MACH

Technical Paper 3

Industrial Pollution and Its Threat to Mokesh Beel Wetland in Kaliakoir

Management of Aquatic Ecosystems through Community Husbandry

May 2006

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CARITAS Bangladesh

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Abstract

A large cluster of industries is located in Kaliakoir, north of Dhaka, where there are many textile and dyeing factories. The Management of Aquatic Ecosystems through Community Husbandry (MACH) project has been working in the area since 1998 with communities that use the Turag River and its connected beels and floodplains to restore and increase wetland productivity and ensure sustainable fisheries. During participatory planning exercises for the project the communities reported that these industries use the surrounding waterbodies, particularly Mokesh Beel and Ratanpur Khal, which flows through the beel, as a disposal ground for untreated waste. They reported that this pollution led to fish kills and poor quality fish that smell of chemicals. Effluent from industries downstream in the Turag catchment also enters the river and is carried upstream during high tide. As a consequence the water quality has deteriorated to a level which is unsuitable for aquatic life during the dry season.

Regular monitoring results indicate that in places in the beel and khal the water has a biological oxygen demand (BOD) more than a hundred times the national standard for inland surface water for fisheries (6 mg/l) as defined in the Environment Conservation Rules (GOB, 1997) and that the median chemical oxygen demands (COD) was found to be nearly 5 times higher than the national standard of 200 mg/l for effluent discharged to open water bodies (GOB, 1997; Annex A). Sulfide concentrations and pH are also high and exceed national standards (GOB, 1997; Annex A). High concentrations of heavy metals such as chromium were also found in the sediments near the industries. Studies of dissolved oxygen in the Turog river found that very low concentrations (0-1 mg/l) exist during the dry season and in many areas the levels were not high enough to sustain aquatic life (less than 0.5 mg/l).

Focus group discussions and in-depth interviews with community members and health practitioners revealed that it is the perception of the community that their health problems are increasing and that this is as a direct consequence of the industrial pollution reaching the wetlands that they traditionally use as a source of water for multiple activities including irrigation, bathing and fishing. The pollution slug from the industries flows through fields of rice and forage for cattle before reaching the wetland and river systems. Uptake of nutrients and chemicals is certainly likely with entrance into the food chain.

Research in the industries themselves identified potential alternative production options which can raise dye fixation to 70% from around 40-65% which is found at present, and thereby reduce the dye that is discharged to the rice fields and water bodies. Such increases in efficiency could save the average factory each year the equivalent of several tens of thousands of dollars in dye costs alone and significantly reduce the necessity for re-dying and re-shading. Some of the industries are now showing an interest in adopting these technologies.

The project work has also highlighted the need for more effluent treatment facilities and better management of those that already exist. Effluent treatment plants (ETPs) are a legal requirement for most factories depending on their categorization under the 1995 Environmental Conservation Act and 1997 Environmental Conservation rules, but in 2000 only two factories in the area had such plants and it was uncertain whether they operated continuously. The project has worked with industries to advise them on setting up ETPs and three new one has been established and two more are under construction. However, the number of textile related factories in the area increased from 20 in 2003 to 166 in late 2005, so overall the pollution problem is getting worse. This means that there is an immediate need to increase the rate of implementation of proposed pollution mitigation options if there is to be any reduction in pollution. Without this, the efforts of the communities and the MACH project that have seen fish yields in the greater Turag-Bangshi area restored from about 60 kg/ha to about 300 kg/ha are likely to be lost due the extreme increase in the number of factories now dumping effluent into the area.

Acknowledgements

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We are also grateful to those industries who participated in conducting this study. We hope that more follow their example.

List of acronyms and abbreviations

AP:	Alternative Production
BAT:	Best Available Technologies
BCAS:	Bangladesh Centre for Advanced Studies
BGMEA:	Bangladesh Garment Manufacturer Exporters Association
BTMA:	Bangladesh Textile Manufacturers Associations
BUET	Bangladesh University of Engineering and Technology
BOD:	Biological Oxygen Demand
Cl^- :	Chloride
COD:	Chemical Oxygen Demand
DFID:	Department for International Development of the UK
DO:	Dissolved Oxygen
DoE:	Department of Environment
ETP:	Effluent Treatment Plants
GIS:	Geographical Information Systems
GOB:	Government of Bangladesh
ISM:	Investment Support to MACH
MACH:	Management of Aquatic Ecosystems through Community Husbandry project
Na:	Sodium
NH_3-N:	Ammonia
NO_3-N:	Nitrate
RMO	Resource Management Organization
S^{2-} :	Sulfide
SEI:	Stockholm Environment Institute
SO_4^- :	Sulfate
TDS:	Total Dissolved Solid
TSS:	Total Suspended Solid
USAID:	United States Agency for International Development
USEPA:	United States Environmental Protection Agency

Glossary

Beel: floodplain depression: a shallow seasonal or perennial lake

Desizing: a step in the pretreatment of fabric prior to dying; in this process the sizing ingredients (for example starch) are removed from the fabric.

Heterobifunctional dye: a dye having two different types of reactive group.

Khal: natural canal

Mercerizing: a step in the pretreatment of fabric prior to dying, in this process the fabric is treated with cold sodium hydroxide solution.

Monochlorotriazine dye: a dye having one chlorine molecule in the reactive group.

Vinylsulphone dye: a dye having two similar reactive sulphato ethylsulphonamide groups.

1. Introduction

The growth of small-scale industrial activities in Bangladesh, and in the rest of South and Southeast Asia, has a positive development dynamic in macro-economic terms but has brought with it a range of problems, including chemical and organic pollution of water resources (Chadwick and Clemett, 2002). In 1998 there were over 24,000 registered small-scale industrial units in Bangladesh (SEHD, 1998) and it is generally accepted there were an equivalent number unregistered, furthermore, industrial growth has continued rapidly in the past decade. Many of these industries are highly polluting and as a consequence of their rapid and largely unregulated development, many ecosystems including wetlands are now under threat and with them the livelihoods of local people. Although existing legislation (Environment Conservation Act 1995 and Rules 1997) specifies stringent effluent standards, they are not adequately adhered to or enforced.

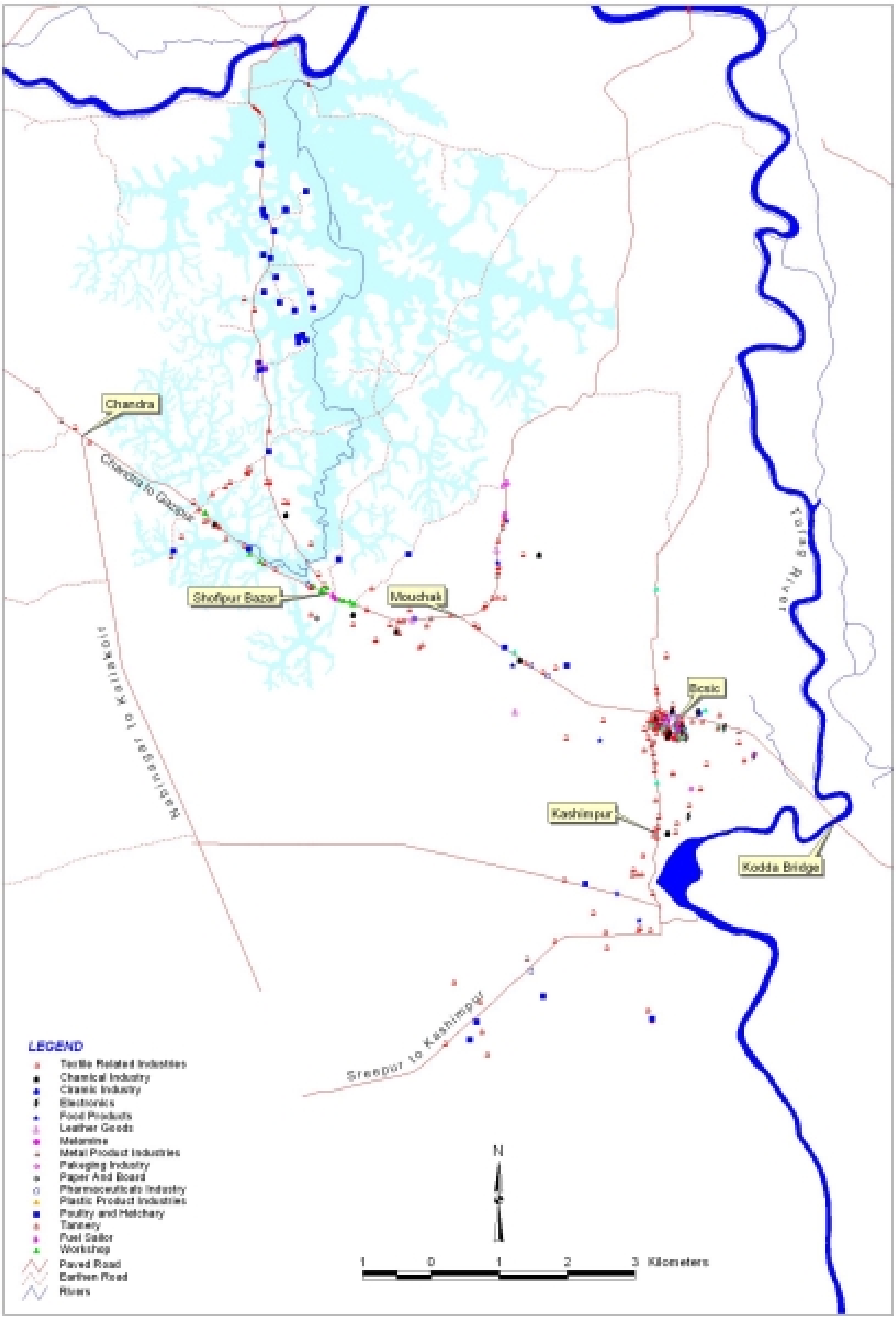
Kaliakoir Upazila in Gazipur District is situated approximately 25 km northeast of Dhaka. It is one of many similar industrial clusters that have developed in response to the rapid economic growth in the country and, as is the case with all, it is also an area of serious water pollution. Several types of industry have established in the area including poultry farms, pharmaceutical industries and a tannery, but it is dominated by textile manufacturers, which include dyeing and printing units (Chadwick and Clemett, 2002). There are currently around 166 textile related industries in the area (Figure 1).

Mokesh Beel is one of the largest wetlands in the area covering approximately 1,100 ha (2,700 acres) in the wet season, but holding only 40 ha (100 acres) of water in the dry season, when it receives most of its water from Ratanpur Khal, which is fed almost entirely by industrial effluent (Figure 1). As a result, water quality has gradually deteriorated in parts of the beel to a level which was reportedly unsuitable for certain types of aquatic life. This study found that water in the khal has high biological oxygen demand (BOD), high chemical oxygen demand (COD), a high pH and high sulfide levels. This pollution was found to be a serious problem affecting the livelihoods of local people. In an initial participatory problem census, conducted in 1999 by the Management of Aquatic Ecosystems through Community Husbandry (MACH) project, local people reported that the fish they caught had a bad smell and were difficult to sell or eat.

Attempts to address the pollution problems in Mokesh Beel have been funded through four initiatives. The first one year pollution project was supported by the MACH project through MACH-BCAS. The MACH project is funded by the United States Agency for International Development (USAID) and the Government of Bangladesh (GOB), and aims at enhancing community-based wetlands and water resource management (MACH, 2005). During this phase the strategy of MACH-BCAS was to create a working relationship with the factory owners in the area and to determine the type of pollution by undertaking analysis of water quality in the khal and beel. The major polluters in the area were also identified. This initial work was followed by a three-year project supported by the UK Department for International Development (DFID) “Managing Pollution from Small- and Medium-Scale Industries in Bangladesh”, which was implemented by the Stockholm Environment Institute (SEI), the University of Leeds and the Bangladesh Centre for Advanced Studies (BCAS). During that project, much more detailed research and analysis was carried out including further water quality analysis at a series of points along the khal and beel, as well as collection of composite samples of factory outflows over a 24-hour period, and investigation of production processes, including analysis of the waste produced from each process. This data, along with information collected about the chemical inputs to the production processes were used to identify ways in which the production processes could be made more efficient and as a consequence generate less waste. A further component of the work was to investigate the extent and type of wastewater treatment facilities in the area and to try to ascertain whether or not they were operated effectively. This led to activities to encourage the construction of effluent treatment plants (ETPs), and their efficient and effective management. As a consequence of the DFID project, the GOB allocated money under the Investment Support to MACH (ISM) to tackle pollution issues in the Kaliakoir area based largely on the model developed by the previous initiatives. The DFID project was then taken into a second phase of funding through collaborative funding from

DFID and the European Commission under its Asia Pro Eco Programme. This funding was intended to scale-up the activities and results in the Kaliakoir area to address national pollution problems arising particularly from textile dyeing processes.

Figure 1: Map of industries around Mokesh Beel and Ratanpur Khal in 2005.



2. Objectives

The objectives of each of the four studies differed slightly but they all maintained the goal of reduction of aquatic pollution through a variety of measures that contributed to improving environmental governance. The activities included monitoring of water quality and reporting findings to local communities and the Department of Environment (DoE), working with industries to reduce pollution, and working with international textiles buyers and trade associations to encourage them to promote cleaner production and effluent treatment from the industries they purchased from.

Specifically the project team assessed the water pollution legislation (including water quality standards) and undertook activities to raise the awareness of industrialists in the area regarding environmental legislation. Activities were also carried out to raise public awareness concerning national and international water quality standards and the failure of local industries in the target area to meet these. Discussions were held with international buyers to encourage them to implement appropriate environmental compliance for factories they purchased from. These activities were combined and oriented towards the development of a framework for discussion and negotiation of means to reduce water pollution between industrialists, community-based groups and relevant national agencies, and to encourage the DoE to take a more participatory approach in their pollution reduction and monitoring strategies.

To enable the industries to identify and reduce pollution, and to facilitate the DoE in efforts to work with factories to reduce pollution, the project aimed to develop and implement appropriate, cost effective and sustainable methods to determine the type and levels of pollution, and to improve production efficiency. This method was also intended to be useful for buyers who could use it to monitor compliance. It would also provide information about overall pollution loads and therefore aid the objective of reducing pollution through the development of effective effluent treatment.

The objective of providing information to the public regarding pollution effects and impacts was addressed through different activities to determine the relationship between pollution and environmental, socio-economic and health impacts. The work also included research to determine whether appropriate indicators could be found that could be used by the community to measure and monitor human and ecological pollution impacts.

3. Methodology

The programs included a number of inter-related activities. These were: environmental monitoring; alternative production for pollution reduction; and effluent treatment.

3.1 Environmental Monitoring

The first activity was to identify the source of pollution that was affecting wetland resource users in Mokesh Beel area and parts of the Turag River. The area was mapped including all surface water resources and locations of potential point source pollution, including all commercial units (Figure 1). In order to assess the extent of pollution exerted by these factories samples were collected from different locations in Mokesh Beel, Ratanpur Khal and river Turag.

Throughout the period water quality samples have been taken along the khal, beel and river to monitor the pollution problem. Additionally samples of benthic macro-invertebrates have also been taken as studies have shown these to be a good indicator of long term pollution, and participatory monitoring of Dissolved Oxygen has started with the aim of helping the community continue monitoring water quality after the project ends.

3.2 Alternative Production Methods

Following on from the initial water quality determinations the textile dyeing industry owners were approached to build relations and to discuss the possibility of the project team gaining access to their industries in order to assess the main sources of pollution and to suggest mitigation measures.

To assess the pollution in industries, a cleaner production audit was carried out with the cooperation of selected textile dyeing industrialists. This basically focused on the raw materials coming on to the premises, the processes undertaken and the materials (products, by-products and waste) that leave each factory site. This method was used to identify the main pollutants likely to be present in the wastewater and to estimate their concentrations. In addition water quality analysis was undertaken for certain parameters expected to be in the effluent, to support the cleaner production audit process data. These parameters included color, COD, BOD, sodium, sulfate, sulfide, chloride and pH. Process water samples were also collected from various stages in the textile pre-treatment and dyeing process. Through this specific processes that were contributing significant quantities of chemicals to the waste stream were identified. From this information, appropriate low-cost interventions or changes to the production process that could reduce this waste and hence the pollution were proposed.

In order to reduce waste, many alternative production (AP) trials were carried out to optimize the production processes. Industries were made aware that a number of interventions could improve their efficiency, reduce waste and therefore pollution and save them money. These interventions included improved housekeeping, training of factory staff and optimization of dyeing conditions.

3.3 Effluent Treatment Processes

Industries in the project area that had Effluent Treatment Plants (ETPs) were also assessed on the performance and management of their ETPs. The project provided guidance on ETP management and worked with the industries to reduce the cost of chemical treatment. Those industries that did not have ETPs were provided with advice on treatment plant design.

4. Results and Discussions

The pollution problem in Kaliakoir area was first identified in 1999 in a workshop arranged by MACH at which the chairmen and members of three Union Parishads, and other stakeholders such as fishers and farmers were present. All the participants highlighted the pollution problem and expressed strong concerns regarding the effect of the pollutants on the taste of the fish catch.

4.1 Problem Identification and Assessment

Initially through MACH support, 11 factories were identified as the most polluting industries, of which the majority were related to textile production including printing, dying and finishing. Physical examination of the water at different locations in Mokesh Beel revealed that water was colored and had a strong unpleasant smell and distinctly sulfurous in nature.

Table 1: Median values of different parameters in water in different locations of Mokesh Beel ecosystem

Parameter	Bangladesh Standard for inland surface water (mg/l)[a]	Median value (mg/l)[b]	Range (mg/l)[b]
BOD (n = 7)	6 or less	407	380-500
COD (n = 7)	*200.0	960	350 – 1600
DO (n = 7)	5 or more	1	0.6 - 1.2
TSS (n = 7)	*150.0	195	115 – 427
Sulfide (n = 7)	*1.0	3.1	1.6 - 10.2
Oil and grease (n = 7)	*10.0	27	17 - 45

Source: [a] GOB (1997); [b] MACH (2001)

* = standard for waste water quality when discharged in inland water surface; Annex A

Results of water quality analysis for BOD, DO and pH were compared to national standards for open water bodies used for fisheries, but these standards do not exist for the other parameters, which were therefore compared to national standards for industrial effluent disposed to open water bodies (Annex A). The test results showed that BOD and COD levels were considerably above the national limit allowed (Table 1). Marked seasonal variation in pollution levels in the rainy and dry seasons was also noted, with COD values almost doubling during the dry season compared to the wet season. Sulfide levels were also found to be above the national limit allowed as well (Table 1).

The main source of sulfides and sulfates is likely to be the sodium sulfate used in textile dyeing processes, as well as some sulfur based dyes, which though banned, are still used to a limited extent (Clemett and Chadwick, 2003). Data collected in five factories showed that on average approximately 320 kg of sodium sulfate is used to dye 400 kg of fabric. In an average sized factory for the area this would result in roughly 6 tonnes of sodium sulfate being used per day, all of which enters the waste stream and thus the beel (Chadwick and Clemett, 2003).

The oil and grease levels in the water were also found to be two to five orders of magnitude higher than the maximum admissible concentrations of 0.003 to 0.025 mg per liter for fish (MACH, 2001). The sources of oils and refined products in the area are likely to be local textile, particularly printing, and tannery industries (MACH, 2001).

Preliminary results of sediment analysis showed that the total chromium concentration near the discharge point of the local tannery and textile industrial area was very high (Table 2). The source of this may be the local tannery which uses chrome sulphate during the tanning process. High lead levels were also recorded in the sediment (Table 2). The source of this has not been confirmed.

Table 2: Concentrations of heavy metals in sediments in Mokesh Beel

Parameter	Canadian Standard (ppm)	Median values (ppm)	Range of values (ppm)
Cadmium (n=6)	0.6	1.35	(0.6 - 4.2)
Chromium (n=6)	37.3	44	(21.5 - 5640)
Lead (n=6)	35	77.25	(46.5 -189.5)
Zinc (n=6)	123	450	(90 - 882)

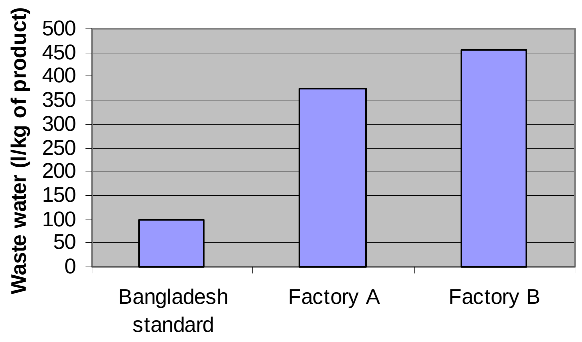
Source: MACH (2001).

Note: no Bangladesh standards exist for heavy metals in sediments.

4.2 Cleaner Production Audit

A cleaner production audit was also carried out under MACH-I in two textile dyeing and finishing factories (Factory A, Factory B). Based on the audit an assessment was made of: energy consumption (electrical and thermal); material consumption (chemical and dye stuff); water consumption; wastewater; and BOD and COD. Environmental loads at each process stage were calculated on the basis of primary data collected

Figure 2: Waste water production



from the factories and whenever necessary, secondary information was used to supplement and facilitate calculations. The functional unit for calculating environmental loads is assumed to be 1 kg of finished product.

The result of the inventory suggested that both factories dispose of much more wastewater for process related purposes than the 100 liters per kilogram of fabric allowed under Bangladesh law (Huq, 2003; GOB, 1997) (Figure 2). Consequently there is a clear need to reduce total water consumption in both factories through recycling, changes in process technology, reducing liquor ratios and by following better housekeeping practices, in order to reduce the pressure on the natural resource base and to mitigate for environmental degradation of the local environment (MACH, 2001).

Table 3: Absorption of heavy metals by water plants

Heavy metal	Mean absorption (n=15)		
	Duck weed	Azolla	Water-hyacinth
Chromium	305 ppb	225 ppb	335 ppb
Cadmium	140 ppb	127 ppb	124 ppb
Lead	100 ppb	68 ppb	75 ppb
Mercury	125 ppb	100 ppb	83 ppb
Zinc	315 ppb	300 ppb	326 ppb
Copper	75 ppb	70 ppb	69 ppb

ppb = parts per billon
Source: MACH experiments, unpublished data.

Consumption of electrical energy by both factories is very close to the best available technologies (BAT). This is because both these factories use modern electrical appliances. However, consumption of thermal energy is almost three times more by factory A and is almost two times more by factory B than that of BAT. There is a need for both factories to undertake energy conservation measures so that the consumption is closer to BAT (MACH, 2001).

The values of effluent BOD and COD for both factories is much higher than the respective Bangladesh standards (Figures 3 and 4). Chemical inputs are the main source of BOD and COD but non-process related activities such as machine cleaning and cleaning of the areas are also an important source. The proper utilization of chemical inputs at process stages, utilization of BAT and good housekeeping practices should result in lower BOD and COD values (MACH, 2001). This of course must be followed by treatment of the residual effluent to meet Bangladesh and acceptable standards before releasing to the outside environment.

Figure 3: BOD of outflow water from sample factories compared to Bangladesh standard

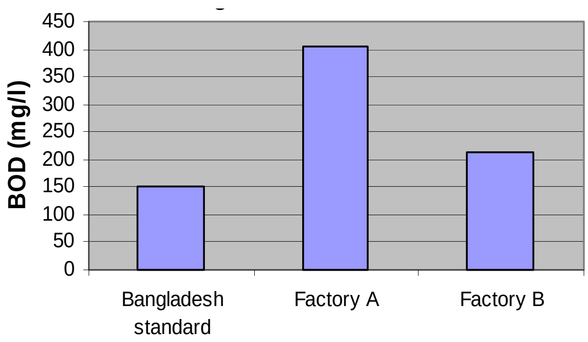
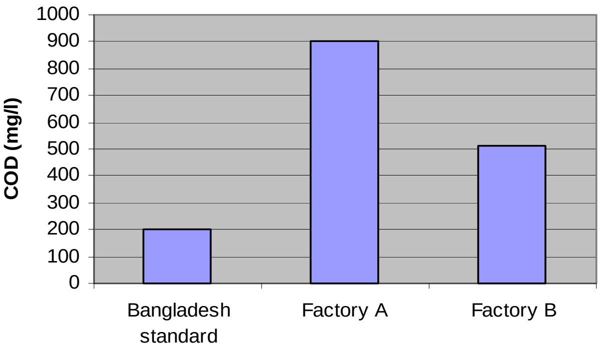


Figure 4: COD of outflow water from sample factories compared to Bangladesh standard



4.3 Role of Aquatic Plants in Removing Heavy Metals

Aquatic plants, such as azolla, duckweed, and water-hyacinth have been found to accumulate heavy metals, for example water-hyacinth accumulates heavy metals, such as cadmium, mercury, chromium, arsenic, and zinc from water (MACH, 2001).

In MACH-I, an investigation was carried out with water hyacinth, duckweed and azolla in Ratanpur Khal to assess the absorption of metals from industrial effluents. The results indicate that all three accumulated heavy metals from water but with each apparently absorbing different metals in greater or lesser amounts (Table 3).

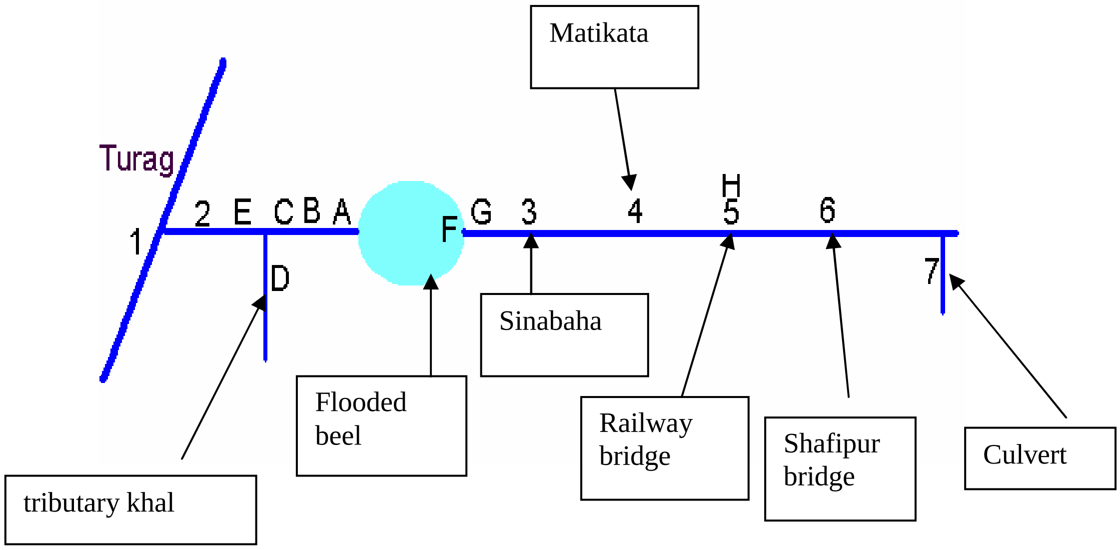
4.4 Systematic Environmental and Factory Sampling

Under the DFID funded project, further analytical work relating to the quality of the water in the khal and beel was undertaken, as well as investigation of the production processes and development of options for pollution mitigation. This work is described below.

4.4.1 Environmental Sampling

Water samples were taken at a number of locations along the khal and beel. Initially samples were taken on two consecutive days to identify possible future sampling points and to get a comprehensive overview of the quality of the whole water body. Samples 1-7 (Box 1 and Figure 5) were taken on 2 February 2003 and samples A-H were taken on 6 February, 2003 (Box 1 and Figure 5). Samples were analyzed in situ for DO and pH and sent to the Bangladesh University of Engineering and Technology (BUET) for further analysis.

Figure 5: Water sampling locations



Box 1: Sampling locations and rationale

Site 1	**River Turag at Gopinpur.** The sample was taken mid stream by local people. The river appeared to be in good condition – clear and colorless with no obvious bad smell.
Site 2	**Khal at Gopinpur** just upstream of the confluence with the Turag at a point where it is crossed by a bridge. The khal had a slight reddish brown appearance; it did not smell clean but was not too bad either. The sediment was grayish in color.
Site 3	**Khal at Sinabaha.** The khal was black in color and hazy in appearance. It has a strong and unpleasant smell, both of sulfide and of ‘organic pollution’. The khal had large amounts of black stinking sediment. One local villager went in (unasked) to get a sample and was up to his mid thighs in black sediment at the edge of the khal. Villagers complained about the strong smell and said that rice paddy irrigated with the khal water gave a very poor crop. The khal had a reasonable current and was probably about 1 m deep and 1.6-2 m wide.
Site 4	**Khal at Matikata** at a point where it is crossed by a bamboo bridge and a new bridge is under construction. Condition here was similar to that at site 3.
Site 5	**Khal at Ratanpur Railway Bridge**. Here 2 factories dispose of waste. The khal was black in color and had the same smell as at sites 3 and 4. It was quite fast flowing.
Site 6	**Khal at Shafipur Road Bridge** – sample taken from bank on left side looking east. The khal was slow moving and wide but water was similar in appearance to that at 3 to 5.
Site 7	**Stream running in culvert under road by one factory**. The sample looked clear and colourless but we have noticed that the color of this stream varies considerably from hour to hour.
Site A	**Khal as close as possible to northern edge of the flooded section of beel**. At sites A, B, C and E the khal and samples were similar in appearance to Site 2
Site B	**Khal**. A villager was fishing near here and had caught some fish.
Site C	**Khal just above the confluence with Mokesh Khal khalia doho.**
Site D	**Mokosh Khal khalia doho link canal**. This flows from a beel west of the main road (which runs north-south from Shafipur Bazaar to the Turag). The water was cloudy with suspended solids but otherwise was not coloured.
Site E	**Main khal north of the confluence with the small khal** (site C/D) and close to the Turag at site 2.
Site F	**Water at the edge of the flooded beel near Sinabaha,** close to where the khal discharges into the flooded beel. The water was cloudy with a strong but dull green color.
Site G	**Main khal near Sinabaha, just before it enters the flooded beel**. Appearance of khal and samples similar to site 3.
Site H	**Khal at Ratanpur Railway Bridge** – same place as sample 5. The khal was a distinct pale navy blue in color.

Samples from sites1-7 were collected on 2 February 2003, samples from sites A-H were collected on 6 February 2003.

The results of DO measurements taken at these sites in 2003 show that the khal is anaerobic up to Sinabaha (there is zero dissolved oxygen) but close to its confluence with the Turag River it becomes highly aerobic (Table 4). Its color also changes. Throughout its length water in the khal is highly alkaline compared to the Turag and is above the range set by GOB for inland surface water bodies and for fisheries (pH 6.5-8.5; Annex A). Between Site 2 and Site 3 there is a flooded section of beel close to Sinabaha and also a further stretch of khal. It appears that the khal in this stretch is further diluted with the beel water although the pH remains high.

Table 4: Levels of dissolved oxygen in Ratanpur Khal and Mokesh Beel, February 2003

Site	DO mg/l	DO - % Sat.	Temp. °C	pH
1	8.42	94	21.3	7.9
2	9.26	108	23.3	9.1
3	0	0	27	9.2
4	0	0	27	9.4
5	0	0	27	10.7
6	0	0	26.8	9.2
7	6.24	89	33.3	8.3

Source: Knapp, Unpublished

Table 5: Levels of Dissolved Oxygen in Ratanpur Khal and Mokesh Beel, February 2003

Site	DO mg/l	DO - % Sat.	Temp. °C	pH
A	7.3	84	21.4	9.1
B	6.09	66	20.6	9.1
C	5.77	66	22.2	9.1
D	7.42	86	23	7.8
E	6.2	70	22.1	9.1
F	>20	200+, super sat.	24.4	9.5
G	0.08	0.9	23.6	8.5
H	0.05	0.2	31.1	-

Source: Knapp, Unpublished

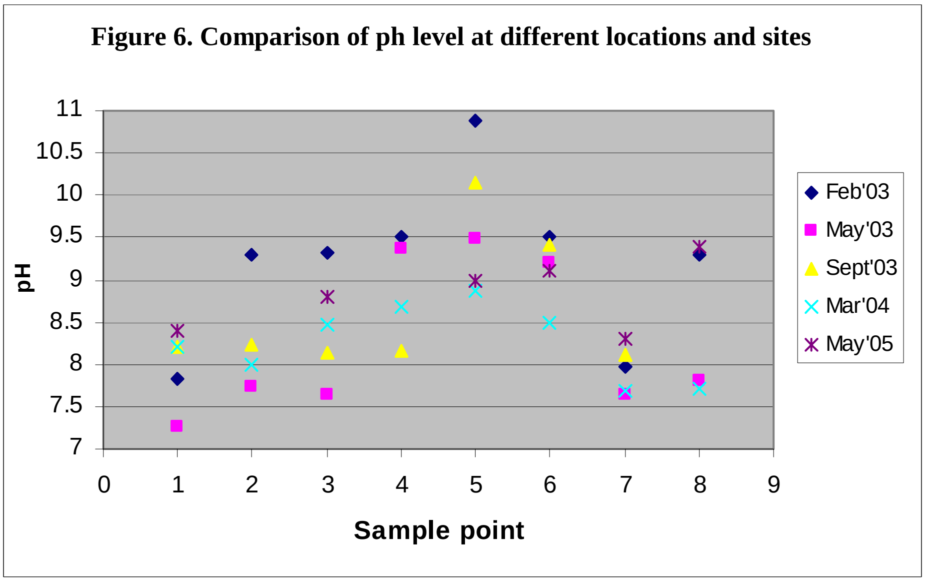
A second set of data was collected from the middle section of the stream (Figure 5, Box 1) where the beel area is greatly reduced to the extent that there is little more water than in the khal. The results confirm that Ratanpur Khal was aerobic north of the flooded zone and also that it is highly alkaline (Table 5). The data also confirm the anaerobic nature and high alkalinity of the khal south of the flooded zone of Mokesh Beel at Sinabaha. Site D appears to be a clean tributary khal and data from this site effectively act as a reference comparison, there DO and pH figures were good and similar to those for the Turag River. The result also indicated extremely high (supersaturated) dissolved oxygen concentration at site F. Later an examination of the sample suggested that it contained a high population of photosynthetic phytoplankton which may be causing re-aeration (Knapp, unpublished).

Initial sampling in February and May 2003 show a clear trend, in which concentrations of most parameters decline moving away from the industrial area towards the river (Table 6). This is particularly evident for pH, COD, BOD and sulfide. Levels of pH were high 7.5 – 10.2 and likely to impact on aquatic organisms either directly or by affecting the oxidation state of metals present in the water and the toxicity of substances such as ammonia, which increases with increasing pH. In many places the DO level is well below the standard of 5 mg/l or more required for water for fisheries (GOB, 1997; Annex A).

Table 6: Surface water quality from the industrial area to the Turag River

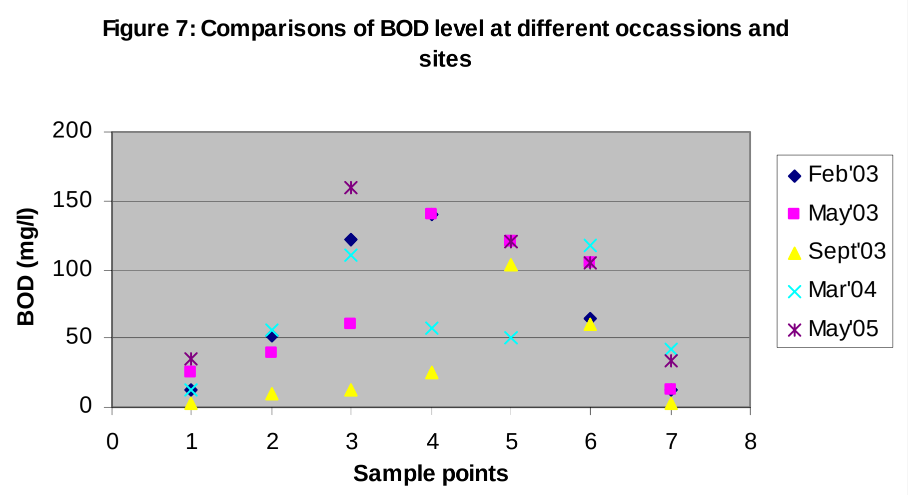
	Average concentrations	pH	COD (mg/l)	BOD (mg/l)	Sodium (mg/l)	Sulfate (mg/l)	Sulfide (mg/l)
Industrial area	Shafipur Road Bridge	9.4	218	85	422	302	0.3
	Ratanpur Railway Bridge	10.2	626	360	374	193	0.6
	Khal at Matikata	9.4	417	140	394	227	1.9
⇩	Khal entering beel	7.9	329	97	342	171	0.5
	Khal end of beel	8.4	209	97	313	201	0.1
	Northern end of beel	8.7	95	50	304	217	0.04
	Khal above tributary	8.6	102	50	263	182	0.06
Tributary khal	Tributary khal from Kaliadha beel which does not receive effluent	7.8	32	12	67	23	0.04
⇩	Khal below tributary	8.6	99	56	273	178	0.06
	Khal at Gopinpur just upstream of the confluence with the Turag	8.5	70	46	244	181	0.03
River	River Turag at Gopinpur	7.5	70	19	40	10	0.03

In total five sampling events were conducted over the project life of three years. These supported the findings from the initial sampling in 2003. The key parameters of pH, BOD and COD were plotted for seven major sampling points over the five sample events. The results for pH clearly show that the pH is highest at sample point 5 (Ratanpur Railway Bridge) where several factories dispose of their waste. It also shows that the pH in February is consistently high in all sites, supporting the theory that pollution levels are greatest in the dry season as there is no source of water for the beel at that time other than wastewater. The Turag (site 1) and the clean khal (site 7 in this chart) have consistently low pH values, within national standards of pH 6.5-8.5 (GOB, 1997; Annex A) (Figure 6).



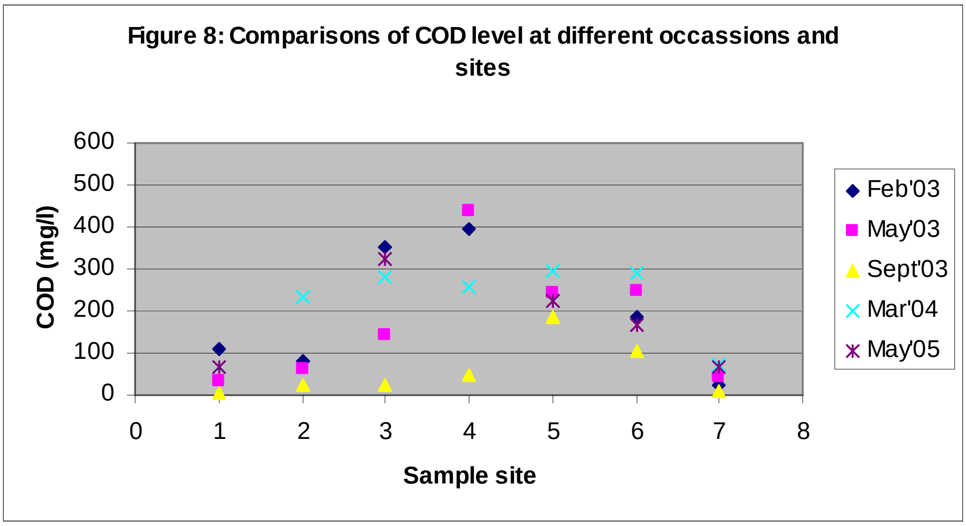
Note: 7 in this chart is sample point D - tributary *khal*
8 in this chart is sample point E – down stream of the tributary *khal*

The results also show that the BOD is highest at sample point 3 (Sinaboho) during summer (May) and lowest during autumn (September) at the sampling point on the Turag (Figure 7). There was also an increasing trend of BOD from September to May. In almost all sites the drier months had higher BOD levels as the only source of water for the beel at that time is wastewater and the waste is more concentrated. The Turag (site 1) and the clean khal (site 7 in this chart) consistently have BOD levels within national standards for effluent (50 mg/l) but now always those for water bodies used for fisheries of 6 mg/l (GOB, 1997; Annex A).



Note: Point 7 in this chart is sample point D, the tributary khal;
Point 8 in this chart is sample point E – down stream of the tributary khal.
The chart has been limited to 200mg/l therefore the maximum of 600 mg/l (recorded at khal at Ratanpur Railway Bridge in 2003) is not shown.

It was found that the month with the peak level of COD varied from site to site but it is clear that COD levels peak at the height of the dry season (January to March) (Figure 8).



Note: Point 7 in this chart is sample point D, the tributary khal;
Point 8 in this chart is sample point E – down stream of the tributary khal.
The COD chart has been limited to 600mg/l therefore the maximum of 61010 mg/l is not shown.

Sediment and fish samples were also collected and tested for several heavy metals. Three individuals from five different species of fish were collected, dehydrated and their soft tissue tested. None of the fish samples were found to contain high levels of any metals. However, given the age of the fish, (none were older than a year) it is unlikely that they would have accumulated high levels of heavy metals in body tissue during the short period in any case.

The sediment samples (Table 7) showed that all but one sample was within the maximum permissible levels set for Europe (no maximum permissible levels have been set for Bangladesh) but several exceeded "normal content intervals" quoted in (Lacatusu, no date).

Table 7: Average metal content of sediment samples from Ratanput Khal and Mokesh Beel

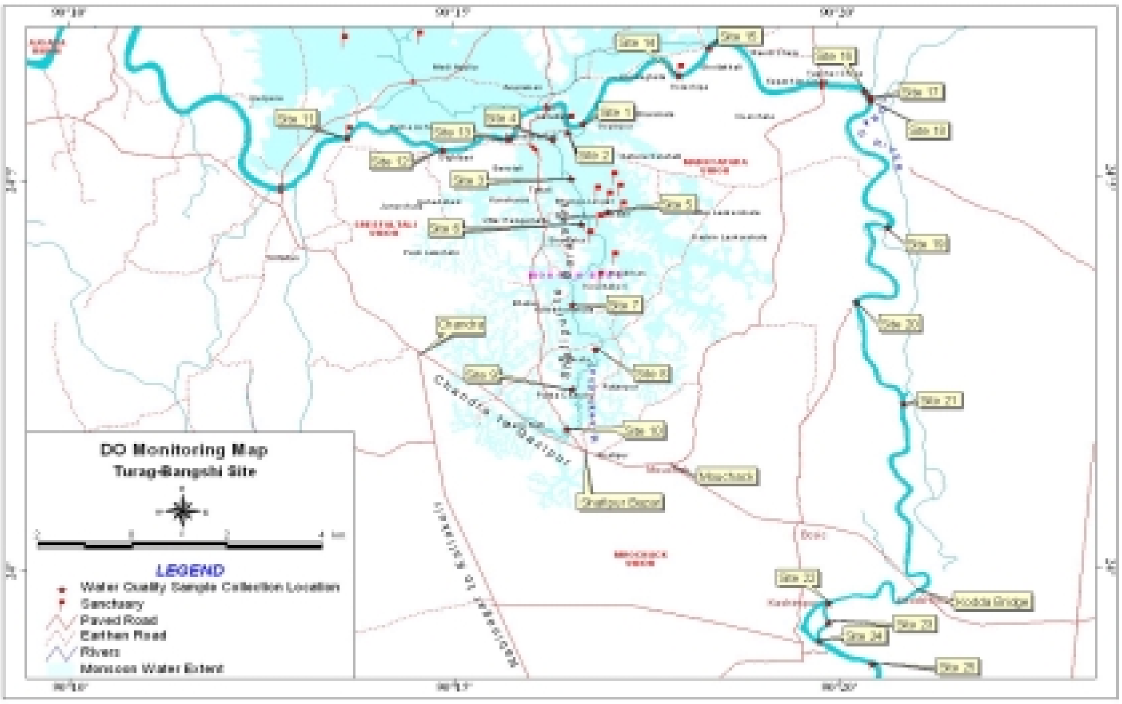
Sample/parameter	Chromium mg/kg	Copper mg/kg	Zinc mg/kg	Cadmium mg/kg	Lead mg/kg
Normal content interval	2 – 50	1 - 20	3 – 50	0.1 – 1.0	0.1 - 20
Maximum allowable limits*	100	100	300	3	100
Sediment sample 1	42.68	38.00	77.32	1.90	79.76
Sediment sample 2	33.64	20.80	40.36	-	27.48
Sediment sample 3	23.36	14.58	35.52	-	-
Sediment sample 4	81.48	31.08	97.20	4.72	188.24
Sediment sample 5	37.32	45.36	145.52	0.60	46.64

Source: Chadwick and Clemett, 2004

There have been reports of fish kills in the Turag River close to fish sanctuaries established by the communities through the MACH project (both in 2005 and 2006) and the number of reported incidents has increased, with the most recent in February 2006. Initially, it was thought that localized industrial pollution was the main cause of these fish kills but it has since been found that some industries away from the project area may bear some responsibility for this as it appears that at times of low rainfall pulses of polluted water are pushed upstream during high tide periods (Figure 1).

In response to this problem and demands from the community, in 2005 a monitoring program was designed for the entire area from Kodda to Chandra on the Turag River. After discussion with members of the Resource Management Organizations (RMOs) created through the MACH project, 25 locations were identified for monitoring (Figure 9). Out of these locations, 13 were sampled by the research team in August 2005 which revealed anaerobic conditions at Ratanpur railway bridge (site 9) and Shafipur (site 10) (Appendix B), which also had the highest BOD levels. These sites were located near industrial discharge points.

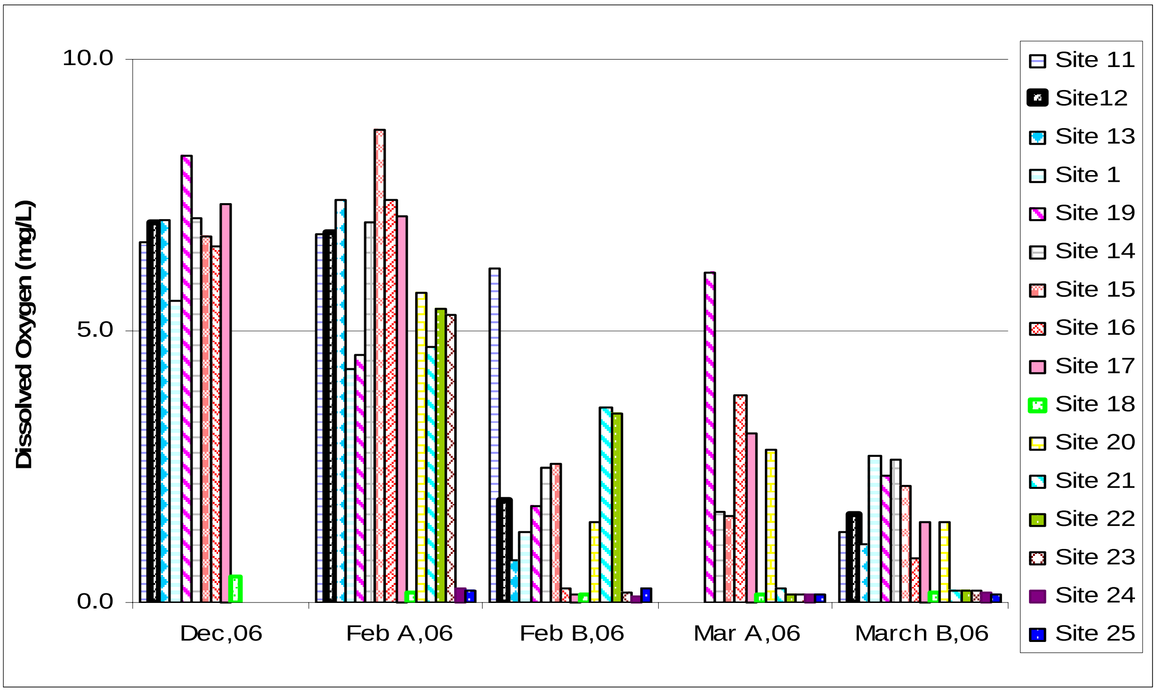
Figure 9: Location of dissolved oxygen monitoring sites



This sampling program has subsequently been developed into a monitoring program that has been adopted by local volunteers linked with the MACH RMOs. The Mokosh Beel and Turag River monitoring sites were divided into five sections, each with a team of local monitors trained to use DO meters, pH meters and conductivity meters. HQ 10 Hach Portable LDO^{TM} Dissolved Oxygen Meters are used for the monitoring program. All sampling has been conducted in the morning for consistency. At each sampling location three sets of measurements were taken: one from the surface water, one from the bottom, and one from the middle. The data was recorded from the meters on the spot and entered into recording sheets. Sampling was done twice monthly from late December 2005.

The monitoring results at the Turag sites (Site 11- Site 25) showed levels of dissolved oxygen (DO) between 20 December2005 and 16 February 2006 that were generally above the national limit (5 mg/l) (Figure 10). However, during this period four sites (1, 17, 24 and 25) had unacceptable DO levels: sites 1 and 17 are located at the confluence of Ratanpur khal and Shaldaha khal, which carry industrial effluent water to the river. Sites 24 and 25 are located downstream near Kashimpur bazaar where industrial waste water is discharged indiscriminately from BSCIC industrial area. In almost all of the sampling sites dissolved oxygen fell to unacceptable levels by 16 February 2006. In some sites (1, 18, 19, 21, 23, and 25) the deterioration came in early February 2006. Notably, Gangetic Dolphins were seen in the area of Sites 17, 18 and 19 from November 2005 to January 2006. After January the monitoring group did not see any dolphins in this area. Later in March 2006, the monitoring group reported dolphins in Kahimpur nodir par, which is further downstream in the river. This is an area that is equally as polluted as some of the monitored upstream sections. Results from pH readings in the river showed alkaline water in most sites (pH of 8.4 – 9.5) in late March. From December 2005 to January 2006 pH conditions were within the nationally acceptable range (6.5-8.5) except for sites 1, 21, 23, and 24.

Figure 10 Monthly trend of dissolved oxygen in different sites of Turag River



Note: site numbers are the same as shown in Figure 9.

Measurements during December 2005 to March 2006 from Ratanpur Khal and Mokosh Beel showed that dissolved-oxygen concentrations at all monitoring locations were below the national limit (Table 8). The only exception among nine locations was site 3 which carries clean water (with DO greater than 5) from Kalia Daha River until early March but later it deteriorated. Ratanpur Khal and Mokosh Beel water was also found to be highly alkaline compared to the Turag River, and is above the range set by GOB for inland surface water bodies and for fisheries (pH 6.5-8.5). This was expected as these three kilometers of khal (Sites 7, 8, 9, 10) are located immediately downstream of the discharge point of several industries operating concealed pipes line carrying waste water into the khal.

4.4.2 Biological Monitoring

Table 8: Monthly trend of dissolved oxygen in different sites of Ratanpur khal and Mokosh Beel

Site	Dec, 05	Feb A,06	Mar A,06	March B,06
2	3.1	0.4	0.85	0.25
3	1.2	7.0	5.8	7.0
4	3.3	0.3	1.0	0.1
5	na	0.2	0.1	0.2
6	na	0.2	0.1	0.1
7	0.3	0.2	0.2	0.3
8	0.3	0.2	0.4	0.8
9	0.2	0.2	0.15	0.1
10	4.8	2.3	2.2	1.5

The longer term impacts of pollution were also investigated through biological monitoring of aquatic invertebrates. It was intended that this methodology could be developed into a simple and effective means through which community members could monitor the health of ecosystems over a longer time period. The benefits of such a system are that depending on the protocol developed it can rely on low-technology equipment (a net or grabber, a white tray and a sieve), and in its simplest form it can be undertaken by people with limited expertise.

The initial result confirms that Ratanpur Khal is biologically dead as no benthic macro-invertebrates were found at its upper reaches where it is fed almost entirely by the factory effluent. This is likely to be due to the presence of a number of pollutants but the key feature of the environment that is restricting life is the absence of oxygen in the water body. The relatively diverse samples found in the river, the khal at the far end of the beel and a tributary canal coming from Kalidaho Beel, suggest that these sites are comparatively less polluted than the upper end of Mokesh Beel (Chowdhury and Clemett, forthcoming). Well known pollution indicator species such as Culex, Chironomids and Tubifex, were found in the study area (Parivesh, 2002; Mustow, 2002; Moss, 1998). These species can survive in heavily polluted waters and will therefore be found in high proportions in places where the water is too polluted for other species to survive.

4.4.3 Composite Sampling of Wastewater

Wastewater samples were collected from five factory outlets. Samples of equal volume were taken every hour over a 24 hour period. The samples were combined and analyzed at BUET for key parameters. It was found that most samples exceeded water quality standards for pH, COD and BOD. All samples were within the limits for sulfide (Table 9), however, it is believed that the sampling procedure missed important dye bath drops as samples were taken at fixed intervals and not proportionally to wastewater flow. Subsequently samples have been taken with an automatic composite sampler that continuously detects the flow rate of the water in the drain and takes a sample that is proportional to the flow.

Table 9: Results of 24-hour composite effluent samples from five textile factories

Parameters	Unit	142 com	25 com	45 com	26 com	26 com	24 com	24 com	BD Standards for effluent from industrial Unit[a]
		2005	2005	2005	2005	2006	2005	2006	
pH		9.95	9.27	9.51	9.47	9.4	8.38	8.52	6.5-9
TDS	mg/l	3,139	114	2,410	2,035	1,946	3,041	3,371	2,100
TSS	mg/l	39	2,357	14	73	113	129	45	100
BOD_5	mg/l	128	164	172	152	260	360	440	150
COD (Duchromate)	mg/l	367	288	344	440	400	656	810	200*
Sulfate	mg/l	1,025	87.5	140	375	650	1,500	1,600	-
Sulfide	mg/l	0.103	0.045	1.685	0.067	0.075	0.183	0.157	2.0
Chloride	mg/l	54	315	840	420	235	38	43	600*
Sodium	mg/l	1,870	914	960	1,180	203	448	606	-
Total Ammonia	mg/l	1.45	0.8	1.5	0.65	1.9	1.75	2	5*
Nitrate	mg/l	0.4	0.2	0.4	0.3	0.8	1.2	0.9	10*

* Standard for waste from industrial unit discharged to the inland surface water

4.5 Health Study

Not only were pollution levels monitored but BCAS also investigated the possible impacts of pollution on human health. Focus group discussions were conducted in 15 villages to prioritize the health problems in the area. The results of this study indicated that diarrhea/dysentery[1], skin disease, common cold, respiratory disease and gastric ulcers are the five most common problems in the area. A further 11 interviews were conducted with health workers in the area and these provided very similar results to those of the community focus group discussions. The health workers identified 20 health problems that were common in the area at the time of the interviews. Of these the five most prevalent were diarrhea, skin diseases, gastric ulcer, cough and cold, and fever (Ullah et al., 2006).

The trend of health problems over the past 10 years was also researched in the interviews. Some of the health workers felt that problems such as dysentery and diarrhea were less in the past because there were fewer people living in the area, as many people have migrated in to work in the factories (Khathaltala interview). Generally they feel that diseases have increased and one said that:

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[1] The community members often group these two health problems.

> “I did not see many patients with skin diseases in the past, and dysentery and diarrhea have increased a lot in the area… Lack of cleanliness and also eating fish from polluted water is the main cause of this disease… Polluted water from industries is mainly responsible for diseases” (Sinaboho village interview, Ullah et al., 2006).

There is other anecdotal evidence from this research of a link between the pollution and health problems. The majority of the respondents reported that children and factory workers suffer the most from skin diseases, and some respondents noted that fishers and those who have frequent contact with beel and khal water, also tended to suffer more from these problems. The symptoms of the skin diseases include a rash, boils and irritation. There are two main reasons given by the communities as to the source of the problem. The first is that it is spread by contact especially among children who are living in unhealthy environments. The second and more frequently reported cause is contact with the chemicals used in the factories. A health worker in Barai Bari village said that:

> “Skin disease has increased in this area. Farmers, children and fishers are mainly affected as they work in the water. The pollutants from industries are responsible for it. Pollutants from industries enter in the Turag River through the khal and beel and end up here. Local Health Complex and Department of Environment should take the initiative to stop the pollution” (Village Baraibari, Ullah et al., 2006).

5. Pollution Mitigation

5.1 Alternative Production

The research, including the cleaner production audit and water quality sampling, showed that improved production efficiency and effluent treatment could substantially reduce the water pollution generated by industries (Chadwick and Clemett, 2003). Alternative production options were therefore proposed for the dyeing process and "Alternative Production Trials" were undertaken in six participating factories to encourage the adoption of simple, low cost alternative (cleaner) production measures. The options comprise of two main components; changing dyeing parameters and introducing alternative inputs or processes. The trials themselves demonstrated the improvement of the fixation (percentage of dye that reacts with the fiber and is therefore not lost to the waste stream) and the possibility of getting more dyeings "right the first time" and therefore reducing the pollution arising from re-shading and re-dying. They also offered the opportunity to inform dye managers about good dyeing practices and training factory floor staff on good housekeeping for improved productivity and reduced pollution, as well as health and safety issues (Ahmed et al., 2005).

Results of the initial study indicated that in many factories around 20-30% of the fabric has to be re-shaded and around 10% has to be re-bleached and re-dyed due to following incorrect recipes or discrepancies between laboratory and bulk practices. Investigations in several factories have also shown that dye fixation in fabric can be very low, ranging from 40-65%. The results of the trials have shown that even in factories with very low fixation rates this can be raised to 70% or higher, which would not only reduce pollution but would also result in significant financial savings. The savings made would depend on many factors but calculations for an average factory predicted savings in the order of US$ 67,000 per year (Ahmed et al., 2005).

The results of laboratory trials conducted at the Bangladesh College of Textile Technology, have further shown that using compatible dyes from the same reactive dye class, (vinylsulphone, monochlorotriazine or heterobifunctional dyes) and using them under the correct conditions can significantly improve fixation and right first time dyeing. On average fixation was 15% higher when compatible dyes were used compared with situations when dye classes were mixed and inappropriate dyeing methods were used (Sultana, Unpublished).

The focus of the work to date has been on improving the understanding of dye managers as regards dye types, their compatibility and the dyeing parameters for each dye type. This has led to the publication of a booklet entitled "Alternative Production and Cost Saving in Winch-Dying" (http://www.sei.se/water/beel/Alternative.pdf). In addition a number of training workshops have been held for industries, to disseminate the knowledge of improved dyeing and house keeping. A Dye Managers Network has been designed and launched to provide technical support to dyers as well as to provide a forum through which they can ask questions to each other and textile dyeing experts. The network can be found at http://www.sei.se/asia/dyenetwork/.

Another area of concern that the project has been attempting to address is the use of sodium sulfate (Na_2SO_4) as an auxiliary in the dyeing process. Sodium sulfate can react in the environment to produce metal sulfides or hydrogen sulfide. Furthermore, under aerobic conditions the sulfides produced can oxidize back to sulfates removing oxygen from the water body. It is, however, possible to replace Na_2SO_4 with sodium chloride (NaCl) a much less polluting salt. Tests were therefore carried out in the laboratory replacing Na_2SO_4 with NaCl. The results showed that there is no difference in fixation and that on this basis alone the two salts are inter-changeable. However other factors currently prevent factory managers from using NaCl, this includes the quality of available NaCl which contains a number of impurities that can affect dyeing and also damage dyeing machinery over a period of time.

5.2 Effluent Treatment Plants

Promotion of effluent treatment and support for existing effluent treatment practices was a component of the work. Originally only two factories had ETPs in the study area. Samples were collected from these ETPs from different stages of the process. Results of the sample analysis showed that these plants do not function optimally. In the case of the biological treatment units, it appeared that in both ETPs there was too little biological activity, suggesting that the plants are not receiving enough effluent, either because insufficient effluent is produced for the size of the ETPs or because the ETPs are not operated properly. For each factory, written reports were provided explaining the results of the samples and making recommendations on how to improve their effectiveness and efficiency. The operation process of one of the existing ETPs has already been changed according to the suggestions of the project team.

The project provided technical support on the design of seven planned ETPs and has offered support to ETP design firms. Since this support, three factories have each established an ETP based on the project recommendations, two more have started ETP construction and others now have detailed designs for ETPs. Work has continued on the newly established ETP to improve operation and management by optimizing chemical dosing and effluent retention times, with the goal of ensuring environmental compliance and reducing the operation cost of effluent treatment.

As part of the process a considerable amount of training and capacity building in effluent treatment has taken place. Many workshops have been held to provide information about ETP design and management and an introductory booklet entitled “Choosing an Effluent Treatment Plant” has also been written in both English and Bengali and has been widely distributed to Bangladesh Garment Manufacturer Exporters Association (BGMEA) members, Bangladesh Textile Manufacturers Associations (BTMA) members, factories in the area and international buyers. In addition a web based network for ETP designers, operators and suppliers has been developed to help build in-country capacity in ETP design and operation. This Effluent Treatment Plant Network can be found at http://www.sei.se/asia/etp/.

6. Conclusions

The work has generated significant knowledge regarding the concentrations of certain pollutants in wastewater from the textile dyeing industries in Bangladesh and environmental pollution of receiving water bodies. The research has also identified and developed interventions to address this pollution through changing production processes and effluent treatment. Project findings have been disseminated widely across Bangladesh through BGMEA and BTMA, and in the project area there is evidence to suggest that factories are beginning to adopt some of the proposed interventions. Certain factories now use compatible dyes whilst others have replaced old equipment, as recommended to them by the project, which greatly improves fixation. The emphasis that the project has placed on using good and consistent quality dyes and chemicals has resulted in some factories testing the chemicals that they buy and only purchasing from reputable suppliers.

The work on effluent treatment has been partially successful with a rise in the number of ETPs existing and being operated in the area. The management of ETPs with which the team has been involved has also improved.

Despite all of these interventions and successes, however, the pollution levels in the study area remain high and are likely to be increasing. This is because the number of factories in the area has increased from around 80 to 274, of which textile related factories (the heaviest contributors of polluted effluent being the textile dyeing factories) have increased from around 20 to 166 between 2003 and 2005 (out of which 51 industries are directly involved in dyeing). The easy accessibility of the area from Dhaka, the availability of infrastructure, and the lack of initiative by GOB in industrial zoning policy are all contributing to the constant growth in the number of industries in the area.

The current situation is clearly unsustainable and the rate of environmental degradation makes the need for change a national imperative. Water resource degradation is a poverty and governance issue that needs to be addressed now and on a national scale. Therefore, there needs to be dialogue between all stakeholder groups to develop a framework and modalities of implementation for improved environmental governance. The process will require bringing together senior representatives from government departments especially DOE, industrial associations and chambers, research institutions, international buyers, non-governmental organizations and legal experts.

These parties must engage in dialogue and form a consensus over environmental standards and implementation of effective pollution abatement strategies. At present government bodies at all levels are inadequately addressing this problem and international buyers place insufficient emphasis on environmental responsibility in their codes of conduct. Only by such a process is it likely that change will be possible, and the degradation of the aquatic environment and peoples' livelihoods can be slowed and eventually reversed. However this requires commitment and financial support; whether these factors exist or can be fostered is the key question. If the current trend is not halted significant reductions in the quality of life and harmful impacts on the poor will continue.

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Annex A: Water Quality Standards Prescribed in the Environmental Conservation Rules 1997

Table A-1: Standards for Water (Schedule-3)

Best practice based on classification	pH	BOD (mg/l)	DO (mg/l)	Total Coliform number/100
a. Source of drinking water for supply only after disinfection	6.5-8.5	2 or less	6 or above	50 or less
b. Water usable for recreational activity	6.5-8.5	3 or less	5 or more	200 or less
c. Source of drinking water for supply after conventional treatment	6.5-8.5	6 or less	6 or more	5,000 or less
d. Water usable by fisheries	6.5-8.5	6 or less	5 or more	------
e. Water usable by various process and cooling industries	6.5-8.5	10 or less	5 or more	5,000 or less
f. Water usable for irrigation		10 or less	5 or more	1,000 or less

Notes:

1. In water used for pisiculture, maximum limit of presence of ammonia as nitrogen is 1.2 mg/l
2. Electrical conductivity for irrigation water – 2250 µmhoms/cm (at a temperature of 25^{o}C); sodium less than 26 %; boron less than 0.2 %.

Table A-2: Standards for Waste from Industrial Units or Projects

Parameter (Unit)	**Inland surface water**	**Irrigated land**
Ammoniacal Nitrogen (mg/l)	50	75
Free Ammonia (mg/l)	5	15
Arsenic mg/l)	0.2	0.2
BOD_5 (mg/l)	50	100
Boron (mg/l)	2	2
Cadmium (mg/l)	0.05	0.5
Chloride (mg/l)	600	600
Total Chromium (mg/l)	0.5	1.0
COD (mg/l)	200	400
Hexavalent Chromium (mg/l)	0.1	1.0
Copper (mg/l)	0.5	3.0
Dissolved Oxygen (mg/l)	4.5-8	4.5-8
Electrical Conductivity (micro mho/cm)	1200	1200
Fluoride (mg/l)	7	10
Sulphide (mg/l)	1	2
Iron (mg/l)	2	2
Total Kjeldahl Nitrogen (mg/l)	100	100
Lead (mg/l)	0.1	0.1
Manganese (mg/l)	5	5
Mercury (mg/l)	0.01	0.01
Nickel (mg/l)	1.0	1.0
Nitrate Molecule (mg/l)	10.0	10.0
Oil and Grease (mg/l)	10	10
Phenol Compounds (C_6H_5OH) (mg/l)	1.0	1
Dissolved Phosphorus (mg/l)	8	10
PH	6-9	
Selenium (mg/l)	0.05	0.05
Zinc (mg/l)	5.0	10.0
Total Dissolved Solids (mg/l)	2100	2100
Temperature (^oC) - Summer - Winter	40 45	40 45
Total Suspended Solids	150	200
Cyanide	0.1	0.2

Sources: GOB (1997) and Huq (2003).

Annex B: Water quality of the monitoring area (Kodda to Chandra)

Sites	Locations	Sample ID	Temp (^{0}C)	DO %sat	DO mg/L	pH	TDS (mg/L)	TSS (mg/L)	BOD$_5$ (mg/L)	COD (mg/L)	SO$_4^-$ (mg/L)	S^{2-} (mg/L)	Cl$^-$ (mg/L)	Na (mg/L)	NH$_3$-N (mg/L)	NO$_3$-N (mg/L)
Site1	Turag above confluence	1	32.6	78.4	4.77	7.37	81	83	4	11	8	0.008	10	0.3	0.75	11.8
Site2	*khal*/*beel* at Concrete Bridge	2	33.2	98.6	5.79	7.87	200	9	7	16	43	0.004	22	0.2	0.63	40.2
Site3	Mid *beel*	A	34.1	107.9	6.39	8.21	211	4	10	20	45	0.003	32	0.2	0.75	37.5
Site4	Clean *khal*/*beel*	D	35.4	77.5	4.53	7.61	179	13	7	18	36	0.003	25	0.2	1.13	30.9
Site5	Amdair, beside sanctuary	F	33.7	109.6	6.49	8.32	199	3	8	20	47	0.003	34	0.1	1.13	38.5
Site6	Sinabaha (mid stream)	3	34.4	118	7.07	8.24	246	5	18	32	45	0.003	39	0.2	1.25	37.3
Site7	Between Sinabaha & Matikata	X	34.7	138.3	8.07	8.24	260	24	18	40	53	0.003	50	0.1	0.88	54
Site 8	Matikata	4	34.7	120.7	6.7	7.94	318	11	22	40	69	0.001	58	0.1	0.5	63.5
Site 9	Ratanpur Railway Bridge	5	38	0	0	8.5	1071	53	70	200	300	0.044	160	0.2	2.75	211.2
Site 10	Shafipur Bridge	6	36.3	0	0	8.11	1258	173	65	159	750	0.6	240	0.4	3.63	332.7
Site 11	Turag near Labon Doha Channel	Y	33.1	75.1	4.54	7.47	87	53	6	14	8	0.005	11	0.2	1.5	3
Site 12	Turag at Kadda railway bridge	K	33.6	74.2	4.5	7.58	58	121	4	10	8	0.1	8	0.3	0.13	0.33
Site 13	Turag near Kopa kanda *beel* and Kalakur village	K2	34	58.9	3.5	7.38	105	32	4.6	12	18	0.008	13	0.2	1	6.05

Temperature, percentage of oxygen saturation and Dissolved Oxygen were measured onsite. Other parameters were measured in the Environmental Laboratory, BUET. Samples were collected in 2 August, 2005.

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