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Increasing Level of Ammonia in the Surface Raw Water Source at Dhaka, Bangladesh

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ABSTRACT: In 2004,ammonia concentration in raw water of Sitalakhya River at the eastern periphery of Dhaka was found higher than the expected rate of 4 mg/Lforecasted in feasibility studies,with a value of about 8 mg/L, which could not be removed by conventional treatment chain employed at Dhaka, hence, recentlyan ammonia removal plant has been constructed. This important background has ledto the current study on ammonia, a single quality parameter to understand the trend of deterioration, its probable causes, and the probable remedy.Water samples have been collected and tested for ammonia for a period of fifteen years, from 2002 to 2017, mostly in the laboratory of the existing plant. Ammonia levels have been found generally below 4 mg NH_4-N/L in the wet season,though during the dry season they rise up to 20 mg NH_4-N/L (sometimes more). The maximum and average values of concentration follow a more or less similar pattern with time, withboth average and maximum values, increasing around 1 mg/L annually,suggesting a similar trend in future which will make the existing treatment process inadequate. This needs attention in terms of both regulatory measures and proactive strategies on how to handle the resulting future challenges.

Keywords: Drinking water, indiscriminate pollution,pollution control, Sitalakhya river water.

INTRODUCTION

Currently Dhaka, with a population of over 15 million, is one of the most populous and congested cities in the world,located on the northern bank of Buriganga River and surrounded by other rivers, namelyTurag to the west, TongiKhal to the north, and Balu andSitalakhya to the east. Yet, the city facesa legacy of water shortage since the independence of Bangladesh in 1971 up to very recently [Serajuddin, 2011, Mujibur, 2009, DWASA, 2007].

Presently, the city dwellers can get around 2240 mld of water, out of which 78% comes from underground. Before 2012 underground water contribution was 87%. As an inevitable corollary of excessive depletion of water level due to overexploitation of groundwater in Dhaka, it was planned to shift most of the supply to surface water sources [Serajuddin, 2012, Mujibur, 2009].In this context, a surface water Treatment Plant (Plant 1) was constructed and put into operation on July 27, 2002, having a capacity of 225 mld, the largest water treatment plant in the country [Serajuddin, 2002]. Sitalakhya River, approximately six kilometers away from Dhaka at the eastern periphery of the city,is

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the source of raw water for the plant (Fig.1). A replication of a similar plant with the same size and almost same design has been commissioned as the second phase (Plant 2), with the third phase of 450 mld of water postulated in near future [Serajuddin, 2011, 2012,Mujibur, 2009].

Unfortunately, Sitalakhya River now facesserious pollution problems, principally contributed by industries owned by influential section of the society [Banani Biswas, 2012, Begum, D.A, 2010, Dalwar, 2005, GOB& UNDP, 2010, Sania,2012, Shahidul, 2011]. During the conceptual stage of the second plant in 2004, it was observed that the tap water of the water supply system, extractingwater from Sitalakhya River, facedproblems of bad smell and color during the dry season. The attempts to find out the reason behind this problem revealed that during dry season the ammonia contents in the raw water werequite higher than the expected highest ammonia concentration of 4 mg/L. This expected figure was forecasted in the feasibility studies as well as in the Environmental Impact Assessment study carried out for the surface water treatment plant project[BCEOM,1992;DWASA ,1992; DWASA: 1994].

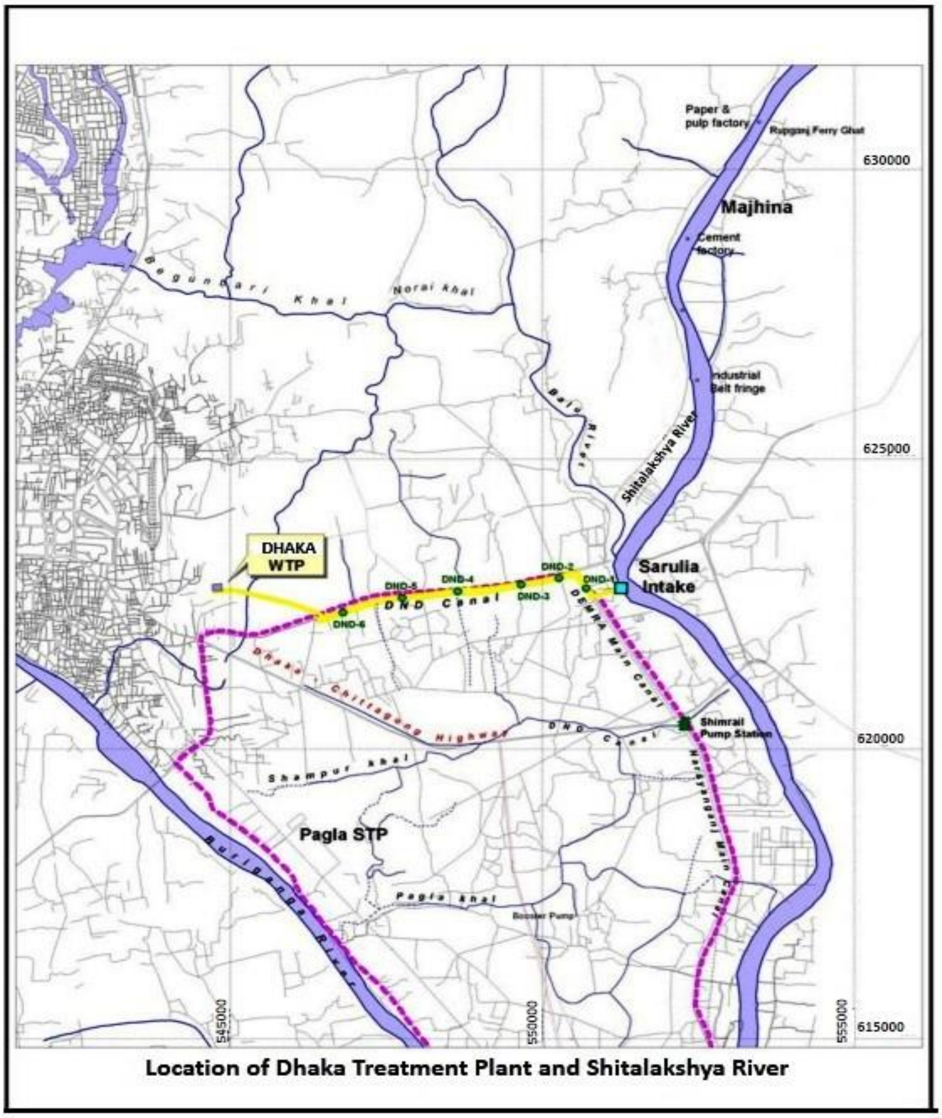

Fig. 1. Raw water source and its transmission network from Sitalakhya River to WTP

In the raw water a concentration of about 8 mg/L of ammonia was detected which could notbe removed via conventional drinking water treatment chainm employed in Plant I [Serajuddin, 2002, 2011, Mujibur, 2009, DWASA, 2007].WhileformulatingPlant II of Dhaka Project, the policy makers came across a pre-treatment unit to reduce ammoniaconcentration [DWASA, 2007, Serajuddin 2011].Prior to conventional treatment chain, abiological pre-treatment process was considered an option,a likely economic and effective treatment process, to remove ammonia along with other pollutants from raw water [DWASA 2007]. Accordingly, a biological nitrification unit was installed as the pretreatment unit primarily to remove the ammonia from the raw water [Serajuddin 2012].

Withregards to ammonia,currently there are no action levels or MCL (Minimum Concentration Level) set by the US EPA [US EPA. 2006] norany guideline value from the World Health Organization [WHO, 2011]. WHO does recognize odorand taste effects at ammonia concentrations of 1.5 mg/Land 35 mg/L,respectively[WHO 1996]. There has not been a health-based guideline for ammonia levels in drinking water of almost all European and North American countries,since itwas observed that the contaminant was low in both raw and treated water [WHO 1996, Hasimi 2011]. In 2013, the US EPA announced water quality criteria for aquatic life as Total Ammonia Nitrogen in mg/L at pH = 7 and temperature of 20^0C for acute (1hr) and chronic (30 days) exposure of 17 and 1.9 mg/L respectively [Water Quality association, Illinois, USA 2013]. The National Academy of Science, USA, recommendeddrinking water standard to be 0.5 mg/L,whichhas been recently adopted by a number of European nations[Oregon Department of Human services, 2000].

In Dhaka,still a long way from 2002,it appears that the ascending trend of ammonia in the surface water, under study, has not diminished after so many precautionary steps. Amazingly, by analyzing the historical data, the feasibility study report of plant I has forecasted that by the next decade, the maximum amount of raw water ammonia will be 4 mg/L which can be handled by breakpoint chlorination [BCEOM, 1992].Given thisimportant context along with the history of installingNitrification unit in Dhaka plant 2,not to mention the existingclearatrocity ofpolluting activitiesby influential peoples,the present paper attempts to study the trend status of this single water quality parameter separately. Although there are a numbers of studies found in the literature concerning surface water quality of water bodies in and around Dhaka city [Dalwar, 2005; Didarul, 2015; IWM, 2005; Ibrahim,2015; Jashua, 2015; Mahbub,2011; Naushad,2006; Shahidul,2011; Shishir,2009; S. Roy, 2011], none of them has been conducted on ammonia solely, in particular with source water of Dhaka’s drinking water.

As such, the present study aims at investigating the deteriorating trend of ammonia in the raw water of the Sitalakhya as well as demonstrating to all stakeholders regarding our unabated atrocity in polluting this valuable water source, making them aware of the probable disaster in near future.

A visual display on this aspect can also facilitate decision makers to efficiently find out a suitable way for keeping the river clean in order to get acceptable raw water quality, hence enabling large withdrawal to meet the anticipated additional demand. Analysis of this study can be a measuringtool for makingdecisionsaboutindustrialization or deindustrialization of certain very polluting industries in the study area. Based on the results, easy and optimal solutions canbe alsosuggested toharness as much as benefit from this naturally-abundant resource.

MATERIALS AND METHODS

The treatment Plant 1,operating in Dhaka, and the raw water from Sitalakhya River are respectively the plant and surfacewater, taken into consideration in this study. Around 3900 raw water sampleswere taken fromSitalakya at the intake of the plant, for a period of fifteen years since the inauguration of operations of Plant I in 2002,which also included the operation of Plant II [Serajuddin, 2002, 2012] formore than four yearsafterits commissioning (2013 – 2017).These were collected, tested, and statisticallyanalyzed forthe historical trend of ammonia in the raw water of Sitalakhya over this period. During the months of dry season,i.e., from November to April one sample was taken for investigation per day, whereas during wet season,i.e., from May to October this rate became three samples per week. For the sake of 'Confidentiality', the selected water treatment plants were named Plant 1 and Plant 2.The quality of collected water sample was evaluated on the basis of the existence of ammonia. In order to cover both dry and wet seasons (monsoon),the average and maximum values of the parameter for each month of the year were used in the trend analysis and for comparison with local Bangladeshi (if any) and international standards on raw water quality abstracted for drinking water [WHO, 1996, GOB 1997, EU Council Directives 1975, Govt. of Malta, 2002, Govt. of France, 2007, Water security Agency, 2015].

Tests on water quality weretaken in the water testing laboratory of the plant itself, withsome supplementary analyses being done in the laboratory at Civil Engineering Department of Bangladesh University of Engineering and Technology (BUET). The ammonia testing was done by means of HACH DR 6000spectrophotometer via Nessler Method, using method 8038.The method, utilized in testing other parameters,along with the equipment was Spectrophotometer (HACH, DR4000U).Once the samples were collected in laboratory prepared pre-washed plastic bottles,they weresealed with cautionso that no air bubble got entrained in the bottles. All the sampleswere properly labeled,having been carefully collectedwith disposable hand gloves and stored in an ice box. Therewerearound 3900water samples,collected and tested throughout the study period for ammonia.

RESULTS AND DISCUSSIONS

Figs.2 and 3 show the monthly Maximum and Average levels of ammonia concentration in the raw water of Sitalakhya, extracted at the intake of Dhaka water treatment plantsfrom2003 to 2017.

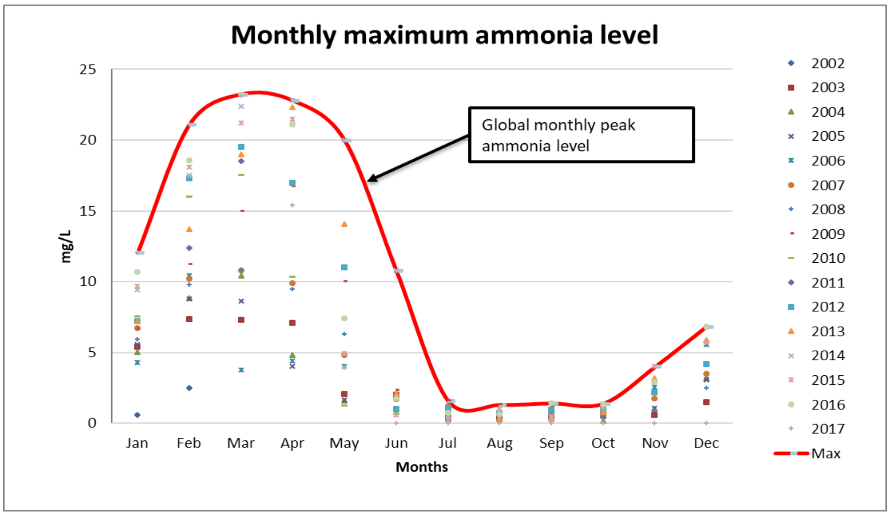

Fig. 2. Trend of the monthly maximum ammonia concentration value over the study period

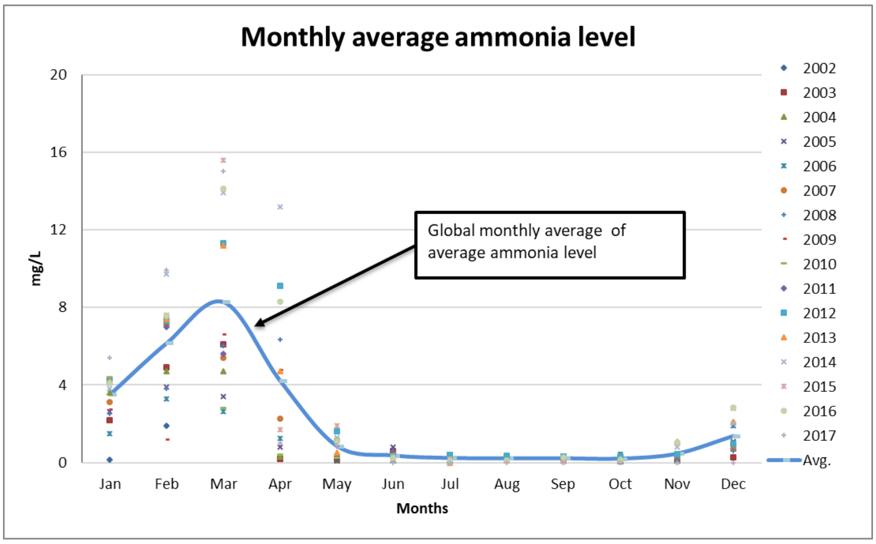

Fig. 3. Trend of the monthly average ammonia concentration value over the study period

As it can be seen in the graphs, theconcentrations is low between June andOctober, but starts to rise sharply until March – April, thenceto plummet, thus giving a more or less symmetric shape. The reasonbehindis the adequate water flow in the river during June – October, i.e., the wet season, dilutesammonia concentration. The water level at the intake generally ranges from 0.9 m PWD to 5.1 mPWD in dry and wetseasons, respectively(IWM, 2006);however, the difference between lowest and highest values of ammonia concentration is very prominent and large, being almost 23 mg/L in case of maximum value, and20 mg/L for the average. It is a matter of concern that even the minimum value reaches up to a concentration of 15mg/L. For the past ten years, the minimum value has been movingbetween 7 and 15 mg/L in the acute dry season. Considering the critical months of dry seasons, February to April, the forecasted 80% dependable flow is 36.2 m^3/ sec atthe intake location of the treatment plant [DWASA. 2014]. Assuming the average ammonia concentration during this time is 15 mg/L,the net increase in ammonia concentration with respect to the expected value will be11 mg/L,resulting in34 tons of additional ammonia per day discharges from the external sources other than natural sources.

It canbe saidthat in the same raw water and over the same period,a notable increase has been found in the concentration ofother parameters as well, like COD, turbidity, color etc., which has beendiscussed in other papers [Degremont, 2010; DWASA, 2007;Serajuddin, 2011; Sida, 2006]. Theaverageconcentrationoftubidity,color, and COD in the dry months have been found tobe 6.8, ২১, and ৪৮mg/Lin 2003,১৯, ৪৬, ১০৮ mg/Lin 2008, andX, ২০, ৬৪ mg/Lin 2017 with COD concentration of ২০০৩ being unknown.

It can be seen from these graphs that with exception of 2006 the maximum ammonia concentration never remainedwithin the limit of 4 mg/L throughout the full dry season (January to April).

During the extended dry season (Nov. - April) throughout the whole study period, out of one hundred seventy-five months, only six months (3.43%) contained less than 4mg/L ammonia, i.e., out of 1804 days in the dry seasons (November to April.), the plant tackled above 4 mg/L of ammonia every day for1530 days (about 85% of total dry season).

It can be said here that similar to EU

and other western and eastern countries guidelines,the raw water to be used as source water for abstraction of drinking water (Category A3) must not contain more than 4 mg/ L of ammonia [EU Council Directives, 1975; GOB, 1997; Govt. of France, 2007; Govt. of Malta, 2002; Indian Standard, 2012; WHO, 1996; USEPA, 2006& 2011].

It is noteworthy that since the start of Plant II'soperation in January 2013,which was equipped with a biological pretreatment unit, the maximum concentration of ammonia in the raw water was below 4 mg/L,only in November of 2013 to 2016,.

Figs. 4 to11 show the individual month-wise trends of maximum and average concentration of ammonia during the study period.Test resultsof all samples,which was around 3900 water samples taken consistently a sample per day during the dry season (from November to April) and three samples per week during the wet season (from May to October) as per sampling protocol across fifteen years of study period,were taken into considerationfor investigation.

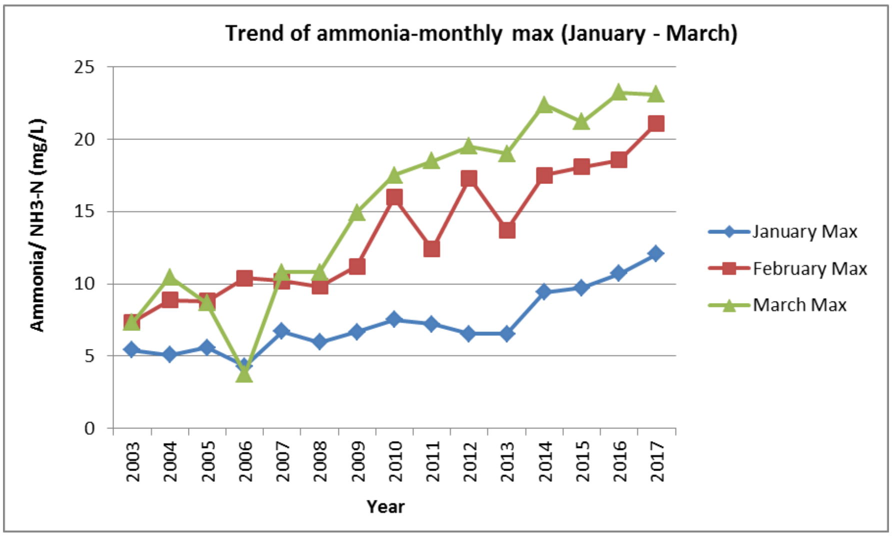

Fig. 4. Trend of the each monthly maximum ammonia concentration value over the study period

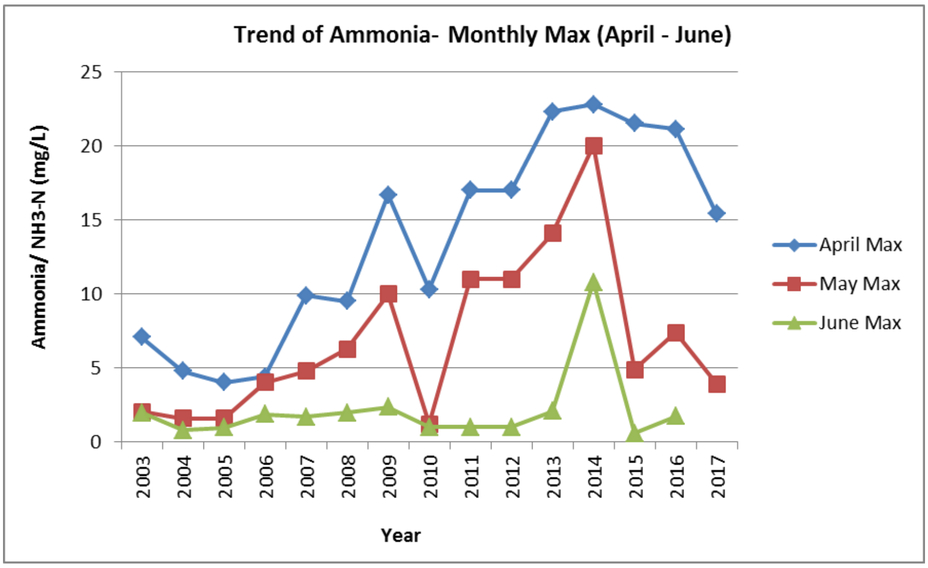

Fig. 5. Trend of the each monthly maximum ammonia concentration value over the study period

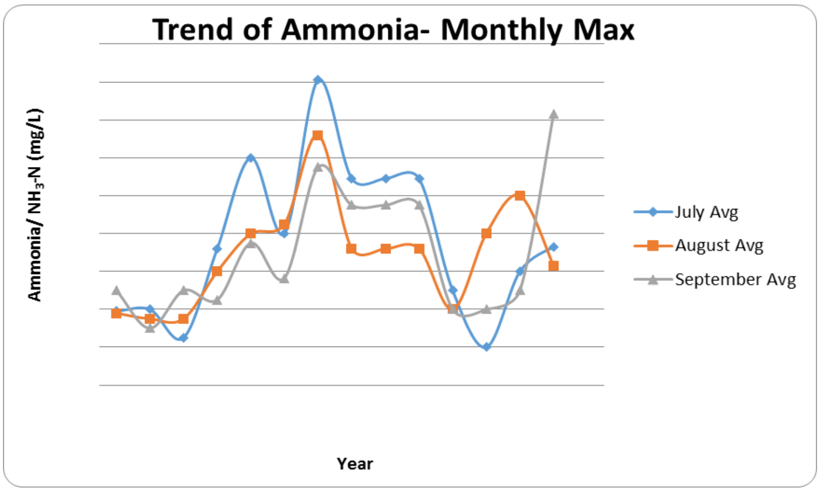

Fig. 6. trend of the each monthly maximum ammonia concentration value over the study period

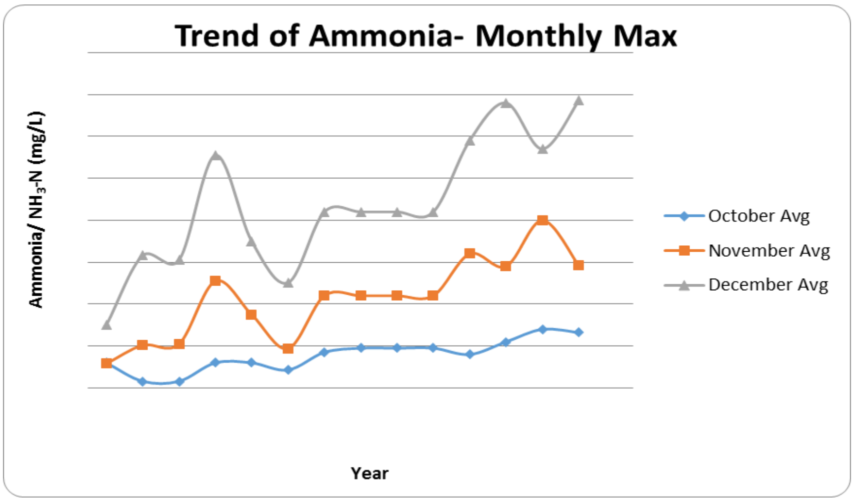

Fig. 7. Trend of the each monthly maximum ammonia concentration value over the study period

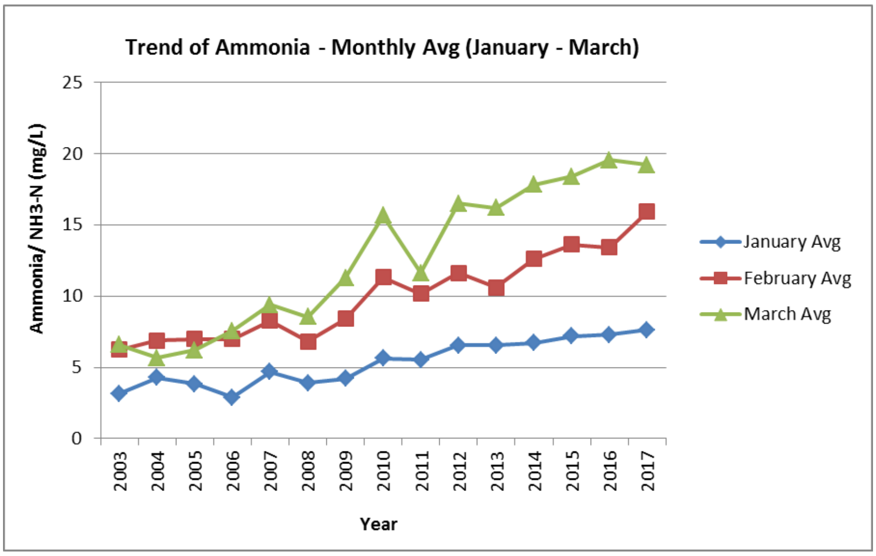

Fig. 8. Trend of the each monthly average ammonia concentration value over the study period

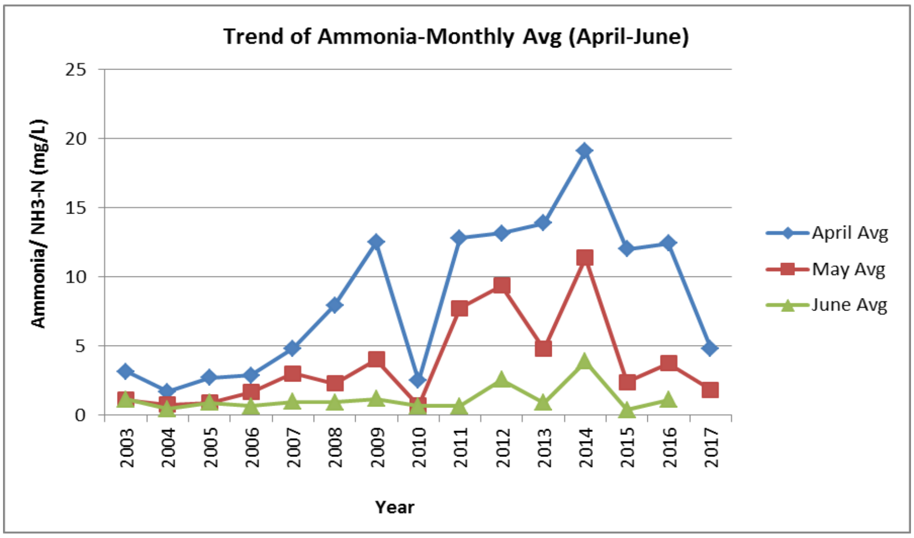

Fig. 9. Trend of the each monthly average ammonia concentration value over the study period

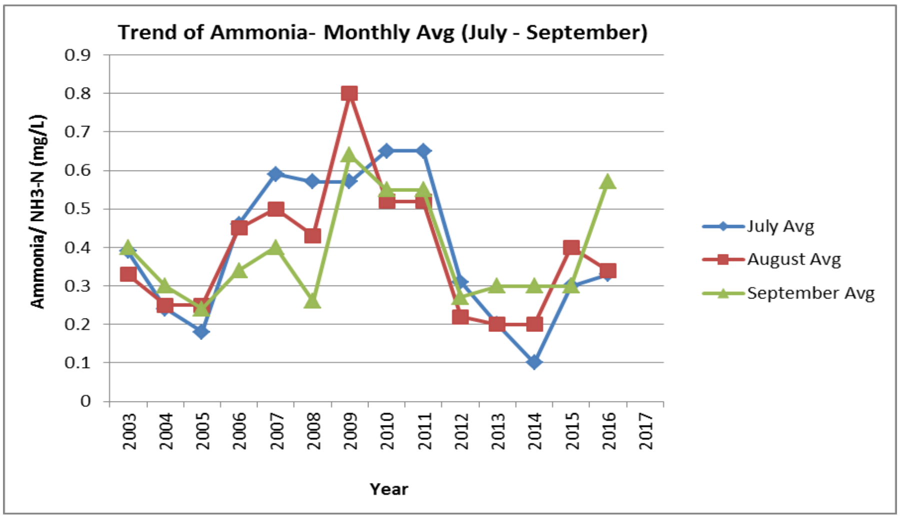

Fig. 10. trend of the each monthly average ammonia concentration value over the study period

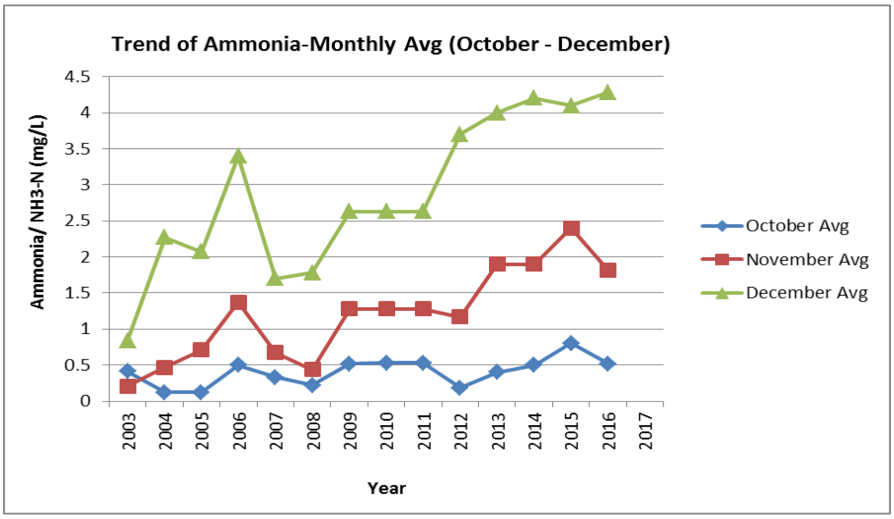

Fig. 11. Trend of the each monthly average ammonia concentration value over the study period

Fig. 12 illustrates a trend line with the statistical regression analysis of the yearly maximum values of ammonia concentration for the study period. The coefficient of determination was also derived, showing R^2 value equal to 0.927, indicating an excellent correlation. By extending this line, we noticed that by 2025, the maximum value might become 35 mg/L and by 2030,40 mg/L. Similarly, Fig. 13 demonstrates separate graphs for each consecutive five-year periods, since the beginning of the study period,showing that during the first five years, the yearly increase rate was 0.685mg/L;inthe next five years,1.92 mg/L;and in the last five years,0.208mg/L. The increase rate in the middle five years (2008–2012) was the highest, showing an R^2 value of 0.7931, while in the first five years (2003-2007),it was 0.5522, which was quite fair. As for the last five years (2013–2017), the R^2 value was 0.2082, signifying that the correlation was not fair andno definitive correlation could be drawn,there.

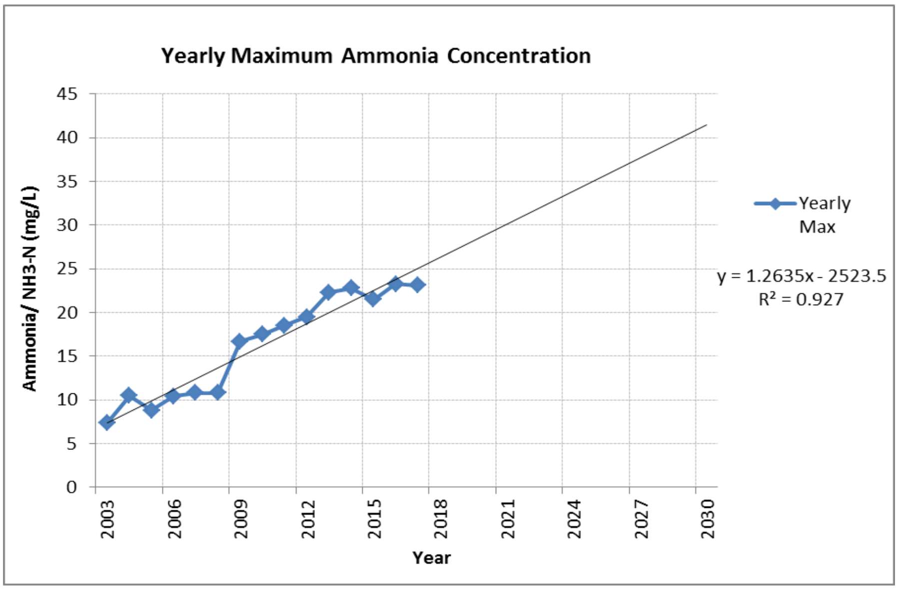

Fig. 12. Trend of the yearly maximum ammonia concentration value over the study period

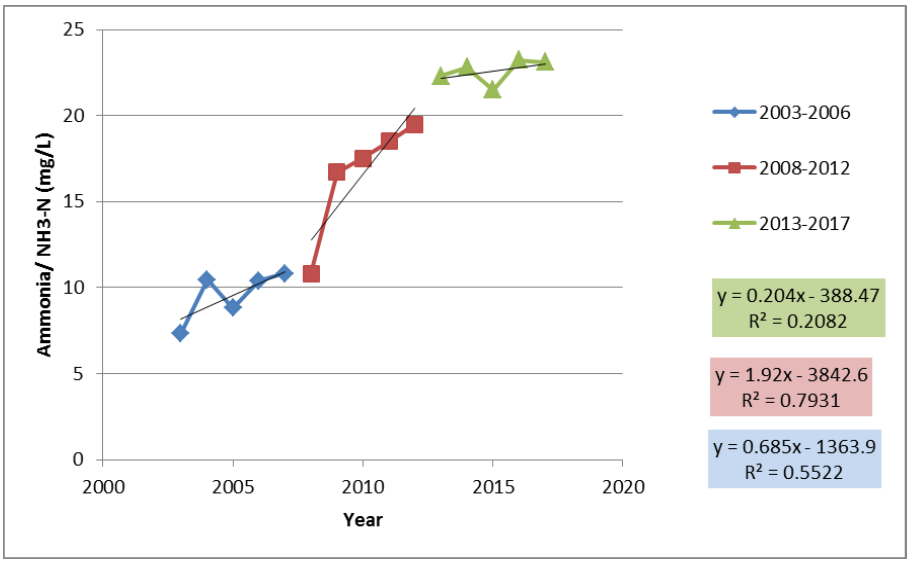

Fig. 13. Five yearly trend of the yearly maximum ammonia concentration value over the study period

Fig. 14 shows the yearly trend of highest average ammonia concentration. With R^2= 0.932,the correlation proved to be excellent, indicating that the highest average concentration values would reach around 30 mg/L and 35 mg/L in 2025 and 2030, respectively.Similarly, the R^2 values for the separate graphs of each consecutive five-year periods (Fig.15) werequite good, too. Virtually, Fig.15 is a modified extended version of Fig.14, showing the same data,yetdividedinto three consecutive periods, each five years long and in a sequential order. This figure shows the difference in correlation coefficient among the first, the second, and the third five-year periods.

Finally, considering only the extended dry season (November–April), Fig. 16 and 17 showthe yearly average of the average concentrationsas well as the yearly average of the maximum values of ammonia concentrations.R^2value in these two figures is 0.912and 0.939, respectively.

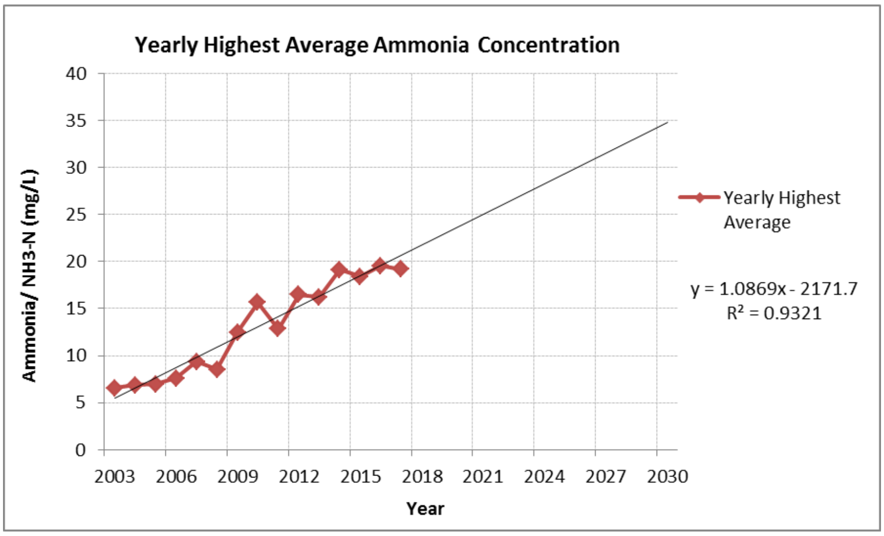

Fig. 14. Yearly highest average ammonia concentration value over the study period

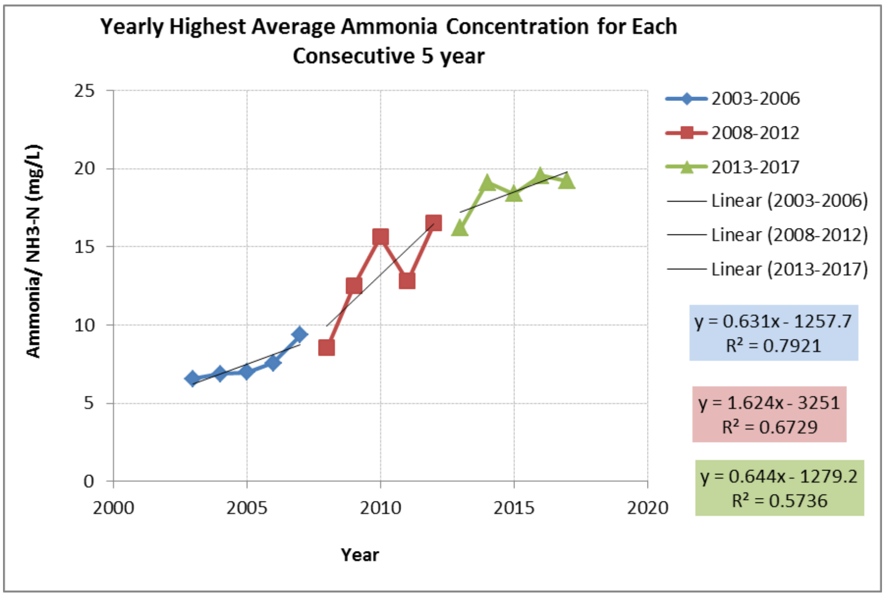

Fig. 15. Yearly highest average ammonia concentration value for each consecutive over the study

These two graphs indicate a very alarming situation, in which the average of maximum values of ammonia concentration will become21 mg/L in 2025 and 24 mg/L in 2030. Similarly, the yearly average of ammonia concentration'saverage values, by 2025 and 2030 will be 15 mg/L and 17 mg/L, respectively,meaning that by 2025, for the dry period the plant will have to treat 15 mg/L ammonia in average, which is a big challenge.

Excessive ammonia in the raw water interferes with both the chlorine disinfection process and free chlorine residual maintenance in the distribution system. Decreased disinfection efficiency as well as taste and odor problems is expected if the drinking water, containing more than 0.2 mg/L ammonia, is chlorinated, since up to 68% of the chlorine may react with the ammonia and become unavailable for disinfection. Required disinfection may not be achieved in water, containing ammonia unless breakpoint chlorination has been reached prior to the distribution. In Dhaka, the ammonia trend is so alarming that breakpoint chlorination is impossible for the water. The presence of 1 mg/L ammonia nitrogen in raw water may require 8 to 10 mg/L of chlorine dose to achieve breakpoint chlorination. In addition, ammonia in water may negatively affect the effectiveness of some water treatment processes [Darren, 2011; Water security agency, 2017; WHO, 1996; Water quality Association, USA, 2013].

Ammonia can cause toxicity in aquatic living organisms along with oxygen depletion and occurrence of eutrophication. Ammonia can also increase oxidant demand, causethe filters fail removingthe manganese, and corrode copper alloy pipes and fittings. Moreover, a major concern with ammonia in drinking water is nitrification, associated with the formation of nitrites and nitrates [Department of Human Services, 2000], which can cause health problems. The formation of nitrates in concentrations, exceeding the internationally acceptable limit,has been found to occur inDhaka, though rarely [Sida, 2006].In case nitrates are not taken care of, short-term exposure to drinking water with a nitrate level at or just above the health standard of 10 mg/l nitrate-N, is a potential health problem primarily for infants. Babies consume large quantities of water relative to their body weight, especially if water is used to mix powdered or concentrated formulas or juices. Also, their immature digestive systems are more likely than adult digestive tracts to allow the reduction of nitrate to nitrite. In particular, the presence of nitrite in the digestive tract of newborns can lead to a disease called methemoglobinemia[Feig Stephen, 1981]. In Dhaka the 20% of treated drinking water from the surface sources are well blended with 80% treated water, coming from underground, thus offsetting any probability of health risk from this situation.

Another health concern is the formation of excessive chloramines,due to the addition of chlorine to water systems [Water quality Association, USA, 2013]. However, the presence of di and tri chloramines in the treated waterinDhaka isvery negligible due to non-favorable pH, during the treatment [NHS, Scotland, 2001].Increasedammonia also leads to excessive algae development. Trihalomethanes (THMs), halogenated acetic acids (HAAs), bromates, chlorates, and chlorides are other concerns with a high dosage of chlorine-based disinfectants [WHO, 1996].

Due toalmost unlimited solubility of ammonia and ammonium salts in water, ammonia is not readily removed from water by conventional treatment systems. It cannot be filtered or precipitated in any way. Heating will drive off some of the free ammonia, but will not remove the dissolved or ionized forms. Ammonia may be removed by Ion exchange, distillation, or reverse osmosis, but such systems can be expensive to purchase and operate. They require careful design, sampling, and maintenance to ensure effectiveness [Department of Human services, Oregon, 2000].

It is a widely discussed fact that in general, Dhaka's rivers are being polluted by the discharge of untreated industrial effluent, urban wastewater, agrochemicals, sewage water, storm runoff, solid waste dumping, oil spillage, sedimentation, and also illegal encroachment of canals and rivers, which increases with population growth[Azimuddin,2011;Dalwar, 2005; Didar, 2015; GOB,2010; IWM, 2005; Ibrahim, 2015; Naushad, 2006; Serajuddin, 2009; Shahidul, 2011; Shishir, 2009; S. Roy, 2006].

Estimationsshow that there are over 12,000 industries in Dhaka metropolitan area,mostly located in three clusters, namely Hazaribagh, Tejgaon, and Dhaka-Narayanganj- Demra dam area (Shahidul, 2011). It has been found that 61% percent of untreated liquid wastecomesfrom industrial and 39%from domestic sources [IWM, 2005, Shahidul, 2011]. Seventy percent of city population does not have access to improved sanitation facilities [Sahidul, 2011]. The fertilizer factories,washing plants, the leachate of the waste dumping sites, and the open drained domestic waste are the main sources of ammonia in raw water.The concentration of ammonia in the collected samples of surface water in Dhaka, wherein the effluent of a textile industry wasdischarged, varied from 62.37mg/L to 98.52 mg/Lwith the average value of ammonia being81.28 mg/L [Khalid, 2014].

Currently, industry owners, under pressure, are constructing Effluent Treatment Plants (ETPs) to comply with the rules of Department of Environment [GOB, 1995, 1997];however, they are reluctant to operate them as a result ofhigh recurring chargesfrom imported ETPs;hence untreated wastes are continuously discharged intowater bodies [Sahidul, 2011].

It has becomelong overdue that all stakeholders have to be careful regarding future man-made willful reckless pollution. The continuous pollution by the vested quarter is going onincessantly,making water system operation a challenge for water issue authorities and a nightmare for city denizens.

ConclusionsandRecommendations

The rivers surrounding Dhaka are the lifeline of the city, the history of which is attuned with the history of both the country anditsculture and development, in general, and whosefuture will determine the destiny of the citizens of the country.

To protect the river the provisions of both ECA (As amended up to 2010) and the ParibeshAdalatAin(2010) should be strictly enforced.The decreefrom High-Court Division of the Supreme Court of Bangladesh on June 23, 2009, toclosethe industries in case of failingto install effluent treatment plants as well asother appropriate pollution-fighting devices by June 30, 2010 should have been enforced [Shahidul, 2011]. In this regard, provisions of monetary incentives, rewards, and recognitions for polluters thatreduce their pollution may work effectively. The polluters should be commanded to shoulder the responsibility of cleaning them under auspices of DoE [GOB & UNDP, 2010].Indigenous low-cost water treatment process with locally available chemicals as developed in BUET should be made mandatory for the industries [Quader, 2010]and public awareness should be raised concerningthe discharge of untreated effluents along withits consequences. The surrounding rivers of Dhaka city have already been declared critically sensitive zones by the Government. The biological pretreatment for ammonia removal, employed on the present site has continued judiciously and,if needed, a de-nitrification unit could be installed after proper feasibility.

The efficient solid waste management system should be introduced andcontinued [Shahidul, 2011]. The whole city should be brought under formal sewerage system as soon as possible [GOB & UNDP, 2010].Like many other countries of the world, implementation of a “Water Police Brigades” system that reports to the court may be enacted in Bangladesh, too.

The upcoming projects of larger-capacity water treatment plants are to be planned at a clean and safe water source. As the immediate measure, the water authority has already started implementingthree large treatment plants, abstracting water from big rivers like Padmaand Meghna, both several kilometers away from the city of Dhaka.

Indiscriminate discharge of untreated industrial effluents and domestic wastes into the rivers has already turned almost all of them into a moribund condition. If the raw water continuesto deteriorate in such a manner, it may end up with a situation whereinthe denizens of Dhaka will water shortage,since the plant has to be shut down, whenever it receives excessively high ammonia. Only one day of shutting down the plant means that at leastthree million people will be directly out of water supply [Serajuddin, 2012], whichis really beyond imaginationin a city like Dhaka. If the situation does not change, Bangladesh will face serious consequences. Every stakeholders have to act to save the rivers from pollution,thus saving Dhaka from becomingabandoned due to lack of potable water.

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