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Surface water quality susceptibility in drinking water treatment at Dhaka, Bangladesh

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Abstract

Ground water depletion in Dhaka indicates that shifting to a surface water source is now inevitable to continue Dhaka's public water supply. But indiscriminate pollution of the rivers of Dhaka has made them difficult to treat. Hence study on the evolution of some of the critical quality parameter is carried to understand the occasional problems of odour and aesthetic in the treated surface water in Dhaka. The Sitalakhya River water & Saidabad water treatment plant (SWTP) at Dhaka is the concern of this study. Water samples were collected & tested for a period of four years from 2002 to 2006 mostly in the laboratory of SWTP following standard methods and analyzed. Ammonia levels are found generally below 0.5 mg NH4-N/l in the wet season but rise up to 10 mg NH4-N/l (sometimes more) during the dry season. Other parameters such as BOD, COD, phosphate, hardness, TDS, and conductivity show the same general pattern of variation. BOD reaches levels of 20 mg/l & BOD to COD ratio is between 1.5 and 2.Colour exists in treated water from around 2 TCU to around 15 TCU respectively in dry & wet seasons. Sulfide presence is negligible. The average and max values, both increasing around three mg NH4-N/l every year with a trend signifying that it will continue further. Compared to design criteria of SWTP of max 4 mg NH4-N per litre the increases are substantial. This needs attention both in terms of regulatory measures and of proactive strategies on how to handle the resulting future treatment challenges.

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Introduction

Dhaka Water Supply and Sewerage Authority (DWASA), a Government-owned autonomous agency, is responsible for the supply of drinking water & sanitation services to the city dwellers of Dhaka, the capital city of Bangladesh. Dhaka WASA at present supplies potable water to about 15 million people daily in Dhaka city. Dhaka WASA is extracting almost 80% of its supplied water from underground. Because of over extraction of ground water every year water level is going down by 2-3 meter. Once, presumably cheap and abundant, ground water source inside Dhaka has gradually been depleted so much that no further over extraction is possible. There is no other way but switch over to surface water (Serajuddin, 2009).

In this context, Saidabad Water Treatment Plant (SWTP) Phase I was constructed with a capacity of 225 million litre per day (mld) and put into operation on July 27, 2002. The Sitalakhya River at the eastern periphery of Dhaka city is the source of raw water for the SWTP (Fig. 1). Different treatment processes like pre-chlorination, coagulation, filtration, disinfection, pH correction are used at SWTP to make the water potable as well as wholesome to the consumers.

But indiscriminate pollution generating human activities surrounding the peripheral rivers of Dhaka have turned the rivers into, especially in dry season, a polluted canal- making them unsuitable to be a source of drinking water.

The water qualities of the surrounding rivers are deteriorated very much which raised concern among the city dwellers as well as the experts. In the dry season there are complains of water with bad smell and aesthetic problem regarding the supplied water. Under such a circumstances, it became imperative to find out the cause of the bad smell & aesthetic in the treated water of the Sitalakhya River raw water.

There is an underlying assumption that the problems observed during the dry season are linked to problems of removing algae. This problem is again assumed to be caused by increased concentrations of ammonia interfering with the intended removal of algae (Serajuddin, 2011).To look deep into the cause & effect of the said problem study on the evolution of some of the critical water quality parameters like Ammonia, BOD, COD, TDS, Sulphide, conductivity, colour, alkalinity, hardness, Algae, DO, PH, etc. were carried out. Besides, the whole treatment chain employed in SWTP was studied.

Surface water being a major source of water supply could be a dependable option for fulfilling water crisis of Dhaka if the pollution level is under specified limit. Though Dhaka City is surrounded by a number of peripheral rivers but if we cannot control their contamination level it will have their limitation to be used as a potable water source in very near future.

On the other hand before treatment, it is imperative to have ideas on the level of pollution of these peripheral river waters.

This study aims to assist in thinking about a possible strategy for water resources managers of critical pollution parameter to lay the foundations for efficient control mechanism against indiscriminate pollution. This study may also facilitate decision makers to efficiently brainstorm a suitable water treatment alternative for present raw water quality for the time being in order to continue water production with acceptable water quality and therefore amenable to greater withdrawal to meet the anticipated additional demand.

Materials and methods

Data and information acquisition

Saidabad water treatment plant phase I being operated by Dhaka WASA and the raw water from the Sitalakhya River is respectively the plant & surface water of concern of the present study. The period being considered in the study is from the commissioning of the SWTP plant I that is from 2002 up to the year 2006 when the concept of plant II was developed.

All the relevant data and information on the existing Saidabad plant I like plant layout, raw water quality, designing loads for key pollutants (ammonia, nitrate, total nitrogen), present performance of treatment plant (in terms of haloforms, ammonia, nitrate etc), troubleshooting experience reports from operational team, present chemical use, dosing system, potable water quality standards (e.g., for ammonia and nitrate), configuration of existing plant, were collected, studied and analysed.

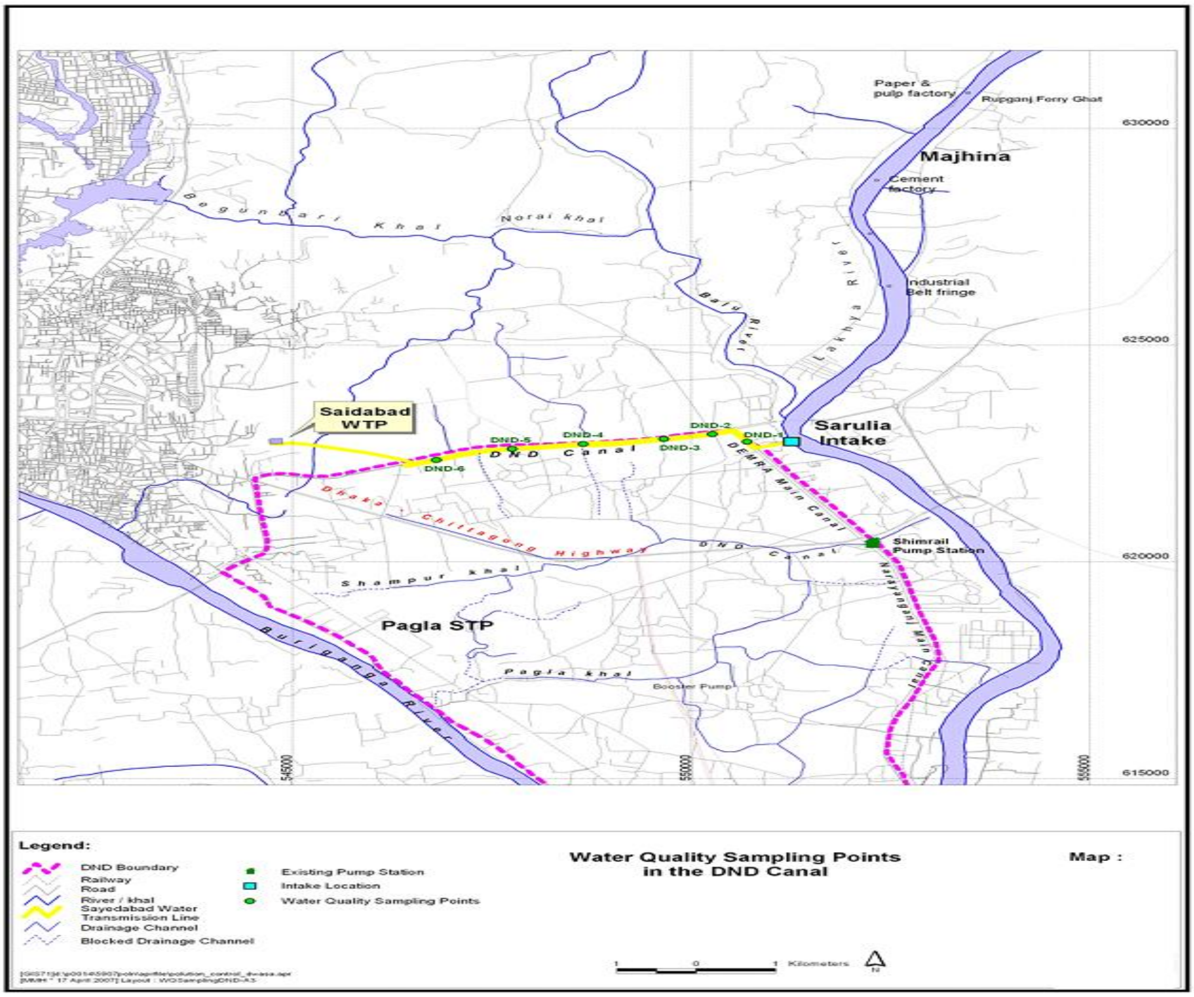

Fig. 1. Water quality sampling points in the DND canal.

The operational data of the plant particularly the raw water quality used in the plant for the whole period of study, i.e. from the commissioning of the plant up to 2006 were collected and analyzed.

In addition for the sake of the study some supplementary data were collected relating to the water quality at DND(Dhaka-Narayanganj-Dhaka) conveyance canal connecting the river & the plant was done for better understanding the total process of the chain of treatment.

Fig. 1 shows Water Quality sampling points in the DND Canal and Tab. 1 provides the locations of sampling points along DND conveyance canal.

Water testing and laboratory analysis

The water quality testing was performed in the water testing laboratory of Saidabad plant itself located in the plant. Some supplementary analysis was done in the laboratory of Civil Engineering Laboratory of Bangladesh University of Engineering and Technology (BUET), Bangladesh.

The method utilized in the testing along with the parameters tested is shown in Table 2.

The general method of assessing water quality is mainly based on comparison of measured parameters with the threshold values recommended by national and international bodies like DOE,WHO.

The study was the continuation of the assessment of the performance of SWTP at Dhaka city and water sample is tested with respect to the presence of critical pollution in Sitalakhya river water. For this purpose water samples were collected from using laboratory prepared pre-washed plastic bottles for collection of sample. The samples were bottled carefully so that no air bubble is entrained in the bottle. The geographic positions of the sample sites were recorded by GPS.

Table 1. Locations of sampling points along DND conveyance canal.

Sampling Location	GPS positions Deg-Min-Sec		Distance*
	Latitude	Longitude	km
DND - 1	23°43'3.8"	90°29'40.9"	0.215
DND - 2	23°43'9.7"	90°29'25.5"	0.695
DND - 3	23°43'3.8"	90°29' 4.1"	1.312
DND - 4	23°43'3.8"	90°28'28.1"	2.344
DND - 5	23°42'3.8"	90°27'56.8"	3.240
DND - 6	23°42'3.8"	90°27'23.1"	4.226

* from the starting point of DND canal.

All the sampling were properly labelled and carried out using disposable hand gloves with proper care and stored in ice box.

Results and discussion

Analysis of Issues

Raw Water Quality

Analyzing the available data for raw water quality brings the following observations:

Ammonia levels generally are below 0.5 mg NH_4-N/l in the wet season, but rise sharply during the dry season to levels of up to 10 mg NH4-N/l (-or even higher).

The duration of ammonia contamination of the Sitalakhya River (>2 mg NH4-N/l) has increased over the years from being mostly a problem January to March every year to the present situation where it starts in December and continues to April.

Other parameters show the same general pattern of variation, such as BOD, COD, phosphate, hardness (Ca and total), TDS and conductivity. BOD reaches levels of 20 mg/l.BOD to COD ratio is between 1.5 and 2, indicating "fresh, but diluted biological contamination with a fairly high biodegradability".

Nitrates have a pattern which (for natural reasons) is to a large extent opposite of the ammonia cycle (e.g. some nitrate present in the wet season and very little in the dry season).

Ammonia levels at the Sarulia intake can vary significantly within hours in the dry season as documented by various data sets .

The Sarulia intake thus seems to be influenced by tidal back-flows or at least by tidal "backing up" of the river flow, causing increased concentrations (IWM, 2006; DWASA, 2006; Khan, 2008; Serajuddin & Rahman, 2010).

Diluted organic pollution enters the DND canal in highly increased concentrations during the dry season. It appears that ammonia is not the only parameter of concern. And further, a clear seasonal variation in the water quality is there.

The trend and the levels observed in the last few years are approaching levels indicating a strong and increasing pollution of the river with waste water. It is worthwhile noting that the trends as seen in Fig. 2 imply that it will continue further.

Table 2. Testing Methods.

Parameters	Methods/ Equipments
pH	pH meter (HACH DR/4000U)
Electrical Conductivity	Conductivity meter (HACH)
Turbidity	Turbidimeter (HACH, 2100P)
TS	Standard Methods
TDS	Standard Methods
TSS	Standard Methods
Color	Spectrophotometer (HACH, DR4000U)
Ammonia	Spectrophotometer (HACH, DR4000U)
Nitrate	Spectrophotometer (HACH, DR4000U)
Nitrite	Spectrophotometer (HACH, DR4000U)
Phosphate	Spectrophotometer (HACH, DR4000U)
Sulfate	Spectrophotometer (HACH, DR4000U)
Sulfide	Spectrophotometer (HACH, DR4000U)
Alkalinity	Titration
Hardness	Titration
Chloride	Titration
COD	Standard Methods
BOD_5	Standard Methods
UV_{254}	Spectrophotometer (HACH, DR4000U)
TOC	Spectrophotometer (HACH, DR4000U)
DOC	O.I. Analytical Aurora (Model 1030)
DO	D.O. Meter
Temperature	pH meter
Chlorophyll-a	BBE Algae Torch

The Fig. 3 illustrates yearly variations of some key water quality parameters:

Turbidity is high in the rainy season (May to October) with monthly average values up to 70 NTU.

Turbidity falls to below 10 NTU at the start of the dry season and then rise slightly during the dry season possibly due to increased concentration of pollutants and/or algae rather than silt;
Colour in both the raw water and the treated water follows the ammonia trend with high values in the dry seasons and low values in wet seasons;

Colour in treated water varies significantly from less than 2 TCU in wet seasons to more than 15 TCU in the dry seasons. This indicates problems with the treatment processes (DWASA, 2007).

Water Quality in the DND Canal

Water was sampled from 6 points located along the DND Canal starting at the intake and ending at the point where water flows through an underground culvert to the WTP.

No significant changes in the chemical quality of the water can be observed from the data, but the data rather indicate (some however not significant) hourly variations of the water quality in the river. This is illustrated by the water flowing through the canal as a plug flow with minimal horizontal mixing and thus sampling point 1 close to the river represent water pumped from the river a few hours before sampling, while sampling point 6 close to the treatment plant represent water pumped from the river approximately 30-40 hours earlier.

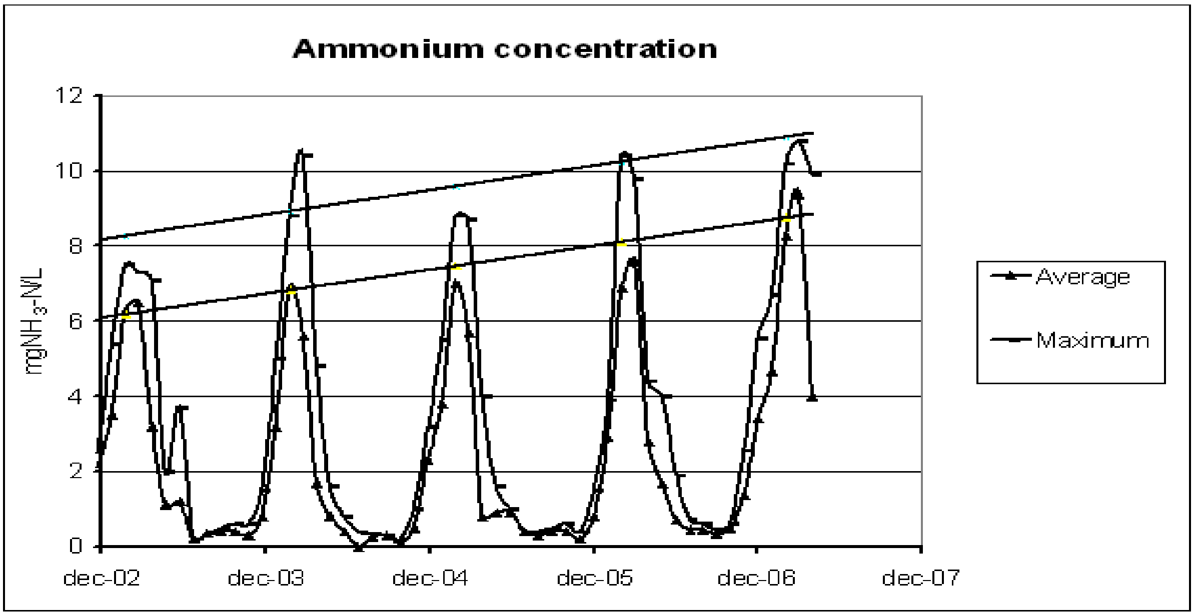

Fig. 2. Ammonium Concentration.

On several days the concentration of all the measured parameters have been noted to increase from the first to the last sampling point with the exception of TOC (Fig. 4); this parameter decreases with 10-50% but still remains very high when entering the plant.

The principle parameter ammonia does not decrease, which can be understood from the short residence time and the very low oxygen content (50% of the samples lower than 1 mg/l).

Fig.5 shows the average concentration of ammonia, TOC, and BOD over the sampling period.

A comprehensive analysis of algae in the canal and in the treatment plant was carried out both quantitative (concentration of Chlorophyll-a) and qualitative (determining the species of the algae present in the water).

The concentration of Chlorophyll-a, illustrating the concentration of algae in the water along the DND canal was analyzed on nine different sampling days. Average, minimum and maximum concentrations are presented in the Fig. 6.

Algal growth in DND canal

It can be seen that a number of algae –which is moderate at the inlet- will on average double (1.5 – 3.8 times increase) during their stay in the canal. This results in a high concentration of algae in the intake of the WTP (DWASA, 2006 & 2007; Khan, 2008 & IWM, 2004).

Analysis of data from the canal

Oxygen demand of the water

The raw water entering the treatment plant during the dry season is anaerobic meaning that the concentration of oxygen is close to zero (anoxic) and that most substances are in a reduced form (low redox potential), like nitrogen is present in the reduced form ammonia, and will contribute to the oxygen demand of the water.

Organic materials

Available data on the concentrations of various indicators for organic materials are a bit confusing. We have the measurement of BOD-5 (biological oxygen demand in 5 days); COD (chemical oxygen demand by dichromate); and TOC (total organic carbon).

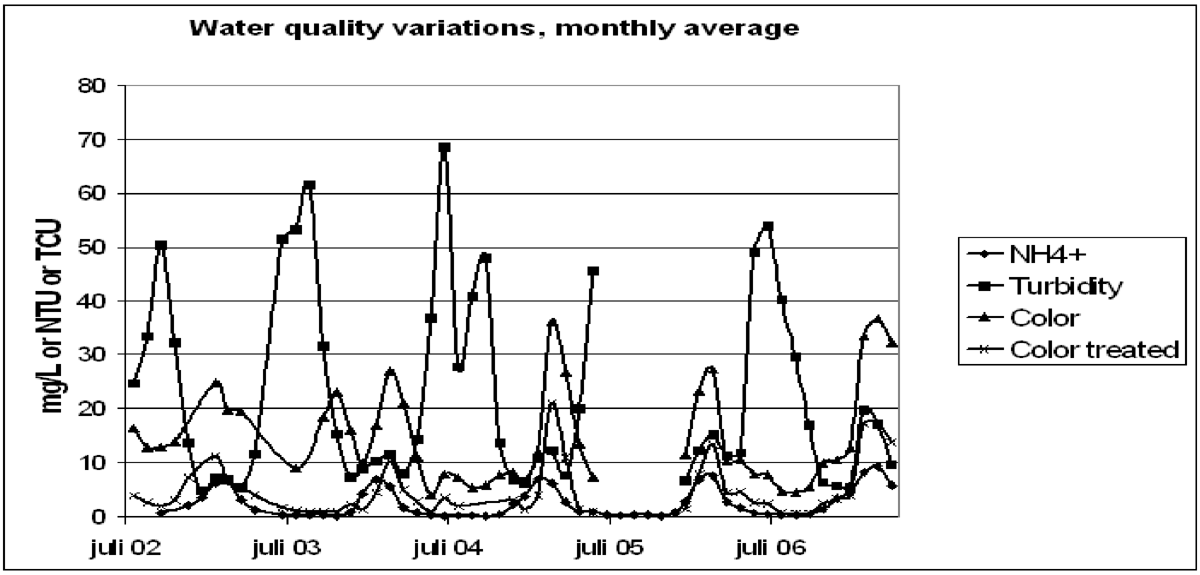

Fig. 3. Water Quality Variations.

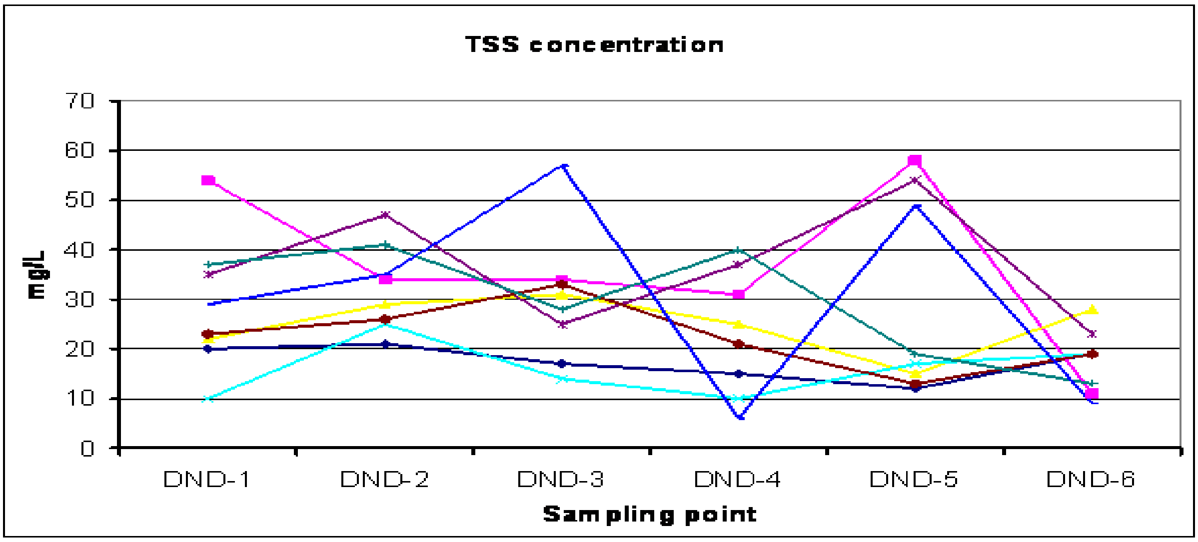

Fig. 4. TSS Concentration.

The data are not always consistent; however, concentrations of COD of around 50 mg/l and TOC of around 100 mg/l have been measured.

It is clear that the observed high chlorine demand (from the breakpoint chlorination attempt) may be due to high concentrations of organic materials.

Algae

The algae are multiplying to a significant level in the Canal. Further, the water quality parameter indicates that the raw water is, in reality, river water mixed with wastewater and thus there will be a wide range of substances and compounds in the water, which are not related to the algae and which also will create taste and smell nuisance.

The Chlorophyll-a data from the channel indicate that the content of Chlorophyll-a builds up from a relatively low level (approx. 20 µg/l) at the beginning of the channel to a higher level (approx. 40-60 µg/l) at the end of the channel near the site of water intake.

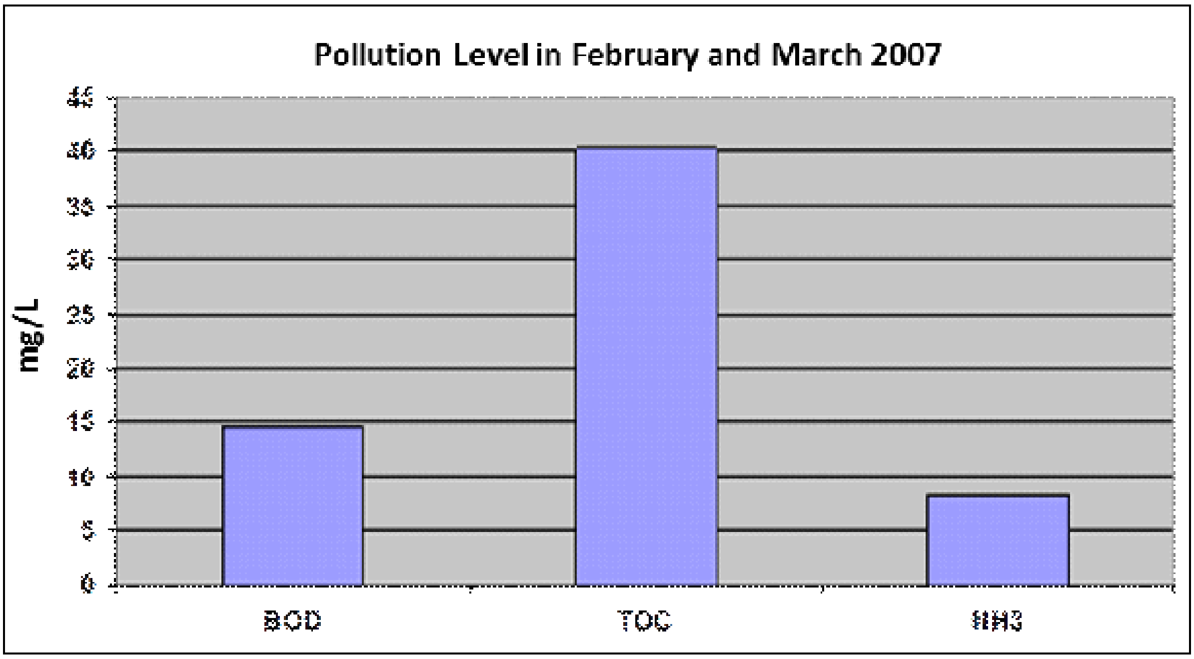

Fig. 5. Pollution Level in February and March 2007.

The Chlorophyll content can be characterized as high at the end of the channel before the point of water intake however not alarmingly high compared to European conditions, where heavy algae bloom is characterized by Chlorophyll content of 150 µg/l. Normally, the Chlorophyll content varies over the year depending on the light intensity. During late autumn, winter and beginning of spring the content is higher than in the summer period where the content is lowered due to a higher light intensity (DWASA, 2007; Khan 2008).

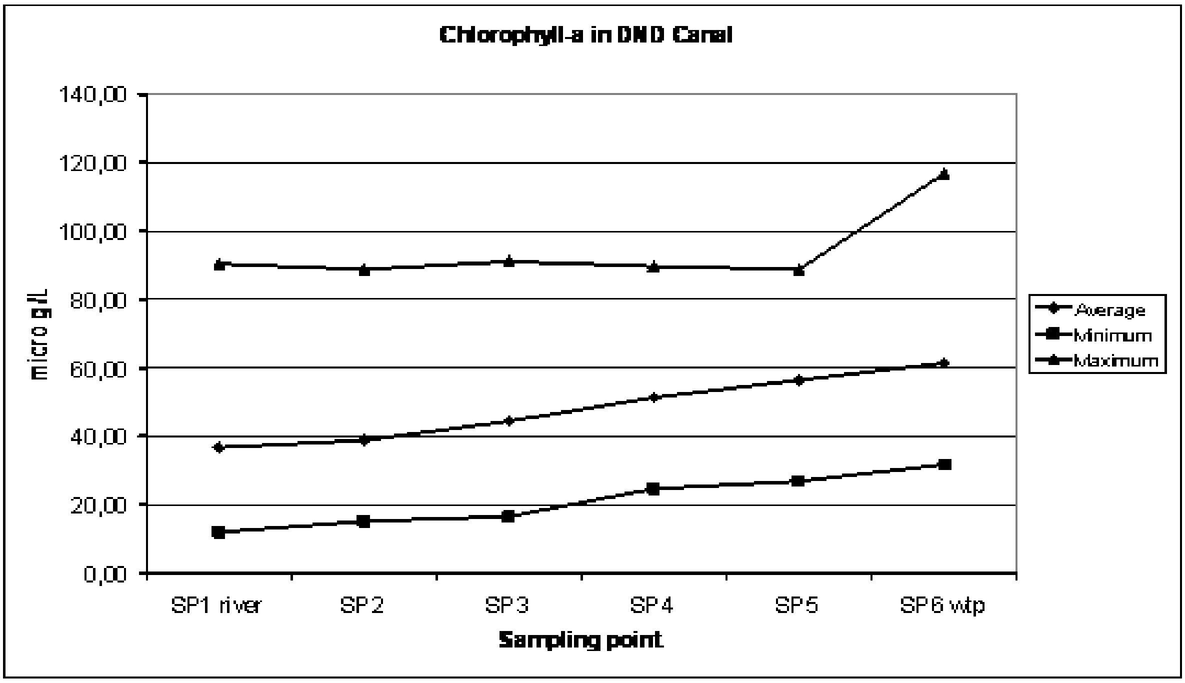

Fig. 6. Chlorophyll-a in DND Canal.

The Existing Plant

The plant is built around a conventional treatment system well suited for usual surface water compositions. Most of the plant looks similar to other surface water treatment plants, but a number of details are special patented solutions developed by Degremont, a French company, such as pulsators instead of traditional clarifiers or flotation units, special regulators for controlling the hydraulic loading of the filters etc. Altogether a good build plant which is well suited for usual raw water quality conditions. The construction of the existing plant, Saidabad I, was commenced in 1999 and the plant started to operate mid-2002 (Serajuddin, 2002).

Fig. 7. Raw water source and its transmission network from Sitalakhya River through DND canal to SWTP.

The raw water system

The raw water supply system and key aspects of its function are as follows:

Hydraulic aspects

The raw water is pumped from the Sitalakhya River into the DND canal (a 4.5 km long open canal, which has a width of 30-70 m and a depth varying between 3 m and 4 m). From the end of the DND canal, the water is led by gravity through a closed culvert some 1500 m to the inlet pump station of the SWTP (Fig. 7)

The total flow in the Sitalakhya River changes significantly between the wet season with plenty of water in the river and the dry season, when the 80 % dependable flow is reduced to levels that are around 10 times bigger than the volumes extracted to the combination of Saidabad I and II. In severe low flow situations, the water extraction in itself, therefore, will lead to increases in the concentration levels (IWM, 2004 & 2005).

In the dry season, the water movements around the location of the Sarulia pump station are influenced by a tidal back-flow/back-up coming from river Meghna and pushing water from the downstream areas up towards Sarulia. Some model results indicate that the net flow in the river almost becomes zero during the dry season in the lower reaches (Serajuddin, 2002 & 2009; Serajuddin & Rahman, 2010).

Pollution aspects

The pollution of the Sitalakhya River to a large extent comes from urban sewage and industrial waste into the Balu River and further into the Sitalakhya River shortly upstream of the Sarulia intake pump station (IWM, 2005).

The pollution being discharged through the Norai Khal/Balu River system originates from (at least) 1.5 - 2 million people.

In the wet season, the flow in the Sitaakhya River is sufficiently high to dilute the pollution to acceptable levels, whereas the concentrations rise to un-acceptable levels during the low flow situation in the dry season (DWASA, 2001).

The DND Canal to some extent works as a treatment reactor. During the wet season there is most likely sedimentation of solids along the canal and in the dry season there is a growth of algae, which removes parts of the pollution in the water, but which also negatively influence the treatment process at the SWTP (DWASA, 2006; IWM, 2006; Serajuddin, 2009; Serajuddin & Rahman, 2010).

Conclusion

The ammonia problem

The analysis shows a clearly increasing trend of the average monthly values and max values, both increasing around three mg NH4-N/l over the four-year period.

Compared with the initial design criteria for of max 4 mg NH4-N per litre and with the Bangladesh Standard for Nitrate of 10 mg NO3-N the increases are substantial in such a short period and the trend must be taken seriously both in terms of regulatory measures against polluters and in terms of proactive strategies on how to handle the resulting future treatment challenges if pollution prevention is not introduced in a sufficiently timely and effective way.
The sulfide problem.

Sulfide has so far not been considered a problem for the operation of the Saidabad I WTP as such and has not been analyzed for earlier.

Sulfide is however associated with a very offensive "rotten eggs" odour and taste which is detectable at concentrations as low as 0.05 mg/l. It must, therefore, be removed. Further, sulfides represent an oxygen demand in the water which is significant at high sulfide concentrations.

Pollution prevention

Though pollution prevention would be the optimal solution from an environmental and social perspective, the present situation and development in Dhaka strongly indicate that this is not a likely scenario in the near future. Large areas are presently being developed without proper pollution management systems on the west bank of Balu River upstream of the Sarulia intake.

The issues discussed above can be further narrowed down to the following problems: Complaints of taste, smell and colour during dry season, and possibly hygienic problems, due to a combination of the following cause effect relations:

High concentration of organic substances; creating anaerobic conditions in the water body and in sediments; formation of sulfides; water smells and tastes rotten.

High ammonia concentration; difficult to disinfect; not possible to control algae nor to ensure a hygienic quality of water.

Algae growth in the canal; release of toxic and nuisance substances.

Diluted wastewater; high concentration of organic substances; high chlorine demand and appearance of nuisance substances

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