Scholars Journal of Engineering and Technology
OPEN ACCESS
Abbreviated Key Title: Sch J Eng Tech
ISSN 2347-9523 (Print) | ISSN 2321-435X (Online)
Journal homepage: https://saspublishers.com

The Concentration of Organic & Ammonium Pollution and their Relationship in River Water: A Case Study

Md. Serajuddin[1*], Md. Aktarul Islam Chowdhury[2], Md. Mahmudul Haque[3], Tanzir Ahmed Khan[4]

[1]Senior Specialist, Institute of Water Modelling, Dhaka, Bangladesh
[2]Professor, Department of Civil & Environmental Engineering (CEE), Shahjalal University of Science & Technology, Sylhet, Bangladesh
[3]Associate Specialist, Institute of Water Modelling, Dhaka, Bangladesh
[4]Water Supply Engineer, DOHWA Engineering Co., Ltd., Seoul, South Korea

DOI: 10.36347/sjet.2024.v12i02.006 | **Received:** 15.12.2023 | **Accepted:** 22.01.2024 | **Published:** 10.02.2024

***Corresponding author:** Md. Serajuddin
Senior Specialist, Institute of Water Modelling, Dhaka, Bangladesh

Abstract **Original Research Article**

Bangladesh's largest water treatment plant sources its water from the Shitalakshya River, which is facing serious problems of organic pollution and ammonia contamination, particularly during the dry months of November to April. This study examines the extent of organic and ammonia pollution in the river and their relationship with each other. The study analyzed daily samples of raw water quality parameters, such as COD and NH_3-N concentrations, from 2013 to 2018 only from the dry months, using standard laboratory methods at Dhaka's largest drinking water treatment plant. During the study period, the global average COD and ammonia concentrations in the dry months were 37.8 and 9.2 mg/L, respectively. These concentrations ranged between 10.6 to 76.3 mg/L and 0.98 to 19.54 mg/L in individual months respectively. The global yearly maximum COD and ammonia concentrations were respectively, ranging from 13 to 127 mg/L and 1.63 to 23.24 mg/L in individual months. These maximum levels occurred in March and April. The monthly minimum concentrations of COD and ammonia varied between 6-42mg/L and 0.17-15.6mg/L, respectively. It is noteworthy that the global average figures are higher than the recommended levels for drinking water sources after conventional treatment. The study found a distinct increasing trend in the maximum values of COD and ammonia concentration over time. Both the average and maximum values increased by around 0.5 mg/L every year. A statistical linear regression between the maximum COD and the ammonia concentration across the years showed an excellent strong correlation marked with an R^2 value of 0.93,0.88,0.95 respectively for maximum, minimum and average values, indicating a potential common origin for these pollutants. If this trend of pollution persists, the authorities will need to modify the treatment chain to ensure that the supply of drinking water is not affected.

Keywords*:* Dhaka, Shitalakshya River, Water Supply, Ammonium, COD.

1. INTRODUCTION

The construction of Saidabad Surface Water Treatment Plant Phase I in Dhaka, the largest water treatment plant in Bangladesh, commenced in 1999, and the plant began operating in mid-2002. During the first dry season (early 2003) following commissioning, issues related to odor and color in the treated water emerged, posing challenges in meeting drinking water standards. There was an initial assumption linking these problems to algae removal difficulties, believed to be caused by increased ammonia concentrations in the raw water. The raw water, particularly during dry months (December-March), was found to have higher ammonia concentrations (DWASA, 2007). However, it was also assumed that environmental deterioration, driven by industrial advancements and population growth, contributed to water pollution and waste disposal issues (Subari *et al.,* 2022).

Amid ammonia concerns, the excessive presence of organic matter in the river's raw water during dry months remained overlooked. Organic matter, composed of carbon-based pollutants like plants and animals, naturally contaminates water. Municipal, agricultural, and industrial wastes, major sources of surface water pollution through runoff, are organic. Despite being omnipresent, the impact of organic matter on water quality was underestimated.

The organic pollutants in the surface water are generally called Natural Organic Matter (NOM). NOM is a complex heterogeneous mixture of organic compounds, consisting of aromatic, aliphatic, phenolic, and quinonic structures with varying molecular sizes and properties. The complexity and heterogeneity of aquatic NOM have made its structural and functional characterization extremely difficult. Yellow-brown colour is observed due to the presence of NOM in water. However, even when water appears colourless the level of organics in the water may still be high. Unfortunately, the NOM has no direct measurement. Typically, NOM chemical characteristics is dependent on the biodegradable dissolved organic carbon (BDOC) content in water sources. The presence of NOM has a significant impact on the quality of drinking water sources (Matilainen *et al*., 2011). NOM removal is a primary concern for water treatment engineers (Ghernaout *et al*., 2011; Liu *et al*., 2015), as it contributes to taste and odor issues, transports metals and harmful organic chemicals, and interferes with conventional water treatment processes (Baghoth *et al*., 2012).

Indeed, NOM is the primary precursor for carcinogenic disinfection by-products (DBPs) such as trihalomethanes (THMs) and haloacetic acids (HAAs) that can form during chlorination (Rook, 1974; Rook, 1977; Rice and Gomez-Taylor, 1987; Gang *et al*., 2005; Roccaro *et al*., 2008; Chow *et al*., 2009; Kristiana *et al*., 2011) and if present in the supplied water contributes to bacterial regrowth and biofilm formation in drinking water distribution systems (Ghernaout *et al*., 2011). NOM's drawbacks include acting as a carrier for pollutants, causing coloration, competing for adsorption sites, supporting biological growth, influencing coagulant and disinfectant dosages, and causing membrane fouling (Frimmel, 1998; Abbt-Braun and Frimmel, 1999; Ahmad *et al*., 2002; Matilainen and Sillanpaa, 2010; Huang *et al*., 2011).

Although ammonia in drinking water does not pose a direct health concern, nitrification of ammonia (i.e., the conversion of ammonia to nitrite and nitrate by bacteria in the presence of oxygen) in the drinking water distribution system may, specifically, nitrification in the drinking water distribution system may lead to potential corrosion problems, oxidant demand, difficulty in maintaining desired disinfectant residual, excessive biofilm growth, taste and odor complaints, and elevated nitrite and nitrate levels (Lee *et al*., 1980; Rittman and Snoeyink, 1984; Suffet *et al*., 1996; Wilczak *et al*., 1996; Bremer *et al*., 2001; Fleming *et al*., 2005;). In addition, ammonia in water may negatively affect the effectiveness of some water treatment processes, including arsenic removal (Lytle *et al*., 2007). Last, water systems that have ammonia in their source water may have problems maintaining free chlorine or chloramine residual, achieving required microbial disinfection requirements, and meeting disinfection byproduct formation limits. Thus, the presence of organic compounds and ammonia both in excessive quantity in the raw water makes the water treatment issue very complex. Analyzing data from the raw water intake up to the year 2006 revealed:

- Ammonia (NH_3-N) levels below 0.5 mg/L in the wet season, spiking to 10 mg/L or higher during the dry season.
- Ammonia contamination of the Shitalakshya river (>2 mg/L) expanded from January-March to November-April.
- Similar patterns were observed in BOD (Biological oxygen demand), COD (Chemical oxygen demand), TDS (Total dissolved solid), and conductivity.
- BOD value reached up to 20 mg/L.
- BOD to COD ratio varied between 1.5 and 2.

In conclusion, the authority faced a complex situation with intensified organic pollution during the dry season. It became evident that ammonia wasn't the sole concern; pollution levels indicated a growing problem with wastewater.

Under the circumstances, the extent of organic pollution in terms of surrogate COD and ammonia pollution and their mutual interrelationship has been examined in this study. Primarily daily tested raw water quality parameters namely COD and NH_3-N concentrations were used from the laboratory of the largest drinking water treatment plant in Dhaka from 2013 to 2018. Besides, water quality data from earlier times available in the archives of the plant were also used. The water quality data particularly of the dry periods of the year (November-April) has been dealt with in this paper.

With this background, this study was initiated, whose primary objective was to analyze quantitatively the latest concentration levels as well as their trend for sixty months continuously (November 2013 –April 2018) of the two water pollution indicators namely COD, and ammonia for a specific surface water source, river Shitalakshya which is the source of the largest surface water treatment plant in Dhaka (SWTP), Bangladesh by comparing with the water quality guidelines in use. In addition, establish regression equations among them and calculate correlation coefficients between the parameters to identify their relationship. Thus, by knowing one of the parameters, one can estimate another parameter fairly.

2. METHODOLOGY

2.1 Study Area

The study area is Dhaka, the capital city of Bangladesh, with a population of more than fifteen million, located in the central part of Bangladesh. The city experiences a distinct monsoonal season, with an annual average temperature of 26°C. Monthly means vary between 19°C in January and 29°C in May, sometimes reaching 40°C. Approximately 87% of the annual average rainfall of 2,123 millimeters occurs between May and October. Dhaka is situated at 23°42′N & 90°22′E, on the banks of the Buriganga River and surrounded by other peripheral rivers. The largest water treatment plant in the country is located beside the Shitalakshya River in the eastern periphery of Dhaka city at Latitude 23°43'11.25"N & Longitude 90° 26' 14.25" E (Serajuddin *et al*., 2018). The raw water from the intake of this plant was collected and used for this study (Figure 1).

2.2 Sample Collection and Analysis

Although the climate of Bangladesh is mainly subtropical monsoon, i.e., warm and humid, the Bangla calendar year is traditionally divided into six seasons: Grisma (summer), Barsa (rainy), Sarat (autumn), Hemanta (late autumn), Shhit (winter), and Basanta (spring). Each season comprises two months, but some seasons flow into others, while others are short. Indeed, Bangladesh has three distinct seasons: the pre-monsoon hot season from March through May, the rainy monsoon season which lasts from June through October, and a cool dry winter season from November through February. From the operational experience of the Dhaka treatment plant, it is revealed that river water quality can be broadly grouped into two distinct periods of the year in terms of the quality and quantity of water available at the river intake, namely the dry season (November-April) and wet season (May-October). The water quality parameters were grouped into two distinct periods (rainy and winter seasons).

During the dry period, water quality is very poor, and in the wet period, it is comparatively better, accompanied by very low flow and large flow at the river, respectively. Water samples were collected from the first 20-30 cm of the water column along the plant intake during both dry and wet seasons, covering all the months around the year using a pre-sterilized two-liter plastic bottle, repeatedly washed with water from that site, and tested for some physical, chemical, and bacteriological water quality parameters required for this study. Water samples were collected during the years 2013–2018 (November 2013–April 2018). The collected samples were transferred to the laboratory of the plant, following the precautions laid out by standard methods (APHA, 2005). pH, DO, temperature, turbidity, chlorophyll, and conductivity were determined within the field of collection and cross-checked later on, while other parameters like COD, Ammonia, Color, TSS, E. coli, etc., were analyzed in the laboratory within the stipulated period following the standard method. For correlation analysis, the monthly average data were used. A total of more than five years of seasonal data were used for statistical analysis.

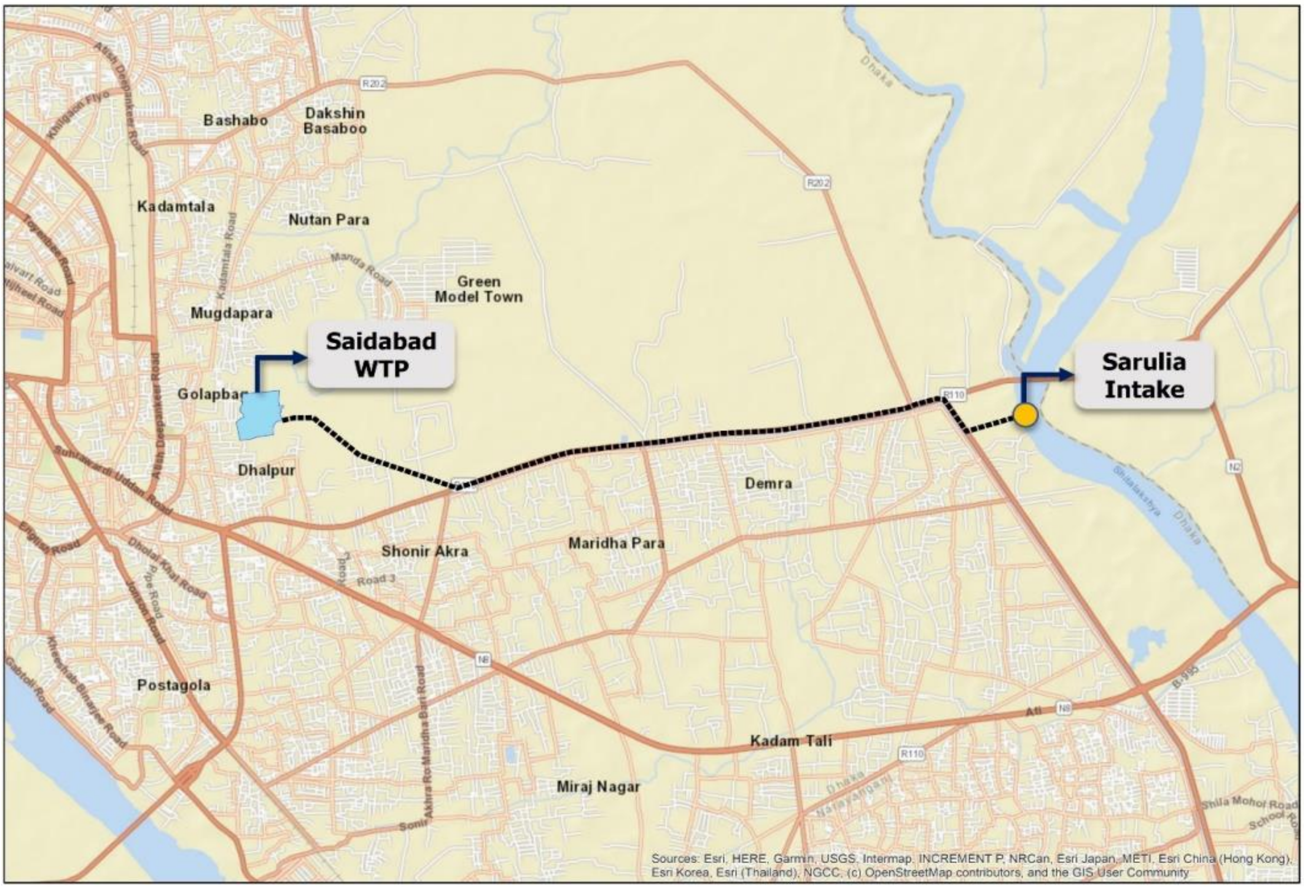

Figure 1: Raw water source and its transmission network from Shitalakshya River to SWTP

2.3 Statistical Analysis

Statistical analysis was conducted using analytical tools available in the Excel spreadsheet program. The physicochemical parameters for all the studies were analyzed by calculating Pearson's correlation coefficient (r) value to assess the relationship between water quality variables. The degree of association that exists between two variables is measured by the correlation coefficient (r), where one is taken as the dependent variable, and it represents the mutual relationship between two variables. When an increase or decrease in the value of one parameter is associated with a corresponding increase or decrease in the value of another parameter, then a direct correlation exists between these two variables (Kumar *et al.*, 2006; Jothivenkatachalam *et al*., 2010). In terms of the strength of the relationship, the value of the correlation coefficient varies between +1 and -1. When the value of the correlation coefficient lies around ± 1, then it is said to be a perfect degree of association between the two variables. As the correlation coefficient value goes toward 0, the relationship between the two variables will be weaker. The direction of the relationship is simply the + (indicating a positive relationship between the variables) or - (indicating a negative relationship between the variables) sign of the correlation. After that, the correlation for significance was tested by applying a p-value (Khatoon *et al*., 2013; Patel and Vaghani, 2015). The variations are considered significant if p is 0.05 or less. Significance is considered at the levels of 0.01 and 0.05 (2-tailed analysis). Correlation is a bivariate analysis that measures the strength of the association between two variables and the direction of the relationship (Grum *et al*., 1997; Vervier *et al*., 1999).

3. RESULTS AND DISCUSSIONS

The water quality data of the dry periods of the year (November- April) has been dealt with in this paper. It is found that the global monthly average of COD in the study period's dry months varies between 10.6 to 76.3 mg/L and the global average of monthly average in the study period stands at 38 mg/L (Figure 2). The figure is quite high in comparison to the recommendation as per ECR 1997 for the source of drinking water for supply after conventional treatment (BOD 6 mg/L) equivalent to 14 mg/L for COD (Serajuddin & Chowdhury, 2017). The minimum monthly average was found 10.6 mg/L in November 2013 and the maximum was 76.3 mg/L in February 2017.

The global monthly maximum COD during the study period was between 13 to 127 mg/L (Figure 3) and mostly happened in March and April. The global average of the monthly maximum COD during the study period is 59 mg/L and the minimum of the monthly maximum COD over the period is 13 mg/L. The monthly minimum concentration of COD varies between 6 to 52 mg/L (Figure 4). The global average of monthly minimum COD during the study period is 22.43 mg/L. The maximum monthly minimum is found in March 2018.

Analysis shows that the ammonia concentration has rapidly increased over the years, especially since 2010. Minimum monthly Ammonia levels during the study periods are found to be between 0.17-15.6 mg NH_4-N/L. The global average of the monthly minimum ammonia during the study period is 5.82 mg/L. The higher minimum monthly ammonia concentrations are found generally in March & April. The global monthly average ammonia in the dry months varies between 0.98 and 19.54 mg/L. The global average of the monthly average values is 8.64 mg/L. The higher monthly average values are found in March & April. The maximum monthly average during the study period is found in March 2016.

The global monthly maximum Ammonia levels in the study period varies between 1.63 to 23.24 mg/L. The global average maximum monthly concentration of ammonia is 13.01 mg/L during the study period. The higher maximum monthly values of Ammonia occurred also in March-April of the year. The maximum monthly maximum ammonia in the study period was found in March 2016. The average, minimum, and maximum values of Ammonia concentration follow a distinct increasing trend with time. The average and maximum values both increase by around 0.5 mg/L every year with a trend of continuation in the future which will make the existing treatment process of the plant inadequate. It is found that the percentage of average ammonia to average COD during the years 2013-2018 is between 20-29 % and the ratio of maximum ammonia to maximum COD varies between 14-54 %, with most figures between 24-38 %. A statistical linear regression between the COD and the Ammonia concentration across the years showed an excellent strong correlation marked with an R^2 value of 0.93, 0.88, and 0.95 respectively for maximum, minimum, and average values, indicating a potential common origin for these pollutants. If this trend of pollution continues the authority has to modify the treatment chain to keep the drinking water supply unhindered.

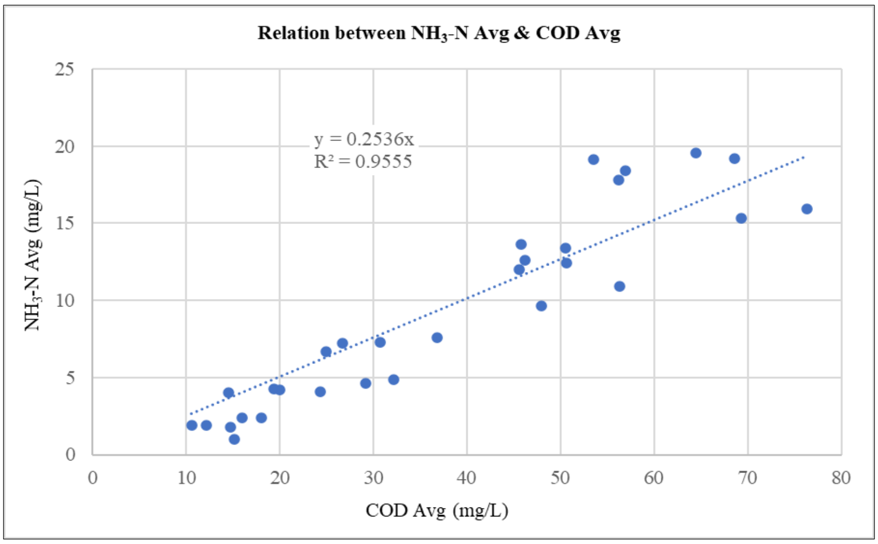

Figure 2: Relationship between monthly average of COD & Ammonia

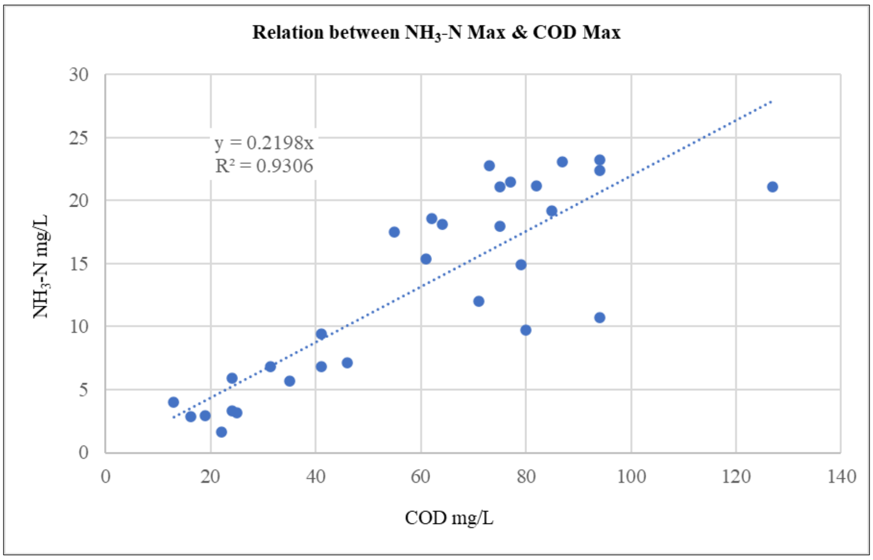

Figure 3: Relationship between monthly maximum of COD & Ammonia

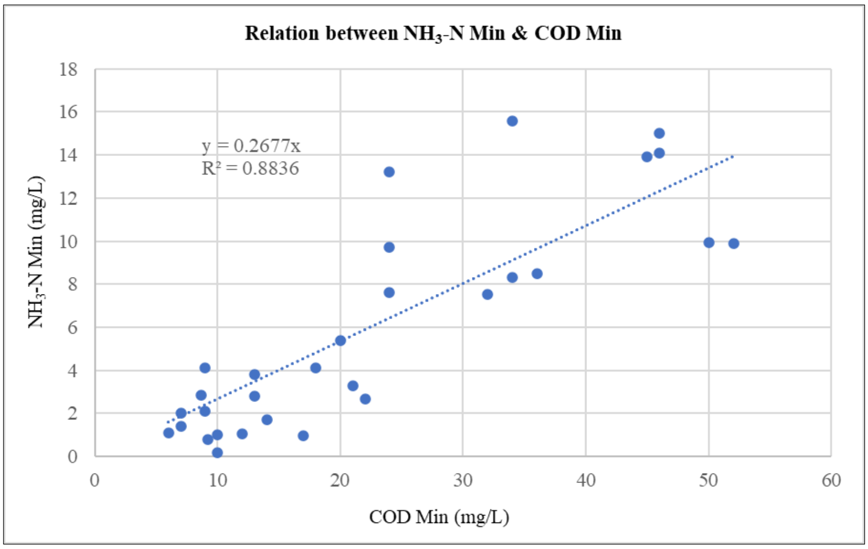

Figure 4: Relationship between monthly minimum of COD & Ammonia

4. CONCLUSIONS AND RECOMMENDATIONS

This paper emphasizes that the much talked about and noted presence of excessive ammonia in the Shitalakshya river water during the dry season is also accompanied by huge organic pollution. Probably ammonia & organics originate from the same sources of pollution. The abnormal simultaneous increase of ammonia and organics in the dry months reiterates the fact that Shitalakshya river water is mostly polluted by industries. 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 (IWM, 2005; Rahman, 2005; Alam *et al*., 2006; Biswas *et al*., 2009; Serajuddin, 2009; GoB and UNDP, 2010; Azimuddin, 2011; Islam, 2011; Roy *et al*., 2014; Islam and Azam, 2015; Sabit, 2015). The attention of the public, as well as the concerned authorities, is needed for proactive strategies on how to handle the resulting present & future challenges lest talking to regulatory measures.

Acknowledgements

It is our pleasure to convey appreciation to Dr. Jean Claude Seropian, who and other professionals from M/s SUEZ International cooperated in this study.

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