industry and 2 hat/bazaar adjacent to the canal and it is estimated that an area of 2 Km^2 was covered by the survey. The density of population for the site was found at $844/Km^2$ and the average family size is 5.66 members for each household of which 41% was male, 37% was female and 22% was children. 68 % of the population was literate out of which 67% had formal schooling and higher education. Employment situation was also similar to most urban areas with 10% employed in service, 9 % in business, 21 % students, 23% housewives and 22 % unemployed. Majority of the houses was tin shed, pucca, and semi-pucca construction at 79%. 10% of the household owned more than one structure 99% household owned land and average land holding per household was found to be 34.26 dec. of which 8.34 dec used as homestead and 18.32 dec. as

cropping land Half of the land is assessed as medium high land subjected to occasional flooding and 26% land falls in to medium low to low category. Paddy and oilseed was the main crop grown, followed by jute, wheat and potato. One third of the household owned cattle and 30% owned chicken or duck
Only 18% household in the surveyed area owned ponds and ditches and practiced natural fish culture Ulceration was found as main fish diseases prevalent Majority of the households income is assessed in the range of Tk 41,000 to 100,000 at 58% followed by 30% in the range of 21000 to 40000, 10% in the range of 100000 + and the rest below 20,000. 38% of the household taken loan for business purpose, majority from commercial Bank (81%). General state of development and infrastructure of site is considered good for electric supply, natural gas, energy, communication and roads.
Water supply and sanitation situation of the IAC area is found to be very good with 92% latrine coverage and 96% tube well water supply and 4% household was connected to water taps. The majority of latrine at 45% was sanitary, 39% pit latrines and only 8% of the latrines were open. Women's participation in economic and household decision was also found to be high at 82% Community response regarding waste and wastewater management was assessed as very good for 75%. Household awareness on wastewater associated problems was low at 70%.

Environmental audit

General. The environmental audit at the site was conducted for the communities, villages and institutions adjacent to the Ispahani Arseen canal. Waste and wastewater around the site primarily consist of domestic and human excreta from latrines directly connected to the canal system. The quantity of wastewater generated is large due to high density of population at the residential Ispahani colony. Wastewater inputs from other sources to the IAC canal like schools, industry, livestock were considered low. Overall availability of wastewater at the site was judged medium as formal collection system is not developed. The wastewater is primarily organic and typical community waste in nature. General cleanliness of the surveyed area was found low and majority of the waste observed to wash in to adjacent canal (46%) and derelict ponds (54%). Quantity of wastewater generated by household was estimated at 155 L/HH/day and estimation of solid waste generated by household was 2.84 Kg/HH/day which is mostly organic in nature. Due to very high coverage of sanitation and water supply in the community the potential collection improvement and eventual treatment is considered excellent

Estimates and measurements wastewater The primary sources of wastewater at IAC are from the community household, municipality area and agricultural activities. The type of wastewater is assessed as organic and agriculture in nature (see Table below)

Overall Availability of domestic wastewater per day at this site was good. Wastewater is collected in Ispahani Arseen canal through some concrete and earthen drains from the adjacent households The large volume of wastewater generated by domestic sources, schools and institutions is collected and accumulated in this canal. The scope for improvement of collection system from households is considered excellent

- Wastewater volume accumulated in derelict water bodies at sites = 4800 M^3
- Total wastewater generated around site (1 Km^2) = 163,000Ltr./day

Source	***Quantity estimation***	***Percentage***
Domestic wastewater from population	129,100 L/day	79 %
Sanitation/sewage wastewater by Schools & Institutions	21,400 L/day	13 %
Wastewater from Industries	1,500 L/day	1 %
Wastewater from Hat/Bazaar	11,000 L/day	7 %

Measurement of water quality and assessment through observations were made in the Pauroshava drain and the Arseen canal at site where the wastewater is accumulated. The water quality measurements in general indicated low BOD and total suspended solids. However total dissolve solid and nutrients was moderate. Presence of small number of industry in the vicinity of the site also suggest that contamination from industrial waste, chemicals and toxic waste is negligible. The number of educational institutes close to the site are quite high (5) and potential for improved collection of wastewater and linking to the treatment system is considered very good.

Water quality measurements			**E. Audit observations**	
Locations	Ispahani CSD canal	adamrasul urrow Pit	Location	anal & urrow Pit
PH	7 4	7 4	Turbidity	High
BOD	12 mg/l	14 mg/l	Organic content	Medium
TSS	276 mg/l	152 mg/l	Fecal contamination	High
TDS	700 mg/l	500 mg/l	Waste input	High
DO	6 mg/l	5 mg/l	Smell	High
N Tot	18 5 mg/l	4 5 mg/l	Wastewater color	Black
P Tot	1 9 mg/l	2 5 mg/l	Level of Arsenic count	Very Low
Fecal coliform /100 ml	0 13 x 10^5 cfu	0 075x10^5 cfu		
Total coliform /100 ml	3 8 x 10^5 cfu	17 0 x 10^5 cfu		

During both the environment audit and Socio-economic survey it was confirmed that wastewater in the area is scattered and are primarily channeled to the Ispahani canal and surrounding derelict water bodies. State of overall wastewater collection and reuse is assessed as low.

Wastewater treatment facility proposed The IAC represents a good situation for duckweed based waster water treatment system and aquaculture in view of the domestic and organic composition of the wastewater. Adequate land availability, good infrastructure and high potential of community household participation and eventual resource recovery make this site attractive Formalizing the casual community latrine connected to the IAC and improving management of domestic wastewater could demonstrate community sanitation improvement aspects with high impacts The design parameters for the proposed duckweed wastewater system selected is 0 5 million liter/day flow capacity.

- Total system treatment capacity = 0 5 million liter/day
- Organic & domestic waste of high BOD = 100-300 mg/L

- Land required for system construction = 1 25 ha
- Wastewater collection system = 50% existing, 50 % to be constructed)
- Improved latrine connection = 100 Household
- Population/household connected or served = 5000

Type of treatment facilities proposed consists of secondary earthen lagoons/plug flow system with primary anaerobic/oxidation clay lined pond and continuous flow through As pre-treatment of wastewater collected from household latrines Biogas plant is proposed. Effluent water reuse will be considered for agriculture irrigation and aquaculture.

Resource recovery systems. The Ispahani and Arseen canal supports a rural community who is engaged in casual fishing from the canal There are 4 fishpond adjacent to the Ispahani canal and are used for traditional fish culture, which offers the opportunity for collaboration with the proposed system for supporting duckweed-based fish production The treatment system output is estimated at (a) duckweed production = 10,000 Kg/Yr. (dry weight) (b) Treated effluent 350,000 Liter/day (c) Composted sludge fertilizer = 5,000 Kg/year The resource recovery production system at IAC proposed will require:

- Duckweed fed Pisciculture in 1 25 ha water bodies - existing (use 85 % of Duckweed)
- Animal & poultry feed ingredient - existing (use 15% of Duckweed)
- Agriculture land for co-cropping = 0 25 ha
- Treated effluent used for agriculture irrigation and aquaculture
- Sludge composted & treated as agriculture fertilizer - sludge drying bed and composting facility developed

Wastewater treatment construction costs

Referring to the financial assumption for the duckweed based wastewater treatment system construction (Annex 9) and applying the design criteria and parameters mentioned in the foregoing paragraph the construction cost of proposed duckweed based wastewater system is estimated as under:

I. Estimates of system construction cost **= Tk.1,534,000.-**
II. Annual Operation and maintenance cost **= Tk. 397,400.-**
III. Projection of Sale revenue from Aquaculture/production(5th year)
(Annual duckweed production = 30,000 kg dry weight/ha) **= Tk.816,000.-**
IV. System depreciation (15 years @ 6.6%) **= Tk. 102,300.-**
V. *Debt-servicing (interest on fixed and working capital)* **= Tk. 78,900.-**
VI. Financial Analysis

- Project earning forecast (in Taka)

Year	Year 1	Year 2	Year 3	Year 4	Year 5
Utilization rate	75%	80%	85%	90%	100%
i) Sale revenue	612000	652800	693600	734400	816000
ii) Direct operation cost	298050	317920	337790	357660	397400
iii) Depreciation	102300	102300	102300	102300	102300
iv) Debt-servicing (interest)	73925	74920	75915	76910	78900
v) Operating profit	313950	334880	355810	376740	418600
Vi) Net profit before tax	137725	157660	177595	197530	237400

- IRR analysis
  NPV 15% 114477
  NPV 20% (224247)
  IRR (Internal Rate of Return) = 16.5%

- Break-even Analysis

A Sales Revenue (based on 5th year of operation) = Tk. 816,000

B Total production, administrative, selling and financial expenses = Tk 578,000 Break-even sales in Taka = Tk. 496,432.- = 61% of utilized capacity

- Financial ratios

Gross profit to sale %	51%
Net profit to sale %	29%
Return on investment	53%
Debt service coverage (Times)	2.31
IRR	16.5%

Overall feasibility analysis

Analysis aspects	***Score***	***Remarks***
1 Primary & secondary site selection criteria	76 %	Found suitable site using 25 indicators meeting most of the critica selection criteria
2 Socio-economic survey results	76 %	Represents typical peri-urban growth center The population density is high and average family size is 5 44 One fourth of the population are unemployed The literacy rate is lower than the other surveyed sites Reference Annex -XI (Socio-economic survey)
3 Environmental audit survey results	78 %	Waste and wastewater primarily consists of domestic waste and human excreta In this site though availability is high but collection of wastewater is medium because no formal collection system exists Thus need to develop the collection system and household sanitation coverage Potential for treatment & reuse of wastewater high
4 Overall assessment based on the findings of the Socio-economic & EA	80 %	Obtained one of the highest score in the overall assessment Reference table-IIH
5 Participation of the community	xcellent	The Ispahani colony community and Pauroshava is very interested to participate in duckweed based WWT system
6 Logistic & facility availability	100 %	Excellent accessibility being located adjacent to the Bandar Pauroshava and Ispahani Bazaar Electricity, water supply, internal roads, communication links & physical facilities very good & reliable
7 Land availability & opportunity cost	xcellent	The CSD owns 4 6 ha land and their authority expressed willingness to provide land and fish ponds proposed for wastewater treatment system construction Adjacent to the site is a poultry farm and Ispahani Bazaar committee who are also keen in project participation The opportunity cost of land is considered moderate being marginal and presently under utilized
8 Assessment of potential impacts	80 %	High in terms of demonstration and technology dissemination Resource recovery potentials high could be developed as a community business Potential community environmental sanitation impacts considerable Demonstration potentials of

		increase protein production, employment generation & income for the community assessed as high
9 Public health consideration	Safe	The system will improve community environmental sanitation, collection/treatment and prevent indiscriminate dispersal of wastewater in IAC area Positive effect on improvement of water quality in the surrounding water bodies used for domestic purposes by households
10 Financial feasibility	RR – 17%	Financial performance ratios satisfactory Has excellent potential for small-scale commercial operation producing protein, employment & income for the community
11 State of preparedness	ood	The Bandar PSVA management and CSD authority are keen on participating as an active partner in the project Land and ponds are available for immediate use after final negotiation with the CSD and community
12 Investment required to install system	Viable	Cost estimates indicate investment requirements are within viable range Bandar PSVA and CSD authority in agreement to make investment in land, physical facilities and production systems

Institutional arrangements

Institutional arrangement proposed for the IAC site for ownership, technical assistance, system operation/maintenance and project implementation for wastewater treatment including adjacent community involvement will be similar to that proposed for other project sites. The stakeholders are the Bandar Paorashova authorities, CSD, IAC community adjacent to the site, DPHE, LGE and the Local District administration. GOB agencies directly linked are MOE, ERD and MOLG.

Potential project impacts

- Considerable impact on community sanitation, health, environment, nutritional status and economy. Total revenue generated from the community and Bandar PSVA area duckweed based wastewater treatment system per anum is estimated at 0.8 million Taka
- CSD staff and neighboring user community members will be trained and partially full time employed in community managed wastewater treatment system The quantity of wastewater treated per day is 0.5 million liter, which is converted in to high protein duckweed biomass for fish and animal protein production
- Biogas collected from pre-treatment of wastewater and used by the community for their energy requirement and sediment sludge from the primary settlement tank will be composted and used as agriculture manure
- High demonstration impact for the community.
- Community environmental sanitation improved and indiscriminate dispersal of wastewater reduced having important public health impacts.

Conclusions

- IAC site is judged suitable for proposed duckweed based wastewater treatment and aquaculture application.
- Overall scoring in socio-economic survey and environmental audit is high indicating good success potentials.
- The project is found to be financially viable, potentially profitable and contributing additional benefits to the owner community.

- Overall project impacts are judged as desırable and makes positive contribution in improving community nutntion, employment, income, publıc health and envıronmental sanitation aspects.
- The proposed partners and owner of the system agree to make contnbutions.

6.3 Sensitivity analyses

The assumptıons and condıtions for the calculatıon of the financial performance of systems with a 500, 1000 and 1500 m^3 per day capacity are outlined in par. 6.1 and in Annex 9 . Thıs paragraph demonstrates the effect of changıng a number of key parameters on the financial performance of a 1000 m^3 system. The parameters considered are: fish yield, fısh pnce, land lease costs, and costs of supplementary fısh feed.

Baseline situation
The baselıne scenano used for calculations of the financıal performance of a 1000 m^3/d system is as follows:

- system capacity: 1000 m^3/d
- Fıxed capital cost = annual system depreciation over 15 years (Tk2381687/15 = Tk 158800
- Fısh yield 12 t/ha year
- Fish price 50 Tk
- Land lease cost 40000 Tk/y
- supplementary feed: 70 kg/d at 7 Tk/kg

Table 11 presents the annual costs and revenue performance of the system under baseline conditions

Table 11 Financial performance of baseline scenano.

Description	Amount in Tk per year
Costs	
Fixed capıtal costs	158800
Recurring costs· • Dırect operatıonal costs • Debt servıcıng	 567000 121000
Revenues	
Fish sales (12 t/ha.y at 50 Tk/kg)	1200000
Agricultural products	75000
Miscellaneous (sludge etc)	19000
Net profit before tax	447200

Effect of fish price
The wholesale price for fish at the KHC facilıty ıs currently (1999) 60 Tk/kg. For the baselıne situatıon, however, a 'safe' wholesale fısh price of 50 Tk per kg was used

Table 12 shows the financial performance of the integrated system as a function of fish wholesale price. Even at the lowest fish price of 42.5 Tk there is still a considerable net profit

Table 12 Effect of fish price on overall financial performance

Description	Amount in Tk per year			
Fish price	42 5 Tk/kg	45 Tk/kg	50 Tk/kg	60 tk/kg
Costs				
Fixed capital costs	158800	158800	158800	158800
Recurring costs: • Direct operational costs • Debt servicing	 567000 121000	 567000 121000	 567000 121000	 567000 121000
Revenues				
Fish sales (12 t/ha.y)	1020000	1080000	1200000	1440000
Agricultural products	75000	75000	75000	75000
Miscellaneous	19000	19000	19000	19000
Net profit before tax	267200	327200	447200	687200

Effect of fish yield

Experience at the KHC system shows that under controlled conditions an annual fish yield of 12 to 15 tons can be achieved The baseline production has been set at 12 t/ha y The effect of lower production rates on the financial performance is shown in table 13 The break-even value for fish production is at 7.6 tons per ha per year

Table 13 Effect of fish yield on overall financial performance

Description	Amount in Tk per year			
Fish yield	7 t/ha.y	9 t/ha y	12 t/ha.y	14 t/ha.y
Costs				
Fixed capital costs	158800	158800	158800	158800
Recurring costs: • Direct operational costs • Debt servicing	 567000 121000	 567000 121000	 567000 121000	 567000 121000
Revenues				
Fish sales (50 Tk/kg)	700000	900000	1200000	1400000
Agricultural products	75000	75000	75000	75000
Miscellaneous	19000	19000	19000	19000
Net profit before tax	-52800	147200	447200	647200

Effect of cost of fish feed

The combined operation of the duckweed based wastewater treatment and aquaculture system generates a substantial part of the total required fish feed via duckweed Therefore the additional amount of commercial feed inputs in the system is rather low and consequently the effect of substantial increases in the price of fish feed do only have a limited effect on the systems net profit (Table 14) Besides, it is likely that increases in the price of fish feed will probably result in higher fish prices in the market.

Table 14. Effect of fish feed price on overall financial performance

Description	Amount in Tk per year			
Fish feed price	12 Tk/kg	9 Tk/kg	7 Tk/kg	6 Tk/kg
Costs				
Fixed capital costs	158800	158800	158800	158800
Recurring costs:				
• Direct operational costs	667000	617000	567000	545000
• Debt servicing	121000	121000	121000	121000
Revenues				
Fish sales (12 t/ha, 50 Tk/kg)	1200000	1200000	1200000	1200000
Agricultural products	75000	75000	75000	75000
Miscellaneous	19000	19000	19000	19000
Net profit before tax	347200	397200	447200	472200

Effect of land lease costs

The location of the duckweed based wastewater system in all sites, except for BLRI is on marginal land with a large outfall of wastewater. For the 1000 cubic meter per day system a lease value of 40000 Tk per year was assumed. Table 15 shows the effect of different lease costs on the overall performance of the system. The break-even value for land lease cost is 479000 Tk per year

Table 15. Effect of land lease cost on overall financial performance

Description	Amount in Tk per year			
Land lease cost	100000 Tk/y	70000 Tk/y	40000 Tk/y	30000 Tk/y
Costs				
Fixed capital costs	158800	158800	158800	158800
Recurring costs:				
• Direct operational costs			567000	557000
• Debt servicing	121000	121000	121000	121000
Revenues				
Fish sales (12 t/ha, 50 Tk/kg)	1200000	1200000	1200000	1200000
Agricultural products	75000	75000	75000	75000
Miscellaneous	19000	19000	19000	19000
Net profit before tax	387200	417200	447200	457200

6.4 Economic feasibility

The previous paragraphs of chapter 6 and chapter 4 have dealt with the financial aspects of the pre-feasibility study The economical feasibility also includes other cost and revenue consequences of the project, including the cost of current poor sanitation and public health situation, the cost of continued environmental pollution and water resource deterioration, and the revenues from improved nutritional status and employment status The project is expected to yield a number of benefits, which eventually will have economical consequences as well. Examples of additional benefits arising from duckweed based wastewater treatment and aquaculture, with a clear economic impact include:

- The generation of employment for rural landless community members, especially poor farmers and women
- Improved sanitation/improved public health condition (reducing illness and mortality)
- Improved nutritional status, because of locally increased availability of fish protein (reduced illness and mortality)
- Over the long term the project will contribute to the improvement of the quality of water resources, making these available for economical uses that are currently not considered because of low quality (e.g water supply).
- More sustainable institutional arrangements are possible, since the system offers incentives and possibilities that allow operation and management by a private enterprise.

7. PROJECT PREPARATION

7.1 State of preparedness five project sites

Consideration of the state of preparedness of each site formed an integral part of the selection process described in chapter 5 The state of preparedness was judged from a number of indicators, as indicated in Table 16. This table provides an overview of the state of preparedness for the five selected project sites. For more detailed information see par. 6.2 and Socio-economic survey report.

Table 16 State of preparedness of five proposed sites

Indicator	BLRI	CPP	SPV	IBC	IAC
Land availability	Excellent Will be provided by BLRI	Good (will be provided by Tangail PSVA) Garinda Beel is khas land	Good Khaas land (beel) owned by Government	Good (canal and water bodies are owned by Government)	Excellent
Institutional arrangements /community participation	BLRI is interested to participate in project development and implementation	Community and Tangail PSVA are very interested to participate	Municipality and Railway are very interested to participate	School, slum community and municipality are motivated to participate	CSD owns 4 6 ha and is willing to provide land and fish ponds
Waste availability	Good availability of farm waste and domestic wastewater	Good, primarily domestic wastewater and excreta	Good (WW of organic and domestic source)	High availability and collection potential (domestic and industrial)	Good, domestic ww and human excreta
Waste collection	Substantial, but needs to be expanded	Partial, needs to be expanded under the project	Substantial, but needs to be expanded	Substantial, but needs to be expanded	Substantial
Available water bodies	Ponds for wwt need to be	Excellent (Garinda Beel),	WWT ponds to be	Canal and water bodies	Land and ponds

	expanded Fish ponds available	fish ponds available	constructed, fish ponds available	available	available for immediate use
Overall	Good	Good	Good	Good	Good

7.2 Capacity and institutional arrangements

7.2.1 *Country capacity*

World-wide, experiences with duckweed based wastewater treatment are scarce, and there are only few groups in a number of countries with some experience in this innovative environmental technology. In Bangladesh a number of institutes, NGO's and Ministries have experimented with duckweed technology over the past years The experiences of different groups are at the level of laboratory research, pilot scale tests or full scale demonstration of the technology.

The in-country capacity for the further development and dissemination of duckweed based wastewater treatment technology is judged to be good There is a good capacity both in the fields of a) sanitation sector policy & development, b) project implementation and guidance, and c) research and development, d) training.

Capacity in sanitation sector policy & development
Sanitation is dealt with in both The Ministry of Local Government and Rural Development, and the Ministry of Health. Specialized departments involved in water supply and sanitation include the DPHE and LGED. These Government agencies are currently investing substantial financial resources (GOB, bi-lateral and multi-lateral funding) in the development of the sector. A substantial number of staff in DPHE and LGED have received postgraduate training abroad. Specific training programs to further strengthen DPHE/LGED capacity in wastewater treatment and re-use (incl cost recovery) in general and in duckweed based technology in particular should be given attention during project implementation.

Capacity in project implementation and guidance
The technical assistance component for the development and guidance of duckweed based treatment facilities is a most crucial requirement for the successful implementation of this new treatment technology. PRISM has over 10 years of experience in setting up duckweed based sanitation and wastewater treatment projects, both as centralized treatment systems, as well as community based systems PRISM has shown to posses an excellent capacity to successfully implement such projects in close collaboration with user groups and public sector organizations In addition to PRISM possibly other NGO's will be interested to participate in the dissemination of this innovative technology. The grassroots mobilization capacities of NGOs in Bangladesh is well known world wide

Research and development capacity
The sustainability of any new technology largely depends on the availability of a good training and research capacity in the wider context of the proposed technology. In Bangladesh a large number of research institutes have been involved in duckweed research over the past years, including: Dhaka University, Bangladesh University of Engineering and Technology, Bangladesh Agricultural University,

ICDDRB, Bangladesh Council for Scientific and Industrial Research (BCSIR), Bangladesh Livestock Research Institute (BLRI), and Fisheries Research Institute (FRI) The institutes mentioned have generally a good laboratory infrastructure for analyses and research (some laboratories have recently been upgraded via cooperative projects). Besides these institutes, also the two proposed demonstration farms (KHC and BLRI) could be strongly involved in applied research. It is proposed that these two demonstration and research centers are upgraded via the project A research grants program should be installed to tap the national research capacity in a flexible, competitive and cost effective way

The implementation of new duckweed treatment systems requires also sufficient monitoring and analytical facilities. ICDDRB has excellent facilities for the monitoring of specialized parameters, such as pathogens, whereas other parameters can be analyzed in other institutes and universities in the country

Training capacity

The present capacity for training in duckweed based treatment technology is rather limited At present only PRISM is involved in this via on the job coaching and via workshops and seminars. The development of a number of demonstration projects on duckweed wastewater treatment and aquaculture will require a substantial expansion of the human capacity development in this field, covering areas of system design, operation & maintenance, optimization of cost recovery, marketing and sales, institutional aspects, etc. The proposed demonstration and research stations will fulfil an important function in the training of new staff to be involved in duckweed technology Besides practical training, also formal workshops and seminar sessions need to be organized. The training of trainers concept will be used by involving staff who already have gained some experience with duckweed based treatment in the training and dissemination programs.

ICDDRB (Prof. Mathan) has indicated that they are willing to provide training to technicians in the field of microbiological water quality analyses. Via ICDDRB technicians will be trained for the KHC and BLRI demonstration and research stations This expertise will also be used for the routine monitoring activities of the duckweed systems, once established.

7.2.2 Institutional arrangements

In order to define the institutional arrangements for the effective implementation and operation of duckweed based wastewater treatment and aquaculture systems (enterprises) the following functions need to be considered: ownership, technical assistance, funding/financial sustainability, and public sector involvement. These functions will be discussed briefly below. Additional information is presented in par. 6.2 of the report. The detailed arrangements for each site will have to be defined during project preparation and project inception.

- <u>Ownership</u>: who will 'own' and implement the technology infrastructure and take care of operation and maintenance, sales and accounts?

The ownership of each system in the 5 selected sites will depend on the local situation, considering aspects such as local leadership, land ownership, water body ownership, waste production source etc. The wastewater treatment via duckweed ponds, linked to aquaculture, should be organized on a commercial basis by a private enterprise. The owners are expected to make investments, to purchase land (if not already owned), to make all required inputs for operation & maintenance, keep accounts, etc. In many cases the local community can be organized in such a way that an enterprise is established by selected community members. In other cases the commercial management of the entire system by a limited number of shareholders should be considered (depending on land ownership) An other option is to delegate the ownership to an NGO or to an 'outside' company. In this case the community will benefit from the company's products (clean water, sanitation facilities, fish, employment).

- Technical assistance: who will provide technical guidance and backstopping during the implementation and operation of the system?

The proposed technology is new and local experience in the communities with the technology is absent It is therefore essential to involve a technical assistance team for the guidance and backstopping during the first years of implementation and operation of the system Considering the unmatched experience by PRISM it seems reasonable to suggest that this NGO should play a crucial role under this function. Foreign consultants (long term and short-term missions) could further strengthen the Technical Assistance capacity. This needs to be considered during the project preparation The technical assistance team will also coordinate the training, analytical and research support services during project implementation

- Funding How will the start up of the system be financed?

It is proposed to develop duckweed demonstration projects for wastewater treatment and aquaculture in the 5 selected sites In order to satisfy the demonstration function and to provide optimal conditions for possible further dissemination of the technology afterwards, substantial investments will be required in technical assistance, training, research and backstopping. The role of a funding agency is therefore crucial to be able to start and implement the project. The enterprises will be set up on a commercial basis and a credit program will be needed for start-up.

- Relationship with public sector agencies: what are the interests and role of public sector organizations?

The duckweed based wastewater treatment and aquaculture systems could be organized as economically viable enterprises. The private sector, however, should link up with the public sector for successful implementation of the proposed system The provision of water supply and sanitation services in Bangaldesh is (currently) basically the responsibility of public sector organizations (mainly Municipal authorities, DPHE and to some extent LGED). Over the past years, a tendency of decentralization and privatization of public services has taken place in many countries For the water sector privatization has mainly taken place for water supply services in large urban areas. Wastewater treatment has not been privatized at a noticeable scale Duckweed based wastewater treatment and aquaculture could offer a good opportunity for privatized management of wastewater, since (partial) cost recovery is part of the systems operation characteristics.

The installation of large duckweed treatment facilities requires large surface areas of land and water bodies, which are likely to be owned by government. The collection of wastes and its transport to a central site requires area which is owned by the municipality An important role of the government is to ensure good sanitation practices and enforcement of water quality criteria as defined via legislation. Duckweed based treatment systems provide a good opportunity to stimulate the cooperation between public and private groups with a common goal: to improve water quality and sanitation services in the local environment in a cost-effective manner (preferably in a profitable manner). The relationship and division of responsibilities between the respective government agency (DPHE) and the enterprise need to be negotiated and worked out in a contractual arrangement during project preparation The following arrangement could be considered as a possible option·

- Municipality and DPHE will take care of infrastructure development for collection and treatment of wastewater, including the purchase of land
- Municipality/DPHE will develop cost recovery mechanisms via taxation of water use and pollution discharges by households, institutions and industry.
- Municipality/DPHE will pay a contribution to the enterprise for the treatment of wastewater on the basis of agreed treatment objectives and tariffs
- The wastewater rights will be assigned to the enterprise
- The enterprise will pay Municipality/DPHE for the lease of land and infrastructure.
- The enterprise will be responsible for treatment of the wastewater to previously agreed standards
- The enterprise will manage the system as a commercially viable activity via income from fish and other sales and from the contractual contribution by DPHE
- Alternatively, the enterprise may be responsible for infrastructure development and will be compensated for this in the contractual payments for the treatment by DPHE/Municipality

7.3 Monitoring and evaluation system

For Monitoring and Evaluation (M&E), a distinction needs to be made between the M&E of duckweed (demonstration) projects and the M&E requirements for the treatment systems themselves This paragraph will not deal with the project M&E activities, since this will be defined during project formulation A brief description for the effective monitoring and evaluation of the performance of duckweed based wastewater treatment and aquaculture systems follows below.

M&E systems need to be defined, keeping in mind the following specific objectives of monitoring and evaluation activities.

- M&E of wastewater treatment performance (monitoring of wastewater parameters) and aquaculture water quality

- M&E of the financial performance of the combined integrated system (monitoring of investments, O&M costs and revenue from sales)
- M&E of possible public health concerns, and
- M&E of possible other impacts (positive and negative) of the system on the environment and socio-economic situation in the immediate environment

Table 17. Parameters and frequencies of sampling and analysis

Parameter	Frequency A	Frequency B
Flow/24h	every day	once per week
24h profile[1)]	once/3 months	once per year
BOD	2 times per week	once per week
COD	2 times per week	once per week
DO	every day	once per week
TSS	2 times per week	once per week
VSS	2 times per week	once per week
Kj-N	2 times per week	once per week
Organic-N	2 times per week	once per week
Ammonia	2 times per week	once per week
NO_2^-, NO_3^-	2 times per week	once per week
Total-P	2 times per week	once per week
Fecal Coliforms	2 times per week	once per week
Total Coliforms	2 times per week	once per week
pH	every day	2 times per week
Conductivity	every day	2 times per week
Alcalinity	2 times per week	once per week
Total-S	2 times per week	once per week
Temperature	every day	2 times per week

1) BOD, FC, TC, TSS, pH, T, Tot-N, Tot-P of samples taken every 2 hours during a 24 h cycle

Wastewater treatment performance

For the evaluation of wastewater treatment performance, routine parameters and frequency of sampling and analysis are proposed as summarized in Table 17 Under this objective it is not necessary to apply high frequency sampling, except for the first 12 month after start up of a new system. The frequency will be determined by the context in which the system will be operating. If the system is developed under an externally financed project, with the objective to study and demonstrate the technology. it is advisable to apply higher frequency of sampling (frequency A). This will generate detailed understanding of the system's performance characteristics under different seasonal and operational conditions Once the system is 'established' and continues operation without external funding, the frequency of sampling and analysis under this objective could be substantially reduced (frequency B). For parameters showing a diurnal pattern (pH, DO, temperature) 24-hour profiles should be analyzed once every 3-months.

The above analyses will be done by taking composite samples from different locations in the treatment system. The exact location of sampling depends on the type of treatment system constructed:

- Continuous flow system: In this system samples will be taken from influent and effluent for analysis. If the system consists of a series of interconnected ponds, the influent and effluent of each pond needs to be monitored. In case the system is designed as a plug flow, samples will be taken at 0% (influent), 25%, 50%, 75% and 100% of the length of the system.

- Static pond system In a static pond the inputs (latrines or irregular disposal) will be analyzed at a low frequency of sampling, while an estimate of the total input will be made The quality of the water in the pond will be analyzed as indicated in Table 10 from composite samples taken from at least 5 different locations in the pond.

At a lower frequency (once per month), a number of specific pathogens should be evaluated, including *Vibrio cholera, Salmonela, Shigella,* and Helminths.

Water quality of the fish ponds should be evaluated on a weekly basis by analyzing the following parameters: BOD, TSS, FC, TC, conductivity, alkalinity, nitrite and total-P Dissolved oxygen (DO), Ammonia, nitrate, pH and temperature need to be monitored on a daily basis.

Duckweed production yields, feed inputs to the fish ponds and fish yields should be monitored continuously. Once every month samples should be analyzed to check duckweed composition and fish health and condition.

A similar sampling and monitoring scheme is suggested for the KHC wastewater treatment system, which is proposed to be financed under the project.

M&E of the financial performance

The M&E system for the assessment of the financial performance of the combined treatment and aquaculture system requires a disciplined keeping of accounts indicating all relevant cost and benefit components. These include:

- Initial investment costs
- Costs of capital loans
- Operation and maintenance costs (labor, gears, consumables, fish feeds, etc.)
- Sales of fish and possibly other products such as fruits and vegetables generated by the system.

The duckweed wastewater treatment and aquaculture activities proposed for the 5 selected sites will be organized as a formal enterprise. Each of these enterprises will be required to produce audited accounts for every fiscal year. The audited accounts will form the basis for calculations of the economic performance of each of the systems managed by the enterprises. In addition to the disciplined recording of all economic components, also detailed accounts will be kept of the produced amounts of duckweed, fish and other products (vegetables, fruits etc.).

M&E of public health aspects

The environmental audit done in this study only provides preliminary information on the presence of pollutants in each of the selected project sites. Before starting the duckweed demonstration project, a detailed monitoring should be done of water quality parameters that may have public health consequences. It is recommended that the various water bodies and wastewater sources in each of the selected project sites are carefully analyzed for presence of pesticides, metals, arsenic, and pathogens The presence of micro-pollutants is important because of the risk of accumulation of such contaminants in the food chain via duckweed to fish to humans We recommend that such detailed monitoring in the five project sites should be done via a separate assignment as part of project preparation.

Routine parameters related to the performance of the treatment systems with respect to the removal of pathogens are included in the 'M&E of wastewater treatment performance' Besides the regular monitoring of the wastewater treatment efficiency, also the microbiological quality of the harvested duckweed, fish pond water and of the harvested fish should be routinely monitored. This will, however, require a lower frequency than the monitoring of the wastewater ponds (suggested is one series of triplicate samples once every month).

During the initial 12 months after starting a new system the following public health related parameters should be analyzed carefully:

- Arsenic (As) content of water and possible accumulation in duckweed and fish (also the form in which arsenic is present needs to be analyzed since organic-As is less toxic).
- Metal content of water and possible accumulation in duckweed and fish
- Presence of pesticides in water and possible accumulation in duckweed and fish

Specific questions regarding optimization of treatment, public health aspects, and accumulation of micro-pollutants in the food chain should be addressed in a well defined research programs, separate from the regular monitoring. The parameters to be considered and their frequency of analysis will be defined during the experimental design of the respective research programs.

M&E of other possible impacts
A well functioning duckweed/aquaculture system is expected to have a number of beneficial effects on the environment and on the local community, such as: improved surface water quality, reduction of water borne diseases, reduction of mosquito breeding, increased employment, improvement of nutritional status, etc

These effects do not need to be monitored frequently, but it is suggested to perform a detailed baseline study at the beginning of the project and to monitor the progress for a number of indicators once every year after the start of the project Possible indicators to be monitored are.

- incidence of diarrheal diseases in the immediate area
- consumer satisfaction for the system (sanitation, benefits)
- employment situation
- household economy situation

- nutritional situation
- measurement and community impressions of surface water quality
- community impressions on mosquito incidence

7.4 Research and Development aspects

During project preparation and formulation sufficient attention needs to be given to system monitoring, (applied) research and technology development aspects. These aspects are considered a crucial component of the proposed demonstration project on duckweed based wastewater treatment and aquaculture. Although a detailed research agenda will be developed during project preparation and project inception, few focal areas for research are listed below.

Wastewater treatment and sanitation research
The main objective of the proposed duckweed demonstration project is the cost effective treatment of wastewater and improvement of sanitation condition. This should be given substantial attention in the research program. Optimization of important treatment parameters (BOD, pathogens, nutrients, TSS) need to be investigated in pilot and full scale systems, both in the KHC demonstration station, as well as in the duckweed systems installed in the selected sites. Optimization of waste collection should also receive attention, whereas the effluent could be investigated with respect to possible re-use options. The acceptability of this new technology to the local communities should also be given attention in the research program

Public health aspects
The main strategy in bringing down the cost of the treatment process is based on the coupling of duckweed production to aquaculture and possibly other animal feeding options Since this strategy will link the wastewater components, including pathogens with the food chain, substantial research efforts will have to address the potential health risks associated with this practice The research should focus on: possible transfer of pathogens to workers and system products, and the accumulation of toxic compounds (metals and pesticides) with special emphasis on arsenic (see also par 8.4).

System optimization
The yields of duckweed, fish and animals that can be produced will directly affect the overall economic performance of the system operation Since duckweed based wastewater treatment and aquaculture technology is relatively new, it is expected that further optimization of the process performance can be achieved via well designed research and technology development efforts.

Animal feeding research
The exact value of duckweed as a feed for fish or other animals is not known. The high protein content and high biomass yields suggest that this could be a cheap and high quality feed, but specific research needs to be undertaken to assess voluntary uptake, feed conversion rates, weight gain and animal growth rates and quality of animal products. The effect of different feeding strategies need to be compared (duckweed versus other feeds), and the effect of duckweed processing (drying,

grinding, pelleting) also requires attention. Besides, the combined feeding of duckweed and other feed components needs to be investigated.

A wide range of questions and practical problems that will arise during the implementation of duckweed treatment systems should be addressed in the research program. The research will be developed, both at the demonstration and research stations (KHC and BLRI), and by a number of institutes, including national universities, ICDDRB, and FRI A research grant is proposed to finance such applied research and monitoring assignments under the project.

7.5 Preliminary budget estimates

The estimated total costs for a project component on 'demonstration of duckweed based wastewater treatment and aquaculture in five selected sites' amount to US$ 4,410,000. This amount includes the cost of investments, credit program, operation (incl monitoring), technical assistance, training, and research. The preliminary estimates for each component are presented in Table 18.

The budget presented here is just a preliminary and rough estimate of the financial inputs required to develop, optimize and operate a full fledged duckweed based component as proposed for the 5 sites selected under this study. The budget includes the upgrading of KHC and BLRI to assume the function of Research and Demonstration Center.

Table18. Preliminary budget estimates for individual project activities

Budget component	Amount in US$
Staff costs: -Local Technical assistance -Expatriate technical assistance -Monitoring&Evaluation	$ 1,350,000
Investments. -Establishment of collection, treatment and aquaculture infrastructure -Upgrading of KHC and BLRI demonstration and research station -Additional analytical facilities	$ 1,550,000
Operational costs -system operation -credit program -research grants program -office and transport	$ 1,100,000
Training pogrom	$ 200,000
Miscellaneous (5%)	$210,000
Total estimated project costs	$ 4,410,000

8. PUBLIC HEALTH RISKS

8.1 Potential public health risks

Wastewater treatment in combination with possible re-use scenarios for nutrients, energy and water provides attractive options for environmental and water resources management Although wastewater re-use has been practiced in many regions for centuries, there is a recent increase in research and demonstration projects in this field Especially in developing regions, the combination of low cost treatment with re-use of treated effluent may provide crucial economic incentives which contribute to the feasibility and sustainability of the overall process A one-sided approach targeting exclusively wastewater treatment and environmental protection will not be feasible for many countries in the world (see table in box 1).

Wastewater has been used, either raw or pretreated, for agriculture and aquaculture purposes Depending on the type of re-use a number of public health concerns need to be considered:

- pathogen transfer into the human food chain
- accumulation of (heavy) metals (including arsenic)
- accumulation of pesticides
- accumulation of other toxic compounds that may be present in the waste (e.g. hospital waste, chemical wastes, specific industrial wastes)
- health risks of workers (in case of direct contact with waste)

Among the above mentioned health risks, the possible transfer of pathogens has been most widely discussed and considered. Numerous examples exist world-wide of the re-use of wastewater in agriculture (irrigation). Although effluent quality standards for a range of re-uses in agriculture have been defined, many practices still exist where the wastewater used for irrigation purposes is not (sufficiently) treated before use. The WHO recommendation for unrestricted irrigation is less than 1000 FC per 100 ml of water. Although this standard can be quite easily achieved, even with low cost treatment options (Mara et al, 1993), (too) many practices still exist of the direct use of sewage with much higher coliform counts A well known example is the use of raw sewage from Mexico City by farmers in the Valle Mezquital, about 100 km downflow of the city. The income from agriculture in this valley is estimated at 16 million Mexican Pesos in 1990 (Gijzen, 1998).
Over the past years, the WHO guidelines or national standards are increasingly considered when applying wastewater effluents for irrigation It is important to note that, on the other hand, discussions between experts are ongoing about effluent standards setting, especially with respect to the coliform indicator (Mara, 1995).

8.2 Wastewater fed aquaculture

Another widely applied re-use option is aquaculture Fish raised in wastewater fed ponds forms an important source of high quality animal protein for many millions of people in developing countries, especially in South East Asia. Also the direct re-use of excreta in aquaculture is a traditional practice in a number of countries, including China, India, Indonesia and Vietnam The fish produced in this way is basically used for human consumption, sewage or excreta are rarely used to culture aquatic plants or animals for animal feed production (Edwards, 1990).

The largest example of wastewater fed aquaculture in the world is the Calcutta wetlands system, immediately to the east of the city (Edwards and Pullin, 1990). The wetland system receives about 550,000 m^3/d of untreated wastewater, flowing into about 3000 ha of fish ponds The system generates about 13000 tons/y of fish (mainly Indian major carp and tilapia), which is supplied to the fish markets of central Calcutta and consumed in the wider region. Similar experiences are found elsewhere in Asia, for instance in China (Ruddle and Zhong, 1988) and Vietnam (Edwards, 1990). Obviously, the above mentioned practices will not be able to comply with the current WHO guidelines for microbiological quality for aquaculture, i.e zero nematodes and less than 1000 fecal coliforms (FC) per 100 ml. Total coliform counts of 10^5 to 10^6/100ml in the influent to the Calcutta wetland system have been reported (Pescod, 1992). Mara et al (1993) suggested that the WHO guidelines for such aquaculture systems could be easily achieved by pretreatment in stabilization ponds at short HRT (1 day anaerobic ponds, followed by 5 days facultative pond).

Substantial research on wastewater fed aquaculture has been done by Edwards and co-workers at AIT. In septage fed fish ponds an initial reduction of FC by 99% (10^6 to 10^4 per 100 ml) due to dilution was followed by a further reduction of 99% (10^4 to 10^2 per 100 ml) within only 30 hours (Edwards, 1996) This suggests that natural die off of pathogens in fish ponds is rather efficient and will contribute to improved microbial water quality after waste addition

8.3 Duckweed based aquaculture

8.3.1 Potential health risks from pathogen transfer

The re-use of excreta and raw sewage in aquaculture to produce fish for human consumption is socially unacceptable in many societies. Ironically this is true especially in many developing countries where insanitation and malnutrition co-exist. One way to overcome this problem, and to be able to satisfy WHO guidelines as well, is the indirect re-use of excreta and sewage. In this case the excreta or sewage are used to produce aquatic plants or fish, which is subsequently used as an animal feed in a separate animal production system. Duckweed based aquaculture is an interesting option to be considered in this respect, duckweed has an excellent animal feed quality, it has a high growth rate and is easy to manage (harvesting, handling).

A first systematic application of duckweed based aquaculture was reported from Taiwan, where about 100 ha of wastewater duckweed ponds were developed in the city of Tainan in 1985 (Edwards, 1990). Since 1989, also PRISM Bangladesh is involved in the systematic cultivation of fish using duckweed grown on a sewage fed plug flow pond system (see par. 3.2).

Since duckweed wastewater treatment ponds and the fish ponds are physically separated and the effluent from the wastewater treatment system generally is not re-used in the fish pond, a better microbiological quality may be expected, compared to direct sewage fed aquaculture. Nevertheless, the direct feeding of freshly harvested duckweed will introduce some associated pathogens in the fish ponds as well and therefore this needs to be considered and studied.

8.3.2 Available information on pathogen transfer

Information on the behavior and health risks of pathogens associated with duckweed based aquaculture is extremely scarce The International Center for Diarrheal Disease Research in Bangladesh (ICDDR,B) conducted a study on possible pathogen transfer from duckweed based wastewater treatment to fish production and to the workers in the KHC demonstration plant operated by PRISM The study demonstrated that the bacteriological quality of duckweed, fish and water were similar when duckweed was taken from the wastewater treatment system or from a fertilizer fed fresh water system (Islam et al, 1996). The results showed that less than 100 FC/100ml were present in the effluent of the duckweed based wastewater treatment system. Surprisingly, FC numbers in the freshwater system were slightly higher, probably due to natural contamination via birds and other animals FC counts in harvested duckweed from both freshwater and wastewater were identical and amounted to about 250 FC per g fresh weight) With an average feeding rate of up to 50 g duckweed per m^3 of fish pond per day (as practiced by PRISM in KHC), a FC count in the fish pond of 1/100ml is contributed by duckweed feeding every day This finding, together with the earlier reported natural background FC number of about 100 FC/100 ml and the rapid pathogen die-off in fish culture, suggests that sewage grown duckweed does not pose a serious health risk in aquaculture, as far as pathogens are concerned.

ICDDRB also tested the workers at KHC who are exposed every day to pathogen containing wastewater during the harvesting of duckweed. The results from mouth, anal, and nail swap tests showed that the pathogen count was not different from the pathogen count of a control population

8.3.3 Data collected under present assignment

In order to confirm the above conclusions, few analysis were done also under the current assignment. Microbial analyses were performed, for the Environmental Audit (by Dhaka University) and for the KHC wastewater treatment and aquaculture system

a) Analyses under the Environmental Audit

The quantity and quality of wastewater in the 5 selected sites was estimated via a limited sampling and analytical program. Among parameters tested were also analyses of total and fecal coliforms.
The data of the microbiological evaluation shows that none of the water bodies tested meets the requirements for restricted irrigation. Fecal coliform levels ranged between 10^3 and 87 x 10^5/100ml. These water bodies are currently used for washing

and bathing activities by the surrounding population. The public health risks associated with the domestic uses of these water bodies seems more urgent than the possible transfer of pathogens via a duckweed system.

b) Microbiological tests in the KHC duckweed system

Samples were monitored from various locations in the wastewater treatment pond. The samples included water samples (pumping station, anaerobic pond, inlet duckweed pond, at 60% of the duckweed pond, effluent, fish pond water), duckweed samples (at 60% and effluent of pond) and fish (fins, gill, intestine, and a composite fish sample).

The results show that pathogen removal in the duckweed pond is very efficient, reaching values as low as 90 and 50 total and fecal coliforms per 100 ml, respectively, at 60% of the pond length. Surprisingly the pathogen count increases again towards the effluent sampling point (1000/100ml). This is probably a result of contamination of the water by birds and other animals. The fecal coliform count for the fish composite sample was rather high (1.6×10^7/g dw). The fecal coliform count for individual fish parts showed the highest value in the intestines of the fish. It is not likely that the high values obtained for fish are caused by duckweed feeding.

The samples were also tested for the presence of *Vibrio* spp./*Aeromonas* spp., *Salmonella, Shigella* and *Campylobacter*. For most samples of water, fish and duckweed the tests were negative, suggesting that the above pathogens were not present. Only the raw sewage and the anaerobic pond tested positive for the presence of *V. cholerae*. The detailed results of analyses are presented in Annex 9

8.4 Possible accumulation of other compounds

Industrial pollution may pose a greater threat to public health than pathogens and parasites Hundreds of factories discharge effluents into the Calcutta wetland, including highly toxic chromium from tanneries. One wastewater fed fishpond in Calcutta received 70% industrial wastewater (Edwards, 1996). Since detailed information is missing, further research is urgently required to assess these public health impacts (also see 7.1.5).

During the mission's field visits in Bangladesh (October 1998), industrial effluents were seen flowing directly into the environment, often in open water bodies, without any form of treatment Only meters away from the site of contamination most water bodies were used for either domestic (bathing, washing) or agricultural purposes (irrigation). A major improvement of this devastating situation can be achieved by two actions:

a) To consider the options for a substantial reduction of waste production by performing a waste minimization and cleaner production review in major industries. Experiences elsewhere have shown that substantial reductions can be achieved often requiring relatively small investments and process adjustments

b) To consider a more logical channeling of the industrial effluents, which ensures that these waste flows are kept separate from water bodies and water flows which are used eventually for domestic and agricultural purposes.

Metal accumulation

A substantial part of the metals present in the wastewater will be removed in the anaerobic pond, as long as sufficient S^{2-} is present. Metal sulfides will precipitate into the sediments The sludge from anaerobic ponds should therefore be checked for metal content before being re-used for other purposes Remaining metals in the influent to the duckweed system may be accumulated into the duckweed biomass. The effective accumulation of a number of metals by duckweed was reported by Landolt and Kandeler (1987). The accumulation factor of metals by *Lemnaceae* depends largely on the type and concentration of the metal, the presence of other metals, presence of chelating agents and the species of duckweed.

In a study at KHC between October 1994 and February 1995, Iqbal (1995) analyzed a number of metals in duckweed from the wastewater treatment system, including Pb, Cd, Hg, Co, Cu, Ni, Zn and As. The concentrations reported for all metals, except As, were judged as acceptable. Although only two measurements were done, the results suggest that duckweed may accumulate Arsenic up to 4 8 ppm (mg/kg dry weight) In the duckweed harvested from the inlet, arsenic concentration could even go up to 24 ppm These results suggest that the drinking water in Mirzapur may contain elevated levels of As. This needs to be verified.

Several analyses of Arsenic were also done under the present assignment, using atomic adsorption spectrophotometer (Dhaka University). Analyses of composite samples of fish from the KHC system showed an As concentration of 17 ppb (0.017 mg/kg) This value is rather low and suggests that the duckweed fed fish is safe for human consumption.

Arsenic requires special consideration since this toxic compound has shown to be present in alarming concentrations in many ground water resources used for drinking water in Bangladesh. Because of the wide-spread use of ground water, arsenic might eventually spread via the wastewater into open water bodies (par. 8.5) In each of the five project sites, selected for pre-feasibility study (chapter 5), arsenic analyses were done of water samples taken from three different water bodies. The analyses were done at the laboratory of DPHE in Khulna, Bangladesh

Table 19 Arsenic concentrations of water samples three open water bodies in five selected project sites

Project site	**Arsenic mg/l**		
	Location 1	**Location 2**	**Location 3**
BLRI	0.02	0 01	0.01
SPV	0.03	0 01	<0.01
CPP	<0 01	<0.01	<0.01
IAC	<0.01	0.02	<0.01
IBC	0.02	0.02	<0.01

The results obtained (Table 19) showed relatively low concentrations of arsenic for all sites, with highest value of 30 micrograms per liter in an open water body in SPV site. Even this highest value is well below the recommended standards for arsenic in irrigation water for most countries (50 to 200 microgram per liter; Chang et al, 1996). The analyses were done in the period September/October 1999, towards the end of the rainy season in Bangladesh. It is likely that arsenic levels in open water bodies are higher towards the end of the dry season, when dilution by rain water does not take place. The preliminary analyses in the project sites suggest that arsenic may not be a major problem, but detailed sampling and analyses in the five sites during different seasons are recommended as part of project preparation. In addition to this, arsenic should be monitored during project implementation, with special emphasis on the possible accumulation in duckweed and fish.

Recent studies at IHE suggests that the accumulation of metals is not caused by plant uptake into plant tissue, but merely is the results of adsorption on the submerged plant surface. For more information on metal accumulation by duckweed the reader is referred to reviews by Landolt and Kandeler (1987) and Gijzen and Khondker (1996)

Pesticides

Many pesticides are hydrophobic compounds which may accumulate in the lipid layer of the cell membrane. Not much information is available on pesticide accumulation by duckweed Vrochinsky et al (1970; as cited by Iqbal, 1995) reported accumulation factors in *L. minor* of up to 800 and up to 1200 for DDT and for HCCH (Hexachlorocyclohexan), respectively

Micro-pollutants produced by KHC

In a study by Iqbal (1995), the substances and chemicals used by the Kumudini Hospital were estimated. The substances and quantities of chemicals used per unit of time as recorded by the medical storehouse keeper at KHC are as follows:

- savlon 5 l/month
- formaldehyde 4-5 pounds per month
- detergent powder 50 kg per 3 months
- detergent cream 70-80 kg per month
- potassium permanganate < 500 g/month
- X-ray photo developer 18 l solution per month (collected and sold)
- X-ray fixer 36 l/month (collected and sold)
- Iodine 18 l/month
- dental filling (40% Ag, 31% Sn, 29% Cu) 50 g per 3 months
- Barium sulfate 8 kg/month
- dyes (microscopic slide preparations) 500 g/month
- acids (pathology lab) < 500 g/month

Part of these chemicals may eventually end up in the wastewater to be treated at the duckweed treatment system The current wastewater production level of about 300 m^3/d (10,000 m^3/month), and an estimated low % of actual discharge of above listed chemicals suggests that these compounds do not pose any problem for the systems operation or for accumulation in the food chain

8.5 Recommended research and monitoring requirements

As part of any duckweed based project based on resource recovery from wastewater, the possible public health concerns require attention. The possible accumulation of metals, pesticides, and pathogens should be verified in an intensive monitoring program of 12 months for each new system. Besides a number of important questions need to be addressed in a carefully designed experimental approach. Experimental research should be undertaken to check:

- The possible accumulation of metals by duckweed
- interventions to prevent metal accumulation (system design, complexing agents, role of S^{2-} in anaerobic pond).
- The possible accumulation of arsenic in areas where As contamination has been reported.
- The behavior of pathogens and parasites in the duckweed-aquaculture system needs to be investigated
- The possible accumulation of pesticides by duckweed and subsequently by fish needs to be studied as well

Special attention should be given to the occurrence and concentrations of arsenic in water bodies and wastewater in the five selected sites If arsenic is present in high levels, it might further accumulate in the food cycle via duckweed to fish and subsequently to humans, and as such present a public health hazard Besides detailed monitoring of this compound, the behavior of arsenic in different stages of the treatment process and its possible accumulation require attention as well. For instance, it is not known, whether arsenic will be chemically precipitated in the anaerobic pond. Also the accumulation of arsenic by duckweed is not well studied, while the fate of arsenic in subsequent feeding of duckweed to fish remains to be assessed.

At IHE, Delft a number of the above research areas are currently being addressed by both MSc and Ph D. research projects A well designed research program should be part and parcel of a duckweed project and it is recommended to coordinate this research via the proposed Research and Technology Development station to be developed at KHC (see par.4 5)

In summary: The few results available from literature together with information collected during the present study suggest that:

- Pathogen transfer from duckweed to fish and subsequently to human consumers is unlikely. The number of pathogens transferred to fish ponds seems to be in the same range as for a non-wastewater grown duckweed Besides, any pathogens associated with fish will be instantly killed because of the heating during food preparation (fish is not eaten raw in Bangladesh).

- The workers are exposed daily to pathogen containing wastewater during the duckweed harvesting. Preliminary analyses of possible direct pathogen transmission of the wastewater to the workers showed that the number of pathogens encountered in mouth, anal and nail swaps from workers is similar to that of a control group not exposed to the same wastewater. The fact that the same workers are employed now for a period of 9 years, without showing a different illness and disease pattern from workers in other sectors suggests that there is no direct public health risk involved. Nevertheless, PRISM aims at the development of newly constructed ponds where direct contact with the wastewater will no longer be necessary

- Preliminary analyses of few water samples in the five project sites suggest that arsenic is not present in high concentrations. For all samples values analyzed were well below the standard for irrigation. Nevertheless, it is recommended that detailed sampling and analyses of arsenic will be done in the project sites as part of project preparation.

- Insufficient information is available on the possible health risks related to the accumulation of arsenic, (heavy) metals, pesticides or other toxic compounds which may be present in the wastewater It is recommended that this will be monitored in the five project locations as part of project preparation, while this should be continued in the monitoring activities of each new system at least for the first 12 months months of operation.

9. FINAL ASSESSMENT AND EVALUATION

The financial analyses and evaluation of past experiences by PRISM at KHC demonstrate that duckweed based wastewater treatment combined with aquaculture has great potential for (partial) cost recovery of wastewater treatment costs (Chapter 4). In fact the KHC system seems to be the first report of a wastewater treatment facility that is able to generate a net profit from the treatment process. The secret of the system is the effective channeling of nutrients to produce high quality fish protein. The potential profits are attractive to an extent that the treatment system could be managed as a business opportunity generating a net income from waste management

World-wide it is generally accepted that private and public sector investments have to be made available to ensure good sanitation and wastewater treatment facilities. Indeed the investments made over the past decades in most western countries in wastewater treatment collection and advanced wastewater treatment have been gigantic, and amount to billions of US$ for individual countries. At the present costs such facilities will not be feasible in most developing nations, including Bangladesh The duckweed based wastewater treatment system combined with aquaculture provides a good alternative for countries where low cost options are required.

This study has made a pre-feasibility analyses for five selected sites in Bangladesh, for cost effective duckweed-based treatment of wastes, combined with safe aquaculture. For all selected sites a positive financial feasibility was calculated for the combined treatment and aquaculture process. The positive economic, sanitation and environmental effects of duckweed based wastewater treatment and aquaculture form a strong justification for the development of demonstration projects at the sites proposed.

In addition to the above selected five sites, duckweed based treatment and aquaculture could be introduced also in the context of other water supply and sanitation projects in Bangladesh. This should be considered especially for projects which are aiming at the improved collection of wastewater (18,16 towns). It is suggested to consider demonstration of the duckweed technology along two scenarios:

a) Aquaculture based Here large flows of waste and wastewater are channeled to a central point, where the waste is treated via duckweed ponds. The duckweed harvested from the system is used for well managed aquaculture and animal raising activities. Here the primary motivation for system implementation is the financial gains, but important positive environmental effects will be generated.

b) Sanitation based In locations with poor sanitation facilities and poor waste collection, latrine based duckweed ponds can be developed to stimulate the construction and use of latrines Also in this scenario duckweed will be used for aquaculture or animal feeding The financial gains will be substantially smaller as compared to scenario b), but the motivation to install the system comes mainly from the improvement of sanitation conditions.

The difference between option a) and b) is basically related to the volume of waste produced and collected Because of the relatively small size of (primary) schools in Bangladesh only a small volume of waste is expected to be produced However, any school sanitation/duckweed scenario could be linked with community sanitation as well (as is the case for most of the five sites proposed). The exact scale of economy will have to be assessed but it is realistic to expect that at least a substantial part of the investments will be recovered from the profits generated by the system

Demonstration of this relatively new and not widely known technology will provide an important step towards wide scale implementation and dissemination of duckweed based wastewater treatment and aquaculture at a later stage The proposed demonstration project will lead to the further optimization of the technology and operation, and implementation modes, while the economic scope will be demonstrated under different conditions. The effects of duckweed cultivation on improved sanitation, hygiene and environment could be substantial These effects can hardly be measured in terms of monetary gains. The improved quality of water bodies will affect many aspects of daily life for the surrounding communities, while this will also have positive impacts on agriculture (irrigation) and fish production Other side effects are that a duckweed cover contributes to the reduction of foul odors, and possibly of malaria incidence by physically blocking the breeding grounds.

The scope of duckweed-based wastewater treatment and sanitation technology seems so bright that serious efforts should be undertaken to develop demonstration level projects under different scenarios. Inclusion of a duckweed component in the SCSP would be justified since this will not only help to improve the sanitation and economic situation, but it would also provide a good basis to incorporate environmental thinking into the education process

To support the effective development and monitoring of the new technology, the consultants suggest that sufficient attention should be given to both training and research Both goals will be satisfied by upgrading the current demonstration facility for duckweed based wastewater treatment at KHC and the BLRI into Duckweed Research and Demonstration Centers. The centers will provide the training, analytical and research requirements for the proposed demonstration projects and for future new duckweed initiatives in the country.

The consultants recommend that a workshop should be organized, where the findings of this pre-feasibility study and the orientation of the proposed demonstration projects will be discussed with all stakeholders before project appraisal (see Annex 17, proposal for workshop).

REFERENCES

Alaerts, G.A., Mahbubar, M R., Kelderman, P. (1996). Performance analysis of a full-scale duckweed covered sewage lagoon. Wat.Res. **30:**843-852

Chang A C, Page, A.L., Asano, T., Hespanol, I (1996). Developing human health-related chemical guidelines for reclaimed wastewater irrigation. Wat Sci Tech **33**:463-472

Chen, T.P (1976). Aquaculture practices in Taiwan Fishing News Books Ltd , Surrey, England

Datco, A.H., Mudd, S.H., Giovanelli, J. (1980). *Lemna paucicostata* Hegelm. 6746, Development of standardized growth conditions suitable for biochemical experimentation. Plant physiol. **65**:906-912

Edwards, P. (1987). Use of terrestrial vegetation and aquatic macrophytes in aquaculture. In: Moriarty , D.J , Pullin, R.S. (eds) Detritus and microbial ecology in aquaculture. ICLARM Conf Proc. 14, p311-335

Edwards, P (1990) An alternative excreta- reuse strategy for aquaculture: the production of high-protein animal feed. In: Edwards, P. and Pullin, R.S. (eds.) Wastewater fed aquaculture Proc. Intl Seminar on Wastewater reclamation and reuse for aquaculture, Calcutta, India, 6-9 December 1988, pp 209-221.

Edwards, P (1996) Wastewater fed aquaculture systems: status and prospects The ICLARM Quarterly, January 1996, pp33-35

Edwards, P., Pullin, (1990). Wastewater-fed aquaculture. Asian Institute of Technology, Bangkok, 296pp

Gijzen, H.J. (1996). Anaerobic wastewater treatment, an important step in rational re-use strategies of nutrients and energy. In. Proc IV Seminario Taller Latino Americano sobre tratamiento anaerobio de aguas residuales, Bucaramanga, November, 1996, pp

Gijzen, H.J (1998). Sustainable wastewater management via re-use – Turning waste into wealth. In. Proc. Agua '98 – Water and Sustainability, 2nd Agua conference, June 1-4, 1998, Cali, Colombia, 22pp

Gijzen, H.J., Khondker M (1996). An overview of the ecology, physiology, cultivation and applications of duckweed Literature Review, Duckweed Research Project, 53pp

Grau, P (1994). What's Next? Water Quality International, no 4:29-32

Iqbal, S (1995) Practical report ETH Zurich/PRISM Bangladesh, 45pp.

Islam, M S., Alam, M.J., Shahid, N.S., Hasan, K.Z., Ikramullah, M., Sacks, R.B. and Albert, M J (1996). Feacal contamination of a fish culture farm where duckweeds grown in hospital wastewater are used as fish feed. In: Proc. 5th Annual Scientific Conference ASCON, Dhaka, Bangladesh, January 13-14, 1996, pp49.

Landolt, E and Kandeler, R (1987). The family of *Lemnaceae*. a monographic study Veroffentlichungen des Geobotanischen Institutes der ETH, Stiftung Ruebel, Zurich, pp638

Leng, R.A., Stambolie, J.H , Bell, R. (1995). Duckweed, a potential high protein feed resource for domestic animals and fish. In: Proc. AAAP Conf., Bali, Indonesia, pp.103-114

Mara, D. (1995). Feacal coliforms everywhere (but not a cell to drink). WQI **3**: 29-30

Mara, D D., Edwards, P , Clark, D., Mills, S.W. (1993) A rational approach to the design of wastewater-fed fishponds. Wat. Res. 27:1797-1799

Pescod, M.B (1992). Wastewater treatment and use in agriculture. FAO Irrigation and drainage paper, 47, FAO, Rome, 1992, 125pp

Ruddle and Zhong (1988) Integrated agriculture-aquaculture in South China.: the dike pond system of the Zhujiang delta Cambridge University Press, Cambridge

Annex 1

Terms of Reference

May 1, 1998

Terms of Reference:
Prefeasibility Studies of Duckweed Wastewater Treatment and Integrated Aquaculture Projects

Background: The Ministry of Local Government and Rural Development is developing a School and Community Sanitation Project in partnership with the World Bank This ToR is one component of the project preparation. The consultancy should be executed in close collaboration with DPHE (the implementing agency), local government institutions and other stakeholders, such as affected communities.

Objective: Identify 10 areas with large quantities of wastewater in different environmental settings, such as on village level, growth center level and peri-urban level outside the metropolitan area and where the local government or others are willing to provide land for demonstration of the duckweed based wastewater treatment technology and linked to this the development of safe (from a public health point of view) aquaculture Prepare for 5 of these areas prefeasibility level reports, based on the results of a survey and an environmental audit, of cost-effective duckweed based wastewater treatment technology to improve surface water quality, improve health and environmental conditions, and explore the potential to convert wastewater into an economic asset, to create rural employment, and to explore the potential of public-private partnerships in innovative wastewater treatment and integrated aquaculture enterprises Develop an effective monitoring system to monitor (i) potential public health impacts, (ii) rural water quality improvements, and (iii) economics of the duckweed based wastewater technology (consider opportunity costs of land) and the economic viability of potential income generating activities, such as aquaculture, and others

Scope: The Consultants, in close collaboration with other national/international team members, the DPHE, local government institutions and local stakeholders will perform the following tasks:

Task 1: Identify, select, survey and execute an environmental audit for 10 demonstration areas in different environments (see above under objective) and with different wastewater streams, including physical estimate of wastewater quantity, composition, and wasteloads, socio-economic data of residents, land availability and willingness by the local government agencies or others to release it for the duckweed based wastewater treatment system Include 4 school complexes and one or more potential industries, such as a food and fish processing industries, in these 10 demonstration areas

Task 2: Based on the results of the survey and environmental audits prepare for 5 of these sites prefeasibility study report and estimate the costs of the duckweed based wastewater treatment system, including the costs and opportunity costs of land and ensure that the duckweed based wastewater treatment option is cost-effective wastewater treatment option Include as well in the prefeasibility study report the potential and economics of resource recovery (e g aquaculture and other income generating activities) This could be for instance through the establishment of fish ponds in each of the 5 systems, biogas plants in areas were duckweed is polluted with toxic chemicals such as heavy metals, explore the potential of integrated chicken farms on some of the sites and explore the use of the treated water as a safe irrigation water source Parameters for final duckweed system design and development will be guided by the cost factor and size of the community served including the quantity and quality of wastewater available

Task 3: Develop an effective monitoring scheme to monitor the pilot duckweed wastewater treatment-cum-fishfarming system for public health impacts (e g pathogens in and on fish and discharge of liquid medicines, such as cytostatica, in the hospital wastewater), effectiveness of the treatment of the wastewater and the economics of the wastewater treatment system and the economic viability of the duckweed based wastewater treatment-cum-fishfarming, possibly combined with poultry or biogas systems

Task 4: Make a general agreement for participation in the duckweed project with the different stakeholders, such as local communities, user groups, possibly government agencies (e g. municipalities, union parishads, thanas or village councils) and others

Task 5: Ensure that the 5 selected sites are in an advanced stage of preparation, largely ready for implementation under the initial stages of the project

Task 6: Assess the in-country capacity and capabilities of organizations/institutions for implementation of duckweed based wastewater treatment systems-cum-fishfarming

Task 7: Start a monitoring program in the Kumudini Duckweed Wastewater Treatment Demonstration Farm and in a village duckweed based production system using domestic wastes to identify any potential public health risks of pathogen transfer from the sewage pond grown duckweed to fish (outside on the skin as well as on the gills and inside the guts of the fish), assess public health risks of discharge of liquid medicines and assess risks to fish handlers, to wastewater workers harvesting duckweed from sewage ponds and the level of pathogen infection of duckweed to be used as animal feed (e g fishfeed) Pathogens to be monitored should include enteric viruses, bacteria and parasites (e g total and fecal coliforms counts, Salmonella, Shigella, Vibrio cholerae, hepatitis and rota viruses, Entamoeba histolytica, Campylobacter spp , Giardia lamblia, Acaris lubricoides, Trichuris trichuria and other important pathogens) The monitoring program should also monitor the die-off rates of pathogens in the duckweed sewage treatment ponds and estimate the efficiency of duckweed based sewage treatment The monitoring program should provide an answer if it is safe from a health point of view to use sewage grown duckweed in aquaculture and in how far it increases the risks as compared to fish grown in ponds fed with non sewage grown duckweed (control) Four rounds of sampling should be done (Cost estimate needed for the health monitoring program).

Task 8: Prepare an economic analysis of the Kumudini duckweed based wastewater treatment plant and the fishfarm separately and determine the IRR for this system Execute a similar economic analysis for a village duckweed based production system using domestic waste.

Task 9: The consultant should consolidate all his relevant findings by preparing
Draft report in English for comments
Final report, including an Executive Summary and with appropriate appendices, such as economics of wastewater treatment plant, economics of potential income generating activities and list of people and organizations contacted, and a full bibliography

Task 10: Provide support (e g , access to materials and guidance) to the School and Community Sanitation Project team in project preparation, and to the relevant Ministries in PCP/TAPP/PP preparation

Task 11: Under separate TOR, organize a National Duckweed Workshop at the end of the consultancy to (i) disseminate and discuss the various components of the study, and (ii) engage stakeholders in discussion of follow-on activities under the proposed School and Community Sanitation Project

Duration: 6 months, starting mid August 1998

Qualifications: The mandatory requirement is a Dutch Consultancy Firm and a Bangladeshi NGO or company with at least 5 years of experience in the above mentioned fields and a proven track record in these activities within Bangladesh Experience in participatory project planning and development is essential.

Responsibilities: The Dutch Consultant Firm will be responsible for advising, supporting and guiding the Bangladeshi counterpart and would be the main responsible for the preparation and quality of the prefeasibility reports The Bangladeshi NGO or firm would be responsible for carrying out the field work, the sampling, environmental audits, surveys and provide a major contribution to the preparation of the prefeasibility reports

Annex 2

List of people and organizations contacted

WORLD BANK PRE-FEASIBILITY STUDY ON DUCKWEED BASED WASTEWATER TREATMENT AND RE-USE

Persons and organisations contacted during first mission H Gijzen (14/10/98-25/10/98)

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Annex 3

Description of KHC wastewater treatment and aquaculture facilities

THE PRISM DUCKWEED BASED WASTE WATER TREATMENT SYSTEM
KUMUDINI HOSPITAL COMPLEX, MIRZAPUR

General Summary:

The PRISM Duckweed (Lemnaceae) Based Waste Water Treatment System is, at its core, also a lagoon system It differs from conventional lagoon systems in that is (a) work to actively remove nutrients from the waste water stream; and (b) rather than encouraging algae growth seeks to prevent it and instead has a standing matt of duckweed covering the lagoon surface (c) the duckweed crop harvested is a high quality protein rich bio-mass used as fish and animal feed. The treated effluent being good quality can be reused for agriculture irrigation and aquaculture

The effect is to produce a high quality effluent typically containing less nitrogen, phosphorus and algae than receiving bodies of water (rivers, lakes or seas) into which it is discharged. Lemnaceae system discharge contains few organic compounds and may therefore be chlorinated without significant tri-halomethane production. Finally, because they are more efficient than conventional lagoon systems PRISM Lemnaceae systems occupy less (expensive) land to achieve a higher level of treatment.

The basic mechanism employed by the PRISM Lemnaceae System is to farm various Lemnaceae species on the waste water requiring treatment. The rapidly growing plants act as a nutrient sink, absorbing primarily nitrogen, phosphorus, calcium, sodium, potassium magnesium, carbon and chloride from waste water. These are then removed permanently from the system as the plants are harvested

Depletion of nutrients causes diminished Lemnaceae growth. The starved plants then begin processing increasingly greater amounts of water as they search for growth nutrients In the process, they absorb virtually every chemical present in the waste water stream The small volume of plants harvested during this Polishing Process may contain, depending on the growth media, high levels of toxins and heavy metals. If so, they should be disposed off as green manure depending on the level of contamination.

Maintenance of efficient Lemnaceae growth requires even distribution of a thick layer of plants across the entire lagoon surface. This has the additional effect of shading the water below from sunlight and preventing growth of algae.

Harvested Lemnaceae plants contains up to 45% protein by dry weight and may be used without further processing (i e drying) as a complete feed for fish. Dried Lemnaceae meal can provide the protein constituent of various animal feeds The vitamin A and pigment content of Lemnaceae have proven particularly valuable in poultry diets

A typical Lemnaceae waste water treatment plant will yield upto 1 ton of harvested Lemnaceae plants (wet weight) per hectare of surface area per day. This daily harvest will produce either 50 kg of fish or 100 kg of dried high protein Lemnaceae meal

The Lemnaceae waster water treatment process is described below:

A Primary System

The Primary Phase of the Lemnaceae waste water treatment system receives all the raw waste water influent Like any primary treatment process, the principal objective is to separate floating material and achieve significant solids removal through sedimentation - all at a low capital cost.

The PRISM Lemnaceae system also seeks to maximize release of nutrients from sediment solids through anaerobic digestion of primary sludge. This process also produces significant release of methane which can be collected for subsequent use or simply vented.

(i) **Sedimentation:**

Achieving efficient sedimentation is important to prevent degradation of initial Lemnaceae treatment runways Septage and influent waste water must also be introduced with minimal aeration to maintain a completely anaerobic system.

(ii) **Sludge disposal:**

Sludge should be analyzed for heavy metal concentrations. If found to meet established criteria, it should then be composted and sold as garden manure. Otherwise is should be disposed of in a responsible manner.

(iii) **Floating trap:**

Floating material must be prevented from proceeding to subsequent treatment processes. This is easily achieved by venting effluent 0 5 meters below the surface. The resulting crust of floating material will also serve to minimize surface aeration.

(iv) **Human Factors:**

Primary settlement tanks where possible (cncrete0 should be covered. This will have a significant impact on acceptance of the facility by persons having occasion to live or work near the facility.

B <u>Lemnaceae Plug Flow System</u>

The essential element of a Lemnaceae waste water treatment facility is the Lemnaceae cultivation system itself It consists of a shallow pond system designated to allow effective cultivation of Lemnaceae plants and incremental treatment of a waste water stream. As such, the system must enable efficient harvesting and maintenance of the Lemnaceae crop while also preventing short circuiting of the waste water flow.

(i) **Temperature buffering:**

Like all biological systems, Lemnaceae plants prefer certain growth conditions over others. Maintenance of these conditions, where possible, is important in achieving both efficient plant growth and effective waste water treatment. Bangladesh, with it's tropical climate and ambient temperature range of 8°C to 39°C during the winter and hot season respectively sustains year round natural growth of duckweed.

The objective of maximizing minimum surface temperatures and minimizing maximum surface temperatures is served by increasing system depth and stimulating system mixing.

An additional consideration dictating system depth is the total detention time (approximately 20 days to achieve acceptable pathogen reduction). It is known that 99.9% pathogen die off in the water column over a long detention period. Enteric pathogen and total coliform of treated effluent for the KHC has been tested over five years from ICDDR'B Laboratory and Envirocare Ltd (a private laboratory) and found to be in the acceptable range.

Experience suggests a system capable of achieving a maximum operational depth of 1.5 meters provides acceptable temperature buffering and detention time without incurring high construction costs.

(ii) **Lemnaceae crop management:**

Among factors affecting Lemnaceae growth, unconstrained access to the pond surface ranks as the most important. Plants should be distributed across the entire surface to avail of the productive potential of that surface They should also be distributed in a manner which does not constrain their growth Increasing the base population of plants in a given area increases the multiple potential of that population.

Efficient distribution of Lemnaceae plants across the entire available growing surface is achieved by placing a floating, interlocking containment grid on the pond surface. The size of the grid is determined by mean ambient wind conditions and the maximum projected system flow velocity.

Having decided on the standing crop density which realizes the highest marginal Lemnaceae productivity, efficient management dictates maintenance of a steady state system at that density. This translates to essentially constant harvesting. A practical manifestation of constant harvesting is daily harvesting. Each cell should be harvested once each day to bring the standing crop density back to the target standing crop density Standing crop density on existing PRISM systems ranges from 400 to 600 grams of Lemnaceae per square meter of the water surface.

Choice of harvesting technique is dictated by system configuration as well as the cost of labour and capital The most simple harvesting mechanism involves scooping of plants from the pond surface standing on the perimeter using simple hand tools

(iii) **Suspended solid removal:**

A significant benefit of Lemnaceae systems over other primarily non-mechanical waste water treatment systems is that they are capable of efficient removal of suspended solids This is achieved through the simple mechanism of shading A dense layer of floating Lemnaceae plants prevents sunlight from reaching algae populations distributed throughout the water column Unable to photosynthesize carbon they simply die and precipitate to the pond bottom.

(iv) **Tertiary treatment:**

Lemnaceae plants do, nevertheless, provide a complete waste water treatment engine Starved Lemnaceae plants i e plants unable to find sufficient nutrients to maintain rapid growth - undergo a remarkable metamorphosis: plant protein drops below 20%; fibre content goes up; roots become long and stringy; fronds become larger and discolored; and most importantly, the begin processing huge amounts of water in their search for sustenance.

(v) **Pathogen removal:**

Pathogen removal in any lagoon system relies on three simple mechanism: dilution, sedimentation and die-off. Parasites and Parasite ova precipitate with other suspended solids and are trapped in the bottom sediment. Other pathogens, suspended in water, simply die as a function of time. Conventional wisdom dictates a detention time of approximately 20 days to achieve a die-off of 99 999% of all pathogens. All PRISM Lemnaceae systems are designed to achieve this.

Under most Bangladeshi circumstances the final effluent from Lemnaceae waste water treatment systems will be superior to the receiving stream or water body. Lemnaceae system runoff may, therefore, be used as input to virtually any water intensive operation - irrigation, factory use, and cooling systems, among others. Providing simple filtration and some form of dis-infection is performed - either chlorination, ozone or UV treatment - treated effluent from a Lemnaceae system may also be used as input to a water supply system or even used directly as drinking water

Technical description of Duckweed based Waste Water Treatment System, Kumudini Hospital Complex, Mirzapur (In operation since 1991)

Sl.	DESCRIPTION	UNITS	TOTAL
1	General Information		
1.1	Total system capacity	Ltr.	14,000,000
1.2	Total user group	No.	3,000
1.3	Total land used	Ha	2.4
2.	Primary treatment system		
2.1	Primary system capacity	Ltr	750,000
2.2	Land requirement	Ha	0 25
2 3	Retention time	hours	24
2.4	Dimension	Length 45m, width 45m, depth 2.5m	
3	Secondary treatment system		
3 1	System capacity	Ltr.	12,000,000
3 2	Land requirement	ha	0.89
3 3	Retention time	Day	20-24
3 4	Dimension	Length 575m, Width 9m, Depth 2m (water depth 0.5 - 1.5 m)	
3 5	Description of DW plug flow		
3 5 1	Lemnaceae species grown	Spirodella, Lemna minor, Wollfia	
3 5.2	Lemnaceae standing crop density	gm/meter^2	650
3 5 3	Methods of harvesting	Manual with net/ring harvesters	
3 5.4	Estimated DW crop harvest	Kg/day	500
3.5 5	Frequency of DW crop harvest	day	Daily
3.5 6	Total annual production of DW	Kg	180,000
3 5.7	Application of DW crop harvested	As fish feed applied fresh daily	
3 5.8	Perimeter crops	Banana, Yum/Taro, Vegetables, etc	
4	Tertiary stage		
4.1	Dimensions	Length 30m, width 10m, depth 2m	

2. Sales proceed from Agro & fruit crop		25,000	30,000	34,000	44,000	65,000	**39,600**
3. Miscellaneous sales	used bags, bamboo, etc.	3,600	4,400	4,600	5,200	5,400	**4,640**
Total income from sales		**157,378**	**288,200**	**355,109**	**451,431**	**475,382**	**345,500**
C. Operating profit		-80,707	38,100	92,287	175,810	181,725	**81,443**
D. Net profit before Taxes		-107,138	10,292	62,860	144,663	148,276	**51,791**

Monitoring of Chemicals, Micro-biological and water quality

The following performance monitoring of the system was conducted on regular basis by the field laboratory operating at site and in collaboration with the institutions like International Diarrhoeal Diseases Research in Bangladesh (ICDDR'B); International Institute for Infrastructure, Hydraulic and Environmental Engineering (IHE), Delft, The Netherlands; Division of Environmental Science, Swiss Federal Institute of Technology (ETH) Zurich, Switzerland; and Department of Fisheries and Aquaculture, Wageningen Agricultural University, Netherlands

The summarised performance data monitored are given below:

1. Chemical and water quality performance monitoring:

Weekly collection of effluent water quality parameter like BOD, Nitrogen (NH_3 & NO_3), Phosphorus, TSS, TDS, pH, Temperature, etc. are being conducted and analysed for the last five years. Periodically compounds like Ca, Mg, Sulphate, NaCl, etc. are being conducted on monthly basis to monitor the nutrient removal performance of Duckweed crop. Consistently water quality of treated effluent met the EPA standard for waste water. Summarised water quality data which was monitored regularly on weekly basis from November 05, 1991 to April 04, 1995 are:

Points	*BOD_5 (mg/l)*	*NH_3 (mg/l)*	*NO_3 (mg/l)*	*SO_4 (mg/l)*	*K (mg/l)*	*P (mg/l)*	*TDS (mg/l)*
Concrete House	319 95	33.37	1.4	10.50	149 30	2.23	470.19
Suction point	236.11	27.22	1 4	7 00	200 25	3.29	402.44
Mixing point	125 12	19.91	0 7	0.50	91.71	1 57	318.20
First bend	89.21	11.41	1 0	0.30	104.32	0.99	294.81
Third bend	30 44	2.38	1.2	0 20	102.74	0.53	243.15
Fifth bend	16.16	1.39	1.2	0 00	73 73	0.60	220.93
Last bend	9.8	1.22	1.2	0 00	96 32	0 26	202.15

2. Pathogen monitoring:

ICDDR'B conducted regular collection of samples of waste water duckweed harvest, effluent water from system at different location, duckweed waste water worker's finger, anal, swab including general health observation, fish gut and scale analysis from fish fed on waste water duckweed were collected for one year and analysed for transmission vector

Total faecal coliform, vibro cholera measurements were conducted and analysed. Their result showed no threat from transmission vector of enteric diseases within the system of waste water treatment, duckweed crop harvested, workers operating the system, fish grown on harvested duckweed feed. In fact there was no difference observed in control rural water bodies and duckweed waste water system. The published performance data & conclusion are given below (Published in Fifth Annual Scientific Conference ASCON V, Dhaka 13-14 January 1996).

(i) **Test:** A bacteriological study was carried out to assess the quality of duckweed, water in which these are grown, and the fish to which these are fed.

Results: The faecal coliform concentrations in water, duckweed and fish ware similar in both wastewater and non-wastewater sources except in raw wastewater. The mean faecal coliform count in raw wastewater was $4.57x10^4$/ml which was reduced to <102/ml after treatment with duckweed

(ii) **Test:** To evaluate the microbial hazards of wastewater grown duckweed as fish feed, the abundance of aeromonads in duckweed, water gills and intestinal contents of fish collected from both wastewater and non-wastewater areas of fish culture project was compared.

Results: The average counts of aeromonads in duckweed were similar in both wastewater and non-wastewater areas. No fish disease was observed in any of the ponds of either area. Moreover, none of the duckweed handlers showed any sign of enteric infection.

3. Monitoring of heavy metal in the waste water:

A study was conducted for heavy metal presence and distribution in the waste water treatment system of the Mirzapur Waste Water Treatment Project in collaboration with ETH, Zurich, Switzerland. The concentrations of Pb, Cr, Co, Cu, Ni, Zn for both sludge and duckweed samples can be judged as acceptable Only one element of all elements tested that gives rise to serious concern is Arsenic (As). High traces of natural Arsenic presence in water bodies and ground water in almost half of the country detected since. The average range values in ppm are:

Metal element	*sediment (sludge)*	*border (sludge)*	*desludging (sludge)*	*polishing (DW)*	*start (DW)*	*Swiss sewage sludge(stnds.1*	*Swiss com-post (stnds.1)*
Pb (Lead)	22-25	24-26	46-50	4-6	0-3	500	120
Cd(Cadmium)	2 5-5	2-2.5	2.5-4	0-1	0-2	5	1
Cr (Chromium)	70-90	84-109	88-93	47-59	20-24	500	100
Co (Cobalt)	14	14-15	14	4	4-6	60	--
Cu (Copper)	44-48	50-55	118-121	30-39	169-249	600	100
Ni (Nickel)	45-46	46-48	50-51	21-26	12-14	80	30
Hg (Mercury)	0-0 6	0-0.8	0-1.25	0	0	5	1
Zn (Zinc)	176-189	148-169	350-368	5-7	28-43	2000	400
As (Arsenic)	3.3 - 3 9	4 3 - 5.0	15.0 - 15.3	4.2 - 4.8	21.9 - 4.3		

4. Overall performance analysis of duckweed based waste water treatment system

Overall performance of the Mirzapur Duckweed Based Waste Water Treatment System on water balance, nutrients profile and removal efficiency of the sewage lagoon by IHE, Delft; ETH, Zurich and AVW, Wageningen was monitored and findings published in the scientific journal (Wat. Res) Finding abstracts are given below.

A sewage lagoon for 2000-3000 capita (0.6 ha) has been operated successfully with a duckweed cover for over four years The cover suppressed algal growth, the effluent turbidity was always below 12 Ntu. Because of inappropriate construction, one fifth of the inflow is lost by percolation and seepage during the dry season, during the wet season the loss is limited. During a detailed sampling period in the dry season actual hydraulic retention time was 20.4 d, and surface loading rate was 48-60 kg BOD_5/ha d. Concentration reduction was 90-97% for BOD_5 for COD, 95-99% for BOD_5, and 74-77% for Kjeldahl-N and total P. Effluent contained 2.7 mg Kjeldahl-N/l and 0 4 mg total P/l. The water column remained aerobic At two-thirds of retention time the plants had absorbed virtually all NH_4^+ and ortho-$PO^{3}_{4}{}^{-}$ from the water column The duckweed harvest would remove in a watertight lagoon 60-80% of the N and P load, or 0.26 gN/M^2.d and 0 05 gN/M^2.d (in the first three-quarters of retention time). The results during the period were representative for the 4-year operation so far. Corrected for leakage, plant productivity under these fertilised and managed conditions was sustained for several years at the level of 58-105 kg(dw)/ha.d, or 715-1200 kg/ha d (over full lagoon surface) in the dry and wet season, respectively. We suggest that the microbial hydrolysis of the more complex organic N and P into NH_4^+ and ortho-$PO^{3}_{4}{}^{-}$ is the limiting step for enhanced biomass production. (Ref· Wat Res Vol 30, No 4, pp.843-852, 1996; Copyright 1996 Elsevier Science Ltd. 0043-1354/96)

Annex 4

Evaluation financial performance of KHC duckweed wastewater and aquaculture facility

KUMUDINI HOSPITAL COMPLEX WASTE WATER SYSTEM, MIRZAPUR
Audited Accounts - Operational Expenditure/Income

A Recurring Operational Costs (annual)	Description line items/ cost center	1993 (Taka)	1994 (Taka)	1995 (Taka)	1996 (Taka)	1997 (Taka)	**5 years average**
1 Land rental (2 Ha)	@Tk 13,000 /Ha/yr	26,000	26,000	26,000	26,000	26,000	**26000**
2 Staff salary & wages	3 x Tk 1500 (Worker) 1 x Tk 2500 & 7 5% benefits	85,600	92,020	98,922	106,341	114,317	**99,440**
3 Field supplies for DW	Bamboo, baskets, bags, stationery, lime, chemicals, etc	10,000	12,000	13,500	14,300	15,200	**13,000**
4 Field supplies for Ag & fish	Fingerlings 12,000, Supl Feed, lime, fertilizer, net, etc	28,000	29,000	30,000	31,000	33,000	**30,200**
5 Energy/fuel cost (pump, etc)	Electricity, POL	43,500	45,500	47,900	50,430	55,720	**48,610**
6 Maintenance	Annual repair ponds, eqpt , etc	13,700	14,000	14,500	15,200	16,720	**14,824**
7. Miscellaneous	Sundry, entertainment, etc	6,285	6,580	7,000	7,350	7,700	**6,983**
Total annual operating cost		**213,085**	**225,100**	**237,822**	**250,621**	**268,657**	**239,057**
8 Depreciation (10 years basis)	Tk 250000 initial investment in sys	25,000	25,000	25,000	25,000	25,000	**25,000**
9 Administrative management OH	@7 5%	15,981	16,883	17,837	18,797	20,149	**17,929**
10 Financial costs	@9 5% on WC	10,450	10,925	11,590	12,350	13,300	**11,723**
Sub-total admin & finance cost		51,431	52,808	54,427	56,147	58,449	**54,652**
Total annual recurring costs		**264,516**	**277,908**	**292,249**	**306,768**	**327,106**	**293,709**
B Income from farm revenue							
1 Sales proceed from fish fed on DW		128,778	253,800	316,509	402,231	404,982	**301,260**
	Kg x Rate	(3380*38 1)	(6345*40)	(7572*41 8)	(9268*43 4)	(8672*46 7)	
2 Sales proceed from Agro & fruit crop		25,000	30,000	34,000	44,000	65,000	**39,600**
3 Miscellaneous sales	used bags, bamboo, etc	3,600	4,400	4,600	5,200	5,400	**4,640**
Total income from sales		**157,378**	**288,200**	**355,109**	**451,431**	**475,382**	**345,500**
C Operating profit		-55,707	63,100	117,287	200,810	206,725	**106,443**
D Net profit before Taxes		-107,138	10,292	62,860	144,663	148,276	**51,791**

4.2	Treated effluent output	Ltr./day	300,000
4.3	Treated quality		
4.3 1	Ammonia (NH3)	mg/l	1 22
4.3.2	Nitrates (NO3)	mg/l	0 8
4.3.3	Phosphates	mg/l	0.09
4.3.4	TSS	mg/l	17.8
4.3 5	BOD	mg/l	8.2
4.3.6	Total coliform count	No.	<100
4 3 7	Total pathogen count	No.	nil
5	Fish pond		
5.1	Land for fish pond	Ha	1
5 2	Fish pond water area	Ha	0.6
5 3	Type of fish culture	6 types of carp polyculture	
5 4	Fingerling stocking rates	No.	10,500
5.5	Mix of fish	Grass carp Rohu Catla Mrigal Silver carp Mirror carp	20% 15% 15% 20% 15% 10%
5 6	Supplementary feed: oil cake & wheat bran	Kg/day/ha	35
5.7	Estimated fish production	Kg/year	6,000
5 8	Fertilizer when necessary	Kg/month/ha	150
5.9	Frequency of fish harvest	Weekly	Twice

KUMUDINI HOSPITAL COMPLEX WASTE WATER SYSTEM, MIRZAPUR
Audited Accounts - Operational Expenditure/Income

A. Recurring Operational Costs (annual)	Description line items/ cost center	1993 (Taka)	1994 (Taka)	1995 (Taka)	1996 (Taka)	1997 (Taka)	**5 years average**
1. Land rental (2 Ha)	@Tk.13,000 /Ha/yr	26,000	26,000	26,000	26,000	26,000	**26000**
2 Staff salary & wages	3 x Tk 1500 (Worker) 1 x Tk 2500 & 7.5% benefits	85,600	92,020	98,922	106,341	114,317	**99,440**
3. Field supplies for DW	Bamboo, baskets, bags, stationery, lime, chemicals, etc.	10,000	12,000	13,500	14,300	15,200	**13,000**
4 Field supplies for Ag. & fish	Fingerlings 12,000, Supl. Feed, lime, fertilizer, net, etc.	28,000	29,000	30,000	31,000	33,000	**30,200**
5 Energy/fuel cost (pump, etc.)	Electricity, POL	43,500	45,500	47,900	50,430	55,720	**48,610**
6 Maintenance	Annual repair ponds, eqpt , etc.	13,700	14,000	14,500	15,200	16,720	**14,824**
7. Miscellaneous	Sundry, entertainment, etc.	6,285	6,580	7,000	7,350	7,700	**6,983**
Total annual operating cost		**213,085**	**225,100**	**237,822**	**250,621**	**268,657**	**239,057**
8 Depreciation (10 years basis)	Tk 250000 initial investment in sys	25,000	25,000	25,000	25,000	25,000	**25,000**
9. Administrative management OH	@7 5% annual operating cost	15,981	16,883	17,837	18,797	20,149	**17,929**
10. Financial costs	@9.5% on WC	10,450	10,925	11,590	12,350	13,300	**11,723**
Sub-total admin. & finance cost		51,431	52,808	54,427	56,147	58,449	**54,652**
Total annual recurring costs		**264,516**	**277,908**	**292,249**	**306,768**	**327,106**	**293,709**
B Income from farm revenue							
1 Sales proceed from fish fed on DW		128,778	253,800	316,509	402,231	404,982	**301,260**
	Kg. x Rate	(3380*38.1)	(6345*40)	(7572*41.8)	(9268*43.4)	(8672*46 7)	

MIRZAPUR KUMUDINI COMPLEX DUCKWEED WASTEWATER TREATMENT SYSTEM (1992-98)

Financial Aspect:

A. Total project cost:

Description of Item	*Cost incurred*	*Cost to be incurred*	*Total cost (Tk.)*
1 Land cost (2 Ha)	524,000	0	524,000
2 Land development	0	220,000	220,000
3 Machinery & Equipment	0	30,000	30,000
4 IDCP	0	25,000	25,000
5 Total Fixed Cost	524,000	275,000	799,000
6 Working capital (6 months)		110,000	110,000
7 Total cost of the project			909,000

B. Means of Financing:

Loan from PRISM	Tk.250,000
Paid up Capital (in long term lease from KWT)	Tk.524,000
Total	Tk.774,000
Deferred IDCP	Tk 25,000
Total	Tk 799,000

C. Debt Equity Ratio (excluding IDCP): 32 : 68

1. Fixed cost of the project:

Description			*Total cost (Tk)*
1	Cost of leased land & fish pond	(1 2 + 0 8) Ha @Tk 262,000	524,000
2	Construction of Secondary plug flow	0 7 Ha (301,00 cft @Tk 0 65	195,650
3	Construction of gates & settlement tank	outlet gates 1nos & Concrete house inlet 1 nos	24,350
4.	Equipment	0.75 cusec Pump with accessories 1 set, weighing scale, hand tools, safety gloves, bamboo grid, etc	30,000
	Total fixed costs		774,000

2. Recurring operational cost:

Description	*Year 1*	*Year 2*	*Year 3*	*Year 4*	*Year 5*
A Salary and Wages	85,600	92,020	98,922	106,340	114,316
i) Supervisor 1 @Tk 2500 pm					
ii) S Workers 3 @Tk 1500 pm					
iii) Benefits @ 7 5% PA					
B DW field supplies	10,000	12,000	13,500	14,300	15,200
Baskets #5, harvest net #5, bamboo grid replacement, herbicide, chemicals, etc					
C Field supplies fish & Agri	28,000	29,000	30,000	31,000	33,000
Fingerlings #12000, suppl feed, lime, fertiliser, net, etc					
D Electricity & POL costs	43,500	45,500	47,900	50,430	55,720
Pump operation, lighting, etc					
E Maintenance	13,700	14,000	14,500	15,200	16,720
WW plug flow, Farm, equipment, plantation, etc					
F Land lease cost PA	26,000	26,000	26,000	26,000	26,000
2 Ha @Tk 13000					
G Sundry & Misc	6,285	6,580	7,000	7,350	7,700
Total recurring operational costs	213,085	225,100	237,822	250,620	268,656

3. Depreciation cost analysis:

Description	*Year 1*	*Year 2*	*Year 3*	*Year 4*	*Year 5*
1 WW plug flow system @ 8 5%	19,000	19,000	19,000	19,000	19,000
2 Equipment @ 20%	6,000	6,000	6,000	6,000	6,000
Total depreciation	25,000	25,000	25,000	25,000	25,000

4. Cost of goods sold:

Description	*Year 1*	*Year 2*	*Year 3*	*Year 4*	*Year 5*
1 DW & fish supplies	38,000	41,000	43,500	45,300	48,200
2 Salary & Wages(direct labour)	85,600	92,020	98,922	106,340	114,316
3 Production overhead	63,485	66,080	69,400	73,180	80,140
4 Land lease cost	26,000	26,000	26,000	26,000	26,000
5 Depreciation on system	25,000	25,000	25,000	25,000	25,000
Total cost of good sold	238,085	250,100	262,822	275,820	293,656

5. Working capital analysis:

Description	*Year 1*	*Year 2*	*Year 3*	*Year 4*	*Year 5*
50% of the ROC is considered as WC for six months to be borrowed @ 9 5% interest rate The lease rent is paid annually	110,000	115,000	122,000	130,000	140,000

6. Statement of sales:

Description	*Year 1*	*Year 2*	*Year 3*	*Year 4*	*Year 5*
1 Sales proceed from fish	128,778	253,800	316,509	402,231	404,982
Harvest Kg. X Sale Rate in Taka	*3380*38.1*	*6348*40*	*7572*41.8*	*9268*43 4*	*8672*46.7*
2 Sales proceed from Ag & fruits Vegetable, banana, papaya, etc	25,000	30,000	34,000	44,000	65,000
3 Miscellaneous sales Gunny bags, baskets, used bamboo, etc	3,600	4,400	4,600	5,200	5,400
Total sales	157,378	288,200	355,109	451,431	475,382

7. Current liabilities:

Description	*Year 1*	*Year 2*	*Year 3*	*Year 4*	*Year 5*
Working capital loan (50%) for recurring operation costs	110,000	115,000	122,000	130,000	140,000

8. Earning from project operation:

Description	*Year 1*	*Year 2*	*Year 3*	*Year 4*	*Year 5*
1. Sales revenue	157,378	288,200	355,109	451,431	475,382
2 Cost of goods sold	238,085	250,100	262,822	275,820	293,656
3 Gross profit	-80,707	38,100	92,287	175,611	181,726
4 Admin. & magt Overhead	15,981	16,883	17,837	18,797	20,149
5 Operating profit	-96,688	21,217	74,450	156,814	161,577
6 Financial expenses (WC inst)	12,950	26,500	27,165	27,925	28875
7 Net profit before tax	-109,638	-5,283	47,285	128,889	132,702
Tax holiday (no tax on agro-production)					
8 Net profit after tax	-109,638	-5,283	47,285	128,889	132,702

9. Financial expenses:

Description	*Year 1*	*Year 2*	*Year 3*	*Year 4*	*Year 5*
a) Interest on Term Loan	0	13,075	13,075	13,075	13,075
b) Interest on working capital	10,450	10,925	11,590	12,350	13,300
c) Amortisation of IDCP	2,500	2,500	2,500	2,500	2,500
Total	12,950	26,500	27,165	27,925	28,875

10. Brake even analysis:

1	Total Sale revenue (3rd year)	= Tk 355,109
2	Variable cost	= Tk 197,322
a)	Field supplies	= Tk 43,500
b)	Direct labour	= Tk 98,922
c)	Energy & POL cost	= Tk 47,900
d)	Miscellaneous cost	= Tk 7,000
3.	Fixed cost	= Tk 80,575
a)	Land lease	= Tk.26,000
b)	Depreciation	= Tk 25,000
c)	Administrative management overhead	= Tk 14,000
d)	Financial expenses	= Tk 15,575
4	Annual regulated cost	= Tk 30,228
a)	Repair & maintenance	= Tk.14,500
b)	Interest on Working Capital	= Tk.11,891
c)	General expenses	= Tk 3,837

Total regulated cost distributed equally to Fixed Cost & Variable Cost

Total fixed cost	= Tk 80,575 + Tk 15,114	= Tk. 95,609
Total variable cost	= Tk 197,322 + Tk 15114	= Tk 212,436

Break-even Sales = FC ÷ {(Sales - VC)/Sales}
= 95,609 ÷ {(355,109 - 212,436)/355,109}
= 95,609 ÷ 0 402
= 240,320

Break even Sales Value = Tk 240,320
Break even operation capacity = 67.7%

10. Brake even analysis:

1	Total Sale revenue (4th year)	= Tk 451,431
2	Variable cost·	= Tk 209,421
a)	Fıeld supplies	= Tk.45,300
b)	Direct labour	= Tk.106,341
c)	Energy & POL cost	= Tk 50,430
d)	Miscellaneous cost	= Tk 7,350
3	Fixed cost	= Tk 80,575
a)	Land lease	= Tk 26,000
b)	Depreciation	= Tk 25,000
c)	Administratıve management overhead	= Tk 14,000
d)	Financial expenses	= Tk 15,575
4	Annual regulated cost.	= Tk 33,867
a)	Repair & maintenance	= Tk 16,720
b)	Interest on Working Capital	= Tk 12,350
c)	General expenses	= Tk 4,797

Total regulated cost distributed equally to Fixed Cost & Variable Cost

Total fixed cost	= Tk 80,575 + Tk 16,934	= Tk 97,509
Total variable cost	= Tk 209,421 + Tk 16,934	= Tk 226,355

Break-even Sales = FC – {(Sales - VC)/Sales}
= 97,509 – {(451,431 - 226,355)/451,431}
= 97,509 – 0 4985
= 195,605

Break even Sales Value = Tk 195,605
Break even operatıon capacıty = 43 33%

11. Project cash flow statement:

(Tk. in '000)

Particulars	*FY – 0*	*FY -1*	*FY -2*	*FY -3*	*FY -4*	*FY -5*
SOURCE OF FUND						
1 Term Loan	250					
2 Deferred Payment of Interest	25					
3 Sponsor's Equity	524					
4 Operating profit		-96 69	21 22	74.45	156 81	161 58
5 Others income		0	0	0	0	0
6 Increase in current liabilities		213 1	14 15	15 25	15 78	21 46
7 Depreciation and wnte-off		25	25	25	25	25
Total Inflow	799 00	141 41	60 37	114 70	197 59	208 04
UTILISATION OF FUND						
1 Fixed capital investment	799.00					
2 Increase in current assets		110 0	5 0	7 0	8 0	10 0
3 Repayment in term loan		0	25	25	25	25
4 Payment of interest		10 45	10 93	11 59	12 35	13 30
5 Decrease in deferred payment of interest		2 50	2 50	2 50	2 50	2 50
Total Outflow	799 00	122 95	43 43	46 09	47 85	50 80
Cash Surplus	0 00	18 46	16 94	68 61	149 74	157 24
Opening Cash Balance		0	18 46	35 4	104 01	253 75
Closing Cash Balance		18 46	35.4	104 01	253 75	410 99

12. Calculation of financial rate of return (IRR)

Year	*Cost of the project*	*Benefit of the project*	*Net cash flow*
0	250000	0	-250000
1	213100	-30700	-243800
2	14150	88100	73950
3	15250	142300	127050
4	15780	225800	210020
5-10	21460	231700	210240
Salvage value		74,500	74,500

NPV @25%	15,520
NPV @30%	(62,480)
IRR (Internal Rate of Return)	25 88%

Assumption

1 Interest during construction is calculated over a period of one year
2 The economic life of the project will be ten years
3 The fixed cost of the project has been estimated at Tk 774 (excluding IDCP)
4 Benefit of the project

Particulars	*Fy - 1*	*Fy - 2*	*Fy - 3*	*Fy - 4*	*Fy - 5*
Operating profit	-55 7	63 1	117 3	200 8	206 7
Depreciation	25	25	25	25	25
Total	-30 70	88 10	142 30	225 80	231 70

5 Project Salvage value

1	Land (on lease)	100%	Tk.524,000
2	WWT System	10%	Tk 25,000
3	Inventory		
	a) Fingerlings stock		Tk 9,500
	b) Field eqpt		Tk 6,000
	c) Plantation		Tk. 30,000
		Actual salvage value	Tk.70,500

13. Financial Ratios:

Items	*Fy – 1*	*Fy - 2*	*Fy - 3*	*Fy - 4*	*Fy - 5*
Gross profit to sales ratio %	(51.28)	13.22	25 98	38 90	38 22
Net profit to sales ratio %	(69.66)	(1 83)	13 31	28 55	27.91
Return on initial equity %	62 95	115 28	142	180	190
Return on investment %	17 31	31 7	39 0	49 66	52 29
Debt-equity ratio %			32 68		
Debt-service coverage (times)	NA	1 74	3 66	6 51	6 46

14. Debt-service coverage ratio (DSCR):

	Fy – 1	*Fy - 2*	*Fy - 3*	*Fy - 4*	*Fy - 5*
Income					
Net profit after tax	-109638	-5283	47285	128889	132702
Non-operating expenses	12950	26500	27165	27925	28875
Depreciation	25000	25000	25000	25000	25000
Total	-71,688	46,217	99,450	181,814	186,577
Liabilities					
Instalment of term loan					
Interest on term loan	0	13,075	13,075	13,075	13,075
Interest on WC loan	10,450	10,925	11,590	12,350	13,300
Amortisation of IDCP	2,500	2,500	2,500	2,500	2,500
Total	12,950	26,500	27,165	27,925	28,875
DSCR (Times)	NA	1 74	3.66	6 51	6 46

Annex 5

UNCDF evaluation of PRISM duckweed based village sanitation and aquaculture projects

PROJECT PERFORMANCE INDICATORS
BGD/91/C06 - INTEGRATED AQUACULTURE (DUCKWEED)
(As on June 1998)

1 Enterprises and borrowers

a)	Number of aquaculture enterprises developed	= 143 nos.	
	i) Joint Stock Company	= (42+3) = 45 nos.	
	ii) Informal Enterprises	= (96+2) = 98 nos.	
b)	Numbers of target producers/borrowers engaged	= 815 nos.	
c)	Average loan size per borrowers	= Tk. 30,799	≈ US$ 655
d)	Average loan size per enterprise	= Tk.174,834	≈ US$ 3,720
d)	Credit management cost per field staff (26)	= Tk. 76,864	≈ US$ 1,635
e)	Credit management cost per all staff (45)	= Tk. 93,849	≈ US$ 1,997
g)	Credit management cost per borrower (all)	= Tk. 5,182	≈ US$ 110
	(current rate $1 = Tk.47 is considered)		

2 Credit Operation (as on June 1998)

a)	Total credit disbursed	= Tk.29,581,200	≈ US$734,754
b)	Total outstanding	= Tk.17,936,384	≈ US$445,514
c)	Total repayment (principal)	= Tk.11,914,816	≈ US$295,947
d)	Total income from credit operation (interest)	= Tk. 2,663,311	≈ US$ 66,153
	(Average rate $1 = Tk.40.26 is considered)		

3 Employment Generation

a)	Total direct employment generation	= 1150 persons	
b)	Cost per employment creation	= Tk. 28,774	≈ US$ 612

4. Production and Income

a)	Total production increased -		
	i) Fish per annum	= 313 MT	
	ii) Duckweed per annum	= 970 MT	
	iii) Associated vegetables and fruits	= 512 MT	
b)	Land brought under production	= 93 Ha	
c)	Annual fish production increased	= 5 - 6 MT/Ha	
d)	Annual duckweed production increased	= 150-200 MT/Ha	
e)	Increased income from fish sale project areas per year	= Tk.17,427,500	≈ $371,000
f)	Increased income per borrowers per year	= Tk.26,400	≈ US$ 562

5. Other Project Benefits accrued

a)	Total capitalisation of rural assets created	= Tk.11,485,500
b)	Increased food nutrition availability	
	i) Fish	= 1138 MT
	ii) Agro products (Vegetables + Fruits)	= 2200 MT
	iii) Duckweed Feed(dry weight)	= 515 MT
c)	Unproductive land brought under production	= 54.5 Ha
d)	Sanitation improvement -	
	i) Latrine installed	= 838 Nos
	ii) Sanitation awareness built	= 815 households
e)	Skill development (training) -	
	i) Staff trained	= 60 persons
	ii) Beneficiaries trained	= 815 persons
	iii) Others organizations	= 400 persons
e)	Women involved in direct fish production	= 96 persons
f)	DW acceptance as a fish feed and duck feed	= Very widely known & practiced in the project area

Annex 6

Evaluation of financial performance of a village duckweed-aquaculture system

UFULKI MATSHA KHAMAR LTD.
Audited Accounts - Operational Expenditure/Income

A Recurring Operational Costs (annual)	Description line items/ cost center	1995-96 (Taka)	1996-97 (Taka)	1997-98 (Taka)	**3 years average**
1 Land rental					
2 Labour & wages	Special Labour hired and own contribution	19,600	1,500	700	**7,267**
3 Supplies					
a) Fingerling Stocking	Yearly stocking	9,500	6,000	4,500	**6,667**
b) Fresh Duchweed	Own source & fed fresh	*14590 Kg*	*16720 Kg*	*15340 Kg*	**15,550**
c) Oil Cake	Supplementary feed	33,000	18,000	18,300	**23,100**
d) Fertilizer		8,300	7,200	7,000	**7,500**
4 Water supply/irrigation		8,250	4,000	2,800	**5,017**
5 Miscellaneous	Bamboo, baskets, lime, stationery, etc	9,900	300	200	**3,467**
6 **Annual operating cost**		**88,550**	**37,000**	**33,500**	**53,017**
7 Depreciation (5 years basis)		33,600	33,600	33,600	**33,600**
8 Administrative overhead	Audit, reporting and profit sharing	3,860	7,100	7,661	**6,207**
9 Financial costs (interest)		27,390	20,106	20,884	**22,793**
10 Sub-total admin & finance cost		64,850	60,806	62,145	**62,600**
11. **Total annual costs**		**153,400**	**97,806**	**95,645**	**115,617**
B Income from farm revenue					**0**
1 Sales proceed from fish fed on DW		147,210	151,100	148,000	**148,770**
	Kg x Rate	(3573*41 20)	(3490*43 30)	(3503*42 25)	
2 Sales proceed from Agro & fruit crop		0	0	0	**0**
Total income from sales		**147,210**	**151,100**	**148,000**	**148,770**
C Operating profit	(Sales - (Annual operating cost + Depr)	25,060	80,500	80,900	**62,153**
D Net profit before Taxes		-6,190	53,294	52,355	**33,153**

INFORMATION ON ENTERPRISE

1 Name of the Enterprise UFALKI MATSHAW KHAMAR LTD

2. Address Village Ufalki P O Borati

P S Mirzapur District Tangail

3 Name of the Chairman Haji Aman Uddin

4 Name of the Managing Director Mohammed Mosharraf Hossain

5 Date of Establishment October 07, 1994

6 Total Members 8 Male 8 Female 0

7 Total Shares 218 Group's share 198 PRISM Share 20

8 Total farming land 198 Fish 148 Duckweed : 50

9 Total no of ponds 6 Fish 3 Duckweed 3

10 Total shareholder's land under the enterprise 198

11 Total licensed land 0 Licensing fee 0

12 Project Cost Fixed Capital Tk 168,000

Working Capital Tk 88,850

Total Tk 256,850

13 Share holder's own investment Fixed Capital 0
Working Capital 0
Total 0

14 Farmer's Category:

Type of farmer	Middle/small	Marginal	Land-less	Total
Male	1	7	0	8
Female	0	0	0	0
Total	1	7	0	8

UFALKI MATSHA KHAMAR LTD. (1995-98)

Financial Aspect:

A. Total project cost:

Description of Item	*Cost incurred*	*Cost to be incurred*	*Total cost (Tk.)*
1 Land cost (0.8 Ha)	99,000	0	99,000
2 Land development (pond excavation)	105,750	0	105,750
3 Latrine construction	4,000	0	4,000
4 Water supply and irrigation	28,500	0	28,500
5 Incorporation & land registration costs	16,400	0	16,400
4 Others fixed cost	13,350	0	13,350
5 Total Fixed Cost	267,000	0	267,000
7 Working capital	88,850	0	88,850
8 Total cost of the project	355,850	0	355,850

B. Means of Financing:

Loan from PRISM	Tk 256,850
Paid up Capital (own source - land contribution)	Tk 99,000
Total	Tk.355,850

C. Debt Equity Ratio: **72 : 28**

1. Fixed cost of the project:

	Description		*Total cost (Tk)*
1	Cost of land & fish pond (capitalized)	0.8 Ha @Tk 123,500	99,000
2	Pond re-excavation	0 8 Ha (162,000 cft @Tk 0 65)	105,750
3	Construction of latrines	Construction of Latrines 2 sets	4,000
4	Water supply and irrigation	Installation of pump & drainage system	28,500
5	Incorporation & land registration costs	Land registration, etc.	16,400
6	Other fixed costs	Weighing scale, hand tools, safety gloves, bamboo grid, etc	13,350
	Total fixed costs		267,000

2. Annual (recurring) operational cost:

Description	*Year 1*	*Year 2*	*Year 3*
A Direct Labour cost	19,600	1,500	700
B Field supplies fish & Agri Fingerlings #12000, suppl Feed, lime, fertiliser, net, etc	50,800	31,200	29,800
C Water supply cost Pump operation, lighting, etc	8,250	4,000	2,800
G Sundry & Misc Baskets #5, harvest net #5, bamboo grid replacement, herbicide, chemicals, etc	9,900	300	200
Total recurring operational costs	88,550	37,000	33,500

3. Depreciation:

Description	*Year 1*	*Year 2*	*Year 3*
1 Depreciation on FC (5 years)	33,600	33,600	33,600
Total depreciation	33,600	33,600	33,600

4. Cost of goods sold:

Description	*Year 1*	*Year 2*	*Year 3*
1 DW & fish supplies	68,950	35,500	32,800
2 Salary & Wages(direct labour)	19,600	1,500	700
3 Depreciation	33,600	33,600	33,600
Total cost of good sold	122,150	70,600	67,100

5. Statement of sales:

Description	*Year 1*	*Year 2*	*Year 3*
1 Sales proceed from fish	147,210	151,100	148,000
Harvest Kg. X Sale Rate in Taka	*3573*41.2*	*3490*43.3*	*3503*42.3*
2 Sales proceed from Ag & fruits Vegetable, banana, papaya, etc	0	0	0
Total sales	147,210	151,100	148,000

6. Current liabilities:

Description	*Year 1*	*Year 2*	*Year 3*
Working capital loan for recurring operation costs	88,850	37,000	33,500

7. Earning from project operation:

Description	*Year 1*	*Year 2*	*Year 3*
1 Sales revenue	147,210	151,100	148,000
2. Cost of goods sold	122,150	70,600	67,100
3 Gross profit	25,060	80,500	80,900
4 Admin & magt Overhead	3,860	7,100	7,661
5 Operating profit	21,200	73,400	73,239
6 Financial expenses (interest)	27,390	20,106	20,884
7 Net profit before tax	-6,190	53,294	52,355
Tax holiday (no tax on agro-production)			
8 Net profit after tax	-6,190	53,294	52,355

8. Financial expenses:

Description	*Year 1*	*Year 2*	*Year 3*
a) Interest on Term Loan	16,680	16,680	16,680
b) Interest on working capital	10,710	3,426	4,204
Total	27,390	20,106	20,884

09. Brake even analysis:

1 Total Sale revenue (2nd year)	**= Tk.151,100**
2 Variable cost	**= Tk.37,000**
a) Field supplies	= Tk 31,200
b) Direct labour	= Tk 1,500
c) Water supplies & irrigation cost	= Tk 4,000
d) Miscellaneous cost	= Tk 300
3 Fixed cost	**= Tk.60,806**
a) Depreciation	= Tk 33,600
b) Administrative management overhead	= Tk 7,100
c) Financial expenses	= Tk 20,106
4 Annual regulated cost	= Tk 0 0

Total regulated cost distributed equally to Fixed Cost & Variable Cost

Total fixed cost = Tk 60,806
Total variable cost = Tk 37,000

Break-even Sales = FC – {(Sales - VC)/Sales}
= 60,806 – {(151,100 – 37,000)/151,100}
= 60,806 – 0.755
= 80,537

Break even Sales Value = Tk 80,537
Break even operation capacity = 53 3%

10. Project cash flow statement:

Particulars	*FY - 0*	*FY -1*	*FY -2*	*FY -3*
SOURCE OF FUND				
1. Term Loan	168,000			
2 Sponsor's Equity	99,000	0	0	0
3 Operating profit		25,060	80,500	80,900
4 Others income		0	0	0
5 Increase in current liabilities		88,550	-51,550	-3,500
7 Depreciation and write-off		33,600	33,600	33,600
Total Inflow	267,000	147,210	62,550	111,000
UTILISATION OF FUND				
1 Fixed capital investment	267,000			
2 Increase in current assets		88,550	-51,550	-3,500
3 Repayment in term loan		33,600	33,600	33,600
4 Payment of interest		27,398	27,398	27,398
Total Outflow	267,000	149,548	9,448	57,498
Cash Surplus	0	-2,338	53,102	53,502
Opening Cash Balance		0	-2,338	50,764
Closing Cash Balance		-2,338	50,764	104,266

11. Discounted Cash flow statement

Year	*Capital outlay*	*Pre-tax profit*	*Non-cash expenses*	*Interest*	*Net cash flow*
0	267,000	0	0	0	-267,000
1	88,550	-6,190	33,600	27,390	-33,750
2	37,000	53,294	33,600	20,106	70,000
3	33,500	52,355	33,600	20,884	73,339
4	33,500	52,355	33,600	20,884	73,339
5	33,500	52,355	33,600	20,884	73,339
6	0	87,039	19,800	0	106,839
7	0	87,039	19,800	0	106,839
8	0	87,039	19,800	0	106,839
9	0	87,039	19,800	0	106,839
10	(126,235)	87,039	19,800	0	233,074

NPV @20%	9,562
NPV @25%	(49,875)
IRR (Internal Rate of Return)	20 7%

Assumption

1 Interest during construction is calculated over a period of one year
2 The economic life of the project will be five years
3 The fixed cost of the project has been estimated at Tk 267,000
4 Benefit of the project

Particulars	*Fy - 1*	*Fy - 2*	*Fy – 3*
Operating profit	20,900	73,400	73,239
Depreciation	33,600	33,600	33,600
Total	54,500	107,000	106,839

5 Project Salvage value

1 Land (own land)	100%	Tk 99,000
2 Inventory		
a) Fingerlings stock		Tk. 1,500
b) Field eqpt & accessories (10%)		Tk. 4,585
c) Fish pond (20%)		Tk 21,150
	Actual salvage value	Tk 126,235

12. Financial Ratios:

Items	*Fy – 1*	*Fy – 2*	*Fy – 3*
Gross profit to sales ratio %	17 02	53.27	54 66
Net profit to sales ratio %	(4.20)	35 27	35 37
Return on initial equity %	25.31	81.31	81 71
Return on investment %	7 04	22 62	22 73
Debt-equity ratio %		72 . 28	
Debt-service coverage (times)	0 90	1 99	1.96

13. Debt-service coverage ratio (DSCR):

	Fy – 1	*Fy - 2*	*Fy – 3*
Income			
Net profit after tax	-6,190	53,294	52,355
Non-operating expenses	27,390	20,106	20,884
Depreciation	33,600	33,600	33,600
Total	54,800	107,000	106,839
Liabilities			
Instalment of term loan	33,600	33,600	33,600
Interest on term loan	16,680	16,680	16,680
Interest on WC loan	10,710	3,426	4,204
Total	60,990	53,706	54,484
DSCR (Times)	0 90	1.99	1 96

Annex 7

Proposal for upgrading of KHC to a Demonstration & Research Station

Annex 7

Upgrading of KHC facilities into a Demonstration and Research Station for duckweed technology

Proposal: To upgrade the duckweed wastewater treatment facilities at Kumudini Hospital Complex (KHC) into a full fledged Demonstration and Research Station for duckweed technology.

Objectives: Under the abovementioned general objective, the following specific objectives can be defined

a) To provide infrastructural support and improvements which will upgrade the present wastewater treatment and aquaculture facility to an optimally functioning demonstration system for wastewater treatment and resource recovery. The same will be done for a nearby village enterprise, in order to demonstrate also the latrine based duckweed system.

b) To provide a good laboratory infrastructure, equipment and chemicals for high quality monitoring of routine (treatment) parameters and for the implementation of laboratory and field research programmes and analyses. The laboratory will also have a support function to duckweed projects in the region (monitoring, sample analyses)

c) To provide facilities for the implementation of training programmes, seminars and workshops on site

Location: The upgrading of facilities will be done at KHC, Mirzapur, Bangladesh A long term agreement exists between KHC and PRISM for the use of land and infrastructure, but this agreement may need to be updated in order to cover arrangements for the new facilities to be brought in under the project.

Project period: The infrastructure improvement and equipment purchases will be implemented during the start of the project Support for routine monitoimg activities and for the applied research programme will cover a period of 4 years (2000-2004).

Estimated budget: The budget required for the investments and monitoring activities is estimated at $ 450,000. Additional budgets for research activities will be provided under the project component for 'demonstration of duckweed bnased wastewater treatment' via a research grant programme.

Brief discription of activities and inputs:

Using the facilities at KHC, PRISM has over the years undertaken an impressive demonstration study on duckweed-based wastewater treatment and aquaculture, with numerous parameters which have been monitored in a standardized and disciplined way. The excellent infrastructure available should be exploited for the implementation of well defined research and optimization studies The current infrastructure available at KHC provides excellent possibilities for further upgrading to a research and demonstration facility to support further initiatives (projects) in duckweed based wastewater treatment in Bangladesh and the wider region. Once upgraded, the KHC demonstration facility could provide a major support funtion to new projects via training, demonstration, analyses and monitoring, and for applied research. In order to assume these functions, the facilities require upgrading and a laboratory for analyses of routine monitoring parameters and research should be established

The proposed infrastructure improvements and purchases include the following:

- upgrading of wastewater/aquaculture ponds (KHC and village)
- expansion of existing laboratory space
- laboratory equipment (pH meter, fotospectrometer, BOD incubator, microbiology facilities such as laminar flow, small autoclave, incubator, combustion stove, DO meters, conductivity meters, ion selective electrodes, portable meters for field testing, glass ware, chemicals)
- construction of training/seminar room (capacity of 30 people) at the PRISM guest house at the backside of KHC, and provision of audiovisual facilities for the training/seminar room.

Annex 8

Selection criteria project sites

Annex 8

Criteria for the selection of areas and sites

General selection criteria A:

- Representing different micro-environments.
- At village level, growth centers level, peri-urban level outside the Metropolitan area.
- Willingness to contribute land by local Govt. & community.
- Potential participation in Duckweed based waste water treatment linked to development of safe aquaculture.
- Good communication & accessibility
- High potential for demonstration impact.
- Ease of the project management?
- Vulnerability to flood.
- Geographical coverage

Indicators B:

- Nature of site.
- Availability of waste water & solid waste
- Source of waste water & solid waste.
- Quantity of waste water & solid waste.
- Availability of school.
- Collection system (Existence/Prospect)
- Presence of separate collection system
- Impact of waste water & solid waste on environment
- Existence of treatment facilities.
- Land availability.
- Land value
- Availability of fish pond & size.
- Availability of derelict pond & size.
- Water supply / Irrigation.
- Existing latrine system
- Communication.
- Size of community.
- Co-operation.
- Marketing facilities
- Security
- Flooding condition.
- Soil condition.
- Retention of water.
- Overall awareness

Primary selection criteria C:

- Sites represent different micro-environments / conditions
- Large amount of waste water produced (waste water sources, quantity & quality accessibility, availability, existing, facilities, type, composition).
- Currently encountered high intensity of waste water & sanitation problem.
- Current uses of the waste & waste water
- Existing practices in waste recycling and resource / re-use experience and practices

  Optimal logistical condition.

  Good demonstration prospects. high visibility, easy access.
- Potential for defining of clear boundaries appropriates size and scales of each project site.
- Compatability between sites and project holders DPHE, directly linked institutes, donors, School & Community sanitation project

  Good prospects for external participation by the stakeholders.
- Current system opportunity cost - land, water, waste, energy, labour etc
- Status of water supply (domestic, industrial, irrigation)
- Experience in aquaculture.

Final selection criteria D:

- Highest score in the primary selection criteria.

  Positive stakeholders perception of problems with respect to waste, sanitation and health situation.
- Best prospect with respect to - investment, economical benefit, secondary benefits, improved water quality, fish and agriculture production, well being and health situation.
- Best logistical support.
- Advanced state of preparedness for project participation.
- Presence of limiting factors in aquaculture.
- Availability of land.
- Positive soil condition / ground water level
- Different types of waste water to be considered for different sites.

FINANCIAL ASSUMPTIONS FOR COST ESTIMATES AND ANALYSIS OF DUCKWEED WASTE WATER TREATMENT SYSTEM CONSTRUCTION

SL	DESCRIPTION	UNITS	For 500M^3/Day Cost (Taka)	For 1000M^3/Day Cost (Taka)	For 1500M^3/Day Cost (Taka)
A.	FIXED CAPITAL COST				
1	Improvement of collection system (Community sanitary latrine installation, maximize collection, reduce loss & dispersal, repair, slope improvement, drains, etc)	500m - 1000m	75000 00	112500 00	150000 00
2	Construction of floating offal trap/grit trap	1 no with collection grid	40000 00	60000 00	80000.00
3	Pre-treatment system for BOD reduction	Anaerobic pond/Bio-gas	50000 00	80000 00	120000 00
4	Primary Settlement Tank Construction (Oxidation)				
4 1	Earthen Work in Excavation	750m^3, 1500m^3, 2250m^3 @Tk 55/m^3	42000 00	84000 00	126000 00
4 2	Perimeter Building	100m, 125m, 175m @Tk 75/ m	7500 00	10000 00	14000 00
4 3	Short circuit prevention barriers/baffle	Created by divider, screens & earthen berms etc Barrier	15000 00	20000 00	30000.00
4 4	Bottom lining (clay) 0 3 m deep and plastic sheet	180m^3, 300m^3, 450m^3 @ Tk 100/m^3	18000 00	30000 00	45000 00
4 5	Inlet & Outlet gates (primary system)	Weir & gates	50000 00	50000 00	50000 00
	SUB TOTAL PRIMARY TANK		132500 00	194000 00	265000 00
5	Lemnaceae Plug Flow/ Lagoon Construction				
5 1	Earthwork in excavation (16 days retention capacity & 25% safety capacity)	10000m^3, 20000m^3, 30000m^3 @ Tk 40/m^3	400000 00	800000 00	1200000 00
5 2	Perimeter building and compacting	1580m, 3143m, 4715m @Tk 20/ m	32000 00	64000 00	95000 00
5 3	Berm / Barrier Construction and Compacting (L6m X B2 5m X T1 5m X H2m)	80 nos , 160 nos , 240 nos @Tk 500/Berm	40000 00	80000 00	120000 00

5 4	Stabilization grids (Bamboo)	160 nos , 320 nos , 480nos @ Tk. 100/no	16000 00	32000 00	48000 00
5 5	Outlet gate construction	1 no	50000 00	75000 00	100000 00
5 6	Plantation on Plug berms and perimeter	Vegetable crop, banana, papaya, sugar cane, taro, trees, etc	15000 00	20000 00	25000 00
	SUB TOTAL PLUG FLOW CONSTRUCTION		553000 00	1071000 00	1588000 00
6	Effluent Recycling Network	LLP - 1, Pipeline/drain	125000 00	150000 00	175000 00
7	Equipment and Machinery a) Agricultural tools b) Harvesters/Measuring tools c) Scales (3 nos) d) Boats e) Fishing Net f) STW (0 75 - 1 cusec) g) Baskets, trays, etc h) Miscellaneous	 Tk 7500 - Tk 10000 - Tk 10000 - Tk 15000 - Tk 15000 - Tk 25000 - Tk 500C Tk 5000 -	92500 00	110000 00	130000 00
8	Fish Pond Improvement, livestock raising, Chicken farm for 500 birds (preparation, perimeter, bottom cleaning, basal fertilizer etc)	Water area = 1 25ha, 2 00 ha, 2 5 ha cattle fattening (25 chicken layers 500	75000 00	110000.00	150000 00
9	Water Testing Laboratory Equipment and Electric Supply (one laboratory for 5 system conveniently located)	1 laboratory	150000 00	150000 00	150000 00
10	Field Office and Store (Tin shed)	500 sft , 500 sft , 500 sft	50000 00	50000 00	50000 00
	SUB TOTAL OTHER CONSTRUCTION COSTS		492500.00	570000 00	655000 00
	DIRECT CONST COST		1343000 00	2087500 00	2858000 00
11	Design and Supervision Overhead (7 5%)		100725 00	156562 50	214350 00
12	Start-up Capital	LS	50000 00	75000 00	100000 00
13	Contingencies (3%)	for cost escalation	40290 00	62625 00	85740 00
	SUB TOTAL START-UP & OVERHEAD		191015.00	294187 50	400090.00
	TOTAL SYSTEM CONSTRUCTION COST		**1534015.00**	**2381687.50**	**3258090.00**
	IN US$ (Exchange rate Tk.50 = US$ 1)		**30680.30**	**47633.75**	**65161.80**

B	RECURRING OPERATIONAL COST (WORKING CAPITAL)				
1	System Operation personnel (FW = Tk 2000/PM, Supervisor = Tk 3500/PM)	(FW-3 & Sup -1), (FW-4 & Sup -1), (FW-5 & Sup -1)	114000 00	138000 00	162000.00
2	Field Supplies (Supplementary Fish/animal feed, fertilizer, baskets, hand tools, seed, fingerling, etc)	Fish - 1 25 ha, 2 00 ha, 2 50ha S Fish feed + fertilizer = Tk 250/ha/day, Other supplies = Tk 50/ha/day	131250 00	210000 00	262500 00
3	Repair and Maintenance Cost	Per Annum	30000 00	45000.00	60000 00
4	Fuel and Utilities Costs	Per Annum	25000 00	40000 00	50000 00
5	Land Lease Costs	Per Annum	25000 00	40000 00	60000 00
6	Office Supplies and Maintenance	Par Annum	10000 00	15000 00	20000 00
7	Travel and Transportation Costs	Per Annum	6000 00	7200.00	9600 00
8	Laboratory Supplies and Testing Cost	Per Annum	20000 00	20000 00	20000 00
9	Management Overhead (Organization)	10%	36125 00	51520 00	64410 00
	SUB TOTAL DIRECT OPERATING COST		397375 00	566720 00	708510 00
10	System Depreciation	6 6% of total fixed cost	102300.00	158800 00	211500 00
11	Debt-servicing a) Interest on Fixed Capital b) Interest on W Capital	 7% 10%	 59000 00 19868 75	 92600.00 28336 00	 126700 00 35425 50
	TOTAL OPERATION COST		**578543.75**	**846456.00**	**1082135.50**
	PROFITABILITY AND RETURN FROM OPERATION				
C	PRODUCTION REVENUE				
1	Fish Sales (at Tk 50/kg) (11200, 22400, 33600 kg dry weight duckweed produced)	1 25ha, 2ha, 2 5ha @ 12000 kg/ha/year	750000 00	1200000 00	1500000 00
2	Agricultural Produce Sale	Per Annum	50000 00	75000 00	100000 00
3	Miscellaneous Sale from various used project materials and waste recycle (fertilizer)	Per Annum	16000 00	19000 00	22000 00
	TOTAL REVENUE FROM SALE PER ANNUM		**816000.00**	**1294000.00**	**1622000.00**

4	DIRECT OPERATION/ PRODUCTION COST	PER ANNUM	397375 00	566720 00	708510 00
5	OPERATING PROFIT	PER ANNUM	418625 00	727280 00	913490 00
6	SYSTEM DEPRECIATION	(15 years @ 6 6%)	102300 00	158800 00	211500 00
7	PROFIT BEFORE DEBT-SERVICING		316325 00	568480 00	701990 00
8	DEBT-SERVICING (INTEREST ON FIXED & WORKING CAPITAL)		78868 75	120936 00	162125 50
9	**NET PROFIT BEFORE TAXES**		**237456.25**	**447544.00**	**539864.50**
10	**NET RETURN ON FIXED CAPITAL %**		**15.00%**	**19.00%**	**17.00%**
11	**NET RETURN ON WORKING CAPITAL %**		**59.76%**	**78.97%**	**76.20%**

Annex 9

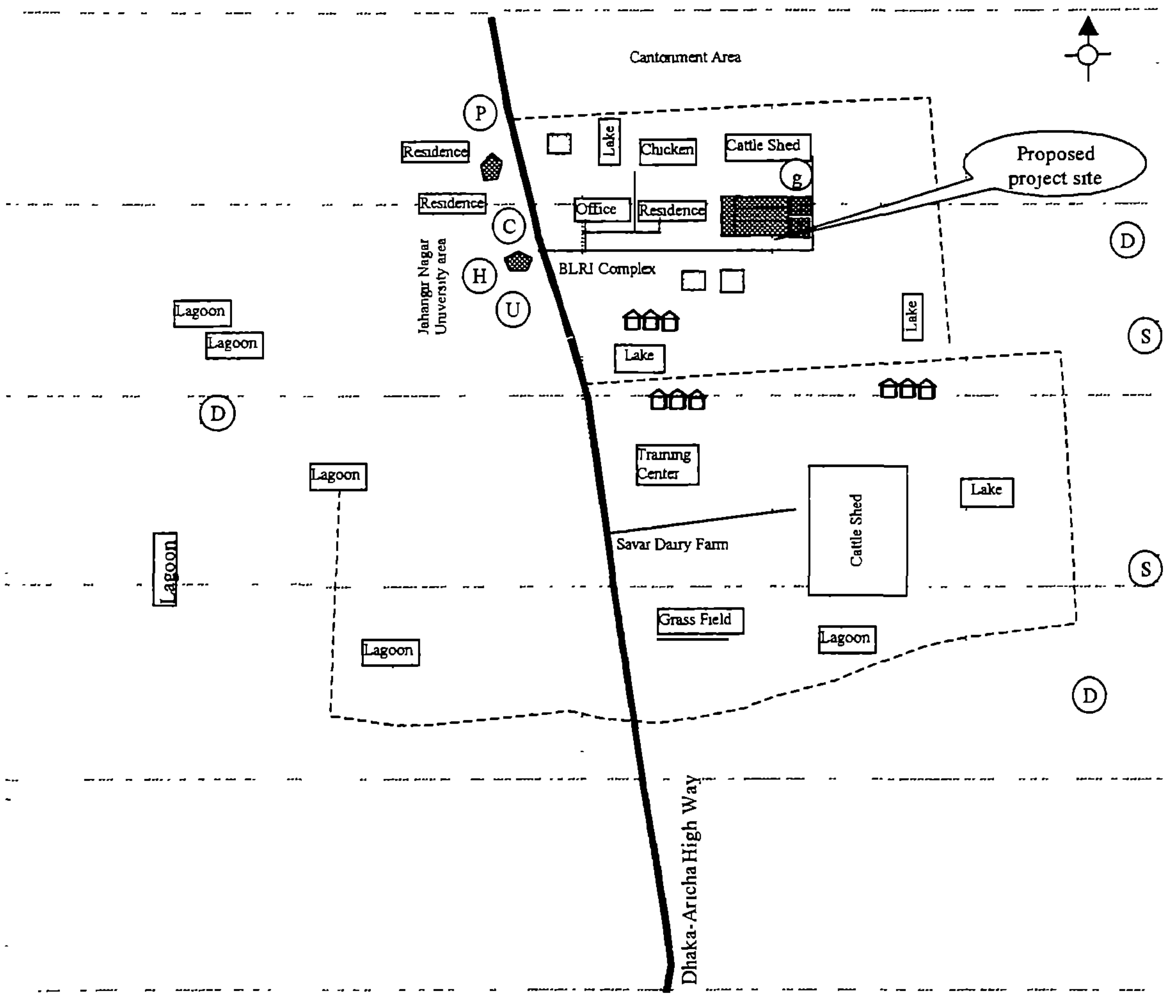
Financial assumptions for calculations of system costs

Annex 10

Detailed project site maps

Legend :

Primary school	(P)	Bio-gas plant	(g)
High School	(H)	Fish pond	□
College / Training / Vocational Institute	(C)	Homestead/ Resident	⌂
University	(U)	Duckweed pond	▦
Deep Tube Well	(D)	Primary Settlement pond	■
Shallow Tube Well	(S)		



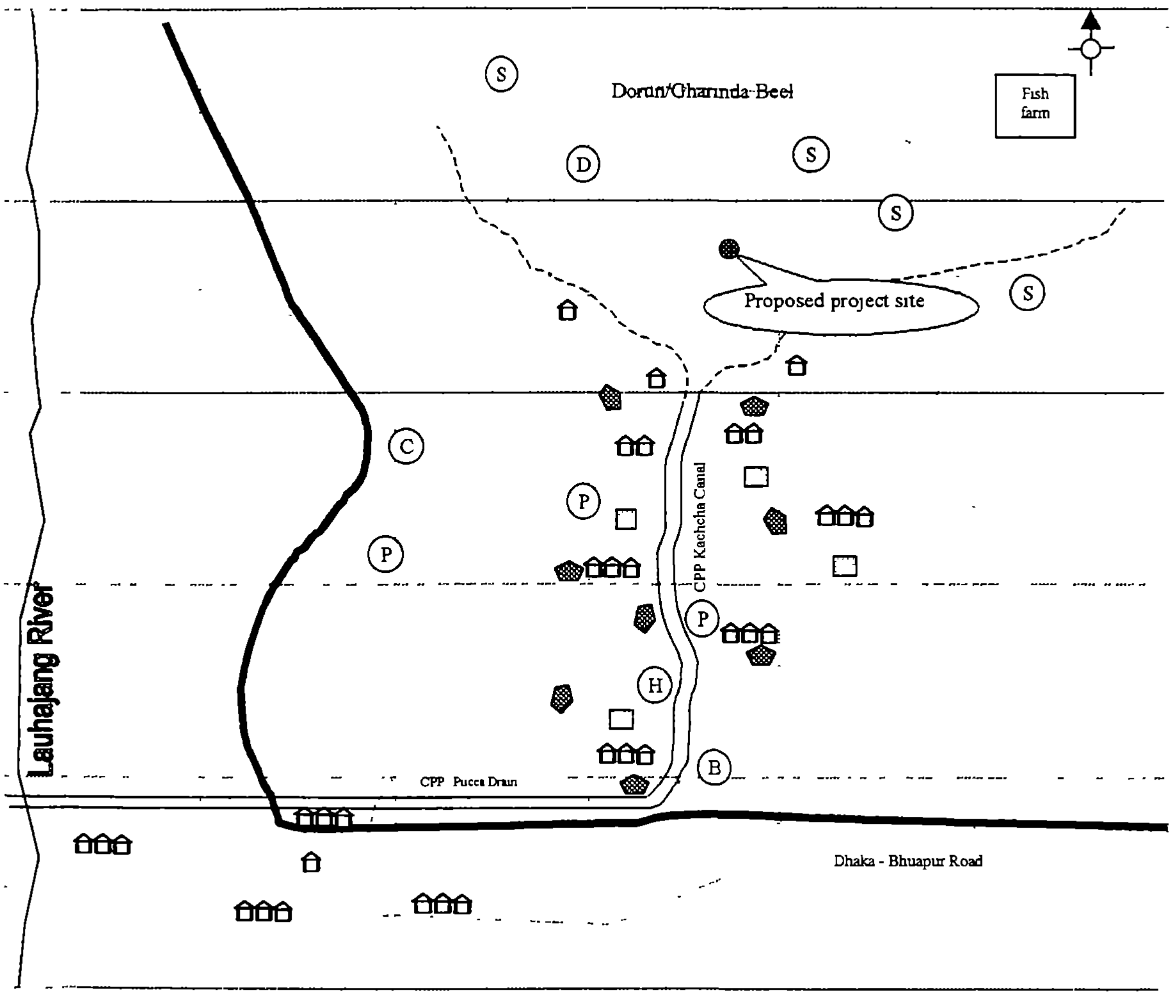
Site Map 1: **BLRI (Savar Diary Farm & Bangladesh Livestock Research Institute) Site:**

BLRI (Bangladesh Livestock Research Institute) System Design

Total Area	= 6.5 Ha
Daily waste water input	= 1500 m^3
Total capacity of the primary tank	= 1973000 l
Retention time for primary treatment	= 1 day (24 hours)
Total capacity of plug flow (secondary treatment)	= 28000 m^3
Retention time for plug flow	= 16 days
Location	= BLRI Complex, Savar Dairy Farm & Jahangirnagar University, Pachutia, Savar, Dhaka.

Legend :

Primary school	(P)	Bazar	(B)
High School	(H)	Fish pond	□
College / Training / Vocational Institute	(C)	Homestead/ Resident	⌂
University	(U)	Duckweed pond	▩
Deep Tube Well	(D)	Municipal	●
Shallow Tube Well	(S)		



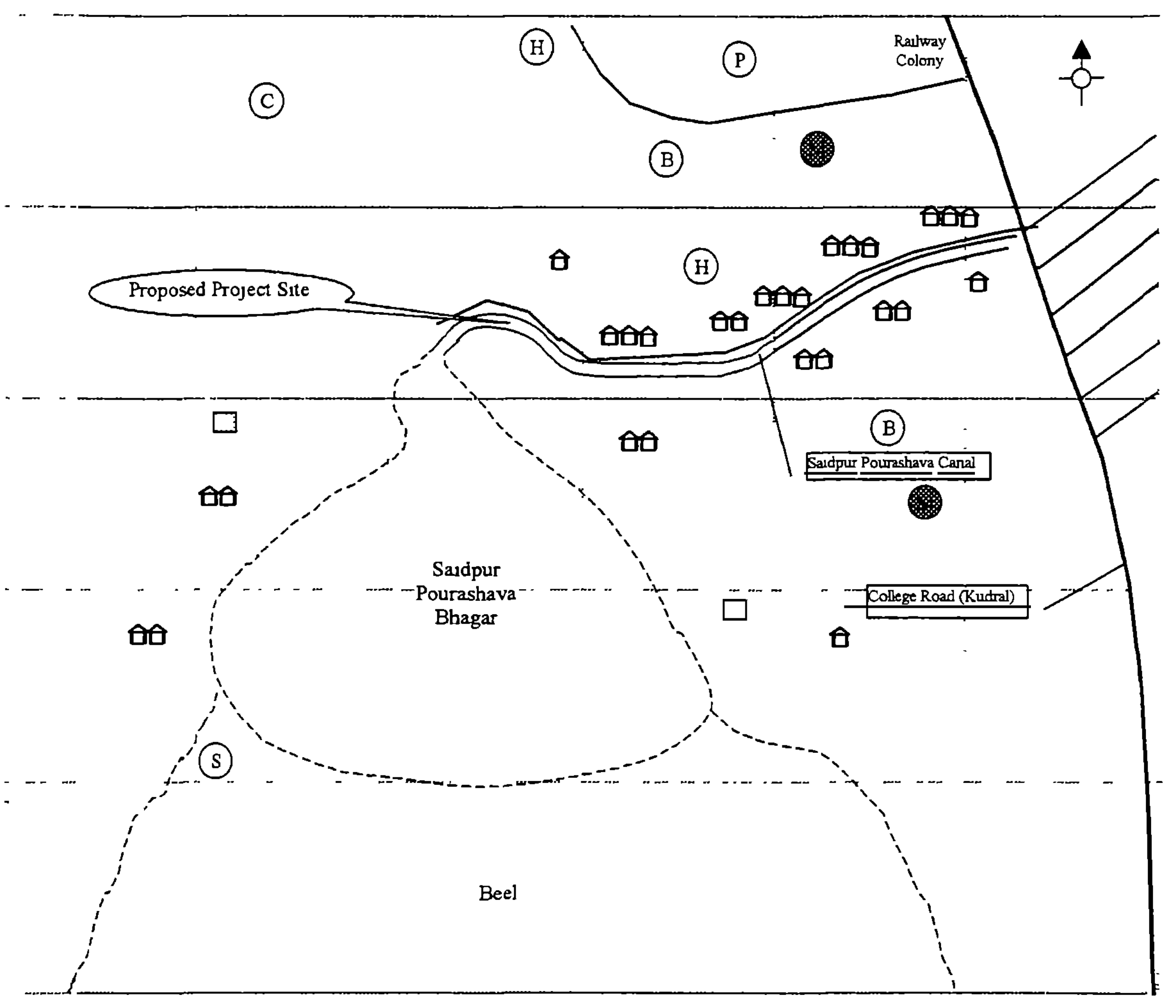
Site Map 2: CPP (Compartmentalisation Pilot Project & Garinda Beel) Site:

CPP (CPP & Garinda Beel) System Design :

Total Area	= 4.5 Ha
Daily waste water input	= 1000 m^3
Total capacity of the primary tank	= 1312000 l
Retention time for primary treatment	= 1 day (24 hours)
Total capacity of plug flow (secondary treatment)	= 16000 m^3
Retention time for plug flow	= 16 days
Location	= CPP outlet *Kaccha* Canal & Garinda Beel, Biswas Betea, Tangail

Legend :

Primary school	(P)	Bazar	(B)
High School	(H)	Fish pond	□
College / Training / Vocational Institute	(C)	Homestead/ Resident	⌂
University	(U)	Duckweed pond	▩
Deep Tube Well	(D)	Municipal	●
Shallow Tube Well	(S)		



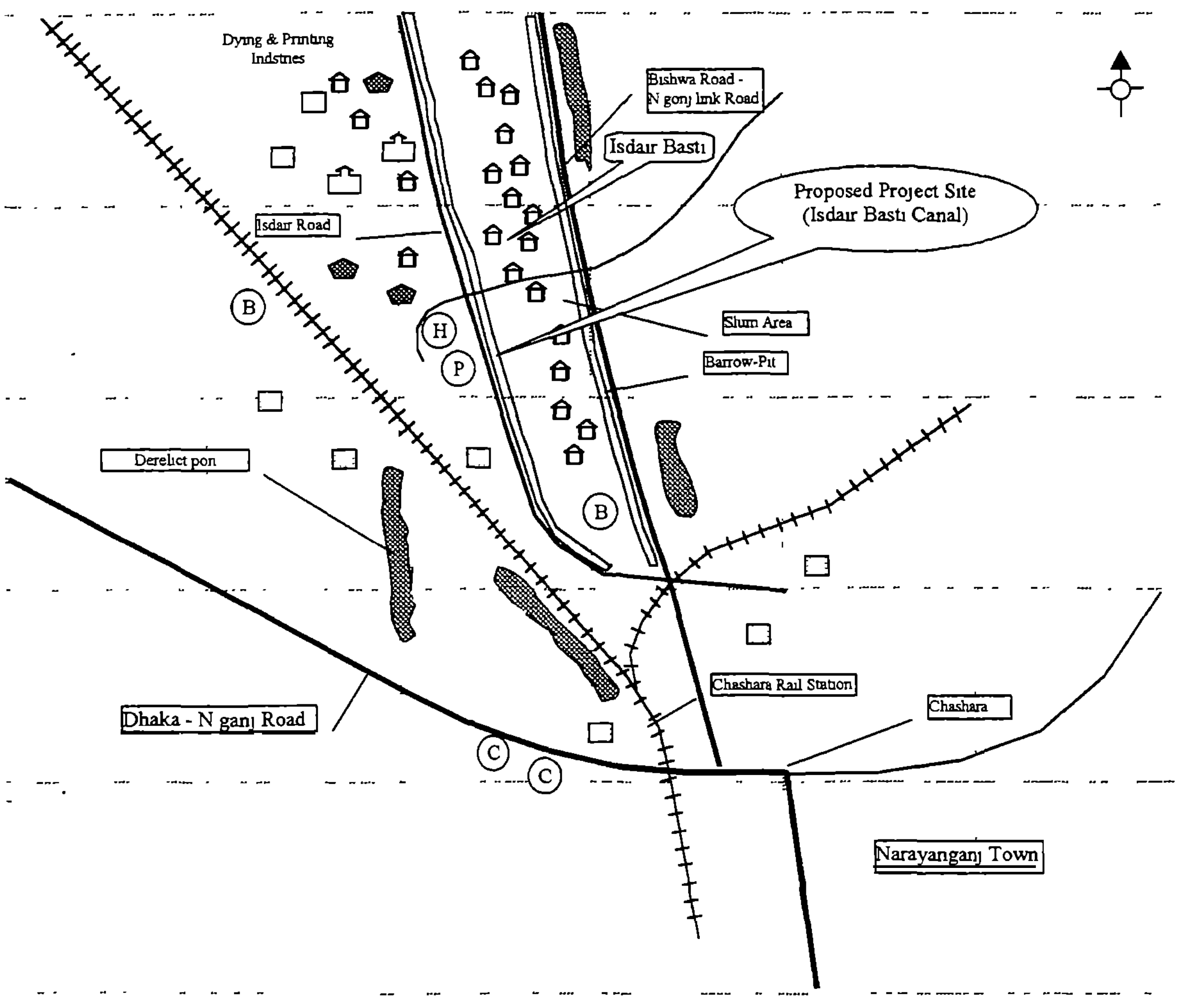
Site Map 3: SPV (Saidpur Pourashava *Vagar*) Site:

SPV (Saidpur Paurashava Bhagar) System Design

Total Area	= 4 5 Ha
Daily waste water input	= 1000 m^3
Total capacity of the primary tank	= 1312000 l
Retention time for primary treatment	= 1 day (24 hours)
Total capacity of plug flow (secondary treatment)	= 16000 m^3
Retention time for plug flow	= 16 days
Location	= Saidpur Pourashava *Bhagar*, Kudral, Saidpur

Legend :

Primary school	(P)	Bazar	(B)
High School	(H)	Fish pond	□
College / Training / Vocational Institute	(C)	Homestead/ Resident	⌂
University	(U)	Duckweed pond	▩
Deep Tube Well	(D)	Industry	⏍
Shallow Tube Well	(S)		



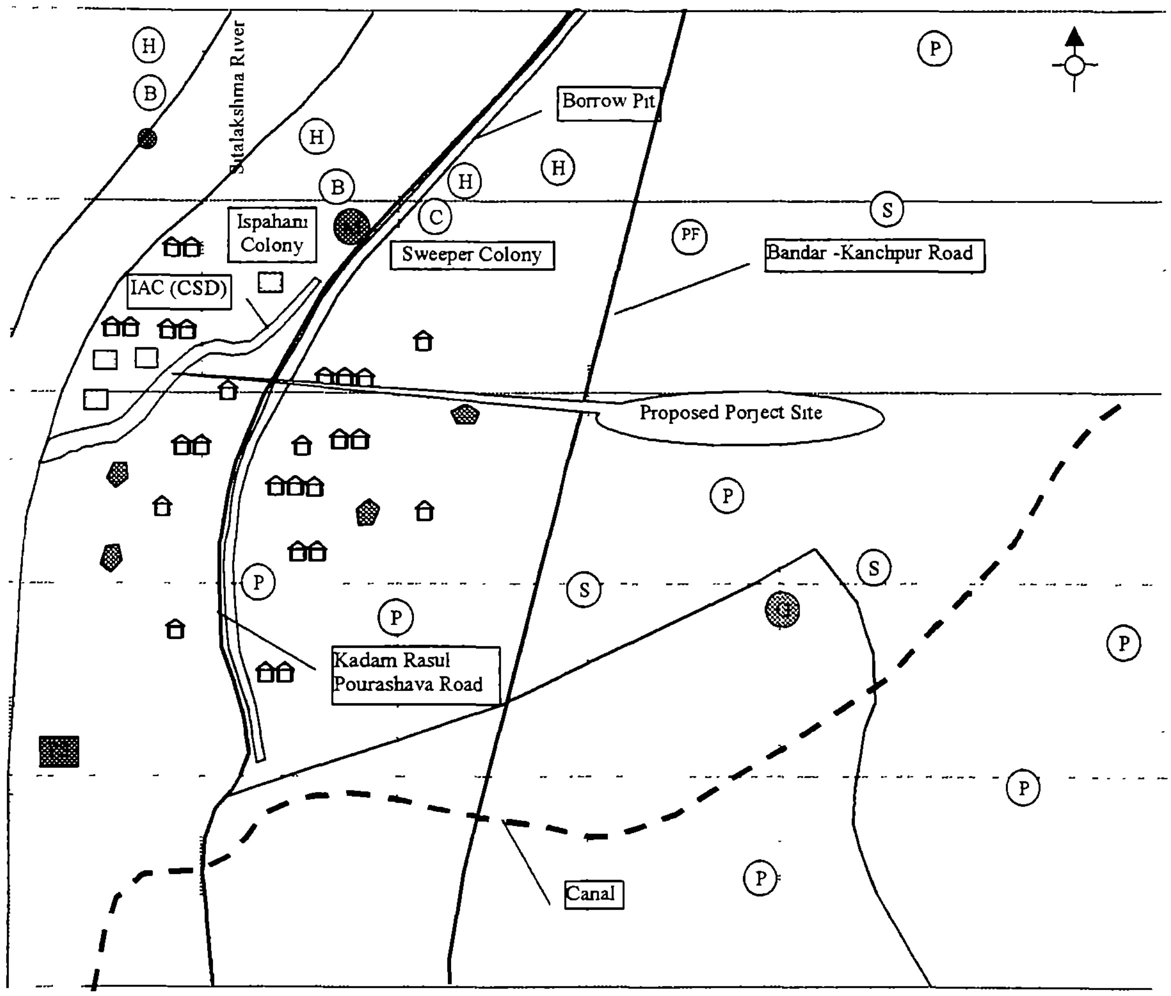
Site Map 4: IBC (Isdair Basti Canal) Site:

IBC (Isdair Basti Canal) System Design

Total Area	= 2 7 Ha
Daily waste water input	= 500 m^3
Total capacity of the primary tank	= 660000 l
Retention time for primary treatment	= 1 day (24 hours)
Total capacity of plug flow (secondary treatment)	= 8000 m^3
Retention time for plug flow	= 16 days
Location	= Isdair Basti Canal, Isdair & Uttar Chashara, Isdair, Narayanganj

Legend :

Primary school	(P)	Bazar	(B)
High School	(H)	Fish pond	□
College / Training / Vocational Institute	(C)	Homestead/ Resident	⌂
University	(U)	Duckweed pond	▩
Deep Tube Well	(D)	Municipal	●
Shallow Tube Well	(S)	Police station	■



Site Map 5: IAC (Ispahani Arseen Canal) Site:

IAC (Ispahani Arsen Canal) System Design

Total Area	= 2 7 Ha
Daily waste water input	= 500 m^3
Total capacity of the primary tank	= 660000 l
Retention time for primary treatment	= 1 day (24 hours)
Total capacity of plug flow (secondary treatment)	= 8000 m^3
Retention time for plug flow	= 16 days
Location	= Adjacent to CSD Complex, Kadam Rasul Pourashava, Bandar, Narayanganj

Annex 11

Summary of results of socio-economic study

SOCIO-ECONOMIC SURVEY ANALYSIS (SUMMARIZED) FOR HOUSEHOLDS/COMMUNITY

BLRI - 05

Sl	*Indicators*	*Observations*					
a	Family composition	Family size - 5 63		Male - 40 %	Female - 37%	Children - 22 %	
b	Educational status %	Literate - 71	School - 61	Higher - 10	Illiterate - 29		
c	Occupational status %	Unemployed 12	Farmer - 4	Service -12	Business - 5	Housewife - 24	Student - 35
d	Housing condition %	Kancha/Semi-kancha - 33	Pucca/Semi-pucca - 28	Tin - 38	Additional housing 17		
e	Land ownership %	99 % have land	Homestead 22 %	Cropped 66 %	Pond & Ditch - 10 %	Fallow/Others 1 %	
	(Average land holding 71 49 dec)	1% have no land	Homestead - 15.76	Cropped - 47 78	Pond & Ditch - 7 36	Fallow/Others 59	
f	Land Tenure status (Ave area in dec)	Mortgage- 100 00	Own-71 43	Share in- 68 20	Lease in- 63 50	Share out - 25	
g	Land situation (flood/high land)	High land 33%	Medium land 49 %	Medium low land 10 %	Low land 8 %		
h	Ownership of Pond/Ditch	10 % HH have pond of which 100 % own pond & 85 % ditch					
i	Family income sources %	Service - 22	griculture-18	usiness-14	Poultry-17	Cattle rearing-14	
j	Family income / range %	41000-100000 60 %	21000-40000 20 %	100000+ 15%	Rest below 20000	Surplus - 66 %	Deficit 13%
k	Loan status	27 % Taken loan	45 % for Business	22 % for agriculture	45 % from NGO	2 % from oney lender	11% from Bank
l	Cropping (Ave area per family in dec)	Paddy-136 dec	Oilseed-70 dec	Sugarcane- 33	Vegetable- 30 82	Total Land- 4734	
m	Involvement in livestock & poultry (No)	Cattle-48	Chicken-162	Duck-95	Goat - 26		
n	Livestock and poultry resources	Cattle - 37 %	Chicken-35%	Duck-18%	Goat-6%		
o	Aquaculture / fishery resources	Ponds no- 5	Pond 73 dec	88 % adjacent HH		88 % own	60% sandy clay
		Ditch no-4	Ditch-5 75	75 % adjacent HH		75 % own	50 % Clay
q	Production constraints %	Capital-100	Knowledge-80	Technology-70		Support service-48	
r	Household wastewater resources %	Homestead 40	Agriculture - 40	Human excreta - 20			
s	Wastewater availability	Waste water - 178 Litre per day /HH & Total waste water 9100 litre/per day					
t	Type & quality of WW	20 % pond have Domestic Waste water & Quality of waste is medium					
u	Latrine coverage %	98%have latrine	Sanitary- 41 %	Pit - 41 %	pen14%		
v .	Solid waste status	Solid waste Average - 6 35 kg per day & Total solid waste 324 Kg					
w	Present disposal of solid waste	45 % wash in to Canal / River	25%Accumulate in derelict pond	12 % use as fuel	5% use Fertilizer		
x	Existence of HH knowledge of duckweed	84 % have Knowledge	75 % use as fish feed	45% as poultry feed	37% as LS feed	13 % as WWT	
y	Source and availability of drinking water	86 % from Tube-well	12 % from Tap water				
z	Female ownership of pond /ditches	None					
Za	Women participation in decision making	80%Participate 14%Occasionally	82% in economic activities	65% future of children			
Zb	Survey Community response	24 % Excellent	65 % Good	12 % Poor			
Zc	Attitude regarding wastewater treatment %	71% have little awareness	14 % Fully Aware	12% aware but apathetic			
Zd	Suitability for future participation	59% not suitable & 10% suitable in DW culture		59% not suitable & 10% suitable in Fish culture			
Ze	General condition	53 % Less potential	33 % Medium potential	8 % High potential			
Zf	Observation on DW prevalence	57 % Medium availability	42 % Not observed				

CPP-19

Sl	*Indicators*	*Observations*					
a	Family composition	Family size - 6 06		Male - 44 %	emale -39%	hildren-17%	
b	Educational status %	Literate - 76	School 62	Higher - 13	Illiterate - 24		
c	Occupational status %	Unemployed-14	Farmer - 4	Service -13	usiness- 7	Housewife - 24	Student - 23
d	Housing condition %	Kancha / Semi-kancha - 34	Pucca/Semi-pucca - 28	Tin - 37	Additional housing 70		
e	Land ownership %	99 % have land	Homestead 20	Cropped-70	ond & Ditch-7	allow/Others -2	
	(Average land holding 108 96 dec)	1% have no land	Homestead 22 82	Cropped 76 30	Pond & Ditch 7 42	Fallow 2 42	
f	Land Tenure status (Ave. area in dec)	Own -101.96	Mortgage-0 24	Share in-5.12	Share out - 17 07	Lease out - 21 95	Lease in - 3 73
g	Land situation (flood/high land)	High land 17%	Medium low land 41 %		Medium land 26 %	Low land 14 %	
h	Ownership of Pond/Ditch	10 % HH have pond of which 60 % own pond & rest are jointly, 87 % ditch own					
i	Family income sources %	Service - 16	Agriculture-19	Business-15	Poultry-19	Cattle rearing-7	Fisheries-7
j	Family income / status %	41000-100000 21 %	21000-40000 13 %	Rest below 20000	Surplus 66 %	47 % from Money lender	Deficit 32%
k	Loan status	42 % Taken loan	41 % for Business	7 % for agriculture	8% from NGO	44 % from Bank loan	
l	Cropping (Ave area per family in dec)	Paddy-157 dec	Oilseed-71dec	Pulse- 46 50	Potato-38 00	Jute - 35 00	Total Land-5831
m	Involvement in livestock & poultry (No)	Cattle-32	Chicken-289	Duck-32	Goat - 7		
n	Livestock and poultry resources %	Cattle - 20 %	Chicken - 64%	Duck-14%	Goat-4%		
o	Aquaculture / fishery Resources	Ponds no- 5	Pond area 55 dec	60 % own	100%adjacent HH	40 % sandy clay	
		Ditch no-23	Ditch-12 56 dec	86 % own	86 % adjacent HH	39 % Loamy	26% Clay
q	Production constraints %	Capital-61	Knowledge-32	Technology-58		Support service-32	
r	Household wastewater resources %	Homestead 42	Poultry 8	Human excreta 18	Livestock 12	Agriculture 10	
s	Wastewater availability	Waste water - 222 Litre per day /HH & Total waste water 11090 litre / per day					
t	Type & quality of wastewater	90 % pond have Medium quality Domestic Waste water & 10% heavily polluted water.					
u	Latrine coverage %	100%have latrine	Sanitary-40%	Pit - 42 %		Open-10 %	
v	Solid waste status	olid waste Average - 5 58 kg per day & Total solid waste 279 Kg					
w	Present disposal of solid waste	64 % wash in to Canal / River		36%Accumulate in derelict pond			
x	Existence of HH knowledge of duckweed	98 % have Knowledge		90 % use as fish feed	34% as poultry feed	8 % as WWT	
y	Source and availability of drinking water	94 % from Tube-well		4 % from Tap water			
z	Female ownership of pond /ditches	6 %female owing pond		Pond no - 3	T Area - 43 dec		
za	Women participation in decision making	68% Participate 14% Occasionally	74% in economic activities	60% future of children	52% Homestead development	8% Social function	
zb	Survey Community response	14 % Excellent	66 % Good	44 % Poor			
Zc	Attitude regarding wastewater treatment %	78% have little awareness		8 % Fully Aware	14% aware but apathetic.		
zd	Suitability for future participation	6% not suitable & 38% suitable in DW culture		12% suitable in Fish culture			
ze	General condition	56 % high potential		40 % Medium potential		2 % less potential	
zf	Observation on DW prevalence	94 % Medium available		6 % Extensively available			

IAC - 14

Sl	Indicators	Observations					
a	Family composition	Family size - 5 66		Male - 41 %	Female - 37%	Children - 22 %	
b	Educational status %	Literate - 68	School - 59	Higher - 8 %	Illiterate - 32		
c	Occupational status %	Unemployed - 22	Farmer - 1	Service - 10	Business - 9	Housewife - 23	Student - 21
d	Housing condition %	Kancha / Semi-kancha - 20	ucca/Semi -pucca - 41	Tin - 38	Additional housing 10		
e	Land ownership %	99 % have land	Homestead 24 %	Cropped 53%	Pond & Ditch 22%	Others 0 17	
	(Average land holding 34 26 dec)	1% have no land	Homestead 8 34	Cropped 18 32	Pond & Ditch 7 54	Others 06	
f	Land Tenure status (Ave area in dec)	Own -31 20	Mortgage-0	Share in-0	Share out - 4 20	Lease out - 0	Lease in- 0 50
g	Land situation (flood/high land)	High land 18 %	Medium land 55 %		Medium low land 22 %	Low land 3 50 %	
h	Ownership of Pond/Ditch	8 % have HH pond of which 77 % own pond & rest are jointly & Leased in, 85 % ditch own rest joint					
i	Family income sources %	Service - 17	Agriculture-8	Business-17	Poultry - 13	Cattle rearing -12	Fisheries-8
j	Family income / status %	41000-100000 58 %	21000-40000 30 %	100000 + 10 %	Rest below 20000	Surplus 76 %	Deficit 22
k.	Loan status	38 % Taken loan	42 % for business purpose	42% house repairing	5 % from NGO	7 % from Money lender	81 % from Bank loan
l	Cropping (Ave area per family in dec)	Paddy-102 dec	Oilseed-120dec	Wheat-75	Potato-72	Jute - 75 00	otal Land-537
m	Involvement in livestock & poultry (No)	Cattle-32	Chicken-123	Duck-131	Goat - 15		
n	Livestock and poultry resources	Cattle - 22 %	Chicken - 30%	Duck-26%	Goat-8%		
o	Aquaculture / fishery Resources	Ponds no- 9	Pond area 28 dec	77 % own	88%adjacent HH	44 % clay	18 %pond
		Ditch no-21	Ditch-7 14	85 % own	100%adjacent HH	52 % clay	46% ditch
q	Production constraints %	Capital-95%	Knowledge-63	Technology-82		Support service-53	
r	Household wastewater resources %	Homestead 43	Poultry 11	Human excreta-31		Livestock-10	
s	Wastewater availability	Waste water - 153 Litre per day /HH & Total waste water 7650 litre / per day					
t	Type & quality of WW	90 % pond have Medium quality Domestic Waste water & 10% Institutional waste water					
u	Latrine coverage %	92%have latrine	Sanitary- 45%		Pit - 39 %	Open - 8 %	None- 8%
v	Solid waste status	olid waste Average - 2 84 kg per day & Total solid waste 142 Kg					
w	Present disposal of solid waste	46% wash in to Canal / River		54%Accumulate in derelict pond			
x	Existence of HH knowledge of duckweed	94 % have Knowledge		92 % use as fish feed	22% as poultry feed	30 % as WWT	
y	Source and availability of drinking water	96 % from Tube-well		4 % from Tap water			
z	Female ownership of pond /ditches	2 %female owing pond	Pond no - 1	Total Area - 25 dec			
Za	Women participation in decision making	82%Participate 14%Occasionally	72% in economic activities	70% future of children	72%Homestead development	38%Social function	
Zb	Survey Community response	14 % Excellent	54 % Good	32 % Poor			
Zc	Attitude regarding wastewater treatment %	42% have little awareness		44 % Fully Aware		12% aware but apathetic	
Zd	Suitability for future participation	10% suitable in DW culture		24 % very suitable & 17% suitable in Fish culture			
Ze	General condition	28% high potential		72 % Medium potential			
Zf	Observation on DW prevalence	84 % Medium availability		16 % Extensively available.			

IBC - 13

Sl	*Indicators*	*Observations*					
a	Family composition	Family size - 5 44		Male - 38 %	Female - 36%	Children - 26 %	
b	Educational status %	Literate - 59	School 45	Higher - 12	Illiterate - 41		
c	Occupational status %	Unemployed-22	Farmer- 36	Service -8	Business- 10	Housewife - 23	Student - 20
d	Housing condition %	Kancha / Semi-kancha - 44	Pucca/Semi-pucca - 33	Tin - 21	Additional housing 12		
e	Land ownership %	99 % have land	Homestead 15	Cropped-48	Pond & Ditch-34	allow/Others 1	
	(Average land holding 33 88 dec)	1% have no land	Homestead 5 42	Cropped 16 50	Pond & Ditch 11 56	Others 40	
f	Land Tenure status (Ave area in dec)	Own -29 26	Mortgage-0	Share in-0	Share out - 4 00	Lease out - 0	Lease in - 0
g	Land situation (flood/high land)	High land 34 %	Medium land 44 %		Medium low land 15 %	Low land 5 %	
h	Ownership of Pond/Ditch	14 % HH have pond of which 100 % own pond					
i	Family income source %	Service - 13	Agriculture-8	Business-31	Cattle rearing - 36	Fisheries- 7	Poultry- 13
j	Family income range %	41000-100000 42 %	21000-40000 30 %	100000 + 16 %	Rest below 20000	Surplus 76 %	Deficit 20
k	Loan status	36 % Taken loan	72 % for business	227%House repairing	63 % from NGO	6 % from Money lender	1% from ank
l	Cropping (Ave area per family in dec)	Paddy-97 50dec	Wheat- 100dec	Pulse- 69	Potato-12 00	Jute - 40 00	Total Land- 1377
m.	Involvement in livestock & poultry (No)	Cattle-31	Chicken-132	Duck-67	Goat - 0		
n	Livestock and poultry resources	Cattle - 16 %	Chicken - 30%	Duck-14%	Goat-0		
o	Aquaculture / fishery Resources	Ponds no- 7	Pond area 69 dec	100 % own	57%adjacent HH	71 % clay	14%pond
		Ditch no-13	Ditch-7	100% own	100%adjacent HH	69 % Clay	26%ditch
q	Production constraints %	Capital-88%	Knowledge- 70	Technology-72		Support service-58	
r	Household wastewater resources %	Homestead- 40	Poultry - 8	Human excreta-24		Livestock-10	
s	Wastewater availability	Waste water - 146 Litre per day /HH & Total waste water 7320 litre / per day					
t	Type & quality of wastewater	80% pond have Medium quality Domestic Waste water & 20% heavily polluted water					
u	Latrine coverage %	98%have latrine	antary- 0%	Pit - 38 %		Open -8%	
v	Solid waste status	olid waste Average - 3 08 kg per day & Total solid waste 154 Kg					
w	Present disposal of solid waste	58 % wash in to Canal / River		36%Accumulate in derelict pond			
x	Existence of HH knowledge of duckweed	88 % have Knowledge		93 % use as fish feed	34% as poultry feed	28 % as WWT	
y	Source and availability of drinking water	94 % from Tube-well		6 % from Tap water			
z	Female ownership of pond /ditches	None					
Za	Women participation in decision making	72%Participate 16%Occasionally	6% economic ctivities	50% future of children	58%Homestead development	28%Social function	
Zb	Survey Community response	16 % Excellent	68 % Good	14 % Poor			
Zc	Attitude regarding wastewater treatment %	64% have little awareness		20 % Fully Aware		10% aware but apathetic	
Zd	Suitability for future participation	4% not suitable & 20% suitable in DW culture		14% very suitable & 12 % not suitable in Fish culture			
Ze	General condition	96 % high potential		2 % Medium potential		2 % less potential	
Zf	Observation on DW prevalence	72 % Medium availability		28 % Extensively available			

SPV - 22

Sl	*Indicators*	*Observations*					
a	Family composition	Family size - 6.52		Male - 36 %	Female - 34%	Children - 30 %	
b	Educational status %	Literate - 60	School - 52	Higher - 7	Illiterate - 40		
c	Occupational status %	Unemployed - 28	Farmer - 2	Service -5	Business-9	Housewife - 17	Student - 26
d	Housing condition %	Kancha / Semi-kancha - 33	Pucca/Semi-pucca - 52	Tin - 13	Additional housing 8 %	No Housing-3%	
e	Land ownership %	99 % have land	Homestead 16	Cropped-66	Pond & Ditch-17	allow/Others 1	
	(Average land holding 46 08 dec)	1% have no land	Homestead-7 60	Cropped-30 27	Pond & Ditch-7 92	Fallow-0 3	
f	Land Tenure status (Ave area in dec)	Own -41 53	Mortgage-1 25	Share in-1 33	Share out - 6 85	Lease out - 0	Lease in - 0
g	Land situation (flood/high land)	High land 35 %	Medium land 50 %		Medium low land 6 %	Low land 8 %	
h	Ownership of Pond/Ditch	16% HH have pond of which 100 % own					
i	Family income sources %	Service - 15	Agriculture-13	Business-20	Poultry - 12	Cattle rearing - 31	Fisheries-7
j	Family income range %	41000-100000 60 %	21000-40000 23 %	100000 + 13 %	Rest below 20000	Surplus-76 %	Deficit-23
k	Loan status	36 % Taken loan	44%for business	20 % for food	9 % from NGO	4 % from Money lender	80 % from Bank loan
l	Cropping (Ave area per family in dec.)	Paddy-103 dec	Oilseed-45dec	Wheat-50	Potato-43 25	Jute - 60 00	Total Land-2688
m	Involvement in livestock & poultry (No)	Cattle-51	Chicken-150	Duck-74	Goat - 31		
n	Livestock and poultry resources	Cattle - 28 %	Chicken - 38%	Duck-13 %	Goat- 25 %		
o	Aquaculture / fishery Resources	Ponds no- 10	Pond area 45 dec	100% own	60%adjacent HH	60 % sandy clay	16%pond
		Ditch no-6	Ditch-4 67	83% own	83%adjacent HH	83 % Loamy	10%ditch
q	Production constraints %	Capital-95%	Knowledge-65	Technology-82	Support service-50		
r	Household wastewater resources %	Homestead 13	Poultry 3	Human excreta-3		Livestock-3	Agriculture 3
s	Wastewater availability	Waste water - 181 Litre per day /HH & Total waste water 10880 litre / per day					
t	Type & quality of wastewater	100 % pond have Medium quality Domestic Waste water & Industrial waste water					
u	Latrine coverage %	95%have latrine		anitary-53%	Pit - 36 %	Open - 6%	
v	Solid waste status	Solid waste Average - 5 28 kg per day & Total solid waste 317 Kg					
w	Present disposal of solid waste	61% wash in to Canal / River		10%Accumulate in derelict pond			
x	Existence of HH knowledge of duckweed	78 % have Knowledge		73 % use as fish feed	21% as poultry feed	11 % as WWT	
y	Source and availability of drinking water	93 % from Tube-well		6 % from Tap water			
z	Female ownership of pond /ditches	1 %female owing pond	Pond no - 1	Total Area - 5 dec			
Za	Women participation in decision making	75%Participate 8%Occasionally	60% economic ctivities	60% future of children	55%Homestead development	40%Social function	
Zb	Survey Community response	20 % Excellent	50 % Good	30 % Poor			
Zc	Attitude regarding wastewater treatment	43% have little awareness		41 % Fully Aware		11% aware but apathetic	
Zd	Suitability for future participation	33% not suitable & 5 % suitable in DW culture		41% not suitable & 30% Potential for promotion in Fish culture			
Ze	General condition	8 % high potential		81 % Medium potential		10 % less potential	
Zf	Observation on DW prevalence	98 % Medium availability		0 % Extensively available			

SOCIO-ECONOMIC SURVEY ANALYSIS (SUMMARIZED) FOR INDUSTRY

BLRI - 05

Sl	Indicators		Observations				
A	Type & category of Industry		No of Industry- 2	Category- 50% Orange A		Category- 50%OrangeB	
B	No of Staff & Workers		Total no - 727	Staff - 20	Worker- 707	Resident - 14	Non-resident - 713
C	Building type %		1 no Pucca - 50 %	1 no Semi-pucca-50 %		Tin - 0	Total area - 42000 M^2
D	Industry Ownership		Proprietor- 0	Private - 0		GOB - 100 %	Joint Venture- 0
E	Land Ownership	No	Housing - 2	Factory Building -2	Pond- 1	Ditch - 2	Fallow - 2
		%	100	100	50	100	100
F	Land situation (flood/high land)		High land - 55 %	Medium land 45 %		Medium low land 0%	Low Land 0 %
G	Land tenure status (Area in dec)		Total Land - 91236	Own - 100 %		Lease in - 0 %	Lease Out 0 %
H	Agricultural cropping Status %		Paddy - 0	Oil seed - 0		Vegetable - 0	thers 50 dec
I	Livestock & Poultry resources		Cattle no - 2650	Chicken no - 1100		Duck no - 15	
J	Production constraints %		Lack of Capital - 66	Lack of Knowledge - 100		ack of Technology-83	Support service- 50
K	Aquaculture & Fisheries resources		Pond no- 3	Area - 800 dec	100% clay	100%Adjacent to HS	100 % Self
			Ditch no-6	Area - 876 dec	100 %clay	100%Adjacent to HS	100 % Self
L	Income, surplus & Deficit %		00,001-500,000 - 50 %	> 2500000 - 50 %		Surplus - 50 %	Deficit - 50 %
M	Expenditure		500,001-10,00,000-50%				
N	Loan Status		50 % taken loan from other source				
O	Source of working capital		Own fund - 33 %	Others - 66 %			
P	Waste water in derelict pond		No - 7	Total area - 866 dec		verage depth -71cm	T WW Qty-0944 L
Q	Status of derelict pond		Seasonal - 14 %	Year round - 86 %		00% adjacent to HS	
R	Type & Quality water of derelict pond		25 % derelict pond have highly polluted Domestic WW & 75 % have highly polluted other waste water				
S	Source of WW in derelict pond		Homestead - 44 %	Agriculture - 44%		Industry - 12 %	
T	Quantity of SW & WW		Total Solid waste - 22000 Kg / day			Total Waste Water - 1010000 Liter / day	
U	Present disposal of WW		Accum in derelict pond - 50 %	Wash into iver/canal- 20%		Use as Fertilizer- 20%	As Irrigation- 0 %
V	Impact of waste water %		Air - 100	Soil - 100	Water body - 100	Public health - 100	
W	Existence of collection system		yes - 100 %	Concrete - 50 %		Others - 50 %	
X	Source of water supply		00%WS from Tube-well			100%DW from Tube-well	
Y	Water consumption source		1000000 from DTW			5000 from HTW	
Z	Usage of Latrine (No)		Sanitary - 12 no 100 %	ndustry waste water ntered in to 1 pond		No Latrine connected on the derelict pond	
Za	Female ownership of Industry		None				
Zb	Woman participation in Management		None				
Zc	Attitude regarding WWT %		100 % fully aware				
Zd	Suitability of future participation		100%pond & 50% ditch very suitable for DW culture			50 % ditch potential for promotion for DW culture	
Ze	General condition of SA		50 % high potential	50 % medium potential			
Zf	Observation on DW prevalence		50 % Mod Available	50 % Extens Available			
Zg	Awareness about impact of WW & Ind Producing WW		Impact of Solid waste - High	Impact of Waste water - High		Ind Producing Solid waste - High	Ind Producing waste water - High
Zh	Workers perception of negative impact		Health - High	Environment - High		Well being - High	
Zi	Awareness & Knowledge of the surrounding people about WWT		Awareness - Medium	Knowledge - High			

CPP - 19

Sl	Indicators		Observations				
A	Type & category of Industry		No of Industry- 1	Category- 100% Orange A			
B	No of Staff & Workers		Total no - 6	Staff - 04	Worker- 02	Resident - 06	Non-resident - 0
C	Building type %		Pucca - 0 %	2 no Semi-pucca - 100 %		Tin - 0	Total area - 1000 M^2
D	Industry Ownership %		Proprietor- 100%	Private - 0		GOB - 0 %	Joint Venture- 0
E	Land Ownership	No	Housing - 1	Factory Building -0	Pond- 0	Ditch - 1	Fallow - 0
		%	100	0	0	100	0
F	Land situation (flood/high land)		High land - 75%	Medium land 0%		Medium low land 25%	Low Land - 0%
G	Land tenure status (Area in dec)		Total Land - 88	Own - 100%		Lease in - 0%	Lease Out - 0%
H	Agricultural cropping Status %		Paddy - 0	Oil seed - 0		Vegetable - 0	Others - 0 dec
I	Livestock & Poultry resources		Cattle no - 35	Chicken no - 0		Duck no - 0	
J	Production constraints %		Lack of Capital - 0	Lack of Knowledge - 34		Lack of Technology-34	Support service- 100
K	Aquaculture & Fisheries resources		Pond no- 0				
			Ditch no-1	rea - 22 dec	00%Loamy	00%AdjacentHS	100 % Self own
L	Income, surplus & Deficit %		100001-300000- 100 %			Surplus - 100%	Deficit - 0 %
M	Expenditure		= 100000 - 100 %				
N	Loan Status		No Loan taken				
O	Source of working capital		Own fund - 100%				
P	Waste water in derelict pond		No - 1	Total area - ____ dec		Average depth - ___cm	T WW Qty-
Q	Status of derelict pond		Seasonal - 0 %	Year round - 100 %		00% adjacent to HS	
R	Type & Quality water of derelict pond		100 % derelict pond have highly polluted Institutional & Industrial WW & Moderately polluted Domestic & Agr run-off waste water				
S	Source of WW in derelict pond		Homestead - 100 %	Agriculture - 100 %		Poultry - 100 %	Livestock - 100 %
T	Quantity of SW & WW		Total Solid waste - 140 Kg / day			Total Waste Water - 500 Liter / day	
U	Present disposal of WW		ccum in derelict ond - 100 %	Wash into river/canal - 0 %		Use as Fertilizer - 0%	As Irrigation - 0 %
V	Perception of Impact of WW %		Air - 100	Soil - 100		Water body - 0	Public health - 0
W	Existence of collection system		Yes - 100 %	Concrete - 100 %		Others - 0 %	
X	Source of water supply		00%WS from Tube-well			100%DW from Tube-well	
Y	Water consumption source		400 from HTW				
Z	Usage of Latrine (No)		Sanitary - 1 no 100 %	No Latrine connected on the derelict pond		100%Industry WW entered in to pond	
Za	Female ownership of Industry		100 %				
Zb	Woman participation in Management		100 %				
Zc	Attitude regarding WWT %		100 % fully aware				
Zd	Suitability of future participation		00% ditch very suitable for DW culture			Not suitable for fish culture	
Ze	General condition of SA		100 %medium potential				
Zf	Observation on DW prevalence		100 % Mod Available				
Zg	Awareness about impact of WW & Ind Producing WW		Impact of Solid waste - High	Impact of Waste water - High		Ind Producing Solid waste - High	Ind Producing waste water - High
Zh	Workers perception of negative impact		Health - High	Environment - High		Well being - High	
Zi	Awareness & Knowledge of the surrounding people about WWT		Aware ness - Low	Knowledge - High			

IAC - 14

Sl	*Indicators*		*Observations*				
A	Type & category of Industry		No of Industry- 1	Category- 100% Orange B			
B	No of Staff & Workers		Total no 5	Staff - 3	Worker- 2	Resident - 2	Non-resident - 3
C	Building type %		1 no Pucca - 100 %	Semi-pucca - 0 %		Tin - 0	Total area - 300 M^2
D	Industry Ownership %		Proprietor-100	Private - 0		GOB - 0	Joint Venture- 0
E	Land Ownership	No	Housing - 1	Factory Building -1	Pond- 0	Ditch - 1	Fallow - 0
		%	100	100	0	100	0
F	Land situation (flood/high land)		High land - 15 %		Medium land 85 %	Medium low land 0%	Low Land - 0 %
G	Land tenure status (Area in dec)		Total Land - 11		Own - 100 %	Lease in - 0 %	Lease Out - 0 %
H	Agricultural cropping Status %		Paddy - 0		Oil seed - 0	Vegetable - 0	Others - 0 dec
I	Livestock & Poultry resources		Cattle no - 0		Chicken no - 1800	Duck no - 0	
J	Production constraints %		Lack of Capital - 100		Lack of Knowledge -33	Lack of Technology-33	Support service- 0
K	Aquaculture & Fisheries resources		Pond no- 0				
			Ditch no-1	Area - 4 dec	100 %Loamy	00%Adjacent to HS	100 % Self own
L	Income, surplus & Deficit %		100,001-300,000 -100%		urplus 100 %	Deficit - 0 %	
M	Expenditure		00,001-300,000 -100%				
N	Loan Status		100 % taken loan from other sources				
O	Source of working capital		Own fund - 100 %				
P	Waste water in derelict pond		No.- 1	Total area - 4 dec		Average depth -90cm	T WW Qty- 144 l
Q	Status of derelict pond		Seasonal - 0 %	Year round - 100 %		00% adjacent to HS	
R	Type & Quality water of derelict pond		100 % derelict pond have highly polluted Industrial waste water				
S	Source of WW in derelict pond		Homestead - 100 %	Human excreta - 100%		Industry - 0 %	
T	Quantity of SW & WW		Total Solid waste - 150 Kg / day			Total Waste Water - 1500 Liter / day	
U	Present disposal of WW		Accum in derelict pond - 100 %	Wash into river/canal - 100 %		Use as Fertilizer-0%	As Irrigation - 0%
V	Impact of waste water %		Air - 0	Soil - 0	Water body - 100	Public health - 100	
W	Existence of collection system		Yes - 100 %	Following into nearby water body - 100 %			
X	Source of water supply		00%WS from Tube-well			100%DW from Tube-well	
Y	Water consumption source		5000 from STW			1000 from HTW	
Z	Usage of Latrine (No)		Sanitary - 1 no 100 %	00%Latrine connected n the derelict pond		100%Industry WW entered in to Pond	
Za	Female ownership of Industry		100 %				
Zb	Woman participation in Management		100 %				
Zc	Attitude regarding WWT %		100 % fully aware				
Zd	Suitability of future participation		100% ditch very suitable for DW culture				
Ze	General condition of SA		100 % high potential				
Zf	Observation on DW prevalence		100 % Mod Available				
Zg	Awareness about impact of WW & Ind Producing WW		Impact of Solid waste - High	Impact of Waste water - High		Ind Producing Solid waste - High	Ind Producing waste water - High
Zh	Workers perception of negative impact		Health - High	Environment - High		Well being - High	
Zi	Awareness & Knowledge of the surrounding people about WWT		Awareness - High	Knowledge - High			

IBC - 14

Sl	Indicators	Observations			
A	Type & category of Industry	No of Industry- 5	Category- 80% Orange A	Category-20%OrangeB	
B	No of Staff & Workers	Total no - 273	Staff - 29; Worker- 244	Resident - 43	Non-resident - 230
C	Building type %	3 no Pucca - 34 %	1 no Semi-pucca - 11 %	5 no Tin - 55	Total area - 6150 M^2
D	Industry Ownership %	Proprietor- 80	Private - 20	GOB - 0	Joint Venture- 0
E	Land Ownership — No	Housing - 5	Factory Building 3	Pond- 0; Ditch - 3	Fallow - 3
	Land Ownership — %	100	60	0; 60	60
F	Land situation (flood/high land)	High land - 58 %	Medium land 42 %	Medium low land 0%	Low Land - 0 %
G	Land tenure status (Area in dec)	Total Land - 235	Own - 82 %	Lease in - 18 %	Lease Out - 0 %
H	Agricultural cropping Status %	Paddy - 0	Oil seed - 0	Vegetable - 0	Others - 0 dec.
I	Livestock & Poultry resources	Cattle no - 0	Chicken no - 0	Duck no - 0	
J	Production constraints %	Lack of Capital - 86	Lack of Knowledge - 26	Lack of Technology-53	Support service- 60
K	Aquaculture & Fisheries resources	Pond no- 0			
		Ditch no-5	Area - 680 dec	40%Adjacent to HS & 100%Loamy	60 % Self own
L	Income, surplus & Deficit %	00,0001-2500,000- 60%	> 2500000 - 40 %	Surplus - 100 %	Deficit - 0 %
M	Expenditure	00,0001-2500,000- 60%	> 2500000 - 20 %		
N	Loan Status	100 % taken loan from Bank			
O	Source of working capital	Own fund - 50 %	Bank - 50 %		
P	Waste water in derelict pond	No - 5	Total area - 700 dec	Average depth 167cm	WW Qty- 16800 L
Q	Status of derelict pond	Seasonal - 0 %	ear round - 100%	60 % adjacent to HS	
R	Type & Quality water of derelict pond	100 % derelict pond have highly polluted Industrial waste water			
S	Source of WW in derelict pond	Homestead - 100 %	Human excreta - 100%	Industry -100 %	
T	Quantity of SW & WW	Total Solid waste - 1260 Kg / day		Total Waste Water - 525000 Liter / day	
U	Present disposal of WW	Accum in derelict pond - 100 %	ash into river/canal - 00 %	Use as Fertilizer-0%	As Irrigation - 0 %
V	Impact of waste water %	Air - 80; Soil - 40	Water body - 100	Public health - 100	
W	Existence of collection system	Yes - 100 %	Following into nearby water body - 100 %		
X	Source of water supply	00%WS from Tube-well		100%DW from Tube-well	
Y	Water consumption source	510000 from STW		9500 from HTW	
Z	Usage of Latrine (No)	Sanitary - 1 no 100 %	100%Latrine connected on the derelict pond	100%Industry WW entered in to Pond	
Za	Female ownership of Industry	No			
Zb	Woman participation in Management	No			
Zc	Attitude regarding WWT %	40 % Little aware	0 % aware but apathetic		
Zd	Suitability of future participation	80% ditch very suitable for DW culture		40 % ditch very suitable for fish culture	
Ze	General condition of SA	80%high potential			
Zf	Observation on DW prevalence	60%Mod Available			
Zg	Awareness about impact of WW & Ind Producing WW	Impact of Solid waste - High	Impact of Waste water - High	Ind Producing Solid waste - High	Ind Producing waste water - High
Zh	Workers perception of negative impact	Health - High	Environment - High	Well being - High	
Zi	Awareness & Knowledge of the surrounding people about WWT	Awareness - High	Knowledge - High		

SOCIO-ECONOMIC SURVEY ANALYSIS (SUMMARIZED) FOR SCHOOL

Site: BLRI05

Indicators	*Observations*			
1 Types and category of school	Total 3 nos	Govt 66% Non Govt 33%	Primary 33%, High 66%	
2 No Student, staff and students	Total 6500	Student 5000 Teacher 300 Staff 1200	Residential 6042 Non Resi 458	
3 Housing type	Total 4	Pacca 100%		
4 Land ownership	Building 2, Staff house 1, Fallow land 3, Pond 2, ditch 2 Building 66%, Staff house 33%, Fallow land 100%, Pond 66%, ditch 66%			
5 Land situation (flood /high land)	Total Area 70252 dec	High 79%, Medium 20%		
6 Land tenure status	Self 100%	Leased out 23%		
7 Agriculture Cropping status	Very negligible	Paddy 1080 (2%)	Wheat 400 (1%)	Pulses 500 (1%)
8 Livestock & poultry resources	Chicken 1000	Duck 100		
9 Aquaculture & Fisheries resources %	Pond 3 /14400 dec Dictch 3 / 530 dec	Self 100% Self 33%	Adj to Sch 60% 50m - Sch 20%	
10 Soil type, water column, and Source of water	(P) Clay 100% (D) Clay 100%		DTW 60%	
11 Fish culture method	Traditional 100%			
12 Availability of fish Feed	Tradition 100%		Trad High (100%) DW high (100%)	
13 Source of fingerlings	From traders 100%			
14 Production constraints in fish culture	Lack of Knowledge 100%, technology 100%, Capital 33%, Inputs 33%, Fingerling 66%, Theft 66%			
15 Sources of income and position	A/C/E 33%		Surplus 66% Deficit 33%	
16 Source of WC	Govt fund 100%, Tuition fee 60%, Other source 100%			
17 Wastewater resources and availability	No of derelict 2	Total area 520	Quantity 20100 ltr	Self owned 100%
18 Wastewater type & quality	Domestic 33%, Institutional 66%		Low 100%	
19 Quantity of solids and wastewater & present disposal	Solid waste 3110 kg Wastewater 60,003,000 ltr		Accu in derelict 60%, washed into river/canal 40%	
20 Perception of Impact of wastewater	Air Pollution 100%, Soil pollution 100%, Pollution of water body 60%, Poor public health 66%			
21 Existence of collection system	Open drain 33%			
22 Willingness of wastewater treatment by duckweed	Interested 100%	By contributing land 66%, assisting in collection 100%		
23 Participation in duckweed based fish culture & DW availability	Interested 100%	Group 100%		Moderately available
24 Wastewater treatment facility	Availability of Land 66%, Pond 66%			
25 Source of water supply	DTW 100%			1005500 liter
26 Usage of Latrine	Total latrine 505 Total users 11175	Sanitary 100%		
27 Head of institution (gender) & female participation in management	Male 3 (100%)			
28 Women participation in management	Excellent 66%, Good 33%			
29 Attitude regarding wastewater treatment	Interest in DW bases aquculture 100%			
30 Suitability of future participation	DW culture Suitable 50%	Fish culture absent	Other than Fish/DW culture absent	
31 General condition and Observation	General cond - Medium potential 100%		DW prevalence - Moderately available	

Site: CPP19

Indicators	*Observations*			
1 Types and category of school	Total 5 nos	Govt 40% Non Govt 60%	Primary 40%, High 40%	
2 No Student, staff and students	Total 1874	Student 1809 Teacher 52 Staff 13	Residential 44 Non Resi 1830	
3 Housing type	Total 5	Pacca 72%, Tin 28%		
4 Land ownership	Building 5, Fallow land 3, Ditch 3 Building 100%, Fallow land 60%, Ditch 60%			
5 Land situation (flood /high land)	Total Area 281 dec	High 84%, Medium low 16%		
6 Land tenure status	Self 100%			
7 Agriculture Cropping status	Absent			
8 Livestock & poultry resources	Absent			
9 Aquaculture & Fisheries resources %	Ditch 3 / 35 dec	Self 100%	Adj to Sch 66%	
10 Soil type, water column, and Source of water	(D) Loamy 100%	STW 33%		
11 Fish culture method	Traditional 100%			
12 Availability of fish Feed	Tradition 100%, DW 100%	Trad High (100%) DW Medium (100%)		
13 Source of fingerlings	From traders 100%, local 20%			
14 Production constraints in fish culture	Lack of Knowledge 40%, technology 80%, Capital 40%, Inputs 20%, Fingerling 20%, Disease 40%, Theft 100%, water avail 20%			
15 Sources of income and position	A 40%/B 40%/E 20%	Surplus 60% Deficit 40%		
16 Source of WC	Donation 20%, Tuition fee 80%, Other source 80%			
17 Wastewater resources and availability	No of derelict 3	Total area 35 dec	Quantity 990 ltr	Self owned 100%
18 Wastewater type & quality	Domestic 33%, Institutional 66%	Very Low 100%		
19 Quantity of solids and wastewater & present disposal	Solid waste 999 kg per day Wastewater 3,100 ltr	Accu in derelict 100%, washed into river/canal 100%		
20 Perception of Impact of wastewater in environment	Air Pollution 80%, Pollution of water body 40%, Poor public health 100%			
21 Existence of collection system	Open drain 20%			
22 Willingness of wastewater treatment by duckweed	Interested 100%	By contributing land 20%, assisting in collection 100%		
23 Participation in duckweed based fish culture & DW availability	Interested 80%	Group 40%		Moderately available 100%
24 Wastewater treatment facility	Availability of Capital 20%, Other than all 60%			
25 Source of water supply	DTW 27%, HTW 73%			2201 liter
26 Usage of Latrine	Total latrine 7 Total users 2106	Sanitary 28%, Pit 72%		
27 Head of institution (gender) & female participation in management	Male 3 (60%) Female 2 (60%)			
28 Women participation in management	Excellent 25%, Satisfactory 50%			
29 Attitude regarding wastewater treatment	Interest in DW culture 75% Bio-gas 25%			
30 Suitability of future participation	DW culture suitable 20 Not suitable 75%	Fish culture absent	Other than Fish/DW culture absent	
31 General condition and Observation	General cond - Highly potential 100%	DW prevalence - Moderately available 100%		

Site: IAC14

Indicators	*Observations*			
1 Types and category of school	Total 5 nos	Govt 40% Non Govt 40%	Primary 40%, High 40%, Other 20%	
2 No Student, staff and students	Total 3163	Student 3034 Teacher 72 Staff 57	Residential 32 Non Resi 3002	
3 Housing type	Total 8	Pacca 88%, tin 12%		
4 Land ownership	Building 4, Staff house 5, Fallow land 4, Pond 3, ditch 4 Building 80%, Staff house 100%, Fallow land 80%, Pond 60%, ditch 80%			
5 Land situation (flood /high land)	Total Area 2290 dec	High 68%, Medium 32%		
6 Land tenure status	Self 100%	Khas land 4%		
7 Agriculture Cropping status	Absent			
8 Livestock & poultry resources	Cattle 20			
9 Aquaculture & Fisheries resources %	Pond 3 / 500 dec Dictch 4 / 450 dec	Self 80% Self 70%	Adj to Sch 100% 50m - Sch 100%	
10 Soil type, water column, and Source of water	(P) Loamy 100% (D) Loamy 100%		DTW 60%	
11 Fish culture method	Natural 40% Traditional 60%			
12 Availability of fish Feed	Tradition 100%		Trad High (100%) DW medium 60%)	
13 Source of fingerlings	From traders 100%, hatchery 16%			
14 Production constraints in fish culture	Lack of Knowledge 100%, technology 75%, Capital 75%, Fingerling 100%, Theft/multi ownership/poor quality water and availability50%			
15 Sources of income and position	A 40%/B 40%		Surplus 20% Deficit 20%	
16 Source of WC	Govt fund 80%, Donation 20%, Tuition fee 80%, Other source 80%			
17 Wastewater resources and availability	No of derelict 7	Total area 700	Quantity 19880 ltr	Self owned 71% Jointly 14%
18 Wastewater type & quality	Domestic 42%, Institutional 58%		Medium 71%	
19 Quantity of solids and wastewater & present disposal	Solid waste 630kg Wastewater 21400 ltr		Accu in derelict 100%, washed into river/canal 40%	
20 Perception of Impact of wastewater in environment	Air Pollution 60%, Soil pollution 60%, Pollution of water body 80%, Poor public health 60%			
21 Existence of collection system	Open drain 80%			
22 Willingness of wastewater treatment by duckweed	Interested 100%	By contributing land 80%, assisting in collection 100%		
23 Participation in duckweed based fish culture & DW availability	Interested 100%	Group 100%		Abundantly available 40% Moderately 60
24 Wastewater treatment facility	Availability of Land 20%, Pond 60%, Other 40%			
25 Source of water supply	DTW 70%, HTW 30%			50000 liter
26 Usage of Latrine	Total latrine 21 Total users 3315	Sanitary 62%, Pit 38%		
27 Head of institution (gender) & female participation in management	Male 3 (60%) Female 2 (40%)			
28 Women participation in management	Excellent 40%, Very Good 40%			
29 Attitude regarding wastewater treatment	Interest in DW bases aquculture 100%			
30 Suitability of future participation	DW culture Suitable/ very suitable 42%	Fish culture very suitable 80%	Other than Fish/DW culture absent	
31 General condition and Observation	General cond - Highly 60%, Medium potential 40%		DW prevalence - Moderately 60% Extensive available 40%	

Site: IBC13

Indicators	*Observations*			
1 Types and category of school	Total 3 nos	Govt 66% Non Govt 33%	Primary 66%, High 33%	
2 No Student, staff and students	Total 3017	Student 2971 Teacher 41 Staff 5	Non Resi 3017	
3 Housing type	Total 6	Pacca 75%, Tin 25		
4 Land ownership	Building 3, Fallow land 3, ditch 2 Building 100%, Fallow land 100%, ditch 33%			
5 Land situation (flood /high land)	Total Area 121 dec	High 100%		
6 Land tenure status	Self 100%	Leased 8%		
7 Agriculture Cropping status	Absent			
8 Livestock & poultry resources	Absent			
9 Aquaculture & Fisheries resources %	Dictch 2 / 5 dec	Self 50% Other 50%	Adj to Sch 50%	
10 Soil type, water column, and Source of water	(D) Loamy 100%			
11 Fish culture method	Absent			
12 Availability of fish Feed	Absent		Trad Low (20%)	
13 Source of fingerlings	From traders 100%			
14 Production constraints in fish culture	Lack of Knowledge 100%, technology 100%, Theft 33%, Poor water quality and availability 60%			
15 Sources of income and position	B/C/D 33%		Surplus 33% Deficit 66%	
16 Source of WC	Govt fund 33%, Donation 66%, Tuition fee 66%, Other source 100%			
17 Wastewater resources and availability	No of derelict 3	Total area 65	Quantity 9340 ltr	Self owned 33%
18 Wastewater type & quality	Domestic 66%, Institutional 33%		Medium 66% High 33%	
19 Quantity of solids and wastewater & present disposal	Solid waste 260 kg Wastewater 7000 ltr		Accu in derelict 100%, washed into river/canal 100%	
20 Perception of Impact of wastewater	Air Pollution 66%, Soil pollution 100%, Pollution of water body 100%, Poor public health 66%			
21 Existence of collection system	Open drain 66%			
22 Willingness of wastewater treatment by duckweed	Interested 100%	Assisting in collection 100%		
23 Participation in duckweed based fish culture & DW availability	Interested 100%	Group 100%		Abundant available 66
24' Wastewater treatment facility	Availability of Land 66%, Pond 66%			
25 Source of water supply	DTW 100%			21550 liter
26 Usage of Latrine	Total latrine 7 Total users 2600	Sanitary 71%, hanging 29%		
27 Head of institution (gender) & female participation in management	Male 3 (100%)			
28 Women participation in management	Very Good 100%			
29 Attitude regarding wastewater treatment	Interest in DW culture 33%, DW bases aquculture 100%			
30 Suitability of future participation	DW culture Suitable 100%	Fish culture potential for promotion 67%	Other than Fish/DW culture absent	
31 General condition and Observation	General cond - High 67% Medium potential 33%		DW prevalence - Extensively 67%, Moderately available 33%	

Site: SPV22

Indicators	*Observations*			
1 Types and category of school	Total 2nos	Govt 50% Non Govt 50%	High 100%	
2 No Student, staff and students	Total 2469	Student 2395 Teacher 58 Staff 16	Residential 6 Non Resi 2463	
3 Housing type	Total 3	Pacca 100%		
4 Land ownership	Building 2, Staff house 2, Fallow land 2, ditch 1 Building 100%, Staff house 100%, Fallow land 100%, ditch 50%			
5 Land situation (flood /high land)	Total Area 505 dec	High 100%		
6 Land tenure status	Self 100%			
7 Agriculture Cropping status	Absent			
8 Livestock & poultry resources	Absent			
9 Aquaculture & Fisheries resources %	Dictch 3 / 530 dec	Self 100%	Adj to Sch 50% 50m - 5ch 20%	
10 Soil type, water column, and Source of water	(D) Loamy 100%			
11 Fish culture method				
12 Availability of fish Feed			Trad High (100%)	
13 Source of fingerlings	From traders 100%			
14 Production constraints in fish culture	Lack of Knowledge 100%, technology 100%, Inputs 50%, Fingerling 50%, Low water availability 50%			
15 Sources of income and position	E 100%		Surplus 100%	
16 Source of WC	Govt fund 50%, Tuition fee 100%, Other source 100%			
17 Wastewater resources and availability	No of derelict 1	Total area 15	Quantity 180ltr	Self owned 100%
18 Wastewater type & quality	Institutional 100%		Low 100%	
19 Quantity of solids and wastewater & present disposal	Solid waste 250 kg Wastewater 5000 ltr		Accu in derelict 100%, washed into river/canal 50%	
20 Perception of Impact of wastewater	Air Pollution 100%, Pollution of water body 100%, Poor public health 100%			
21 Existence of collection system	Open drain 50%, Septic tank 50%			
22 Willingness of wastewater treatment by duckweed	Interested 100%	By contributing land 50%, assisting in collection 100%		
23 Participation in duckweed based fish culture & DW availability	Interested 100%	Group 100%		Moderately available 100%
24 Wastewater treatment facility	Availability of Land 50%			
25 Source of water supply	HTW 100%			9000 liter
26 Usage of Latrine	Total latrine 13 Total users 2500	Sanitary 100%		
27 Head of institution (gender) & female participation in management	Male 2 (100%)			
28 Women participation in management	Excellent 100%			
29 Attitude regarding wastewater treatment	Interest in DW bases aquculture 100%			
30 Suitability of future participation	DW culture Suitable 100%	Fish culture absent	Other than Fish/DW culture absent	
31 General condition and Observation	General cond - Medium potential 100%		DW prevalence - Moderately available 100%	

ENVIRONMENTAL AUDIT & SOCIO-ECONOMIC SURVEY OBSERVATIONS AND ANALYSIS ON THE EVALUATED FOURTEEN SITES

A. Qualitative assessment (survey observations)

1. Relative contribution by different sources to total Wastewater production

	Very High		High		Moderate		Low		Very Low	
Sites	Nos.	%	nos	%	nos	%	nos	%	Nos	%
Domestic	2	14%	6	43%	2	14%	3	21%	1	7%
Municipal	2	14%	7	50%	2	14%	3	21%	0	0
Industrial	3	21%	2	14%	1	7%	4	29%	4	29%
Agriculture	1	7%	7	50%	2	14%	3	21%	1	7%
School	0	0	1	7%	6	43%	5	36%	2	14%

- 56% of the sites (8 sites) have very high domestic, Municipal and agricultural waste water prevalence in their composition
- Industrial waste production is high for 35% of the sites (5) and 56% of the sites(8) prevalence is low and of the primarily Orange A & B type
- 50% of the sites has low/moderate availability of School sanitation waste and 43% of the sites have moderate prevalence of School sanitary ww available
- Majority of the sites audited have waste water composed of Domestic, Municipal and agricultural Waste primarily
- In 80% of the sites solid waste and waste water are all mingled and scattered
- The 5 sites finally selected for potential Duckweed Based Wastewater treatment all fall under the above composition category and are not likely to have heavy industrial waste or toxins present Majority of the site represent in peri-urban areas and growth centers where agricultural waste is going to further decrease over a period and industrial waste may increase with increased urbanization

2. Source of Waste Water by sector

Observation	Very High		High		Moderate		Low		Very Low	
Domestic/ municipal / sanitation	1	7%	8	57%	3	21%	2	14%	-	-
Food processing	-	-	-	-	-	-	3	21%	11	79%
Agriculture	-	-	-	-	-	-	2	14%	12	86%
Livestock	-	-	1	7%	1	7%	3	21%	8	57%
Aquaculture	-	-	-	-	-	-	-	-	1	7%
Industry	-	-	2	14%	2	14%	4	28%	4	28%
Workshop	-	-	-	-	1	7%	6	43%	4	28%

- Major source of waste at all sites were observed to be domestic, municipality and sanitary sources
- Next source of waste was industries but at low rate for 56% (8 sites) of the sites and 14% (2 sites) at high rate
- Very low waste was contributed by the agriculture sector in all sites except one site (BLRI) which is high being a Livestock research farm & dairy farm

3. Quality assessment of open Water bodies (14 sites).

Observation	Very High		High		Moderate		Low		Very Low	
Turbidity	0	0	8	57%	6	43%	0	0	0	0
Smell	2	14%	2	14%	5	36%	5	36%	0	0
Organic matter	2	14%	4	29%	5	36%	3	21%	0	0
Fecal contamination	1	7%	1	7%	6	43%	5	36%	1	7%
Waste input	2	14%	5	36%	3	21%	4	29%	0	0
	Black		*Grey*		*Green*					
Wastewater color	55	27 8%	50	25 3%	73	36 9%				

- Observation of turbidity in site adjacent water bodies indicated 57% sites having high turbidity followed by moderate for the other sites
- smell emission from majority of the water bodies at all sites was observed as low to moderate
- organic matter content present was observed as moderate to high in all sites except in three sites where it was low

- Fecal contamination for 80% of the sites was observed as moderate to low One site (IAC 14) indicated very high contamination due to large amount of fecal matter & open latrines outputs being directly connected to the Ispahani Arseen Canal from the workers & their families dwelling besides the canal
- Water color observed in the water bodies indicated that 37% was Green , 28% black and 25% Grey confirming the high loading of organic matter, turbidity and waste input into the water bodies at majority of the sites
- Overall loading rate of waste in surrounding water bodies observed as Moderate from mainly organic waste input

4. State of Wastewater in Environment

Observation	Very High		High		Moderate		Low		Very Low	
Scattered	-	-	8	57%	5	36%	1	7%	-	-
Collection	1	7%	1	7%	1	7%	10	71%	1	7%
Re-used	-		-	-	1	7%	6	43%	7	50%

- Wastewater at 93% (13 no) sites were observed to be scattered in the surrounding environment uncontrolled and its state of collection is assessed as low At present reuse (Irrigation, Aquaculture & feeding in to ponds etc) of wastewater was also found to be very Low to low for 93% of the sites

5. General Situation of Wastewater-Disposal

Quality Observation	Yes, one		Yes, some		Yes, all	
Waste source channeled to one site/pond, not mixed with other waste stream	1	1.5%	32	47 7%	10	14 9%
Variety waste streams are channeled to a central pond /site	3	4 5%	31	46 3%	21	31 3%
Waste are flowing into the environment in a totally uncontrolled way	5	7 5%	37	55 2%	24	35 8%
Waste sources are channeled to a specific location for re-use	1	1 5%	6	8 9%	3	4 48%
Waste flows are not controlled, but eventually the waster is reused	-	-	32	47 8%	9	13 4%

- Observing the fate of wastewater at the sites, 57% of the site waste is channeled into a pond.
- Half the waste steam is channeled into one central pond/a site
- 55% of waste water is flowing uncontrolled into the environment.
- Very little wastewater is ultimately reused in either case

6. Negative Impact

Qualitative Observation	Very High		High		Moderate		Low		Very Low	
Agriculture	-	-	-	-	3	21%	8	57%	3	21%
Livestock	-	-	-	-	3	21%	5	36%	4	28%
Aquaculture	-	-	-	-	1	7%	9	64%	3	21%
Industry	2	14%	2	14%	3	21%	5	36%	2	14%
Workshop	1	7%	2	14%	1	75	4	28%	2	14%

- Presently very little negative impact from wastewater was perceived on Agriculture, Livestock and Aquaculture Whereas 21-28% of the site perceived very high/high negative impact from industries and workshops waste Overall perception of impact of waste water on various sectors & human activities is unformed as awareness of people on this phenomenon is a slow process & relatively new

7. State of Solid Waste in Environment

Observation	Very High		High		Moderate		Low		Very Low	
Scattered	1	7%	7	50%	4	28%	2	14%	-	
Disposed into pond water	-	-	3	21%	7	50%	4	28%	-	
Collection	-	-	1	7%	-	-	6	43%	7	50%

- Similarly solid waste was found to be scattered at very high/high intensity for 57% (8 nos) of the sites and moderately for 28% of sites At 71% of sites solid waste is being disposed off in the surrounding ponds at high/moderate scale Collection of solid waste was assessed at very low to low rate for all sites confirming the observation of high rate of scattered solid waste in the surrounding at all site

8. Water Supply coverage

Observation	Very High		High		Moderate		Low		Very Low	
Drinking water	-	-	-	-	6	43%	6	43%	2	14%
Domestic chores	-	-	-	-	1	7%	10	72%	2	14%
Agriculture	-	-	-	-	3	21%	5	36%	5	36%
Aquaculture	-	-	-	-	1	7%	-	-	2	14%
Industrial										
state of satisfaction			1	100%						

- Water supply coverage for 86 % (12 nos) of sites were found to be low/moderate & the rest 14 %(2 nos) have very low coverage Similarly water supply for domestic chores was low/very low for 86 % (12 nos) of the sites Water supply availability for aquaculture & agriculture was also low/very low Industrial water supply was high as majority of the industries had their own DTW/STW water supply sources installed

9. Latrine Coverage

Observation	Very High		High		Moderate		Low		Very Low	
Sanitary Latrine	-	-	-	-	7	50%	6	43%	1	7%
Pit Latrine	-	-	2	14%	8	57%	4	28%	-	-
Hanging Latrine	-	-	1	7%	3	21%	5	36%	3	21%
Faces into pond	-	-	1	7%	2	14%	2	14%	7	50%
Open field	-	-	-	-	1	7%	1	7%	7	50%

- Sanitary latrine coverage is observed to be moderate to low for 93 % of sites and similarly for pit latrine 85 % sites had moderate to low coverage All the sites had small population defecating directly in the open or water bodies

10. Willingness of participation in wastewater treatment

Observation	Very High		High		Moderate		Low		Very Low	
Comty. Participation	3	21%	7	50%	3	21%	1	7%	-	-
School	3	21%	6	43%	4	28%	1	7%	-	-
Industry	-	-	1	7%	3	21%	6	43%	4	28%
Other	-	-	1	7%	-	-	-	-	-	-

- Willingness to actively participate in Wastewater treatment by the communities and schools was judged as very high to high at 64-71% of the sites & the rest willing to participate at moderate scale Industries willingness to participate was in comparison low to Very low at 71% of the sites and only one site (BLRI) showed moderate interest

B. Quantitative assessment

11. Estimate of Solid waste and waste water generate per day

Waste Sources	Solid Waste generated per day			Wastewater generated per day		
	Total Kg	Kg per Unit	%	Total Ltr	Ltr per Unit	%
Household	40131	4 6	48%	1254018	186	17%
School	9586	29	12%	2248300	39443	30%
Industry	25740	355	31%	2683110	24600	36%
Hat/Bazaar	7880	362	9%	1198000	36055	16%

- All the site indicated that both solid waste & waste water quantity generated by household & school is the major source & constituted 50 % of the total waste water Industries at sites contributed 34 % of the waste & waste water by quantity for all sites

12. Latrine Coverage

Source Observed	Sanitary		Pit		Hanging		Open		Field	
	No	%	No	%	No	%	No	%	No	%
Household	298	43%	266	38%	59	8%	71	10%	4	1 %
School	839	78%	29	3%	210	19%	2	-	-	-
Industry	91	75%	21	17%	6	5%	2	1 5%	2	1 5%
Hat/Bazaar	67	99%	1	1%						

- The sites being primarily located in the peri-urban & growth center areas indicated high coverage of sanitary latrines in comparison to the national average. Schools, industries & hat/bazaar being public areas indicated very high coverage of sanitary latrines, which are collectively used. Pit latrine coverage was the next highest & very low numbers of open latrines or defecating in the field was observed.

13. Drinking Water Coverage

Quality Observed	Very High		High		Moderate		Low		Very low	
Coverage (HTW)	14	100%	-	-	-	-	-	-	-	-
Availability	5	36%	8	57%	-	-	1	7%	-	-
Satisfaction	-	-	11	79%	3	21%	-	-	-	-
	Good					*Bad*				
Quality	98.5%					1.5%				

- All sites confirmed 100 % coverage of drinking water from hand tube-well. This at the same time conforms to the national statistics for drinking water supply. Both availability and community satisfaction for drinking water supply was judged as high.

14. Drinking Water Sources

Source Observed	HTW		STW		DTW		Tap water		Well/Pond	
Household	14	91%	-	-	-	-	9	7%	6	2%
School	11	62%	1	4%	7	32%	1	2%	-	-
Industry	11	89%	1	3%	-	-	1	7%	-	-
Hat/Bazaar	3	50%	-	-	-	-	-	-	3	50%

- The coverage & the source of water supply for households, schools, industries & hat/Bazaar at all sites was judged as high confirming the survey results for quantity & quality of drinking water.

15. Fate of wastewater (Current disposal)

Sources	Households		School		industry		Hat/Bazaar	
	Nos	%	Nos	%	Nos	%	Nos	%
Washed in canal/river	419	60%	38	67%				
Derelict pond accumulation	217	31%	38	67%				
Use in fish pond	3	0.43%	-					
Use as irrigation	3	0.43%	-					
Other use	83	12%	10	18%				
Derelict pond usage								
Bathing	52	23%	-	-				
Domestic chores	137	61%	36	84%				
Latrine connected	66	30%	6	14%				
Fish culture	55	25%	11	26%				
Fallow	58	26%	-	-				

Annex 12

Environmental Audit results (1)

ENVIRONMENTAL AUDIT SUMMARY AND ANALYSIS

Site: BLRI 05 (Savar Dairy Farm & BLRI Complex)

Sl	*Indicators*	*Observations*
1	Estimated quantity of ww at site	4200 m^3
2	Composition of wastewater	
2 1	Domestic	Low 60%, Medium 40%
2 2	Municipal	Low 60%, Medium 40%
2 3	Industrial	High 40%, Medium 40%
2 4	Agricultural	Low 60%, Medium 40%
2 5	School	Low 80%
3	Status of cleanliness	
3 1	Cleanliness of the site	High 60%, moderate 40%
3 2	Intensity of traffic	Very high 80%, moderate 20%
3 3	Drinking water coverage	High 75%, Very high 25%
3 4	Level of arsenic count	Very low 100%
3 5	Channeling of selected waste sources	Medium 100%
3 6	General perception regarding local environment and public health	Low 60%, moderate 40%
3 7	Prevalence of duckweed	High 60%, Medium 40%
3 8	Air pollution sources	Other than domestic wastewater Medium 100%
4 1	State of waste water in the area	Moderately scattered 80%, Collection high 75%, moderately reused 100%
4 2	State of solid waste	Moderately scattered 80%, Disposed into water medium 100%, moderately collected 50%
4 3	Maintenance of water sources	Pond moderately (100%)
4 4	Latrine coverage	Sanitary medium 80%, Pit low 80%
4 5	Availability of waste water in the project site	Overall availability medium 100% Community low 75%, School low 80%, Industry & other waste Medium 80%
4 6	Waste from different sources	Domestic/municipal/san. Medium 80%, Industry, Agri , Food processing low 100%
4 7	Negative impact of waste	Moderate 80%
4 8	Willingness of participation in duckweed based WW treatment	Comm Participation, School & industry medium 100%,
4 9	Logistic situation	Logistic situation medium 80%, State of preparedness medium 100%
4 10	Prevalence of Duckweed	Very Good 100%
5 1	Drinking	HTW 100%, High avail 80%, Highly satisfactory 100%, Quality good 100%
5 2	Other domestic purposes	HTW 100% High availability 70%, High satisfactory 100%, Quality good 100%
5 3	Agriculture	STW 40%/ DTW 60%, Low avail 100%, Satisfactory/medium 60%, Quality good 100%
5 4	Aquaculture	Absent
5 5	Industrial	Absent
5 6	Other	Absent
6	Status of open water bodies	
6 1	Turbidity	Medium 90%, Black 50%, Green 30%
6 2	Smell	Moderate 90%
6 3	Level of organic content	Medium 50%, High 50%
6 4	Level of fecal contamination	Medium 100%
6 5	Input of waste	Medium 50%, Low 50%
7	General situation of wastewater	
7 1	Waste source is channeled to one site/pond, not mixed with other waste streams	Yes some 100%
7 2	Various waste streams are channeled to a central site/pond	Yes some 60%, Yes all 40%
7 3	Wastes are flowing into the environment in a totally uncontrolled way	Yes some 40%, Yes all 40%
7 4	Waste sources are channeled to a specific location for re-use	Absent
7 5	Waste flows are not controlled, but eventually the water is re-used	Absent
8	Energy sources	
8 1	Domestic	Electricity 100%, Nat gas 100%, Fossil Fuel 100%
8 2	Workshops	Electricity 100%, Nat gas 40%, Fossil Fuel 60%
8.3	Industries	Electricity 100%, Nat gas 80%, Fossil Fuel 100%
8 4	Aquaculture	Fossil Fuel 100%
8 5	Transportation	Electricity 10%, Fossil Fuel 100%

Site: CPP19 (CPP Outlet and Garinda Beel)

Sl	*Indicators*	*Observations*
1	Estimated quantity of ww at site	5700 m^3
2	Composition of wastewater	
2 1	Domestic	High 100%
2 2	Municipal	High 100%
2 3	Industrial	Very low 100%
2 4	Agricultural	High 100%
2 5	School	Low 100%
3	Status of cleanliness	
3 1	Cleanliness of the site	Medium 50%, High 50%
3 2	Intensity of traffic	Medium 50%
3 3	Drinking water coverage	Very High 100 %
3 4	Level of arsenic count	Very low 100%
3 5	Channeling of selected waste sources	Medium 50%, High 50%
3 6	General perception regarding local environment and public health	Medium 75%, High 25%
3 7	Prevalence of duckweed	Medium 75%, High 25%
3 8	Air pollution sources	Other than domestic wastewater Very High 85%
4 1	State of waste water in the area	Highly scattered 100%, Collection low 100%, Low reused 90%
4 2	State of solid waste	Highly scattered 80%, Disposed into water medium 50%, Poor collection 100%
4 3	Maintenance of water sources	Pond low 50%, Pump moderate 50%, Tap water very low 100%
4 4	Latrine coverage	Sanitary medium 66%, Pit low 100%
4 5	Availability of waste water in the project site	Overall availability medium 66% Community high 100%, School low 100%, Industry & other waste very low 100%
4 6	Waste from different sources	Domestic/municipal/san High 100%, Food processing very low 100%, Agri, very low 66%, Livestock very low 75%, Industry low 100%
4 7	Negative impact of waste	Agri & livestock low 75%, Aquaculture medium 100%, Industry 75%
4 8	Willingness of participation in duckweed based WW treatment	Comm Participation high 100%, School medium 75%, Industry very low 100%,
4 9	Logistic situation	Logistic situation High 50% State of preparedness medium 75%
4 10	Prevalence of Duckweed	Satisfactory 75%
5 1	Drinking	HTW 100%, Very high avail 75%, Highly satisfactory 75%, Quality good 100%
5 2	Other domestic purposes	HTW 100% High availability 100%, Medium satisfactory 75%, Quality good 100%
5 3	Agriculture	STW 100% High avail 75%, Satisfactory medium 70%, Quality good 100%
5 4	Aquaculture	Absent
5 5	Industrial	Absent
5 6	Other	Absent
6	Status of open water bodies	
6 1	Turbidity	Medium 60%, Low 16%, Grey 25%, Green 62%
6 2	Smell	Moderate 58%
6 3	Level of organic content	Medium 45%, Moderate 45%
6 4	Level of fecal contamination	Low 75% Medium 25%
6 5	Input of waste	Low 62%, medium 20%
7	General situation of wastewater	
7 1	Waste source is channeled to one site/pond, not mixed with other waste streams	Yes some 75%, Yes all 25%
7 2	Various waste streams are channeled to a central site/pond	Yes all 75%, Yes some 25%
7 3	Wastes are flowing into the environment in a totally uncontrolled way	Yes some 75%
7 4	Waste sources are channeled to a specific location for re-use	Yes some 75%, Yes all 25%
7 5	Waste flows are not controlled, but eventually the water is re-used	Yes some 100%
8	Energy sources	
8 1	Domestic	Electricity 100%, Nat gas 100%, Fossil Fuel 100%, Bio-mass 75%
8 2	Workshops	Electricity 100%, Nat.gas 25%, Fossil Fuel 100%
8 3	Industries	Electricity 100%, Nat gas 25%, Fossil Fuel 100%
8 4	Aquaculture	Electricity 100%, Fossil Fuel 100%
8 5	Transportation	Fossil Fuel 100%

Site: SPV23 (Saidpur Pourashava *Vagar*)

Sl	*Indicators*	*Observations*
1	Estimated quantity of ww at site	(3600 + 840) 4440 m^3
2	Composition of wastewater	
2 1	Domestic	Very high 80%, High 20%
2 2	Municipal	Very high 80%, High 20%
2 3	Industrial	Low 80%, Very low 20%
2 4	Agricultural	Very high 80%, High 20%
2 5	School	High 40%, Medium 20%, Low 40%
3	Status of cleanliness	
3 1	Cleanliness of the site	Low 80%, Very low 20%
3 2	Intensity of traffic	Very high 60%, high 40%
3 3	Drinking water coverage	High 60%, Very high 40%
3 4	Level of arsenic count	Very low 100%
3 5	Channeling of selected waste sources	H100%
3 6	General perception regarding local environment and public health	Medium 100%
3 7	Prevalence of duckweed	Low 60%, Medium 40%
3 8	Air pollution sources	High due to domestic waste 100% High due to other waste Medium 60%
4 1	State of waste water in the area	Highly scattered 100%, Collection low 60%, Low reused 60%
4 2	State of solid waste	Highly scattered 100%, Disposed into water high 80%, low collection 60%
4 3	Maintenance of water sources	Pond medium 80%, Pump very low 80%, Tap water low 80%
4 4	Latrine coverage	Sanitary low 60%, Pit medium 100%, Hanging low 80%, faces into pond low 40%, Open field low 60%
4 5	Availability of waste water in the project site	Overall availability high 100% Community very high 80%, School medium 100%, Industry low 80%
4 6	Waste from different sources	Domestic/municipal/san high 80%, Food processing low 60%, Very low Agri 60%, Livestock low 60%, Workshop low 60%
4 7	Negative impact of waste	Agri/Industry/Workshop medium 80% Low aquaculture 100%
4 8	Willingness of participation in duckweed based WW treatment	Comm Participation very high 60%, School very high 80%, industry low 100%,
4 9	Logistic situation	Logistic situation medium 100% State of preparedness medium 80%
4 10	Prevalence of Duckweed	Good 70%
5 1	Drinking	HTW 100%, High avail 100%, Highly satisfactory 80%, Quality good 100%
5 2	Other domestic purposes	HTW 100% Medium availability 100%, Medium satisfactory 100%, Quality good 100%
5 3	Agriculture	STW 100%, Very high avail 80%, Satisfactory high 80%, Quality good 100%
5 4	Aquaculture	Absent
5 5	Industrial	Absent
5 6	Other	Absent
6	Status of open water bodies	
6 1	Turbidity	Medium 40%, High 40%, Black 40%, Green 50%
6 2	Smell	Medium 40%, Very high 40%
6 3	Level of organic content	Very high 40%, Medium 30%
6 4	Level of fecal contamination	Very high 40%, Low 40%
6 5	Input of waste	Very high 40%, Medium 40%
7	General situation of wastewater	
7 1	Waste source is channeled to one site/pond, not mixed with other waste streams	Yes some 20%
7 2	Various waste streams are channeled to a central site/pond	Yes all 80%, Yes some 20%
7 3	Wastes are flowing into the environment in a totally uncontrolled way	Yes some 100%
7 4	Waste sources are channeled to a specific location for re-use	Absent
7 5	Waste flows are not controlled, but eventually the water is re-used	Yes some 80%
8	Energy sources	
8 1	Domestic	Electricity 100%, Fossil Fuel 100%, Bio-mass 20%
8 2	Workshops	Electricity 100%, Nat gas 20%, Fossil Fuel 60%, Bio-mass 20%
8 3	Industries	Electricity 100%, Nat gas 20%, Fossil Fuel 100%, Bio-mass 20%
8 4	Aquaculture	Fossil Fuel 100%
8 5	Transportation	Fossil Fuel 100%

Site: IBC13 (Isdair Basti Canal)

Sl	*Indicators*	*Observations*
1	Estimated quantity of ww at site	2700 m^3
2	Composition of wastewater	
2 1	Domestic	High 80%, Very high 20%
2 2	Municipal	High 80%, Very high 20%
2 3	Industrial	Very High 60%, Low 20%
2 4	Agricultural	High 80%, Very high 20%
2 5	School	Medium 80%
3	Status of cleanliness	
3 1	Cleanliness of the site	Very low 60%, Low 40%
3 2	Intensity of traffic	Medium 40%, Very high 60%
3 3	Drinking water coverage	High 100%
3 4	Level of arsenic count	Very low 60%, Low 40%
3 5	Channeling of selected waste sources	Medium 80%, High 20%
3 6	General perception regarding local environment and public health	Medium 60%
3 7	Prevalence of duckweed	Medium 80%, High 20%
3 8	Air pollution sources	Very high due to Industrial waste 80% High due to vehicle 60%
4 1	State of waste water in the area	Highly scattered 60%, Collection medium 60%, Low reused 80%
4 2	State of solid waste	Very highly scattered 40%, Disposed into water medium 60%, Very low collection 80%
4 3	Maintenance of water sources	Pond low 60%, Pump low 100%, Tap water medium 60%, Other water use low 60%
4 4	Latrine coverage	Sanitary medium 60%, Pit high 60%, Hanging low 80%, faces into pond medium 60%, Open field very low 60%
4 5	Availability of waste water in the project site	Overall availability medium high 100% Community high 80%, School medium 80%, Industry high 80%
4 6	Waste from different sources	Domestic/municipal/san Medium 60%, Food processing low 60%, Agri/livestock/aquaculture very low 100%, Workshop low 100%
4 7	Negative impact of waste	Agri/livestock/aquaculture very low 80%, Industrial / Workshop very high 70%
4 8	Willingness of participation in duckweed based WW treatment	Comm Participation high 70%, School high 80%, industry medium 60%
4 9	Logistic situation	Logistic situation medium 60% State of preparedness medium 80%
4 10	Prevalence of Duckweed	Good 80%
5 1	Drinking	HTW 100%, High avail 100%, Medium satisfactory 80%, Quality good 100%
5 2	Other domestic purposes	HTW 100% High availability 80%, Medium satisfactory 50%, Quality good 75%
5 3	Agriculture	STW 75%/ DTW 25%, Low avail 70%, Satisfactory medium 50%, Quality good 80%
5 4	Aquaculture	Absent
5 5	Industrial	Absent
5 6	Other	Absent
6	Status of open water bodies	
6 1	Turbidity	Medium 38%, High 30%, Very high 23%, Black 77%, Green 23%
6 2	Smell	Medium 77%, High 15%
6 3	Level of organic content	Medium 54%, High/very high 23%
6 4	Level of fecal contamination	Moderate 46%, Medium 15%, high 38%
6 5	Input of waste	Medium 46%, High 50%
7	General situation of wastewater	
7 1	Waste source is channeled to one site/pond, not mixed with other waste streams	Yes some 60%
7 2	Various waste streams are channeled to a central site/pond	Yes some 60%, Yes all 20%, Yes one 20%
7.3	Wastes are flowing into the environment in a totally uncontrolled way	Yes some 40%, Yes all 20%, Yes one 20%
7 4	Waste sources are channeled to a specific location for re-use	Absent
7 5	Waste flows are not controlled, but eventually the water is re-used	Yes some 60%, Yes all 20%
8	Energy sources	
8 1	Domestic	Electricity 100%, Nat gas 100%, Fossil Fuel 80%, Bio mass 80%
8 2	Workshops	Electricity 100%, Nat gas 60%, Fossil Fuel 80%
8 3	Industries	Electricity 100%, Nat gas 80%, Fossil Fuel 80%
8 4	Aquaculture	Electricity 20%, Fossil Fuel 100%
8 5	Transportation	Electricity 20%, Fossil Fuel 100%

Site: IAC14 (Ispahani Arseen Canal)

Sl	Indicators	Observations
1	Estimated quantity of ww at site	4800 m^3
2	Composition of wastewater	
2 1	Domestic	High 80%, Very high 20%
2 2	Municipal	High 80%, Very high 20%
2 3	Industrial	Low 80%, Medium 20%
2 4	Agricultural	High 80%, Very high 20%
2 5	School	Medium 60%, Low 40%
3	Status of cleanliness	
3 1	Cleanliness of the site	Low 80%, medium 20%
3 2	Intensity of traffic	Low 60%, Very low 40%
3 3	Drinking water coverage	High 100%
3 4	Level of arsenic count	Very low 100%
3 5	Channeling of selected waste sources	Low 80%, Medium 20%
3 6	General perception regarding local environment and public health	Medium 60%
3 7	Prevalence of duckweed	High 60%, Medium 40%
3 8	Air pollution sources	Due to domestic use high 40%, Solid & other waste medium 40%
4 1	State of waste water in the area	Highly scattered 60%, Collection very low 60%, Low reused 100%
4 2	State of solid waste	Highly scattered 60%, Disposed into water high 80%, Low collection 100%
4 3	Maintenance of water sources	Pond medium 60%, Pump low 100%, Tap water low 80%
4 4	Latrine coverage	Sanitary low 80%, Pit medium 80%, Hanging medium 90%, faces into pond 85%
4 5	Availability of waste water in the project site	Overall availability medium 80% Community high 100%, School medium 75%, Industry very low 85%
4 6	Waste from different sources	Domestic/municipal/san high 70%, Food processing/Agri /workshop very low 100%, Livestock /industry 80%
4 7	Negative impact of waste	Medium impact 60%
4 8	Willingness of participation in duckweed based WW treatment	Comm Participation very high 60%, School high 75%, industry low 40%
4 9	Logistic situation	Logistic situation high 50% State of preparedness medium 70%
4 10	Prevalence of Duckweed	Very Good 60%, Satisfactory 40%
5 1	Drinking	HTW 100%, High avail 75%, Highly satisfactory 50%, Quality good 100%
5 2	Other domestic purposes	HTW 100% High availability 100%, Medium satisfactory 75%, Quality good 100%
5 3	Agriculture	STW 100%, Very low avail 75%, Satisfactory /medium 75%, Quality good 100%
5 4	Aquaculture	Absent
5 5	Industrial	Absent
5 6	Other	Absent
6	Status of open water bodies	
6 1	Turbidity	High 45%, Medium 36%, Black 55%, Green 45%
6 2	Smell	Medium 36%, high 36%
6 3	Level of organic content	Medium 45%, High 45%
6 4	Level of fecal contamination	Very high/high 36%, Medium 27%
6 5	Input of waste	Very high/high 36%, Medium 18%
7	General situation of wastewater	
7 1	Waste source is channeled to one site/pond, not mixed with other waste streams	Yes all 80%, Yes some 20%
7 2	Various waste streams are channeled to a central site/pond	Yes one 20%
7 3	Wastes are flowing into the environment in a totally uncontrolled way	Yes all 80%, Yes some 20%
7 4	Waste sources are channeled to a specific location for re-use	Absent
7 5	Waste flows are not controlled, but eventually the water is re-used	Yes all 80%
8	Energy sources	
8 1	Domestic	Electricity 100%, Nat gas 60%, Fossil Fuel 100%, Bio mass 40%
8 2	Workshops	Electricity 100%, Nat gas 80%, Fossil Fuel 40%
8 3	Industries	Electricity 100%, Nat gas 100%, Fossil Fuel 60%
8 4	Aquaculture	Electricity 60%, Fossil Fuel 100%
8 5	Transportation	Electricity 20%, Fossil Fuel 100%

Annex 13

Environmental audit results (2)

SOURCE-WISE ESTIMATION OF WASTE AND WASTE WATER GENERATED AT SITES

A. Household & Community

Location	Household generated solid waste & waste water				
	Population Density HH / Km^2	Waste water Generated Ltr. / day / HH	Total Quantity Ltr. / day	Solid waste Generated Kg / day / HH	Total Quantity Kg / day
BLRI - 05	289	178	51,442	6 35	1835
BO - 08	324	190	61,560	6 62	2145
CPP - 19	253	222	56,166	5.58	1412
ENB - 09	2300	171	393,300	3 32	7636
IAC - 14	844	153	129,132	2 84	2397
IBC - 13	163	146	23,798	3.08	502
KBD - 07	324	214	69,336	3 85	12474
KCC - 16	253	187	47,311	4 32	1093
KGC - 17	253	188	47,564	4 90	1240
NZP - 23	362	169	61,178	4 62	1672
SPV - 22	362	181	65,522	5.28	1911
SUC - 01	289	229	66,181	6 10	1763
TOS - 15	844	178	150,232	4 14	3494
ZZK - 10	163	192	31,296	3 42	557
TOTAL	7023	2598	1,254,018	64 42	40131
Average	501 64	185 57	89572 71	4.60	2866 5

B. Industry

Location	Industry generated solid waste & waste water				
	No. of Industry	Waste water Generated Ltr. /day/ Industry.	Total Quantity Ltr. / day	Solid waste Generated Kg/day/Industry	Total Quantity Kg / day
BLRI - 05	2	505000	1010000	11,000	22,000
BO - 08	5	1500	7500	165	825
CPP - 19	1	500	500	140	140
ENB - 09	1	400	400	10	10
IAC - 14	1	1500	1500	150	150
IBC - 13	5	105000	525000	252	1260
KBD - 07	8	94075	752600	73	580
KCC - 16	1	360	360	40	40
KGC - 17	-		-	-	-
NZP - 23	3	233	700	10	30
SPV - 22	-		-	-	-
SUC - 01	3	126717	380150	162	485
TOS - 15	-		-	-	-
ZZK - 10	4	1100	4400	55	220
TOTAL	34	836385	2683110	12,057	25,740
Average		24599 56	78915	354 62	757 06

C. School

Location	School generated solid waste & waste water				
	No. of School	Waste water Generated Ltr. /day/ School.	Total Quantity Ltr. / day	Solid waste Generated Kg/day/School	Total Quantity Kg / day
BLRI - 05	3	20,001,000	60,003,000	1037	3110
BO - 08	2	1250	2500	32	65
CPP - 19	5	620	3100	200	999
ENB - 09	4	2500	10,000	60	240
IAC - 14	5	4280	21400	126	630
IBC - 13	3	2333	7000	86	260
KBD - 07	4	10150	40600	82	328
KCC - 16	4	3913	15650	225	902
KGC - 17	5	7240	36200	196	980
NZP - 23	8	1388	11100	50	400
SPV - 22	2	2500	5000	140	280
SUC - 01	4	13313	53250	170	680
TOS - 15	4	2125	8500	44	175
ZZK - 10	4	7750	31000	135	540
TOTAL	57	20,060,362	60,248,300	2583	9589
Average		1099 3	4,542 59	28 63	119 98

D. Hat / Bazaar

Location	School generated solid waste & waste water				
	No. of Hat/Bazaar	Waste water Generated Ltr. /day/ Hat/Bazaar.	Total Quantity Ltr. / day	Solid waste Generated g./day/Hat/Bazaa r	Total Quantity Kg / day
BLRI - 05	1	20000	20000	1500	1500
BO - 08	1	2000	2000	200	200
CPP - 19	1	1000	1000	60	60
ENB - 09	2	50000	100000	200	400
IAC - 14	2	5500	11000	150	300
IBC - 13	1	100000	100000	1000	1000
KBD - 07	1	300000	300000	200	200
KCC - 16	1	2000	2000	100	100
KGC - 17	1	5000	5000	100	100
NZP - 23	-	-	-	-	-
SPV - 22	2	101500	203000	310	620
SUC - 01	1	30000	30000	2000	2000
TOS - 15	2	11500	23000	150	300
ZZK - 10	2	20500	401000	550	1100
TOTAL	18	649000	1198000	6520	7880
Average		36055 56	66555 56	362 22	437 78

Annex 14

Environmental Audit results (3)

WATER QUALITY MEASUREMENTS OF IMPORTANT WATER BODIES AND WASTEWATER SOURCES AT FOURTEEN SITES

Date	Name of site	Identification of Water body	Estim-ated vol. M^3	emp (°C)	pH	DO mg/l)	TDS mg/l)	onductivity S /cm	ecchi cm)	TSS mg/l	BOD_5 mg/l	N_{tot} Mg/l	P_{tot} mg/l	ecal coli. cfu x 10^5 100 ml)	T. coli (cfu x 10^5 /100 ml)
9-12-98	SUC-1A	SUC-derelict pond	10080	25	5 4	1	760	1060	12	130	135	44 8	4 2	0 24	1 7
	SUC-1B	Savar Girls School's Pond		25	6 2	2	390	550	20	142	< 1 0	4 5	2 9	0 03	0 07
9-12-98	BLRI-5A	BLRI- Stabilization Pond	4200	26	5 2	1	900	1260	10	1584	240	89 6	4 7	0 85	3 10
	BLRI-5B	J University derelict-2		25	6	2	650	910	15	6	10	8 4	5 3	0 03	0 62
2-12-98	KBD-7A	KBD-Derelict Pond	2400	25	6 4	3	280	390	20	204	2 8	8 4	2 6	0 05	0 30
	KBD-7B	C&B - Burrow-pit		26	8 5	0	1900	2650	8	844	6 0	14 0	1 8	0 01	0 20
4-12-98	BO-8A	BO Adjacent Derelict 1	1920	26	8 2	2	260	365	15	22	2 5	7 3	2 7	0 03	0 60
	BO-8B	BO Adjacent Derelict 2	1080	26	8 3	2	360	504	14	114	3 0	5 6	2 8	0 09	0 13
6-12-98	ENB-9A	Tekbari outlet	22000	26	7 8	0	1800	2520	6	266	325	112.0	4 4	1 60	180 00
	ENB-9B	ENB Pond # 6		25	7 4	2	360	420	15	184	4 5	10 1	3 0	4 30	26 00
17-12-98	ZZK-10A	Zeem's Khal	13500	25	7 0	3	1200	1700	9	16	128	56 0	2 8	0 60	2 70
	ZZK-10B	Zalpar Khal	4000	25	6 5	0	2000	2800	5	364	185	85 7	5 0	2 50	17 00
17-12-98	IBC-13A	Isdair Basti Canal	2700	25	7 6	4	820	1100	10	104	15	24 1	3 9	0 40	1 30
	IBC-13B	Railway Canal		24	6 7	1	1300	1800	7	122	32	29 7	3 9	2 80	6 00
17-12-98	IAC-14A	Ispahani (CSD) canal	4800	24	7 4	6	700	1000	15	276	12	18 5	1 9	0 13	3 80
	IAC-14B	Kadam Rasul (PSVA) Burrow-pit		24	7 4	5	500	800	17	152	14	4 5	2 5	0 075	17 00
17-12-98	TOS-15A	Alamchan School's Pond	3600	24 5	7	3	250	450	19	78	<1 0	4 5	2 3	0 056	0 10
	TOS-15B	Jabed Ali's Pond		24 5	7	4	400	650	18	152	2 0	7 3	2 6	0 63	3 60
28-11-98	KCC-16A	KCC-Derelict Pond	4000	26	5 6	3	310	450	30	70	<1 0	4 5	2 5	0 15	1 00
	KCC-16B	Bazaar/A Textile mills adjacent po		27	6 4	2	460	690	12	158	1 5	5 6	2 6	0 065	0 20
25-11-98	KGC-17A	KGC-Derelict Pond	2400	25	6 5	3	310	400	15	96	3 0	7 3	3 6	2 30	4 10
	KGC-17B	Adjacent Canal		25	8 5	3	330	490	12	198	4 7	11 2	2 4	3 60	8 50
12-11-98	CPP-19A	Starting pt of CPP - outlet	5760	25	5 9	1	900	1260	7	42	46	64 4	4 2	9 50	32 50
	CPP-19B	Middle pt of CPP - outlet		25	6	2	540	750	8	410	10	28 0	1 8	0 62	4 20
27-12-98	SPV-22A	Saidpur PSVA drain	840	22	7 1	1	950	1400	7	164	125	75 6	32 3	24 00	33 00
	SPV-22B	Saidpur *Bhagar*	3600	22	7 7	3	900	1300	9	184	150	78 4	32 2	37 00	43 00
27-12-98	NZP-23A	Niamatpur Zora pukur - 1	6000	22	9 3	6	300	500	16	200	114	70 0	35 6	73 00	140 00
	NZP-23B	Niamatpur Zora pukur - 2		22 5	8 2	5	800	1200	11	324	170	81 2	35 9	87 00	120 00
ξ (n = 28)				24 7 ±1 3	7 04 ±1 04	2 50 ±1 7	737 ±503 3	1049 ±698	12 9 ±5 5	236 ±310	59 ±89	34 3 ±33 9	7 6 ±11 0	9 2 ±21 63	24 ±45 8
A large pond polluted with fecal matter, Mirpur (Islam 1995, Afroze and Khondker 1996)				23 2	7 4	0 60	-	520	19 3	-	-	-	-	0 042	0 33
Banani Lake heavily polluted with fecal matter (Khondker *Et al* 1994)				18 9	7 2	4 20	-	348	40 0	49	10 4	16 8	1 3	-	-
Gulshan Lake moderately polluted with fecal matter (Khondker *et al.* 1995)				20 6	6 9	5 9	-	173	60	20 5	3 6	14 7	1 7	-	-
Raw sewage sample, Dhaka (Khan *et al* 1986)				-	-	-	-	-	-	8337	326	-	-	21 4	172 7
Environmental Standard for effluent discharge (Rahman 1993)				20-30	5-8	-	-	-	-	25	6 0	-	-	-	0 05
Environmental Standard for effluent discharge (Mara 1978)				-	-	-	-	-	-	<30	25	-	-	<0 05	-

MICROBIOLOGICAL WATER QUALITY MEASUREMENTS
(KHC DUCKWEED BASED WASTE WATER TREATMENT SYSTEM)

SI	Sampling location / Point	Units	Fecal coliform	Total coliform
1	Water from primary anaerobic pond WW	Cfu x 10^5 / 100 ml	4 x 10^5	25 x 10^5
2	Water from mixing Point of secondary lagoon	Cfu x 10^5 / 100 ml	0.96 x 10^5	13 7 x 10^5
3	Duckweed from mixing point of secondary lagoon	Cfu x 10^5 / gm	0 25 x 10^5	2 7 x 10^5
4	Water from middle point of secondary lagoon	Cfu x 10^5 / 100 ml	0 16 x 10^5	0 18 x 10^5
5	Duckweed from middle point of secondary lagoon	Cfu x 10^5 / gm	0 0007 x 10^5	0 02 x 10^5
6	Effluent water from outlet of secondary lagoon	Cfu x 10^5 / 100 ml	< 0 001 x 10^5	0 31 x 10^5
7	Duckweed from outlet secondary lagoon	Cfu x 10^5 / gm	0 0003 x 10^5	0 009 x 10^5
8	Water from fishpond, waste wate DW applied as feed	Cfu x 10^5 / 100 ml	0 2 x 10^5	0 75 x 10^5
9.	Fish body slime	Cfu x 10^5 / inch^2	0 0003 x 10^5	0 0005 x 10^5
10	Fish gut	Cfu x 10^5 /gm	0 002 x 10^5	0 005 x 10^5

ARSENIC CONCENTRATION IN POND WATER / DICKWEED/ FISH
KUMUDINI HOSPITAL COMPLEX, MIRZAPUR

SI	Site	Location	Sample Type	Concentration in *ppb*
1	KHC	Deep Tube-well	Water supply	15 10
2	KHC	Tap supply	Water supply	14 80
3	Demo farm	Duckweed pond A	Water	12 56
4 .	Demo farm	Duckweed pond B	Water	15 21
5	Demo farm	Duckweed pond A	Duckweed	21 04
6	Demo farm	Duckweed pond B	Duckweed	7 21
7	SSVE	Village pond 1	Water	3 33
8	SSVE	Village pond 2	Water	3 18
9	SSVE	Village pond 1	Duckweed	38 70
10	SSVE	Village pond 2	Duckweed	30 40

Note SSVE = Shobuj shona village enterprise, KHC = Kumudini Hospital Complex
500mg fresh duckweed sample was air dried at room temperature, ground and dissolved in 10 ml nitric acid and perchloric acid (5 1), digested under closed system at 60-70°C for two hours The extract was measured using atomic absorption spectrophotometer *The above measurement were taken during the final pre-feasibility study in March 1999*

FINAL SCORING FOR SITE SELECTION BASED ON THE SELECTION CRITERIA

Basis of Scoring. Scale 1 - 5
Most favorable condition for the project = 5
Least favorable condition for the project = 1

Sl. No	Indicators	SUC - 1	BLRI - 5	ENB – 9	ZZK-10	IBC - 13	IAC - 14	TOS - 15	KCC - 16	CPP - 19	SPV – 22
01	Representation of micro-environments	5	4	4	3	5	5	4	4	4	4
02	Waste water quantity	4	4	4	4	5	5	2	3	4	5
03	Wastewater quality	4	4	4	4	5	5	3	3	4	5
04	Source of wastewater	4	4	4	4	4	4	2	3	4	5
05	Wastewater collection system	2	3	2	3	3	4	2	2	5	4
06	Wastewater treatment facility	3	5	2	3	3	4	2	4	3	3
07	Intensity of WW & sanitation problems	4	3	4	4	5	4	3	3	4	4
08	Use/re-use of waste / WW	2	3	2	2	5	4	2	3	3	4
09	Potential for making clear boundaries	2	4	2	2	3	4	3	4	3	4
10	Land availability / opportunity cost	3	5	2	2	3	4	4	5	3	4
11	Communication / accessibility	5	5	4	3	5	3	3	5	4	4
12	Visibility for demonstration	5	5	4	3	5	4	4	5	4	4
13	Flooding condition	3	5	3	3	4	3	2	4	3	3
14	Soil condition & ground water table	4	4	4	3	4	4	3	4	4	5
15	System opportunity cost	3	5	2	2	2	4	4	2	3	4
16	Availability of fish pond	3	5	4	2	4	5	4	5	3	4
17	Experience in aquaculture	4	5	2	2	3	4	2	4	4	3
18	Presence of limiting factors in aquaculture	3	3	2	2	3	3	2	2	4	3
19	Prospect of diversified DW production	4	4	3	2	4	4	3	4	4	4
20	Status of water supply	4	4	3	3	3	4	2	4	4	4
21	Scope for improving community health, sanitation and economic benefit	4	3	5	4	4	4	3	3	4	4
22	Investment for collection system & treatment facility development	3	2	2	3	3	4	2	2	2	4
23	State of preparedness project start up	3	4	2	3	3	4	3	2	3	4
24	Acceptability & cooperation from community and other project partners	4	4	2	2	3	4	4	4	4	4
	Total	85	97	72	68	91	97	68	84	87	96
	%	70 83	80 83	60 00	56 67	75 83	80 83	56 67	70 00	72 50	80 00

Annex 15

System design assumptions and specifications

GENERAL DESIGN ASSUMPTIONS AND SPECIFICATION

Description of Proposed Duckweed Based Wastewater Treatment Systems

(With daily wastewater input of 500 m^3, 1000 m^3 & 1500 m^3)

SL	*Description/parameters*	*For 500 m^3/day*	*For 1000 m^3/day*	*For 1500 m^3/day*
1 0	General information			
1 1	System's total capacity	8 x 10^6 l	16 x 10^6 l	24 x 10^6 l
1 2	Total user groups	7500 - 10000	10000 - 15000	15000 - 25000
1 3	Total land requirement	2 65 ha	4 5 ha	6 5 ha
2 0	Primary treatment system			
2 1	Primary system's capacity	660000 l	1312000 l	1973000 l
2 2	Land requirement	500 m^2	785 m^2	1180 m^2
2 3	Retention time	24 hours	24 hours	24 hours
2 4	Dimensions	Can be any size depending on the available land, but depth of system should be fixed at 2-3 m		
3 0	Secondary treatment			
3 1	Secondary system's capacity	8 x 10^6 l	16 x 10^6 l	24 x 10^6 l
3 2	Land requirement	0 8 ha	1 6 ha	2 5 ha
3 3	Retention time	16 days	16 days	16 days
3 4	Description of lemnaceae plug flow	It is a continuous flow through		
3 4 1	Lemnaceae species growth	Spirodella, Lemna minor, Wolffia		
3 4 2	Method of harvesting	Manual with net/ring harvesters		
3 4 3	Perimeter crops	Banana, yam/taro, sugar cane, papaya, vegetables, etc		
3 4 4	Application of Lemnaceae crop harvested	As fish feed applied fresh daily and as ingredient to animal / poultry feed dried		
3 4 5	Lemnaceae standing crop density	450 - 600 gm/m^2	450 - 600 gm/m^2	450 - 600 gm/m^2
3 4 6	Estimated daily duckweed crop harvested	360 kg	720 kg	1100 kg
3 4 7	Frequency of Lemnaceae crop harvest	Daily	Daily	Daily
4 0	Tertiary treatment			
4 1	Dimension	Usually last section of the duckweed plug flow		
4 2	Treated effluent output	400000 l / day	800000 l / day	1,600,000 l / day
4 3	Treatment quality	Used for irrigation and agriculture application		
4 3 1	Ammonia	≤ 1 mg/l	≤ 1 mg/l	≤ 1 mg/l
4 3 2	Nitrates	≤ 1 mg/l	≤ 1 mg/l	≤ 1 mg/l
4 3 3	Phosphates	≤ 1 mg/l	≤ 1 mg/l	≤ 1 mg/l
4 3 4	TSS	≤ 20 mg/l	≤ 20 mg/l	≤ 20 mg/l
4 3 5	BOD	≤ 10 mg/l	≤ 10 mg/l	≤ 10 mg/l
4 3 6	Total coliform count	1000 / ml		
4 3 7	Total enteric pathogen count	0 / ml		
5 0	Fish pond			
5 1	Land requirement	1 8 ha	2 8 ha	3 5 ha
5 2	Fish pond water area	1 25 ha	2 ha	2 5 ha
5 3	Type of fish culture	Carp polyculture		
5 4	Fingerling stocking rate (15000 nos / ha)	19000 nos	30000 nos	37500 nos
5 5	Mix ratio of fish	Grass carp 20%, Rohu 15%, Catla 15%, Mrigal 20%, Silver carp 15%, Mirror carp 15%		
5 6	Supplementary feed (Oil cake & wheat bran 35 kg / ha / day)	44 5 kg/day	70 0 kg/day	87 5 kg/day
5 7	Estimated fish production per year	15 tons	24 tons	30 tons
5 8	Fertilizer when necessary	System treated fertilizer		

Annex 16

Detailed results pathogen transfer

Interim/Final

SUMMARY COMPLETION FORM FOR PROTOCOLS

Title : Microbiological investigation of a duckweed project in Mirzapur.

Investigator(s) : Dr. Md. Sirajul Islam

Budget Code # : 20 95 21 (Protocol No.93-030)

Findings (Abstract) : The preliminary results demonstrated that the faecal coliforms (FC) in the waste water lagoons are absorbed by the duckweeds and there was a reduction in number of FC from 10^6/ml to 10^2/ml which is a 4 log decrease. Therfore the duckweeds can purify the sewage water to a great extent from microbiological point of view. Among the pathogens Vibrio cholerae 0139 was once isolated from water, duckweeds and fish (grass carp and telapia) from the ponds in which the contaminated duckweeds are used as fish feed.

Salmonella group C_1 was also isolated once from the waste water. However, no Shigella sp. and Campylobacter sp. could be isolated from the waste water as well as from the workers using conventional cultural technique.

As it is very difficult to isolate bacterial pathogens from the environment using conventional cultural technique, we may have missed the pathogens though they may be present in those ponds. It is, therefore, needed to use more sensitive techniques to be sure that the pathogens are not there and as such there is no mocrobiological hazard of using waste water lagoons for growing duckweeds which could be used as feed for fish culture. Therefore we want to carry out this study using more sensitive and specific techniques e.g. PCR, immunomagnetic beads assay and fluorescent antibody method. Moreover, we were also unable to isolate any bacterial pathogen from the handlers of duckweeds and fish of duckweed project of Mirzapur. We, therefore, want to have a comparative study to investigate the incidence of diarrhoeal diseases among the workers of the duckweed project and a control group from the neighbours of the workers

Policy implications :

To demonstrate the consistency, reproducibility and seasonal variation in detection of pathogens, a two year study needs to be carried out. We are in the process of preparing a protocol for two years which will be submitted in due time.

Dissemination plans:

Manuscripts are in preparation.

INTERNATIONAL CENTRE FOR DIARRHOEAL
DISEASE RESEARCH, BANGLADESH
(Laboratory Report Requisition)
(Not for Clinical Chemistry)

From: ICDDR,B/LAB-2A
LAB I.D.: 96-122
Date 24 03 99

Particular of sample: Water, Duckweed, Fish and R/S
Location : PRISM, Bangladesh

Examination Requested: Test for total coliform, faecal coliform *Vibrio* spp., *Aeromonas* spp., *Salmonella* spp., *Shigella* spp. and *Campylobacter* spp.

Authorized by

REPORT

Date Received	Lab#	Sample#	Total coliform /100 ml	Faecal coliform /100 ml
15.03.99	96.	Concrete house(water)	$2.0X10^7$	$8.0X10^5$
	97.	Anaerobic pond(water)	$1.6X10^7$	$1.2X10^7$
	98.	Mixed pond (water)	$1.6X10^5$	$1.6X10^5$
	99.	Middle pond (water)	$9.0X10^1$	$5.0X10^1$
	100.	End pond(water)	$3.0X10^3$	$1.0X10^3$
	101.	Fish pond (water)	$3.0X10^4$	$2.8X10^4$
			Total coliform /gm	Faecal coliform /gm
	102.	D/W(middle)	$8.0X10^3$	$4.0X10^3$
	103.	D/W(end)	$2.0X10^5$	$8.0X10^4$
	104.	Various fish parts (Fin)	$8.4X10^6$	$6.8X10^4$
	105.	Various fish parts (Gill)	$8.0X10^7$	$5.6X10^7$
	106.	Various fish parts (Intestine)	$3.2X10^3$	$2.3X10^8$
	107	Composite sample	$2.4X10^7$	$1.6X10^7$

Date Received	Lab#	Sample#	*Vibrio* spp./ *Aeromonas* spp.	*Salmonella* spp./ *Shigella* spp.	*Campylobacter* spp.
15.03.99	108.	Concrete house(water)	non-01/non-0139 *V. cholerae* present	Absent	Absent
	109.	Anaerobic pond(water)	non-01/non-0139 *V. cholerae* present	Absent	Absent
	110.	Mixed pond (water)	Absent	Absent	Absent
	111.	Middle pond (water)	Absent	Absent	Absent
	112.	End pond (water)	Absent	Absent	Absent
	113	Fish pond (water)	Absent	Absent	Absent
	114.	D/W(middle) /gm	Absent	Absent	Absent
	115.	D/W(end) /gm	Absent	Absent	Absent
	116.	Fish surface /gm	Absent	Absent	Absent
	117.	Various fish parts (Fin) /gm	Absent	Absent	Absent
	118.	Various fish parts (Gill) /gm	Absent	Absent	Absent
	119.	Various fish parts (Intestine) /gm	Absent	Absent	Absent
	120.	Composite sample /gm	Absent	Absent	Absent
	121.	Belal (R/S)	Absent	Absent	Absent
	122.	Tofu (R/S)	Absent	Absent	Absent

M. S. Islam

Dr. Md. Sirajul Islam
Scientist and Head
Environmental Microbiology Laboratory
Laboratory Sciences Division

Annex 17

Proposal for a workshop

Annex 17

Proposal for the organization of a national workshop duckweed based wastewater treatment and resource recovery

Proposal: To organize a two day National Workshop in order to:

a) disseminate and discuss the results of the duckweed prefeasibility study

b) engage stakeholders in discussion of follow-up activities leading to project formulation

Coordination: IHE (Prof. H.J.Gijzen) and PRISM (Mr. Ikramullah)

Dates: The workshop shall be organized sometime August or September 1999, depending on availability of funding

Invited speakers:

Mr Ikramullah, PRISM
Prof H.J.Gijzen, IHE
Mr P Skillicorn, Green Gold Ltd
Prof P Edwards
Dr R. Schertenleib, EAWAG
Representative AEETC, Bangkok

Participation: A total number of participants of about 60 is expected for the workshop. Participation by representatives of following organizations is proposed:

Bilateral and multilateral agencies	GOB	NGOs
World Bank	MoEF	PRISM
World Bank/UNDP	MoLGRD	Grameen
UNICEF	ERD	Proshika
ADB	Planning Commission	KWT
UNDP	LGED	
WHO	DPHE	
NEDA	MoH	
DANIDA	BLRI	
SDC	FRI	
DFID	Universities	

Belgian Embassy — MoE
GTZ
NORAD
CIDA, and SIDA

Programme:

First day: presentations, discussion in groups, definition of conclusions
Second day: round table with selected GOB and donor agencies

Budget estimate:

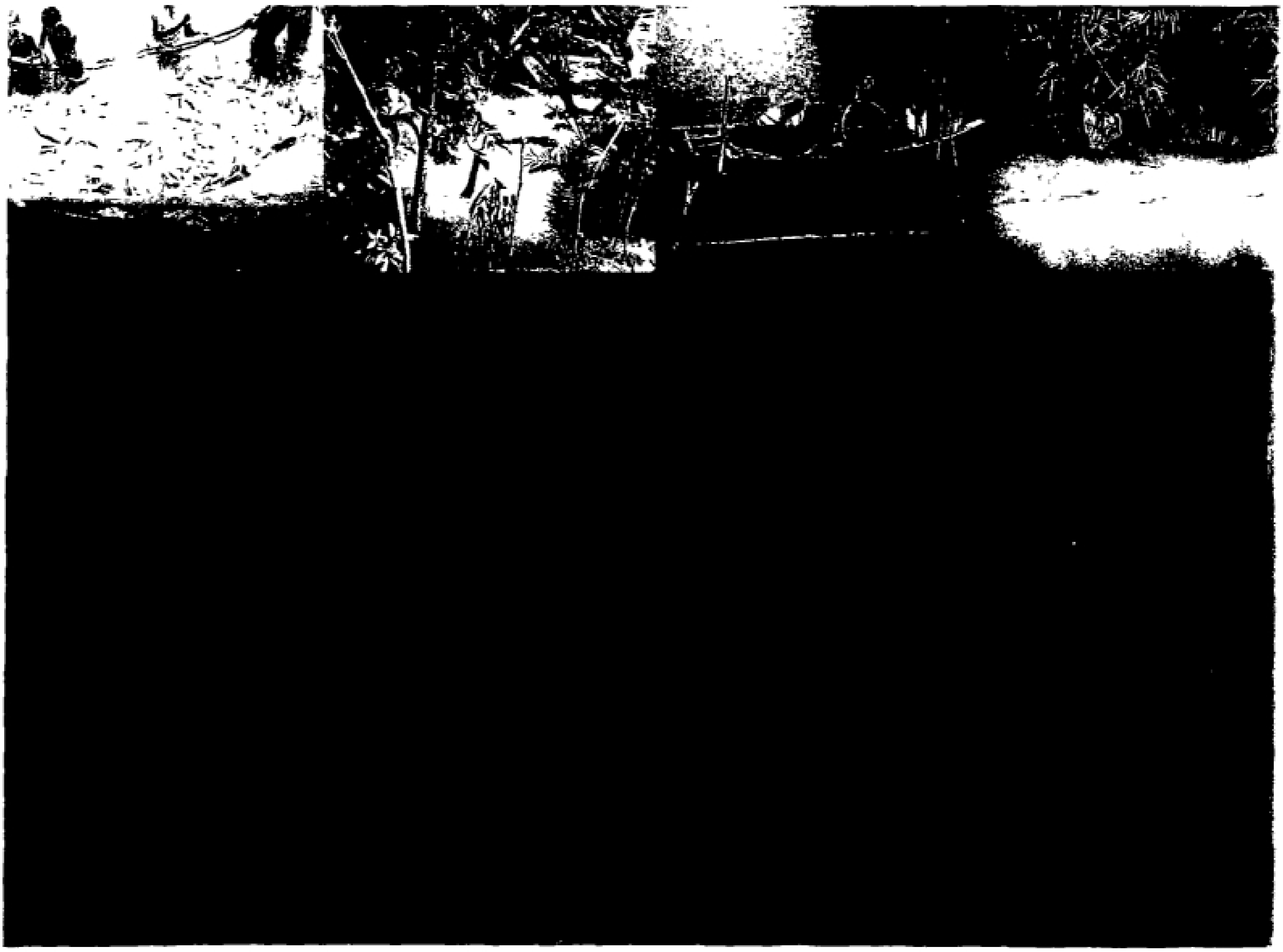
Coordination:

Local staff.	8 days x $130	1040
Expatriate staff.	9 days x $600	5400
Secretary	7 x $ 80	560
Coordinator	4 x 130	520
communication, stationary etc		700

Guest speakers:

5 x international travel	8000
DSA 1 x 8, 4 x 3 = 20 x $150	3000

Seminar room	
rental room	1000
audiovisual equipment	500
meals/drinks	1800
local transportation (participants)	1000
Miscelaneous	1480
Total	25000



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