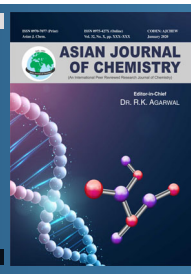
Asian Journal of Chemistry; Vol. 32, No. 4 (2020), 827-834

ASIAN JOURNAL OF CHEMISTRY

https://doi.org/10.14233/ajchem.2020.22347



An Overview of River Side Pollutants and their Effects on Physico-Chemical Changes in Water Quality of River Halda, Bangladesh

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Received: 21 July 2019; *Accepted*: 22 November 2019; *Published online*: 25 February 2020; AJC-19799

Halda is an important river of Bangladesh, is now polluted in different ways through industrial, agricultural, domestic and sewage disposal. Increased anthropogenic activities have increased the potential pollution of the river and excessive pollutants may be toxic to humans and aquatic fauna. Presence of heavy metals in the river water causes perilous impact on the aquatic organisms. Hence, regular monitoring of pollution levels in the river is indispensable. In this study, we discuss about physico-chemical assessments of water quality parameters *viz*. pH, dissolve oxygen (DO), biochemical oxygen demand (BOD), chemical oxygen demand (COD), total solid (TS), total suspended solid (TSS), total dissolved substance (TDS), total alkalinity, turbidity, salinity, electrical conductivity (EC), hardness, chloride and heavy metals in the water of Halda river during rainy and winter seasons, at different points; sources of pollutants in water and their effects given starting from the early research until the current research.

Keywords: Halda river, Physico-chemical assessments, River side pollutants, Fish culture, Heavy metals.

INTRODUCTION

Water is an important element of our life and it is the most useful natural resource on earth. Rivers are the most important part of earth's water cycle. It is the only unique elements of ground that makes everything greener. Rivers are carrying million tons of ground water towards the sea which plays an efficient and prominent role in sculpting earth's topography [1]. Moreover, ground water traditionally has made major contribution to all forms of development of this world from the ancient time. Still now big cities are developed on the banks of a river [2]. It plays a crucial role for the development of city areas as well as in village areas. River water is the lotic type of water *i.e*. flowing water body that is running and the whole water body is flowing in a definite direction [3,4]. Moreover, river water is use for innumerable rural and urban communities and livestock, fish culture, recharge of ground water, control of floods, shipping, *etc*. [3]. In progress, water control and utility management governing by traditional, human-built infrastructure and the enormous potential for NBS (Nature based solutions) remains under utilized. It also includes green infrastructure may be which substitute, enlarge or work in parallel with grey infrastructure in a productive manner [5].

Industrial progress plays an imperative rule for development of economic growth in fact it has also negative impact [6]. Rivers and industries are intimately related to each other but only industrial activities may affect nature in different ways. Anthropogenic activities such as discharge of domestic and industrial effluent and other major activities have accelerated considerable pollution to river [5,7]. Ever-growing industrialization for steady development is causing concern to the pollution of surface water because almost all industries are disposing or releasing off their waste immediately to the nearby water source without making any treatment and violating the provisions for standard laid out for the same [8]. Industrial wastes are known to adversely affect natural life by direct toxic action of indirectly through qualitative alternations in the character of the water as well as that of the stream bed [9,10]. Now a day very few companies are practicing waste water treatment using ordinary method which is insufficient and discharging insuffici-

ently treated waste into the rivers or streams makes deadpan problem to aquatic flora and fauna [5]. Due to haphazard industrialization bathe water quality is being humiliated continuously [6]. Polluted water reduces fish production and availability of fish and also has an impact on other aquatic resources in the water [11]. Discolour of wastewater is the cause of disinfects on biota and also prohibit the photosynthetic activity by lessening the daylight [10,12]. Few researchers mentioned that rivers around the cities are continuously eroded of their capacity to sustain fish and other aquatic life and are polluted to a point where their use as domestic sources of water and for recreational and other purposes rendered impossible. As a result, river pollution control of populated areas is becoming increasingly a concern of Urban Environmental Management (UEM) [13]. The physiology of areas the river regimes has changed and causing problems of water adulteration due to various types of unnatural man-made activities. Urbanization is the main reason of pollution for all form of water bodies [14]. The water in south Asia is being contaminated noteworthy and now a day it becomes serious problem in Bangladesh. Both expanding population and a warming climate risk further worsening the already compromised situation. We need a renewed commitment to water quality evaluations and by rigorous assessment of efforts to improve the water quality [8,15]. Bangladesh is an in-advanced country in terms of industrialization having only 6,000 large and medium scale industries. Third Asian ministerial meeting of the ESCAP region countries in Jakarta October 1987 focused on management of industrial effluent, water quality and rehabilitation of polluted rivers as their coordinated activity in this region [16]. UNEP predicted that the future will be predominantly urban and most immediate environmental concern of most of the people will be metropolitan ones. The world is being swiftly urbanized especially in the Asian countries [17]. Ever increasing population, unplanned modernization of south Asian countries like Bangladesh are posing problems of sewage, disposal and contamination of surface waters mainly lakes ponds and river [18,19]. A rapid interpretation of river water quality is a compulsory since river is a dynamic ecosystem, influenced by various activities on the river bank [20].

At present, Bangladesh observe express industrial enterprise, in the recent decays this process was less significant based on primarily agricultural raw materials [21]. Now a day industrial product and residues have higher limit of toxicity for the territory like fertilizer manufacturing, textile, tanneries, pulp and paper, oil refineries, paint, power plant companies, construction sites, *etc*. [22]. In the developing country, like Bangladesh most of these factories are located near the river because of the sustainability of transportation. Changes in the course of rivers made by Bangladesh, rivers are said to be the life belt of this country [23]. Now river water is not the main source of drinking purpose but on the healthy existence of river gives the periodic endurance of millions of people of this country in circumstances of irrigation, bathing, washing, shipping and fishing practices [24]. Moreover, rivers are treated as major sources of drinking water of big cities like Dhaka and Chattogram. Since from 1980′s, water supply coverage of Bangladesh has been broadening both in big and small city areas [25]. Industrial employees and/or daily wages workers are absolutely unaware about the natural hazard due to the open disposal of effluents and other wastes near the water bodies. Further upstream withdrawal and scarcity during dry season affect all wetlands of the country [26]. This may contribute to the degradation of water quality parameters as impurities of such contains variety of inorganic, organic, soluble and non-soluble pollutants like plastic, dyes, salts, suspended solid, oil, grease, phenols, xylene, *etc*. [12,27,28]. All forms of effluents from industrial establishments cause the modification of physical, chemical and natural properties of aquatic environment by counting change in colour, temperature, odour, pH, turbidity and alkalinity and to the original quality of water may be harmful to public health, live-stock, wildlife, fish and other biodiversities [29,30]. The change in water quality varies owing to a change in physical and chemical properties of the underlying sediments and aquifers [15,22,31]. There are about hundreds of big rivers in Bangladesh and all rivers have its own geographical, hydraulic, sediment logical and biological characteristics affect river ecosystems. Though these rivers bear a huge potential for fisheries sector, but relatively little is known [16,32,33]. This river is geographically isolated from other major rivers very much famous as a natural interbreeding ground of Indian major carp (ICM) and reproduction field of Bangladesh, possibly in South Asia [34,35].

Halda river originates in the Batnatali hills from halda chora area of Hasukpara, 2 no. Patachora union in Ramgarh upozila under Khagrachhari district of Bangladesh. It comes crossing downwards with other small chora and keeping off the higher hill regions to the north and south past Narayanhat, Bojpur, Bibirhat, Fatickchari then it passes through plain land of Hathazari, Raozan and Kotwali of chittagong which form basin [36] and finally falls into the Karnafuli at Kalurghat. The major tributaries of Halda river are Manikchari, Dhurang, Talpari and Sareakhal [37,38]. Forest resources like timber, bamboo, sungrass from the southern parts of Ramgarh upazila are floated down the river and the bulk of merchandize from Chittagong town is carried up in big cargo boats. It is a flashy river and is 88 km long. Bangladesh Water Development Board (BWDB) has 13 hydrometric stations on it, and data are available since 1959 [23,39,40].

Halda river is one of the most valuable rivers in Chattogram city after Kornofulli river and is only tidal river in the world from where fertilized eggs of carps are collected during the breeding season. It's unique features and importance made as a most valuable river both for environment and country. There are no rivers found in the world where extracting Rui type fish fertilized eggs and collect them directly in native manure from a tidal river [41-43]. Resources, financial contributions and some distinct features of Halda river deserve breeding traditions of Bangladesh. But due to lack of information and promotion of national heritage and identity of the river still hidden. From immemorial time the river has been the richest natural spawning ground mainly of four species of IMC (*Catla catla*, *Labeo rohita*, *Cirrhinus mrigala* and *Labeo calbasu*). This is the only tidal river of Bangladesh from which naturally-produced fertilized eggs of major carps are collected and hatched in the mud-made scoop on the river bank and has long been the source of naturally-produced carp fry for country's pond culture [29].

This river is one of the vital sources of hatch and post-larvae of monstrous freshwater shrimp (*Macrobrachium rosenbergii*). An easy accumulation of coastal, estuaries, riverine, floodplain, migratory fin fish and shell fish occupy in Halda river [18]. Other than fishery there are numerous uses of this river *i.e.*, navigation, irrigation, sand extraction bamboo and sand transportation and supply of drinking water to the Chattogram metro city residents. The river is delivering by hundreds of hilly streams outset from its root, including 12 far reaching tributaries. This is one of the prime contributing rivers to the national economy of Bangladesh. The total value in million US $ segmented contributions of fishing, fish fry, irrigation, drinking water, water passage and sand extraction respectively were 0.07, 0.005, 15.78,1.33, 0.12, 2.51 [41]. According to a study the assets of this river are being diminish day by day by the reasons of changes in water quality, cutting off of existing oxbow bands, sedimentation on the river bed, unplanned sluice gate establishment, over-fishing, shortage of sanctuaries, change in ecological system, lack of proper assessment of brood fish and management of the broods at their origin, immense sand quarrying, water contamination by industrial wastes, denudation of various species of fishes towards gradual extinction including carps, unchecked riverbank erosion and above all global climate change [9,23,40,43].

Halda river has been under constant threat because of man-made hazards, including industrial wastes, sewage contaminations and sand extractions [44]. Halda river is losing fish species at a alarming rate and recently it lost 26 of its fish species because of water impurities and an ailing biotic community due to the dams and dikes built on both side of the river [45]. Water qualities play an important role for the production of fisheries [9,46]. This article covers the study of some sorts parameters of the properties of the this river water which is extremely polluted by the wastes coming out from different industries set up at the bank of the river or at a place which is indirectly through water to Halda along with different human activities. Water quality can be assessed by its physical, chemical and biological components [47]. River Pollution Index (RPI) has been used in analyses of water quality [48] and also indicated that water from rivers at Kalurghat and Modhunaghat varied (Table-1) from low to high dirtiness, which is due to the former area′s being mostly industrial zone with some domestic sewage, while the latter underwent less industrial activities [40] on the contrary, lots of agricultural activities have been found in Modhunaghat. Climate changes could have a significant impact on the hydrology of the catchment area, which supplies water to Chattogram and is the major piece culture center in Bangladesh. A major portion of the country′s pond carp culture is dependent on these wild seed [49]. But it is widely accepted that aquatic diversity of Bangladesh including this river has not been described statistically [50,51]. This river provides favourable physico-chemical factors for the carps and creates a congenial environment for their spawning during monsoon between April and June [52]. For the implementation of National Biological dissimilarities Strategy and Action Plan, it is important to manage some of the separate elements of which biodiversity in composed [13,40]. Though most of the polluted rivers are the lifeline of this country but those rivers will soon become lifeless river if we can stop polluting now [40,49,53]. This study has been designed to find out the current status of different physico-chemical assessment of water quality parameters like pH, DO, BOD, COD, TS, TDS, alkalinity, turbidity, electrical conductivity, hardness, chloride and heavy metals in the water of Halda river, at different points; sources of pollutants in water and their effects given starting from the early research until the current research, in order to facilitate further studies on this fauna by interested researchers [13,40].

Different types of pollutants present in Halda river: The water quality of the river is being contaminated regularly by the direct and indirect disposal of the industrial wastewater, solid wastes, domestic and municipal garbage and agricultural run-off to the river [23,54,55]. The most fundamental reason of river water pollution is the surrounding industries like chemical, dying, tanneries, *etc*. [56]. In common usage "pollutants" is a term which is applied usually to non-living man made substance or other nuisances and it refers to their being in excess in a particular to location [57,58]. It is also caused by chemical substances such as (excessive use of fertilizer and insecticides) the runoff that finds its way into waterways from factories, bazar, sewage treatment facilities, drainage of municipalities and physical debris such as solid substances, plastic bottles, and polythene begs or rubber tires [53]. The previous study showed that the river water quality of Halda river was highly degraded because of the presence of various waste product discharged from riverside manufacturer or agro firm mainly of Hathazari and Chattogram cities. Moreover, almost 36 channels through which the pollutants from industries and tanneries discharge to this river. Khandokia khal released maximum toxicants from tanneries and textile industries into the river [41].

Now a days, several small industries are located near lower stream of this river and never the less held responsible for discharging their effluents into water like highly poisonous heavy metals such as zinc, chromium, cupper, arsenic, lead, mercury, *etc*. along with hazardous acids, alkalis, cyanides, chlorides, sulphate, nitrates, *etc*. This river receives wastes from textile, jute, power generator, paper and pulp mills, tanneries,

TABLE-1
RIVER POLLUTION INDEX (PRI)

Water quality/item	Non (slightly)-polluted	Lightly-polluted	Moderately-polluted	Severely-polluted
Dissolved oxygen (mg/L)	DO ≥ 6.5	6.5 > DO ≥ 4.6	4.5 ≥ DO ≥ 2.0	DO < 2.0
Biochemical oxygen demand (mg/L)	BOD ≤ 3.0	3.0 < BOD ≤ 4.9	5.0 ≤ BOD ≤ 15.0	BOD > 15.0
Suspended solids (mg/L)	SS ≤ 20.0	20.0 < SS ≤ 49.9	50.0 ≤ SS ≤ 100	SS > 100
Ammonia nitrogen (mg/L)	NH_3-N ≤ 0.50	0.50 < NH_3-N ≤ 0.99	1.00 ≤ NH_3-N ≤ 3.00	NH_3-N > 3.00
Point scores	1	3	6	10
Pollution index integral value	S ≤ 2.0	2.0 < S ≤ 3.0	3.1 ≤ S ≤ 6.0	S > 6.0

plastic, rubber and pesticide industries. Most of these pollutants are resistant to breakdown by microorganisms, therefore damage the growth of crops and even the polluted water is not safe for industrial, domestic or other purposes [59]. The large number of water polluter of this river may be broadly classified under the following categories:

Pathogens: Pathogens of river water can be bacteria, protozoa or viruses. Two of the most common pathogenic bacteria *viz.* coliform and *E. coli* bacteria were found in the river [9,41]. Presence of *E. coli* usually mentioned by different researchers indicates that water has been contaminated with human, animal wastes and sometimes from floating of dead animals [41].

Inorganic compounds: Industrial process has resulted in the introduction of heavy metals like arsenic, mercury, iron, copper, chromium, barium, zinc, *etc*. into this river water [30]. This can be due to leaching from waste disposal, increased human activity or industrial accidents. Ammonia, nitrates, sulphates and phosphates are some inorganic pollutants, which were found in the river [23,41,59].

Organic materials: Most frequently detected organic materials of this river water were oil products, plastic, pesticides, solvents, detergents, *etc*. [40,41]. Likely some more unknown organic substances were present, which may be responsible for some environmental degradation of this river [53,60].

Salinity: Bangladesh has a deltaic location and topography, which causes the increasing salinity. Salinity intrusion is an important weather parameter was found as the main natural risk for this river [8]. The people of Chattogram city are facing serious water problem in the dry season because of salinity. During the dry season, due to the rise of sea level sea water intrusion into the Halda, Karnafuli, Sangu and Naf rivers will destroy the biodiversity of these rivers for increasing salinity. Because of high salinity of the river water in recent years, it could not be used by the Chattogram Urea Fertilizer Limited (CUFL) to fulfill their requirements [7,36,41] argued that inadequate flow released from Kaptai dam is another reason for increased salinity in the river basin of this river. Moreover, release of 20 % of untreated garbage from Chattogram city to the Karnafuli river and this river are identified as one of the main problems of salinity and quality of water in river [40].

Macroscopic pollutants: The pollutants which are large in size and visible items in waterways or bodies of water called macroscopic pollutants [30]. Huge amount of solid wastes and effluents are discharged through different canals from Fatikchari, Raozan, Hathazari and kalurgat of Chattrogram into the river; contains macroscopic contaminants [36]. The first common polluter of this river is trash: especially plastic wastes. Plastic and polybag wastes are often thrown directly into river water illegally. Other types of macroscopic waste waters include small plastic pellets, pieces of wood, metal and even noticeable things such as shipwrecks and shipping containers [36,40].

Sediments: Sedimentation is a long-term process happened when soil and sand are carried by flood water through different Khals from croplands and municipalities [54,56]. Regular effects of human impact and climate change on sediment appear to enhance downstream sediment transport delivery in rivers [56, 61,62]. Due to a regular exchange of particulate matter between sediments and the water column causing dissolved metals to be released [63,64]. Soil particles large amount of nutrient matter some other organic and inorganic insoluble substances. Soil erosion, deforestation, oxbow cutting, sluice gate, rubber dam and sand extraction from different streams of this river responsible for sedimentation in the lower part of this river [41,52].

Suspended substances: The suspended substances consist of non-soluble soil or mineral participles, other organic and inorganic substances were found in this river [23]. Mainly abiotic components of this type most were commonly seen around the bazar region where thousands of people use terminals, bus stops, drainage, residential areas, bridge of the river side [40,41].

Thermal pollutants: Degradation of water quality by any process that changes ambient water temperature is called thermal water pollution [13]. A common source of thermal pollution in this river is the use of water as a coolant by power plants, brick field and industrial manufacturers. Moreover, global warming and various salts coming from sea increases water temperature [56].

Radioactive materials: Radionuclides found in water were radium and potassium-40. These isotopes come from natural sources due to leaching from minerals [18]. Water bodies were also contaminated by accidental leakage of waste material from research laboratories and diagnostic center and hospitals which frequently use radioisotopes [49,59,65].

Sources of pollutants in river Halda: Surface water of Bangladesh is completely unprotected from runoff pollution from chemical fertilizers and pesticides and industrial effluents as well as wastewaters of densely polluted catchments [9] and thus despite abundance of water from various sources surface water being polluting and has always been the question of quality [66]. In Chattogram, industries are located mainly at Barabkunda, Fauzdarhat, Bhatiary, Kaptai, Nasirabad, Patenga, Sholashahar and Kalurghat and wastewaters from Nasirabad industrial area (mainly chemicals, leathers, textiles and steel re-rolling industries) were discharged into surface drains that ultimately carry it to the Halda and Karnaphuli river [67]. This also endangers the drinking water supply in Chattogram by polluting water at the intake region of Mohara, Modhunaghat and Rangunia water treatment plants [68].

Halda river wastewater has various known and unknown sources. These can categorize as:

Point and non-point sources: Pollution caused from a single source, such as an outfall pipe directly to water, is known as point source pollution [3]. Liquid waste coming from sewerage and industrial waste pipes are easily identified example of this type. There are several point sources of Halda water misuses mainly rubbish wastes, solid and hazard wastes disposal, urban and rural drainages, dumping daily wastes, floods and intensive animal husbandries [26,36,52,69]. Pollution originating from diffuse sources rather than from one discrete location is known as non-point source pollution [23]. There are several types of land use activities that can serve as sources of non-point source in this river water including land construction, construction, sand extraction, firming and crop production, animal feeding lots, timber harvesting, failing septic systems, landfills, roads

and paved areas and wildlifes [56,70]. The most common non-point source of this river water is runoff that carries pesticides, insecticides and fertilizer from agricultural fields.

Natural and anthropogenic sources: An increase in the concentration of naturally occurring pollutants *e.g.*, soil, sand, wood straw, leaf and mineral particles is called natural sources [27]. Few common natural phenomena′s, which occurs in Halda water bodies are indiscriminate deforestation makes soil loose and flood waters bring silt from upper hilly region into lower streams [9,18,71]. It can also be arising with different frequencies to the river most important source of surface water. Some sources of pollution may discharge impurities randomly, while others may release only some interval or seasonally [53,72,73]. Thus, sources of pollution can also differ periodically or cyclically. All the previous studies showed that Halda is being polluted by untreated waste seasonally from different sources mainly industries, agricultural, irrigation, trash, tobacco firming, rubber dam, sand extractor, brick field, construction, bazar, house-holds, *etc*. Most serious conditions were found during the dry season.

Recently, it has been observed that an industrial belts in Bayazid, Kulgaon, Aman bazar, Fotheabad and Nondirhat discharge the industrial wastes through different canals [33]. It was found that several industries even had not set up an effluent treatment plant (ETP). Several industries exposed liquid tannery wastes in their drain and also household wastes from Bayezid-Oxygen areas of the city was flowing into the river directly [33,39,42,45].

Surface water quality of the rivers of Bangladesh is highly polluting day by day [22]. River water quality degradation is closely related to increasing anthropogenic activities in catchments, such as increasing wastewater discharge, intensive land use pattern and excessive fertilizer application [56,72, 74]. Earlier agriculture was a natural process that did not mistreat but not long-ago farmers are unable to perform any firming without fertilizers and pesticides. Both biotic and abiotic by-products of farming practices in the river basin result in contamination of the river. From the previous study, it was found that this river becoming polluted, even beyond the level of maintenance. In the last few years, tobacco farming has increased 50-folds in the area of upper Halda [40].

Pesticides and insecticides like organochlorines, organophosphates and carbonates are toxic to the pests which also tend to bioaccumulate [33,36,41]. This can be passed up the food chain of different fishes of this river. Pesticides are not only discriminatory in nature also cause harm to several microorganisms which help to build ecosystem of river. Applying before rainstorm can lead to fertilizer runoff and the production of algae causes deoxygenates the water. Moreover, due to poor management of loss of soil material around river bank causes drop off to the river depth [66,75].

Paddy field always uses huge amount of water from Halda river or its tributaries for irrigation which reduces significant volume of Halda river water. The soil or sediments carried off into river water bodies cause a lot of catastrophic [21,76,77]. Sedimentation reduces the amount of sunlight reaching the water beds affecting the plants and animals living in it and also turbidity causes interferes with the feeding patterns of the fishes and affects their population.

In recent years, salinity intrusion is another major issue of this river ecosystem [78]. The people of Chattogram city are facing serious water problem in the dry season because of salinity. Besides, crop land of river bank is significantly affected, and this reduces the production of crops [23,36]. From the different studies, it is found that the degradation in Halda river due to erosion, over flow, irrigation, water logging, fish habitat salinity intrusion, dredging, excessive use of fertilizer and insecticides, rubber dam, siltation and sluice gate. The Kaptai dam and job transformation also plays a significant impact and responsible for the causes of the anthropogenic environmental degradation of river ecosystem.

Impact of pollutants in Halda river: The effect of pollution on water bodies depends on source as well as environmental conditions and also depends on the type of pollutants. For example, polluting at the parts of high river flow may result in lowering of contaminants than the same discharge released of low river flow [74]. Once a water source, such as a river or ground-water aquifer, is polluted, it could remain contaminated for a very long time. Pollution prevention and management strategies must take into consideration the amount and timing as well as its interaction with variable natural conditions with different season [78]. Impurity in the water column can undergo chemical transformation, be taken up by aquatic animals or plants, flushed downstream, or adsorb (attach) to aquatic sediments. Some pollutants can persist for years in sediments and can be re-released into the water column depending on environmental conditions (*e.g.*, pH, dissolved oxygen levels). This form of water impurity is arguably the most manageable, however it is an urgent environmental issue that these larger of aquatic ecosystems and contamination upon the chemical breakdown of these objects. When water used as a coolant is returned to the natural environment at a higher temperature, the sudden change in temperature decreases oxygen supply and affects ecosystem composition [79]. These results in thermal and leads to the imbalance in the ecology of water bodies of a river. Fish and other aquatic organisms can get affected by a sudden change in water temperatures [11]. Decreases solubility of oxygen, thermal plants in water, disrupts aquatic ecosystems, natural erosion and runoff affects water quality, reduces agricultural land and construction fish population sites [80,81]. Poor quality water may affect irrigated crops by causing accumulation of salts in the root zone, by causing loss of permeability of soil due to excess sodium or calcium leaching, or by containing pathogens or contaminants which are directly toxic to plants or to those consuming them.

Most importantly, depth of the river becomes very narrow due to sedimentation [9]. The sediments may damage the water bodies by introducing a large amount of nutrient mat. Reducing water quality due to dumping of dead animals, dissolve oxygen is getting lower and salinity is increasing in this river and carp eggs cannot sustain the high salinity of seawater [13,67]. It was also mentioned that the decrease in upstream flow increases salinity intrusion from downstream of the river. Salinity has indirect impact on spawning [82]. One of the main reasons for the fall off aquatic biodiversity of wild stock resource of this river is undesirable fishing gears and technique used for fishing. Due to oxbow cutting the normal flow of the river is

interrupted and that's why the aquatic ecosystem is degrading and for these reasons lesser number of brood fish lying eggs on Halda river [8]. In Bangladesh, fish is generally used in a regular meals in every household. Heavy metals react with protein, DNA and RNA, affecting the metabolic processes and with other substances, resulting in the physiological changes. The lead toxicity affects the nervous system, both in adults and children [18].

Importance of Halda in the prospect of Bangladesh: It is well known that Bangladesh is an agricultural country but having serious call into questions an ascending demand of underground water pressure, droughts floods and other natural disasters due to climate change and population increasing with unplanned industrial growth, swage and sanitation [39,40,45]. The water supply coverage in Bangladesh has been increasing both in urban and rural areas since the 1980′s. However, almost 88 % of water is withdrawn for irrigation & animals activities while just 10 % and 2 % for household chores and industries, respectively. Total irrigation withdrawals were 118,000 Mgal/d, causes for 42 % of total freshwater withdrawals. Withdrawals from surface-water sources were 60,900 Mgal/day, causes for 52 % of the total irrigation withdrawals. Groundwater withdrawals for 2015 were 57,200 Mgal/day.

Recent studies on physico-chemical assessment of Halda river water: Bangladesh is a small country having hundreds of water resources. Though it is neither big nor small, Halda is one of our main water resources flowing south-east part of the country. This zig-zag river features possess a one and only environment that differs from other. Now days, this river is facing serious ecological and environmental changes from different position all the places. River pollution is a matter of concern all over the world [21,66]. Pollution is the main threat of this river. Last 50 years researchers are working to know the causes of different types of pollution assessing water quality parameters and its impact. All the studied has been summarized that the physico-chemical parameters influencing the water purity, aquatic productivity and biodiversity of the river water bodies. Studied of this river water quality can be concluded that the condition of the river is critical, affected by the polluted Karnafully river, contamination from different industries, salinity, domestic wastes and agrochemicals. Moreover, sand extraction, sluicegate, rubber dam, brickfields changes the water flow causing serious problem to fish production [33,40]. The third Asian ministerial meeting of the ESCAP region countries in Jakarta October 1987 focused on management of industrial effluent, water quality and rehabilitation of polluted rivers as their coordinated activity in this region and after that ESCAP in year 1991 observed about 30 % of the country′s territory and about 33 % of the population are affected by salinity of the supplied water. Despite the importance of this river only a few studies on the side pollutants and water quality parameters are available and detailed report on the hydrological conditions of the river Halda has not yet been made.

In year 2010, Sarwar *et al*. [18] investigated the water quality of Karnaphuli river in Chattogram, Bangladesh. They have analyzed 15 sampling points for various physico-chemical parameters during winter and observed effects of industrial waste. Moreover, they had suggested monitoring of water flow in Karnaphuli river must be under monitoring and people should be aware of the possible future threats on water pollution.

A comprehensive study on environmental flow assessments in Halda river was performed by Akter *et al*. in year 2012 [23]. These authors assessed the water flow with different return periods from 2002 to 2005 in two stations using the log reason types 3 distributions (LP3) and observed extreme water levels at panchpukuria, Nazirhat, Telpari and Enayethat station. They recommended for comprehensive awareness program, investigations and trade off-analysis. Ahmed *et al*. [9] assessed the physico-chemical parameters of surface and groundwater quality of river water at greater Chattrogong situated at southeastern Bangladesh. Tables 2 and 3 illustrate a comparative study of physico-chemical parameters conducted by different researchers time to time of Halda and Karnaphuli river.

Studies on indirect and non-use values of Halda river was performed by Kabir *et al*. [41] in year 2013. They have estimated the value of basic type indirect and non-use of this river and found total indirect use values of river $ 50 million per year and total non-use value US $ 4.5 million per year. In this study, non-use value of this river calculated greater contribution for the nation.

Similarly, Kabir *et al*. in year 2013 [36] also estimated a economic value of tangible and intangible resources from Halda river using primary and secondary data from January 2011 and January 2012 and found a total of US $ 20.5 million. They had estimated by measuring the total cost of catching fish, prawn, fish fry, sand extraction, water transportation, irrigation, drinking water, *etc*. and found to be a most resourceful river in Bangladesh, which provides a number of products and

TABLE-2
PHYSICO-CHEMICAL HALDA WATER QUALITY PARAMETER DATA FOUND FROM DIFFERENT RESEARCHERS

Parameter	Patra and Azadi [83]	Patra and Azadi [13]	Ahmed *et al.* [9]	Aysha and Hazarat [23]	Islam *et al.* [33]	Bhuyan and Bakar [45]	WHO	ECR	BD standards
	Min-Max	Min-Max	Min-Max	Min-Max	Min-Max	Min-Max	Min-Max	Min-Max	Min-Max
Temp. (°C)	19.5-31	25.5-28	20.3-35.1	23-32	–	–	20-30	20-30	20-30
pH	–	6.4-6.8	7.03-8.6	7.2-7.4	7.1-8.8	6.3-7.3	6.5-8.5	6.5-8.5	6.5-8.5
DO (mg/L)	6.7-13.6	5.5-9.0	3.02-9.90	6.6-7.4	3.35-4.70	0.93-5.15	6	6	6
BOD (mg/L)	–	–	0.70-5.08	1.2-1.5	0.055-5.0	31-545	0.2	0.2	0.2
COD (mg/L)	–	–	14.78-49.28	8-15	–	43-983	4.00	4.00	4.00
TSS (mg/L)	–	–	200-653	288-366	–	–	≤ 20.0	10.00	10.00
TDS (mg/L)	–	–	20-30	66-330	–	–	1000	1000	1000
EC (us/cm)	51.06-145.33	38.64-168.9	72-414.0	140-250	–	110-524	–	–	800-10k
Turbidity (mg/L)	127.5-450.0	2.5-8.9	–	25-90	–	–	10	10	10

TABLE-3
CHEMICAL WATER QUALITY PARAMETER DATA OF HALDA RIVER FOUND FROM DIFFERENT RESEARCHERS

Parameter	Patra and Azadi [83]	Ahmed *et al.* [9]	Aysha and Hazarat [23]	Islam *et al.* [33]	Bakar and Bhuyan [45]	WHO	ECR	BD standards
	Min-Max	Min-Max	Min-Max	Min-Max	Min-Max	Min-Max	Min-Max	Min-Max
Alkalinity (mg/L)	–	6.28-90.78	32-52	73-220	35-67	–	–	–
Hardness (mg/L)	–	9.0-380.00	58.3-69	–	38-121	200-500	200-500	200-500
Salinity (mg/L)	–	–	–	–	–	–	–	–
NO_3-N (mg/L)	–	0.00	2.1-3.0	0.12-3.1	–	50	10	–
PO_4-P (mg/L)	0.1325-0.2225	0.73-4.28	0.3-0.5	0.06-0.14	–	0.80	0.6	–
Cl^- (mg/L)	–	2.41-7.50	7.5-89.5	8.4-69.30	12-56	–	150-600	–

services all-round the year to the communities living its vicinity [33,38,40].

Water quality assessment studies along with the pollution sources of Halda river at Chattogram was performed by Islam *et al*. [33] in year 2017. They have studied four major canals (namely Mondakini, Madari, Cheng khal and khondakia khal) those discharged waste product to this river. The data revealed that pH, DO, BOD showed significant changes at Mondakini canal and chengkhali canal for monsoon. According to them it is being polluted due to industrial wastes, garbage, natural calamity, tobacco farming, rubber dam and sand extractor.

Bhuyan and Bakar [26] in year 2017 also surveyed the surface water quality at two sampling sites from September 2015 to March 2016. They have found some sort of deviation but a very strong positive linear relation between COD and BOD, hardness and EC (0.993), pH and DO (0.979), hardness and COD (0.929), hardness and BOD (0.924), EC and COD (0.922), and EC and BOD (0.916) at a significance level of $p \leq 0.01$, proving their common origin entirely from industrial effluents, municipal wastes and agricultural activities. Same authors [45] had related data with PRI (River Pollution Index) and indicated that the water from rivers at Kalurghat and Modhunaghat varied from low to high pollution (Tables 2 and 3) considering the former area′s being mostly industrial zone with some domestic sewage, while the latter underwent fewer industrial activities. Unplanned, low management system of river bank, industrialization, urbanization and agricultural activities were the prime responsible factors for continuous pollution of river water [2]. However, On the contrary, lots of agricultural activities have been found in Modhunaghat.

Conclusion

The present study concludes that Halda river is being polluted due to carrying industrial pollutants, land wash, urban wastages, sewage discharges, some shipping activities, city run-off, atmospheric fallout, domestic wastes, *etc*. from its surrounding areas mainly from Hathazari. At several places, river water is highly contaminated. Upper stream area side is less polluted because of the residential colony but those areas which are responsible for withdrawing water mainly for agricultural purposes effect river water quality in the lower part. The polluted area with heavy influx of different industrial wastes has drastically reduced the biodiversity in downstream of river. From year 1978 to 2017, there is a large variation in water quality. A decrease in pH, DO, COD, BOD alkalinity and phosphate contents in the water and increase in the value of turbidity, pH, temperature, TS, TDS and hardness.

ACKNOWLEDGEMENTS

The authors acknowledge the research project code: CUET/DRE/2018-19/CHEM/015 of Chittagong University of Engineering & Technology, Chattogram, Bangladesh.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interests regarding the publication of this article.

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