Surface and Ground Water Pollution in Bangladesh: A Review

Article · December 2019

DOI: 10.20448/journal.506.2019.61.47.69

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Asian Review of Environmental and Earth Sciences
Vol. 6, No. 1, 47-69, 2019
ISSN(E) 2313-8173/ ISSN(P) 2518-0134
DOI: 10.20448/journal.506.2019.61.47.69

Surface and Ground Water Pollution in Bangladesh: A Review

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Abstract

Environmental analysis does not become properly meaningful unless follow the standard procedure in sampling, preserving and also in analysis. This study investigates different studies on surface and groundwater pollution and discusses their findings along with impacts on environment, human health and aquatic ecosystem demolition. Fresh water is a vital need for drinking, household, agricultural and industrial use. Fresh water availability is shrinking worldwide due to imprudent use. Abound availability of fresh water in Bangladesh is now polluting due to unwise dumping of industrial, household, agricultural and municipal wastes. Water body in urban arena is severely polluted rather than rural part. The over concentration of DO, BOD, COD, EC, TDS, Cr, Cd, Pb was observed in Dhaka region. The highest arsenic concentration was found in the ground water of Lakshimpur. The main sources of pollution in industrial cities are anthropogenic sources like untreated industrial effluent and municipal wastes whereas in rural part the main sources of pollution are agricultural and naturogenic. Transboundary impact also intensifies some river water pollution. Government approved the policies, ordinance, acts and laws however, due to lack of proper implementation and monitoring water pollution problem increasing day by day.

Keywords: Effluent, Heavy metal, Pesticides, Ecosystem, Pharmaceuticals, Environmental policy.

Citation | Akash Mamon Sarkar; A. K. M. Lutfor Rahman; Abdus Samad; Arjun Chandra Bhowmick; Jahida Binte Islam (2019). Surface and Ground Water Pollution in Bangladesh: A Review. Asian Review of Environmental and Earth Sciences, 6(1): 47-69.
History:
Received: 13 August 2019
Revised: 17 September 2019
Accepted: 23 October 2019
Published: 9 December 2019

Publisher: Asian Online Journal Publishing Group

Acknowledgement: Author wants to acknowledge library of BCSIR and the library of the University of South Dakota for information access.
Funding: This study received no specific financial support.
Competing Interests: The authors declare that they have no conflict of interests.
Transparency: The authors confirm that the manuscript is an honest, accurate, and transparent account of the study was reported; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained.
Ethical: This study follows all ethical practices during writing.

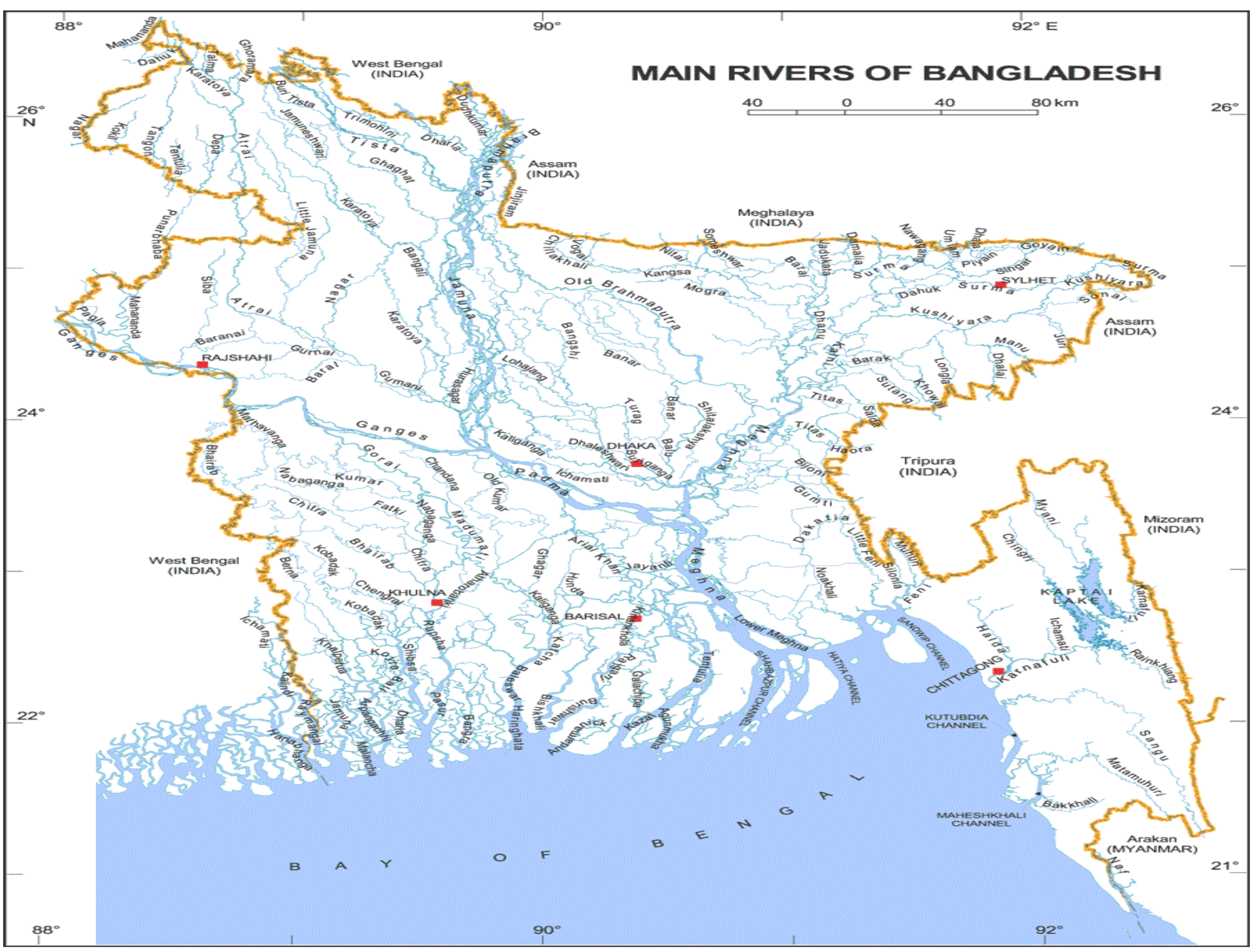
Contents

Contribution of this paper to the literature
This study contributes to the existing literature by investigating different studies on surface and groundwater pollution and discusses their findings along with impacts on environment, human health and aquatic ecosystem demolition.

1. Introduction

Bangladesh after forty four yours of achieving independence entered into the list of lower middle income country in 2016 according to the World Bank. Industrial development policy was upheld by the government in first five year plane after liberation in 1973 [1]. This industrial development policy has been carried out by all the following government unless some alterations even till now. Therefore, agriculture based economy of Bangladesh is gradually shifting into the industry based economy. That industrial journey was significantly started through the establishment of garments and textile industries in the last two decades of previous century. Contribution of agriculture to the GDP in 1981 was 30 % [2] whereas in 2016 that was 14.8 % [3, 4]. Agricultural constant price GDP growth rate in 2016 was 11.1 % and by industries was 32.4 % [3]. However, the contribution of manufacturing sector to the GDP in 1981 was 13 % [2] where as in 2016 that was 29.3 % [3, 4]. Bangladesh is now a middle income country and the Government already has divulged their target to enter in the list of developed country by 2041. To reach that goal, government emphasized the industrial development by local and foreign investment. Eight export processing zones (EPZ) have already been established in response of foreign investment and technology transfer for creating employment opportunities. Recently, an economic zone is going to establish in cox'sbazar area. To support the industrial development, port and power facilities is trying to improve on priority basis. Therefore, construction of the Paira sea port is running fast with special care. The coal based power plants in Rampal and atomic energy based power plants in Ruppur are under consideration.

In accordance with industrial development policy, the government has not divulged the environmental protection policies. Already, the surface water quality of different rivers around Dhaka and Chittagong region has been demolished. A strong protest has already been raised among the national and international environmental scientist, environmental protection organization and concerning people about the establishment of Rampal coal based power plants in Sundorban arena. This concern has been raised because of the different environmental issues like hot water will increase the temperature of surrounding river, particulate matter emitted from the kiln will may affect the local and far away environment [5, 6] the pH may be declined by sinking of coal carrying cargos etc. All of these concerning incidents might be the reasons for destroying the ecosystem of world heritage Surdarban forest. Environment is one of the prime concerns all over the world for sustainable development nevertheless the government has taken of consideration about environment in development program.



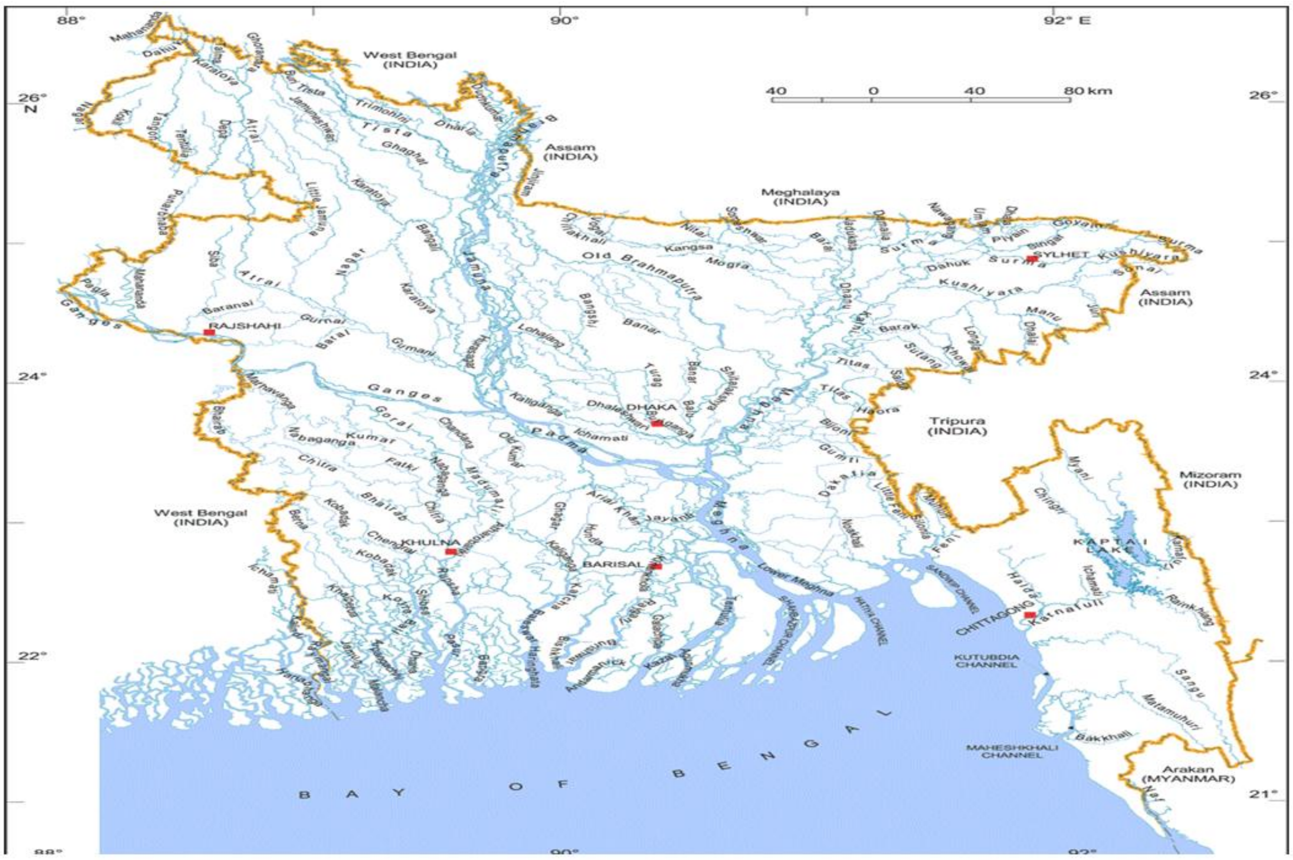


Figure-1. Main rivers in Bangladesh.

Source: Banglapedia, 2005.

Bangladesh is a large delta and 230 rivers have been flown over this country Figure 1. Most of the industries have been established on the bank of the river and are dumping their wastes into the nearby river without proper pretreatment subsequently damaging the aquatic environment [7]. As a consequence the river water quality in industrial region is deteriorating day by day. The rivers in the urban area are mainly polluted by industrial effluent, municipal wastes, hospital wastes and the sources of river pollution in the rural area are mainly land run off (fertilizer, pesticides), human wastes and naturogenic. The portion of Buriganga river near the southern edge of Dhaka city is almost biologically dead [8] as well as the Turag, Shitallakhya and Balu river water quality is unfavorable for aquatic life [9-11]. The color of the Buriganga, Turag, Shitalakkhya, balu and some other river water during dry season becomes dark [8, 10, 12, 13] which is not suitable for sunlight penetration. Therefore, the photosynthesis becomes hindered in the water body which affects the hydrochemistry and ecosystem. The surface water of the rivers in the rural district far from the industrial region is till suitable for aquatic biota [14, 15] whereas in the urban or industrial districts are polluted by organic as well as inorganic sources and are exposing adverse effects for aquatic ecosystem [16-18]. All over the world, water borne diseases are prime concern among people. A wide range of mortality and morbidity occurs by dint of water related diseases especially in developing countries through ingesting pathogenic bacteria, viruses, penetration through human skin by infective forms [19]. The common sources of pollution and its effects are summarized in Figure 2.

Figure-2. Water pollution and its effects.

Source: Prensa Latina; FakeSick; IWA, India Celebrating.

This review has an aim to discuss some handicap in polluted water analysis, the sources of water pollution, adverse effects of pollution on hydrochemistry and ecosystem and environmental policies in Bangladesh. The concentration of major pollutants aggregation in surface and groundwater and their health risks have been discussed. Some statistical analysis and the inter-correlation of pollution causing parameters have also been embodied in this review.

2. Water Pollution

In recent past decades, Bangladesh had been faced the dangerous arsenic pollution problem which is attributed to tremendous public health problem. Beside this, the ecological condition mortification of some rivers in the industrial zone has been drawn the concern. Severe water pollution may be caused by organic (indicated by COD, BOD, DO, grease, oil, volatile organic carbon etc.), inorganic (indicated by Temperature, acid, base, TSS, salinity, metals etc.), ions (e.g. anion, cation) and pathogenic (e.g. bacteria, virous, protozoa etc.) sources from industrial, municipal, hospital wastes as well as naturogenic sources.

2.1. Organic Pollution

Organic pollution of water occur by the bio-degradable wastes from industrial and domestic sources which stimulates the growth of micro-organism in the water body [8]. As a consequence of microbial decomposition, the oxygen in the water body is consumed and the quality balance is disturbed. Water pollution mostly occurred in developing countries as a result of miss management of industrial, municipal, hospital wastes and dumping into the water body [20-22]. Dissolve Oxygen (DO) and Chemical Oxygen Demand (COD) are commonly used for the determination of organic pollution level of water body [8, 10]. According to the WHO, the permissible limit of DO and COD in industrial wastewater and drinking water is 4.5-6.5 mg/l and 10 mg/l, respectively [23].

Pollution of surface and groundwater in different regions of Bangladesh from organic sources has been summarized in Table 1. The main rivers around Dhaka city have been polluting drastically due to the untreated industrial and municipal wastes from the last couple of decades. Buriganga is one of the main rivers in Dhaka city which has lower level of DO (0.9-2.8 mg/l) [24] and higher level of COD (140-800 mg/l) value [8]. Similar condition has been observed in case of Turag rive which flows beside the Dhaka city [9, 25]. The water quality of Shitalakkha river is also unfavorable for aquatic biota due to organic pollution [10, 26, 27]. As a consequence of high level of organic pollution aquatic ecosystem in the surrounding rivers of Dhaka City is almost ruined [8, 12, 28]. Beside the peripheral river of Dhaka city, Dhanmondi lake, Gulsan lake, Rampura lake, Ramna lake are polluted by volatile organic carbon (VOC) [29]. Burignaga river is also polluted by VOC [30]. However, the rivers far from the industrial region are not such highly polluted. The DO, COD and BOD levels of Jamuna, Meghna, Podma, Mahuri, Surma, Ganges river are in the permissible level [31-34]. The permissible level of DO, COD and BOD indicates that the lower dumping of organic wastes and lower aerobic bacterial decomposition has been occurred in those rivers. A very recent study showed that COD level (20.84-114.6) in the Meghna river is higher than permissible level [15]. This is may be occurred due to the transboundary water flow from polluted Buriganga and Shitalakkhya river into the Meghna river.

DO is a conventional parameter for assessing the water quality which indicates the availability of life in water body [10]. DO provides essential direct and indirect information about water body such as, bacterial activity, photosynthesis, availability of nutrients, stratification and so on Premlata [19]. At the lower level of DO value, fish and other aquatic organisms may not survive [40]. The rivers Buriganga, Turag, Shitalakkhya, Dhaleshwari, Bongshi, Surma Table 1 are polluted by organic pollutant as those have lower DO value according to DoE [41] and WHO (World Health Organization) [42].

COD is another essential parameter for assessing the soundness of water body. Higher value of COD indicates more organic pollution. COD value is enhanced by the urban runoff with household wastes and wastes from streets and sidewalks, fertilizers, leaves, grass clippings and paper from residential areas [43]. The enhanced level of COD value makes the water dark in color which hindered the penetration of sunlight. As a consequence, the photosynthesis of aquatic weeds affected drastically. Therefore, the hydrochemistry and aquatic ecosystem disturbed badly. Beside this, higher level of COD value makes the water nuisance in smell. Fish, aquatic biota feels suffocating with higher level of COD in a water body. COD enriched water is another source of pathogenic bacteria and virus. The use of COD enriched water is not suitable for drinking, washing and other household uses. The use of this water may highly risk for sore on skin. The river Buriganga [8] Turag [9, 25] Shitallakhya [10, 26] and Meghna [15] are highly polluted which is indicated by higher level of COD value.

BOD represents the amount of oxygen required by the living organisms in water body which are associated with utilization and ultimate destruction or stabilization of organic matter [44]. BOD is an indicator of water pollution. It may represents, how much oxygen is necessary for oxidizing a given quantity of organic matter by microbes [45]. BOD value is lower in clean water which reveals more oxygen is present in water body and ultimate more nutrients is available for high forms of life in water body. The reason of higher BOD value is same as lower DO value. At higher BOD value the aquatic biota are stressed, suffocated and in some cases died. The consequence of higher value of BOD is leaves and woody derbis, dead plants and animals, animal manure, effluents from different industries and urban storm water runoff [46]. Most of the rivers in industrial arena show BOD value above the permissible level however, the rivers in rural zone that show in the permissible level Table 1.

VOCs are concerning environmental pollutant as a consequence of their toxicity exerted to the environment and widespread occurrence. VOC comes from solvent and important raw materials used in different industries, oil from water vehicles and oil spilling from tanker, ship scraps, paints, adhesives, deodorants and refrigerants [47]. Some VOCs are used in agricultural practices and as fumigants, as herbicides and as solvent for pesticides [48]. Oceans, marine algae, phytoplankton and forest soil consist remarkable sources of biogenic VOCs [49] Water sample from 5 to 25 m depth is used for VOC detection.

Table-1. Organic contamination of various surface and groundwater samples in Bangladesh.

Sampling location	No. of observation		Polluting parameters						References
	Total	Polluted	DO mg/l	COD mg/l	BOD mg/l	VOC (µg/ml)			
						Benzene	Toluene	Xylene	
Surface water									
Buriganga river	10	-	-	-	-	0.35-0.37	0.16-0.23	0.12-0.14	[30][c]
Buriganga river	5	5	1.8-6.5	-	17.3-41.9	-	-	-	[20][b]
Buriganga river	4	4	1.1-4.1	140-800	-	-	-	-	[8][a]
Buriganga river	-	-	0.9-2.8	17.2-60.1	2.5-34.5	-	-	-	[24]
Gulsan lake	-	-	-	-	-	-	33.09-52.12	2.11-2.29	[29]
Turag River	3	3	2.1-6.8	21-220	10-180	-	-	-	[25]
Turag River	4	4	0.6-3.6	220-1550	-	-	-	-	[9]
Bangshi River	1	1	3.2-6.3	0.02-2.1	15.23-96.12	-	-	-	[35][d]
DMD embankment	12	12	0.0-2.57	400-2004	150-977	-	-	-	[27]
Dhaleshwari river	5	0	6.37-6.63	-	-(4.1-1.46)	-	-	-	[36][b]
Surma river	5	0	3.5-7.6	0.9-2.6	0.6-1.8	-	-	-	[31][b]
Surma river	167	-	1.40-7.60	0.16-2.60	0.10 -1.80				[37][b]
Meghna river			6.23	8.54	6.38	-	-	-	[32]
Meghna river	11		4.66-8.35	20.84-114.6	1.2-10.1	-	-	-	[15]
Ganges river	1	-	10.7-6.4	10.3-15.75	4.55-1.1	-	-	-	[33][e]
Brahmaputra river	1	-	9.85-6.7	75-16	4.6-0.66	-	-	-	[33][e]
Padma river	-	-	6.21-9.61	-	3.9-5.1	-	-	-	[34][d]
Dhanmondi lake	-	-	-	-	-		16.98-23.78	2.68-2.92	[29]
Rupnagar lake	-	-	-	-	-	-	19.33-24.02	2.08-2.15	[29]
Ramna lake	-	-	-	-	-	-	13.78-16.87	2.74-2.99	[29]
Shitalakkhya river	3	3	1.2-3.12	89.72-118.1	25.12-35.12	-	-	-	[26][e]
Shitalakkhya river	5	5	0.5-3.3	80-480		-	-	-	[10]
Jamuna river	-	-	6.8	-	3.2	-	-	-	[38]
Padma river	-	-	6.1	-	1.9	-	-	-	[38]
Dakatia river	-	-	5.06	3.09	2.41	-	-	-	[32]
Muhuri river	-	-	4.88	2.87	2.61	-	-	-	[32]
Vahirab irver	-	-	1.22-5.51	3.80-10.80	0.22-5.79	-	-	-	[39]
Groundwater									
Feni	-	-	1.25-3.34	-	-	-	-	-	[32]

[a]Observed every two month over the year; [b]Observed in wet and dry seasons; [c]Observed in 0 cm and 15 cm depth, in C_{18} column; [d]Observed at every month over the year, [e]Observed in monsoon, premonson and postmonson.

Fondekar and Gupta found higher values of hydrocarbon in the 10 m depth of an oil tanker route in Northern Indian Ocean [50]. It was observed that mentionable amount of Benzene, Toluene and Xylene has been found in the Burigana river, Gulsan lake, Dhanmondi lake, Raman lake and Rampura lake Table 1. Among them Gulsan lake is more polluted by Toluene by amounting 33.09-52.12 μg/ml [29]. The sources of this high concentration of Toluene are may be the industrial and municipal wastes and insecticides used by the municipality. At a very low concentration of VOCs exerts severe health risk as many of these materials are toxic, carcinogenic or mutagenic [51].

Oil pollution depletes the water quality by dropping down the level of DO and increasing the COD, BOD, TSS and TH value of water body [52]. According to APA, ≥ 10 ppm concentration of oil in water body can cause lethal for aquatic habitant [53]. In December 2014, Chowdhury and Akter found 295-1650 ppm and 6.68-11.3 ppm oil at the contaminated and uncontaminated region of shela river, respectively due oil tanker slammed in eastern part of Sundarbans mangrove forests [54]. Islam and Hossain also found high concentration of oil (9280-10800 ppm) at ship scrapping area in Chittagong [55]. Another oil tanker slammed in the Karnafui river on October 24, 2019. Beside these, the oil pollution in Buriganga river is a common scenario from ship terminal and shipyard due to pore management. The natural decomposition of oil is highly slow and may endure for decades [56]. Oil spill affects the fisheries breeding place. The high concentration of oil restricts the sunlight penetration underneath of oil layer in water body. Lack of light intensity suppresses the photosynthesis of phytoplankton which impairs the oxygen and carbon dioxide balance across the air-water interface [55] substantially depletes the water ecosystem. It also inhibits the swimming and flying capacity of wetland birds due to over-weight [57].

2.2. Inorganic Pollution

Inorganic pollutants (especially acids, salts and metals) are not biodegradable. They form homogeneous or heterogeneous mixture and persist in the water body. Over the permissible limit, they exert toxicity and adverse effect for aquatic ecosystem, diversity of aquatic life and human health. Inorganic pollutants are in active pollutants group. The sources of inorganic pollution are the industrial untreated wastes, municipal wastes, hospital wastes, road wash, agricultural wastes and in some cases naturogenic. Bangladesh is an emerging industrial country with its unplanned industries. Most of the industries dump their wastes without proper treatment into the nearest water body. Textile manufacturing and garments industries are the main contributing industries in Bangladesh and prime surface water pollution causing industries with their untreated effluent [58, 59]. Inorganic pollutions have been treated major pollution causing components in Bangladesh from last couple of decades because of the deficiency of wastes treatment facilities. Many studies mentioned highly inorganic pollution in surface and groundwater in the different parts of country is summarized in Table 2 which is directed by the higher level of EC and hardness. Surface water is seriously polluted by discharging of agricultural effluent [8, 20] industrial effluents, random throwing of household, clinical, pathological and commercial wastes, fuel and sewage wastes [60]. Groundwater pollution may be due to the naturogenic sources [61] and the leaching of industrial waste water.

pH is an important water quality assessing parameter which determines the corrosive characteristic of water [10]. Intuitively, pH significantly affects the biological activities and efficiency of toxic substances present in the aquatic environment [9]. Photosynthesis of water body is greatly affected by the pH level of water. If photosynthesis rate is decreased then carbon dioxide and bicarbonates inclusion are increased subsequently pH of the water body is increased [72]. The pH level is affected by the reaction of carbon dioxide, organic and inorganic solutes present in water [34]. The buffer (pH level) protection of water body is one of the major parameters. The pH maintained by a well-buffered is attributed by the fact of normally running water and is influenced by the nature of the deposits over which the water flows [73]. A slight change from the certain pH level of water for an organism can be abolishing cause for that organism [74]. In summer, water show alkaline nature may be due to the increase of photosynthesis of the algal blooms resulting into the precipitation of carbonates of calcium and magnesium from bicarbonates, whereas in winter pH level decreased due to the decrease of photosynthesis [34]. pH value of the surface and groundwater samples recommended by WHO is 6.5-8.5 [23]. According to EQS the pH levels in industrial water, fishing water and drinking water are 6.0-9.5, 6.5-8.5 and 6.5-8.5, respectively [75]. In all the studies the pH level was in the permissible limit recommended by EQS except karnaphuli river which shows higher level of (pH = 9.86) alkalinity [61]. The higher value of pH in the karnaphuli river may be due to the untreated karnaphuli paper mill effluent discharged into the river. Beside this some other industries situated on the bank of the karnaphuli river are discharging their effluent without any treatment. pH value in surface water is slightly higher than the groundwater could be due to the increased photosynthetic assimilation of dissolved inorganic carbon by plankton [70].

Electrical conductivity (EC) demonstrates the total ionic species in the water. Higher value of EC depicts that larger quantity of mineral salts are present in the water [76]. High content of mineral salt affects the irrigation scheme. EC is strongly related with total solid [60]. According to the WHO the maximum permissible limit of EC is 1500 μS/cm [77]. EC found well below than the WHO recommended limit in surface water however, the EC concentration in groundwater of Feni, Noakhali, Lakshmipur, Khulna and Comilla region was found in dangerous limit Table 2. Higher level of EC in these regions is may be attributed to the proximity of Bay of Bengal where saline water flow comes with tidal force. Higher level of conductivity as well as dissolved solids may have certain physiological effects on desirable food plants as well as habitat-forming plant species, give mineral testes in drinking water and create problem in irrigation [78].

Table-2. Inorganic contamination of various surface and groundwater samples in Bangladesh.

Sampling location	No. of observation		pH	EC µS/cm	TDS mg/l	TSS mg/l	Salinity mg/l	Alkalinity mg/l	Hardness mg/l	References
	Total	Polluted								
Surface water										
Panguchi river	-	-	7.23-8.09	201.96-465.87	228-284	-	-	42.66-71.16	56.68-74.79	[60][a]
Buriganga river	-	-	6.92-7.82	622.2-1093.47	544-789	-	-	67.43-159.42	91.94-163.1	[60][a]
Buriganga river	-	-	6.7-7.7	146-1309	98-871	-	71-642	-	-	[8]
Turag river	-	-	8.23-9.45	985-1362	684-898	-	436-612	-	-	[12]
Padma river	-	-	6.8-8.66	-	43-112	20.4-237.4	80-240	-	60-120	[34][b]
Surma river	4	-	-	-	51.5-301.6	-	-	30.67-115.67	61.67-175.17	[62]
Bongshi river	-	-	-	545-605	384-429	-	261-305	-	-	[43]
Karnatoli river	2	2	-	-	90.7-1148.0	78.35-1282.4	0.0-1.03	-	-	[63][a]
Dhaleshwari river	5	0	5.0-7.65	136-540	69-299	-	-	126-640	16-68	[40][a]
Mouri river	6	-	7.3-8.3	164-275	255-305	74.5-123.3	-	354-570	34.45-280	[64]
Muhuri river	-	-	-	65.90	32.70	-	-	66.82	40	[32]
Shitalakhya river	-	-	6.6-8.0	135-4768	-	-	-	49-355	-	[65]
Shitalakhya river	-	-	6.9-8.0	121-1167	80-754	-	57-582	-	-	[10]
Dakatia river	-	-	6.78	179.15	89.85	80.00		56.02	107.00	[61]
Dakatia river	-	-	-	112.40	56.25	-	-	52.71	58.0	[32]
Meghna river	-	-	7.04	414.95	207.40	70.0	-	50.75	90.0	[61]
Meghna river	-	-	-	1193.5	598.5	-	-	50.75	340.0	[32]
Rajakhali canal	-	-	6.5-8.8	-	334-951	-	0.0002-0.001	78-270	36.3-88.9	[66]
Sunamganj	-	-		117.51-503.61	-	-	-	-	215-48250	[67]
Halda river	-	-	7.03-8.60	72.00-414.00	30.0-200.0	20.0-653.0	-	2.12-35.36	9.0-380.0	[68]
Karnafuli river	-	-	6.36-9.86	90.0-45600.0	45.0-20000.0	14.4-5100.0	-	1.60-52.25	10.0-4500.0	[68]
Groundwater										
Feni	-	-	6.08-8.86	172.2-2528.0	85.3-262.0	-	-	75.48-258.0	26-554	[32]
Noakhali	-	-	6.57-7.91	483.0-9520.0	241.0-4800.0	-	-	148.24-760.32	148-1530	[32]
Lakshmipur	-	-	6.83-7.52	52.2-3800.0	129.3-1920.0	-	-	108.6-1017.72	134-630	[32]
Northwest region	-	-	5.4-5.6	160-460	95-287	-	-	-	100-300	[69]
Mohanpur	-	-	6.9-7.1	701-987	490.7-990.9	-	-	373.8-495.8	301.6-400.0	[70]
Khulna	26	25	-	962-9370	480-4640	-	-	-	-	[71]
Comilla	-	-	5.8-7.58	73.20-1797.0	36.50-749.0	-	-	21.33-1046.69	26.0-684.0	[61]

[a]Observation was made three times over the year; [b]Observation was made by monthly.

Total dissolved solid (TDS) in water mainly consists of ammonia, nitrite, nitrate, phosphate, alkalis, some acids, sulphates, metallic ions and so on [27]. TDS is not generally treated as a primary contaminant (as it is not directly associated with health effect) but used as an indicator of aesthetic characteristics of drinking water and as an aggregate indicator of the presence of a broad array of chemical contaminants [34]. Excess amount of TDS makes the water more turbid and increase its electrical conductivity [79, 80]. Higher quantity of TDS in effluents can increase the density of water, influence osmoregulation of fresh water organisms, reduce solubility of gases (like oxygen) and impair the utility of water for drinking, irrigation and industrial purpose [27]. TDS indicates the saline behavior of water. The high concentration of TDS means higher concentration of salinity in the water. Salinity could also be a major limiting factor for crop yield in poorly drained soils [81]. According to the WHO guide line the maximum permissible value of TDS in drinking water is 500 mg/l and in irrigable water is 1500 mg/l [77]. Both surface and groundwater in and around industrial area shows higher level of TDS vales for drinking water than the WHO's guideline value Table 2. However, the rivers in the rural area show TDS value well fit into the permissible level.

Total suspended solids (TSS) depict the suspended impurities present in the water which are responsible to transport pollutant in the aquatic environment [27]. Suspended solids may be appear in the form of course, floating, fine or colloidal particles as a floating film which cause ecological imbalance in the aquatic ecosystem by mechanical abrasive action [34]. Untreated or partially treated industrial, municipal, hospital and agricultural wastes intensify the TSS value in water body [12]. TSS is highly pH susceptible. Therefore, with pH change the dissolved matter can be aggregated and precipitated [82]. The permissible limit of TSS in drinking water is 5 mg/l [83] and in industrial waste water is 150 mg/l [84]. The Karnafuli, Halda and Bongshi rivers contain the exceed limit of TSS value for industrial effluent Table 2. These rivers are situated in the industrial belt of the country. Most of the industries have no well-organized effluent treatment plant and they are dumping their effluent into the nearest river. Therefore, higher value of TSS has been experienced in the river of industrial region.

Salinity means the saltiness or dissolved salt content in the water such as sodium chloride, magnesium and calcium sulfates and bicarbonates [34]. The elevated saline content in water affects the soil construction, permeability and aeration which affect the growth of seedlings [85]. Ecologically salinity is an important factor for influencing the types of organisms that live in the water body [34]. Various species of fresh water fish cannot get suitable environment for reproduction in high content of saline water [8]. Highly concentrated saline water declines the fish diversity at an alarming rate which effects on biodiversity subsequently correlates with ecosystem as well as human food chain [8, 86]. The ultimate effect of high saline content in drinking water is detrimental on blood pressure, kidney as well as menstrual process of women [8]. Dietary salt intake guideline has been established by WHO, but guideline for safe salinity has never been published except the sodium contents > 200 mg/L in drinking water [87]. Higher rate of preeclampsia and gestational hypertension in pregnant women living in the southwestern coastal region of Bangladesh has been noticed compared with noncoastal pregnant women which may be caused by saline contamination in drinking water [88]. In surface water highest level of salinity was recorded in Buriganga river (642 mg/l) and Turag river (612 mg/l) [8, 12]. The dominant sources of salinity are tidal force, irrigation and industrial effluents.

Alkalinity is the capability of water to neutralize a strong acid into a designated pH [60]. In natural water most of the alkalinity is attributed to the dissolution of CO_2 into water [70] and in industrial region most of the surface water turned alkaline due to the untreated effluent. Surface water of the Buriganga, Dhalashari, Mouri rivers and ground water of southeast region (Feni, Noakhali, Laxmipur, Comilla) consists higher level of alkalinity Table 2.

According to the WHO, acceptable limit of total hardness is 200 mg/l for drinking water which can be extended up to 600 mg/l in case of non-availability of fresh water source [77]. Hard water does not exert any known health impact but it forms foams which creates heat insulating scales in the boilers and reducing the efficiency [80]. Karnafuli river showed the highest range of hardness like 10-4500.0 mg/l [68] which is attributed to the industrial effluent. Groundwater in Comilla and Noakhali regions experienced hardness over the WHO guided limit for drinking water [32, 68]. This higher value may be due to the naturogenic as the industrial source in those regions is limited. Hard water exerts unpleasant test in drinking water.

2.2.1. Trace Metals

Water from natural sources contain impurities of trace metals as it dissolves these metals while flowing downward through hydrological cycle [102]. Beside the natural pollution, some human activities like large scale use of chemicals in agricultural field, unauthorized disposal of industrial, hospital, mining and research wastes are attributed to pollute surface and groundwater. Some trace metals are essential for human health whereas overloading these metals cause health problems in living organism especially human. Trace metals are immobilizing in aquatic system as well as non-biodegradable and can accumulate onto sediment and in plant tissue [12, 103]. Trace metals are accumulated as a consequence of coagulation, ion exchange with dissolved and suspended species in water, incorporation into the mineral lattice structure and precipitation due to the formation of insoluble species [104-106]. Trace metals are remained in the form of oxides, hydroxides, sulphides, shlphates, phosphates, silicates, organic bindings forming complexes with humid compounds and complex sugars [107]. Surface water is a vital source of irrigation in Bangladesh. Therefore, by irrigation as well as wreath of clouds, trace metals can enter into the food chain [12]. Trace metals may contaminate sediment significantly at some concentrations which may be toxic to aquatic ecosystem [105, 108]. However, the concentration of trace metals cannot provide enough information to evaluate the effect on sediment due to trace metal contamination is deposited in different chemical forms which determine their mobility, toxicity and bioavailability [108, 109]. The results from various studies of metal pollution in Bangladesh are summarized in Table 3.

Table-3. Metal contamination of various surface and groundwater samples in Bangladesh.

Sampling location	Cr	Cd	Hg	As	Zn	Cu	Fe	Co	Pb	Ni	Mn	References
Surface water (mg/l)												
Khiru river	-	0.054-0.175	-	-	0.005-0.008	0.004-0.005	-	-	0.012-0.033	-	0.082-0.324	[89]
Dhaleshwari river	0.13	0.001	-	-	-	BDL	-	-	0.20	-	-	[90]
Turag river	-	BDL-0.004	-	-	0.12-0.16	0.06-0.08	1.4-2.44	-	0.02-0.08	-	-	[14][a]
Meghna river	-	0.006-0.009	-	0.001-0.003	0.019-0.022	0.003-0.009	-	-	0.0005-0.0022	-	0.01-0.04	[91]
Meghna river	0.006-0.074	0.001-0.007	-	-	0.01-011	-	0.47-1.6	-	BDL	BDL	0.0003-0.025	[15]
Balu river	-	0.01-0.016	-	0.001-0.002	0.021-0.028	0.006-0.01	-	-	0.0002-0.001	-	0.044-0.049	[91]
Balu river	<0.004-8.44	<0.003-3.30	-	-	-	-	-	<0.004-0.054	<0.0179-0.0282	0.0106-0.0191	-	[92]
Shitalakshiya river	-	0.004-0.02		0.001-0.003	0.017-0.029	0.001-0.009	-	-	0.0005-0.002	-	0.045-0.056	[91]
Karatoa river	0.033-0.126	0.0009-0.022	-	0.01-0.092	-	0.023-0.119	-	-	0.008-.064	0.0093-0.071	-	[93][a]
Karatoa	0.002-0.009	-	-	Trace	-	Trace	Trace-0.89		Trace	0.001-0.012	Trace-0.32	[94]
Dhaleswari river	0.379-0.501	0.005-0.008	-	-	-	0.0984-0.188	-	-	0.038-0.063	0.00547-0.00974	-	[95][b]
Buriganga river	0.557-0.0645	0.007-0.0123	-	-	-	0.107-0.201	-	-	0.058-0.072	0.00715-0.0103	-	[96][b]
Surma river	0.036-0.040	-	-	-	0.00259-1.443	0.0042	0.00028-0.0032	-	0.013	-	-	[31][a]
Turag river	0.011-0.0127	0.0116-0.0195	0.0009-0.0151	0.001-0.0055	0.186-0.45	0.1203-0.380	2.012-3.461	-	0.0078-0.029	0.1282-0.1333	0.4381-0.978	[12][a]
DEPZ	0.0037-0.0175	0.0022-0.0039	0.0025-0.0059	0.002-0.007	0.0146-0.0818	0.0015-0.0092	0.05-2.014	0.0037-0.0175	0.0160.033	0.0051-0.022	0.0049-0.0479	[97]
Hazaribagh canal	0.0-20.20	<0.01-0.28	-	0.01-1.10	0.01-2.50	<0.005-1.50	0.01-15.50	<0.005-1.10	0.01-2.5	0.0-1.10	0.0-1.22	[98]
Vahirab river	0.001-0.006	0.0002-0.0094	-	0.001-.004	-	-	0.1-2.6		0.004-0.025	-	-	[39]
						-						
Groundwater (mg/l)												
Feni	BDL-0.005	BDL-0.011	-	0.1-0.5	BDL-0.015	BDL-0.01	0.1-8.46	BDL-0.008	0.02-0.07	BDL-0.02	BDL-3.47	[32]
Noakhali	BDL-0.006	BDL-0.013	-	0.1-0.5	BDL-0.017	BDL-0.012	0.15-3.08	BDL-0.005	0.01-0.08	BDL-0.024	BDL-1.49	[32]
Lakshmipur	BDL-0.007	BDL-0.009	-	0.1-3.0	BDL-0.019	BDL-0.015	0.08-8.10	BDL-0.009	0.05-0.07	BDL-0.018	0.01-2.39	[32]
Kustia	<0.002	<0.001		0.114-1.16	0.012-0.021	0.004-0.009	6.77-7.19	<0.002	<0.004-0.005	<0.002	0.69-0.74	[99]
Western region	<0.0002-0.0031	-	-	0.0002-1.955	0.012-0.073	0.0002-0.0008	-	-	ND-0.0001	Trace-0.001	-	[100]
Mohanpur	-	0.0036-0.019	-	0.00208-0.00316	-	-	-	-	0.0136-0.0159	-	0.0072-0.0037	[70]
Dhaka city	<0.01	<0.001	-	0.0023-0.0033	<0.025-0.102	<0.001-0.003	<0.025	<0.001	<0.001-0.0014	0.0025-<0.025-	0.0063-<0.056	[101]

[a]Observed in wet and dry seasons; [b]Observed in monsoon, premonson and postmonson, DEPZ-Dhaka Export Processing Zone.

Chromium (Cr) is one of the most health and environmental concerning metals found in earth crust and water. Chromium becomes hazardous for public health if the daily intake is exceeded by WHO recommended value (0.05 mg/l) but the deficiency of Cr can cause the disturbance of glucose, protein and lipid metabolism [110]. Chromium is generally present in trivalent oxidation state (Cr^{3+}), tetravalent oxidation state (Cr^{4+}) as well as hexavalent oxidation state (Cr^{6+}). Among those three states Cr^{3+} is least toxic. Hexavalent state of Cr is highly toxic and is mainly responsible for different types of skin irritation like ulcerations, dermatitis, allergic skin reactions [111]. In different studies, higher concentration of Cr has been documented in the surface water from last two decades Table 3. Chromium concentration in the water of Dhaleshwary river [90, 95] Balu river [92] (higher limit 8.44 mg/l), Karatoa river [93] (higher limit 0.126 mg/l), Buriganga river [96] Hazaribagh canal [35] was higher than the WHO (World Health Organization) [42] and DoE [41] recommended (0.05 mg/l) limit for drinking water. Chromium concentrations in groundwater of Noakhali [32] excided the DoE recommended [41] value for drinking water. The main source of Cr concentration in surface water has been attributed to the industrial wastes especially tannery effluent [12, 112]. However, in all cases summarized in Table 3, Cr concentration in groundwater is lower than the surface water as well as belongs to permissible limit.

Cadmium (Cd) is rarely found in surface water however, in industrial arena it can be found over the danger level. Cadmium is an eco-toxic metal exposes highly adverse effects on the soil overrate, biological activity of soil, plant metabolism and human and animal health [113]. A very mild concentration of Cd intake can cause anemia, anosmia, cardiovascular diseases, renal problems and hypertension [114]. Cadmium is used in battery, pigment and paint, plastic, ceramics and glass manufacturing industries and causes pollution when the untreated wastes of those industries are dumped into the water body. It is a health hazardous element over the concentration of 0.005 mg/l in drinking water [42]. The observed concentrations of Cd are above the danger level in Khiru river [89]; Balu river (0.003-3.30 mg/l) [92] Meghna river [91] Buriganga river [96] Turag river [12] as well as in groundwater from Noakhali [32] and Mohammadpur [70]. Intense mortality rate of red tilapia has been observed due to the higher intake of Cd and it also has an effect on the decreasing of sperm number [115]. The intake of Cd over the permissible level through water or food causes acute and chronic illness for human and also treats as a carcinogenic agent [116].

Mercury (Hg) a natural occurring trace element exerts its hazardous impact on public health even a very dilute concentration. In aquatic environment, Hg combines with methyl ion and forms methyl mercury which exerts its highest toxic effects [117]. As a potential toxic element, Hg interferes on the production of neurotransmitter and also reduces the production of different important hormones including thyroid and testosterone [117]. The sources of Hg are anthropogenic and naturogenic. The anthropogenic sources are metal processing, chemical industries, mining, sewage, fungicides etc. [118]. A study [42] reported that in absence of Hg emitting source, an area can be polluted by Hg due to the global Hg cycle through the air and water. The concentration of Hg in the Turag river is in the range of 0.009-0.0151 mg/l [12] and that of in the DEPZ area is 0.0025-0.0059 mg/l [97] both are over the safe level 0.005 mg/l [119].

Last decades of previous century, arsenic (As) in drinking water was a tremendous public health threat in Bangladesh. Groundwater As concentration in northern and southern district of Bangladesh has been found over the permissible level of safe drinking water. A plethora of arsenicosis patients have been identified over the past two decades. Uptake of As over a period causes melanosis, leuko-melanosis, hyperkeratosis, cardiovascular diseases, neuropathy and cancer [120]. Nowadays, the arsenicosis problem has been changed due to awareness program and safe water treatment plant conducted by WHO, government and different NGOs, howbeit, owing to over exposure of ground water still arsenic problem in ground water is an alarming problem in Bangladesh. Arsenic problem is also faced by some other Asian countries like India, Pakistan, China, Mayanmar. In surface water the concentrations of As lie in the limit of DoE [41] and WHO [119] except Korotoa river [93] and Hazaribag canal [98]. However, the concentration of As in groundwater of Noakhali, Feni, Lakshmipur, Kustia, Western region is highly above of the DoE and WHO recommended drinking water standard Table 3. The DoE recommended [41] value of As in drinking water is 0.05 mg/l and that of by WHO is 0.01 mg/l [119]. In Bangladesh, the main source of As is the naturogenic. This can be rationalized by the fact that the over irrigation and decreasing the ground water level owing to the lower availability of water in dry season, As get readily mixed from earth crust to the groundwater. Arsenic contamination in body may decrease the production of white and red blood cells, can cause gastrointestinal irritation, weaken the heart beat and red spots on hand and feet [121].

Zinc (Zn) is an essential element in enzyme and protein [122]. It has a protective effect against Pb and Cd toxicity [123]. However, the over exposure to Zn can have adverse effect in aquatic life [12] ecosystem and public health. Higher accumulation of Zn in body exerts toxic and carcinogenic effects and subsequently neurologic, hematological complications, hypertension, kidney and liver function disorder [124]. WHO recommended acceptable value of Zn for drinking water is 3.0 mg/l [119]. In both surface and groundwater Zn lies in well below of permissible level Table 3. The source of Zn is naturogenic, industrial effluent and agricultural runoff. Zinc is highly mobile element. At alkaline condition, Zn lead to precipitate as $ZnCO_3$ [116] and settle down on sediment and on plant tissue. Radial oxyzen loss rate of *V. serpyllifolia* wetland plant can significantly decrease the mobility of Zn as an essential element of plant in metal contaminated soil under flooded condition where iron plaque is formed on the root surface which hinders the mobilization of Zn through the plant tissue [125].

Copper (Cu) is a biogenic element in hemoglobin which is necessary for the metabolism of all organisms [126]. However, the over dose of Cu may cause parkinson's disease [127]. WHO recommended value of Cu in safe drinking water is 1.5 mg/l [119]. The concentration of Cu in surface and groundwater lies below enough the permissible limit for drinking water except Hazaribagh canal [98]. In Hazaribagh arena more than 250 tannery industries had been operated and they used copper salts for tanning purpose. Therefore, may be the concentration of Cu (0.005-1.50 mg/l) was higher in Hazaribagh canal. Recently, tannery industries have been shifted from the Hazaribagh area to a well-organized industrial area in Savar and we are expecting this situation will be changed in near future.

As an important element of earth, Iron (Fe) is found on earth crust. It is an important element in the physiology of living organisms [128]. The concentration of Fe in surface and groundwater is very high than the

WHO prescribed (0.3 mg/l) value [119] for drinking water Table 3. In groundwater of Fenni, Laxmipur and Kustia the concentration of Fe in some samples is more than 8 mg/l. The source of Fe in ground water is the naturogenic. In some cases Fe may be mixed from industrial sources. Higher concentration of Fe makes the water bad tested and addled color. Gorell, et al. [127] found the highest relation of Parkinson's diseases with the elevated dose of iron for over 1-20 years. The over exposure to Fe causes cancer [129] diabetes [130] liver and heart diseases [131]. In contrast to the over dose, the deficiency of iron causes improper physiological metabolism of living organisms especially for women.

Cobalt (Co) is as an essential element of vitamin B_{12} [132]. The concentration of Co in both surface and groundwater is very low except Hazaribagh industrial region (1.1 mg/l) [133]. In surface water the source of Co is mainly the industrial wastes. Mass population can consume Co from beverage and food. Co poisoning of human body may be linked with allergic dermatitis, rhinitis, asthma and lung cancer [132].

Lead (Pb) is a toxic heavy metal which has no known biological function [134]. Pb shows very high mobility and associates with clay minerals like manganese oxide, aluminum and iron hydroxide and organic materials [135]. Both surface and groundwater are contaminated by Pb compared to the permissible level of drinking water Table 3. The permissible level of Pb in drinking water fixed by WHO is 0.01 mg/l [119] and by DoE is 0.05 mg/l [41]. Despite the lacking of heavy industrial zone, the concentration of lead in the groundwater of the southeast part of the country (Feni, Noakhali, Laxmipur) shows raised value than the permissible level [130]. The source of Pb in the groundwater of southeast part may be the naturogenic. The other sources of Pb in surface and groundwater are household paint, vehicle exhausts and industrial wastes [136] lead gasoline, municipal runoffs, atmospheric deposition [137, 138] battery industries [12] scrap batteries, thermal power plants and iron industries. Higher intake of Pb over time may exert bad effect on nervous, digestive, haematopoietic, cardiovascular, reproductive and immunological system and kidneys [139, 140].

Nickel (Ni) exerts its toxicity on human health due to over consumption through food or drinking water. Permissible level of Ni in drinking water is 0.07 mg/l [119] and in Bangladesh that is 0.10 mg/l [41]. All the surface and groundwater sample satisfy the permissible level except Turag river wherein the concentration of Ni is 0.128-0.133 mg/l [12]. The sources of Ni are attributed to the alloy, battery and pigment industries wastes. Consumption of Ni through food chain or with drinking water have connection with heart and liver damage can decrease the body weight and cause skin irritation [141] dermatitis, lung fibrosis, cardiovascular diseases, cancer in the respiratory tract [142, 143] rhinitis, nasal sinusitis and nasal mucosal injury [17].

Manganese (Mn) forms 0.1 % of earth crust [144]. It is an essential element for animal and plant for their physiological functions and deficiency of Mn may cause brutal skeletal and reproductive abnormalities for animal [126]. The WHO recommended value of Mn in drinking water is 0.5 mg/l [119]. In different observations the concentration of Mn in surface water is in the WHO prescribed value except Turag river Table 3. However, in groundwater the concentration of Mn in the southeast part (Feni, Noakhali, Laxmipur) and southwest part (Kustia) of Bangladesh is surprisingly above the WHO suggested value for drinking water Table 3. The source of Mn in groundwater may be naturogenic. The ingestion of higher dose with drinking water affect adversely in nervous system [145].

Most of the metals are in the permissible level recommended for drinking water. Heavy metals concentration is slightly higher in the industrial region. Most of the authors described that the higher concentration of metals are attributed to the untreated industrial effluent, municipal wastes, and agricultural runoff. However, the ground water as concentration in the southeast and northern region is over permissible limit for drinking water. This is due to the consequence of naturogenic activity.

2.2.2. Ions

Some ions are essential for plants however; overdoses of those may cause adverse effect. Some major ions those are reported from surface and groundwater have been tabulated in Table 4.

Main source of Na^+ in the river water and in sediment may be the untreated or partially treated industrial effluent which is dumped into the river. Different types of sodium salt are used by industries (mainly tannery, dying) for their production purpose. The excess amount of sodium salt in effluent potentially pollutes water body unless proper treatment accounted. If sodium concentration is higher as combined with chlorine and sulfate then the water would not be suitable for irrigational use [128]. Sodium polluted irrigated water makes the soil puddling and therefore, decreases the water intake capability and becomes hard which makes seed germination difficulties [149]. Higher concentration of sodium may impose osmotic stress on the aquatic biota [149]. Therefore, the population of biota may be decreased which makes a poor aquatic ecosystem.

Magnesium is the key component of chlorophylla, plays an important role in ecosystem. Higher concentration of Mg^{2+} makes hard water which creates difficulties in household washing. Like Mg^{2+}, Ca^{2+} also creates problem in household washing. Long time ingestion of excess calcium may cause hypercalcmia, urinary tract calculi, calcification in soft tissues like kidneys and in arterial walls and suppression of bone remodeling [150].

The source of fluoride is naturogenic character. Beside this pesticide, fertilized, industrial wastes and agricultural runoff, cosmetics enhance the concentration of fluoride in wetland. It consists in the environment by combining with other elements and minerals as fluorite and fluorapatite [151]. Fluoride is an essential element for human, plays an important role for teeth and bones structure. However, more than 1.5 mg/l intake of fluoride causes dental and skeletal fluorosis [152]. It also causes non-skeletal fluorosis when affected the soft tissues in the organs such as endocrine glands, thyroid, liver, kidney and other systems of the body [151].

Like fluoride ion, chloride ion presents in different rocks. It has a high affinity towards metals. Therefore, it has a high concentration in ground water, hard water and metal polluted water. The other sources of chloride in surface and groundwater might be chlorinated pesticides and wastes from industries.

Table-4. Contamination by ions of various surface and groundwater samples in Bangladesh.

Sampling points	Na^+	K^+	Ca^{2+}	Mg^{2+}	Cl^-	F^-	CO_3^{2-}	NO_3^-	SO_4^{2-}	PO_4^{3-}	References
Surface water (mg/l)											
Buriganga river	9.4-39.3	4.2-10.6	17.2-34.0	6.4-22.7	39.6-98.3	-	-	12.9-34.5	2.0-9.8	1.7-6.1	[146]
Turag river	13.2-32.3	7.6-20.4	11.2-25.5	2.0-5.7	80.7-147.4	0.03-0.6	-	1.0-4.9	101.2-148.9	9.9-26.1	[147]
Dhaka District	-	-	-	-	21.38-214.0	-	-	2.10-13.50	22.09-151.0	1.21-7.58	[98]
Karatoa river	0.0125-0.025	0.0085-0.0215	0.024-0.071	0.0039-0.0301	-	-	Trace	-	3.08-25.92	1.13-2.56	[94]
DEPZ	-	-	-	-	-	-	-	-	-	0.27-0.66	[97]
Northwest region	-	-	-	-	-	-	-	0.01-1.65	0.007-0.096	0.004-0.275	[69]
Hazaribagh Canal	2211.76	44.49	244.1	48.47	2465.0	-	-	44.80	546.0	-	[101]
Hazaribagh Canal	-	-	-	-	108-6840	-	-	0.1-194.00	5-1163	0.07-52.1	[98]
Groundwater (mg/l)											
Sylhet City	0.10-48.30	0.02-26.52	0.69-96.6	0.27-64.02	1.45-142.0	-	-	-	-	-	[148]
Northwest region	0.36-1.13	0.17-0.48	0.64-2.32	1.05-3.81	-	-	-	-	-	-	[69]
Kustia	-	-	-	-	3.27	0.268	-	0.98	0.424	0.23	[99]
Mohanpur	-	-	-	-	13.1-151.2	-	-	0.08-2.8	-	-	[70]
Pabna District	0.43-1.59	0.02-2.95	0.67-6.29	0.23-1.23	1.13-7.75	-	ND	-	-	-	[99]
Dhaka city	28.37-42.96	1.67-2.27	30.75-50.14	9.04-14.82	9.44-64.09	-	-	0.40-5.57	0.18-9.21	-	[101]
Khulna	3.91-73.08	0.01-0.78	0.70-8.28	0.69-8.00	0.82-84.62	-	-	0.00-0.11	0.00-0.57	0.00-0.48	[71]

*ND=Not detected.

Phosphate ion is sparingly soluble in water and adsorbs with clay particles and precipitates as Fe, Al and Ca compounds. The sources of PO_4^{3-} in the surface water may be fertilizer and industrial wastes. Concentration of PO_4^{3-} in surface water of Dhaka region [98, 146] shows slightly higher than the other part of country which indicates mainly industrial effluent is the main source of PO_4^{3-} pollution. Safe limit of phosphate in drinking water has been prescribed by WHO is 5.0 mg/l [23]. Soft drinks contain almost about 170 mg/l phosphorus which is a potential threat for public health.

The possible sources of nitrogenous ions are fertilizer, industrial effluent and human excreta [153] and agriculture runoff. Excessive nitrate content in drinking water causes infant methemoglobinemia (blue baby) [154]. Nitrate is not itself carcinogenic but it form N-nitroso compound in stomach which is carcinogen [155].

2.3. Pesticides

The residue of pesticides from agricultural and non-agricultural sector increases from last few decades due to the enormous use for higher agricultural farming. Surface water is more vulnerable to accept the residual pesticides due to rain and flood. Nowadays, the contamination of pesticides residue is more common concern worldwide as they expose their toxicity to human animal and living organism by penetrating into food cycle and water cycle. Some common pesticides which are reported in different articles are illustrated in Table 5.

Table-5. Level of pesticides in surface water.

Sampling location	No of observation		Detected pesticides	Concentration (µg/l)	Mean recovery (%)	References
	Total	Polluted				
Buriganga river	3	-	Chlorpyrifos	484.0	-	[156]
	3	0	Diazinon	19.0	-	
Lakes in Rangpur	5	5	Chlorpyrifos	0.544-0.895	86.25	[157]
	5	5	Carbofuran	0.949-1.671	90.13	
	5	1	Carbaryl	ND-0.195	92.65	
Savar and Dhamrai	5	1	Malathion	ND-105.2	81.25	[158]
	5	1	Diazinon	ND-0.90	96.38	
	5	2	Carbaryl	ND-18.1	93.75	
	5	2	Carbofuran	ND-198.7	85.00	
Savar	12	0	Methoxychlor	ND	89.3	[156]
	12	0	DDT	ND	91.45	
	12	0	Chlorpyrifos	ND-9.31	94.54	
	12	1	Diazinon	ND-7.86	88.32	
	12	0	Ethion	ND	93.12	
	12	0	Fenthion	ND-56.3	85.98	
	12	3	Fenitrothion	ND-33.41	89.25	
	12	0	Malathion	ND-59.9	91.62	
	12	0	Parathion	ND-6.23	90.41	
	12	2	Carbaryl	ND-6.3	92.51	
	12	1	Carbofuran	ND-43.2	93.41	
	12	3	Cypermethrin	ND-80.5	87.32	
Dhanmondi Lake	3	-	Diazinon	28.0		[156]
	3	-	Chlorpyrifos	629.0		
Kollanpur Lake	3	-	Diazinon	19.0		
	3	-	Chlorpyrifos	982.0		
Ramna Lake	3	-	Diazinon	ND		
	3	-	Chlorpyrifos	177.0		
Ponds in Dhaka City	30	-	Diazinon	ND-33.0		
	30	-	Chlorpyrifos	ND-108.0		
Feni	-	-	DDT	4.16		[159]
			Heptachlor	ND		
Nawabganj	-	-	DDT	3.01		
			Heptachlor	ND		
Rajshahi	-	-	DDT	0.133		
			Heptachlor	ND		
Nator	-	-	DDT	ND		
			Heptachlor	5.24		
Comilla	-	-	DDT	8.29		
			Heptachlor	ND		
			DDE	4.06		
Sunamganj	-	-	DDT	5.60		
			Heptachlor	5.04		
Madaripur	-	-	DDT	ND		
			Heptachlor	5.14		
Bandarban	-	-	DDT	ND		
			Heptachlor	5.08		
Pagla, Narayanganj	8	3	Diazinon	ND-2.144		[160]
	8	3	Carbofuran	ND-2.181		
Savar	-	-	Heptachlor	1.4795		[36]

* Bold concentrations are unsafe for human.

Chlorpyrifos is an organophosphate pesticide used to kill insecticides and worms. The concentration of chlorpyrifos is very high (484.0 µg/l) in Buriganga river [156]. Sumon and coauthors [161] reported that the chlorpyrifos is moderate to high chronic to fish in the spray spot and about its 10.0 m periphery. During dry season, the Burignga river water turn into dark color and according to the fisherman there is no fish in the metropolitan region [8]. This high concentration of chlorpyrifos gives evidence in favor of biological death of the Buriganga river. Chlorpyrifos level reported in the lake of Ramna, Kollanpur, Dhanmondi is also high Table 5. Diazinon is also an organothiophosphate pesticide used as pest control especially for cockroach, fleas and ant. The level of diazinon in the Buriganga river, Dhanmondi lake and Kollanpur lake is higher than the Australian permissible limit (3 µg/l) for health [162].

However, in rural area of Bangladesh the concentration of DDT, heptachlor is much higher than chlorpyrifos Table 5. DDT is an organochlorine pesticide used in farming and household insecticidal killing. Authors did not find detectable DDT level in the water samples collected from Bandarban, Nator, madaripur. This may be due to the prohibition of marketing and use of chlorinated pesticide according to the Bangladesh Environment Conservation Act 1995. Organophosphate pesticides are nowadays, mostly using in Bangladesh although some unethical organochlorine pesticides are still available. Therefore some authors detected higher DDT level in the Feni, Nawabjong and Comilla region [159].

Carbofuran is a toxic carbamate pesticide used in farming especially potato cultivation. In Savar and Dhamrai region [158] carbofuran has been detected very higher level (198.7 µg/l) than prescribed by the Austrlian guideline (5 µg/l) [162].

An article [163] reported higher concentration of cypermethrin in the sample collected from savar which is used in agricultural field and by rain and flood gets mixed in water body. Cypermethrin is a hydrophobic chemical and thus precipitate on sediment. As a consequence cypermethrin exposes long term toxicity to the water cycle [164].

2.4. Pathogenic Pollution

Pathogenic pollution is one of the concerning diseases causing sources in developing and developed countries which is mainly spread through water and foods. The subsequent effect of pathogenic pollution is different types of diseases including diarrhea, vomiting, dysentery, typhoid, hepatitis etc. In Bangladesh pathogens are attributed to the 80 % of all diseases [16]. According to GOB-UNICEF, about 0.3 million children under five die every year of which one third in city slums and quarter settlement [165]. Microbial waterborne diseases also acute in developed countries. In USA, every year 0.56 million people affected by severe waterborne diseases and 7.1 million suffer from mild to moderate infection [166]. Some pathogenic bacterial count observed by different authors in different regions of Bangladesh is presented in Table 6.

Table-6. Pathogenic bacterial count in surface and groundwater.

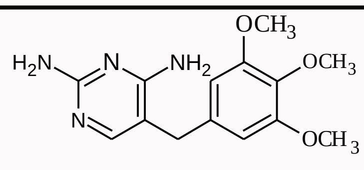
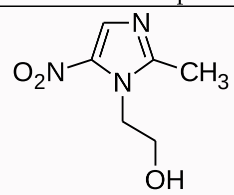
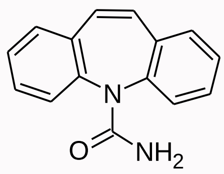
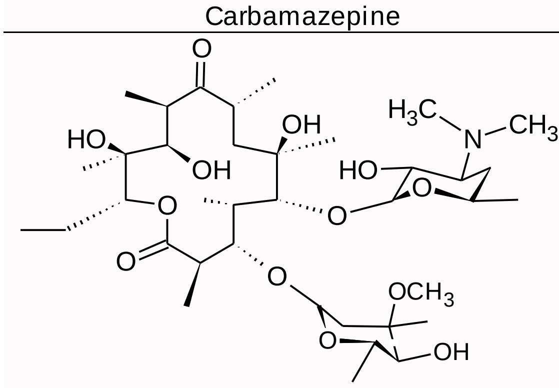
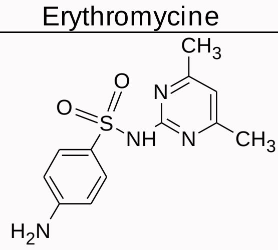
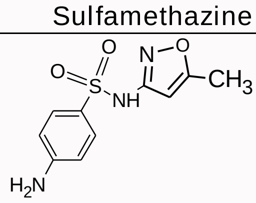
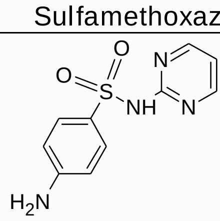
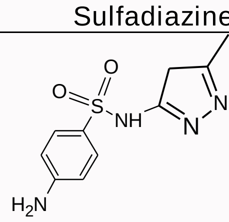
Sampling location	Vibrio Cholerae	Pseudomonas spp	Heterotrophic Bacteria	*E. coli* cfu/100ml	Total coliform cfu/100 ml	Fecal Coliform cfu/100 ml	References
Dhaka District	-	-	-	-	1.1×10^3-8.7×10^6	225-6.8×10^5	[98]
Turag river	-	-	-	75-7500	25-2.0×10^4	-	[167]
Buriganga River	-	-	-	10-55000	125-8.0×10^4	-	
Dhaleswari River	-	-	-	4-4.0×10^3	50-6.5×10^3	-	
Khulna Area Pond	37	4-37	220-1.35×10^4	<1-4.0×10^3	-	12-5.010^4	[168]
Buriganga River	-	-	$1.0\times 10^8 - 3.0\times 10^{11}$	-	1.1×10^3 - >$2.4\times10^{5*}$	1.1×10^3 - >$2.4\times10^{5*}$	[169]
Mirpur	0-7.5×10^4	0-4.6×10^4	1×10^{10}-9.4×10^9	-	-	-	[170]
Satkhira	-	-	-	2.74×10^2-3.32×10^2	1.55×10^3-1.95×10^4	9.50×10^2-1.73×10^3	[171]
Ponds in Dhaka	-	-	-	-	-	<1-9.05×10^4	[172]
Turag river	-	-	-	<18000	-	-	[12]
Souther part of Bandladesh	-	-	-	-	-	0.0-448	[173]
Rajshahi	-	-	-	-	-	184	[174]
Groundwater							
Matlab	-	-	-	1-2000*	-	-	[175]
Rajshahi	-	-	-	-	-	5	[174]
Potenga	-	-	-	-	6.5×10^3	-	[176]
Bhatiari	-	-	-	-	2.0×10^4-1.2×10^5	-	[176]
Kumira	-	-	-	-	1.7×10^4-3.0×10^4	-	[176]

*Unit is MPN/100ml (Most Probable Number).

Total coliform and fecal coliform are shown highest count in all of the samples which indicate the samples are polluted by sewage and human as well as animal feces. *E. coli* is a subgroup of fecal coliform its concentration is also high in all of the samples. *E. coli* 0157:H7 strains in drinking water can cause abdominal pain, bloody diarrhea and hemolytic uremic syndrome [177]. The presence of coliform bacteria in the surface and groundwater samples indicates the presence of disease causing agent in the water.

Heterotrophic bacteria count has been used for counting all aerobic and anaerobic bacteria shows higher bacterial count in a pond of Khulna [168] and Dhaka region [98]. They are not prone to pathogenic but some of them like Pseudomons are causing infectious to skin and lung and other type like Aeromonas cause gastroenteritis [178]. Heterotrophic bacteria are considered as an indication for measuring the coliform in water [179].

Table-7. Pharmaceuticals concentration in surface water of the old Brahamaputra river [185].

Pharmaceuticals	Uses [186, 187]	Concentration ng/L
 Trimethoprim	Antibiotic, antibacterial, primarily used for urinary tract infections	<LOD-17.20
 Metronidazole	Antibiotic, antiprotozoal, nitromidazole	0.05-13.51
 Carbamazepine	Anti-epileptic, Neuropathic pain reliever, anti-psychotic	<LOD-8.80
 Erythromycine	Antibiotic, Macrolide, Human and veterinary application	<LOD-6.46
 Sulfamethazine	Antibiotic, sulfadrug, broad spectrum antibacterial, human and veterinary application	<LOD-4.19
 Sulfamethoxazol	Antibiotic, sulfa drug, broad spectrum antibacterial, human and veterinary applications	<LOD-7.24
 Sulfadiazine	Antibacterial, primarily used for urinary tract infections	<LOD-0.58
 Sulfamethizol	Antibiotic, antibacterial, primarily used for urinary tract infections, intestinal infections, pneumonia	<LOD-11.35

*LOD = Limit of detection.

2.5. Pharmaceuticals Pollution

Undoubtedly, pharmaceuticals are revolutionary for easy and safe life. However, their occurrence in surface water can exert negative impacts for animals and ecosystem. Unlike developed countries due to insufficient health services and lack of awareness, people buy pharmaceuticals from drug store without physician's prescription, substantially, misuse the dose and real need of drugs. Total doses of pharmaceuticals after administration are not always completely undergoing metabolic transformation by gut microbes or host enzymes [180] and used up by our immune system and find their way into natural water bodies. The hospital and clinic waste treatment process in Bangladesh is very limited and most cases absent in rural area and consequently accumulated in surface and ground water. In Bangladesh formulated feeds and in some cases poultry droppings are used for aquaculture and those are enriched with pharmaceuticals [181] and accumulating in the water bodies. Huerta-Fontela [182] and coauthors found 55 commonly prescribed pharmaceuticals and hormones in raw water used for drinking water supply and 5 of them were unable to remove up to a reasonable limit via standard water treatment procedures. The essential and frequently used pharmaceuticals in Bangladesh are sulfamethoxazole, sulfamethazine, trimethoprim, erythromycin, penicillin, metronidazole and carbamazepine. A group reported that approximate 13 % of consumed carbamazepine is discharged from the body through excreta and urine without any substantial structural modification [183]. There are only few articles have been reported the pharmaceuticals (Table 7) in surface water in Bangladesh [181, 184].

Metronidazole is one of the frequently used pharmaceuticals in Bangladesh and detected in all of the sampling points in Brahamaputra river [181]. The possible sources of metronidazole in surface water are human excreta, veterinary and fish farming [188]. Among the sulfonamides drugs, the concentration of sulfamethizole was observed in higher concentration in Brahamaputra river (11.35 ng/L) [181] and Rajshahi (10.81 ng/L) [184]. Sulfonamides show quite persistent characteristic in aquatic system owing to their hydrophilic nature and can be transported far from their point of origin [189, 190]. The occurrence of pharmaceuticals in water bodies cans bioaccumulate on nontargeted organism e.g. mollusks, fishes and aquatic biota even at very low concentrations [191, 192] and affect the aquatic ecosystem. The increasing use of antibiotics is concerning issue worldwide and intensify to create the bacterial resistant strains (known as superbug) for human and animal health [193, 194].

2.6. Naturogenic Pollution

In conjugation with anthropogenic sources, water has been polluting from the naturogenic actions. Arsenic is a natural element in earth crust can mix with underground water [195] and causes health risk. Nitrogen also mixed with water during thunderstorm. Rain and flood washed away waste materials and drained into river which may pollute water body. River is also polluted by bank erosion. Volcanic eruption emits different metals which get mixed into water and makes the water polluted. Waste materials from different ore mine pollute nearby water system by adulteration of different ore. The chemical interaction of water-rock in aquifers contributes to pollution of ground water [196]. Pyrite and marcasite are common components in coal mine. Pyrites when exposed to the environment get hydrolysis and produce sulfuric acid and acidify the water body [197]. Organic matter and nutrients leaching from soil surface to ground aquatic level may change the physical and chemical composition of water through biological process [196]. Rain and drought can change the water quality by diluting and concentrating water.

2.7. Statistical Study

Statistical studies allow us to discuss and rationalize the analytical data and their interrelation, coexistence as well as distribution of pollutants in study area. It becomes noteworthy for understanding the impact of pollution on ecosystem and puts forward important and significant information about calculating ecological risk.

2.7.1. Pearson's Correlation

The degree of interdependency of one parameter to another is illustrated by Pearson's correlation tool [198] and it explains the deep root of mutual interaction of parameters in the study area. Understanding of pollutant source types typically becomes refulgent through correlation study. The result of correlation study in a specific area may be inconsistent with the result of other study where different environment may exist. In the Buriganga river water COD shows significant positive correlation ($p < 0.01$) with pH, salinity, TDS and EC and significant negative correlation with DO as well as the metal Cr demonstrates significant positive correlation with Cd, Zn and Cu [8]. The results obtained from the shitalakkhya rive reflected that TDS has positive correlation with salinity, EC and COD [10]. In Karnaphuli river, Pb is insignificantly and negatively correlated with As and positively correlated with Cr and Cd [199]. Correlation matrix of BOD, TDS, TSS, PO_4^{3-} in tannery and textile effluent and adjacent river where the effluent has been dumped demonstrates strong positive correlation [63]. Alkali reflects strong correlation ($p < 0.05$) with COD and Cl^- which reveals that they are originated from similar sources [35]. The correlation of DO and pH in the Halda river is significant ($r = 0.663$) and that of in the Karnofuli river during the same season is positive but insignificant. In ground water of that region DO is negatively correlated with pH ($r= -0.04$) [68] which indicates that the correlation is completely depends on surrounding environment and sources. A correlation study of the Mouri river visualized that temperature, pH, hardness, TA, DO, free CO_2 and sulphate were in positive correlation [64].

2.7.2. Principal Component Analysis

Principal component analysis (PAC) is a useful tool used to sort out patterns in a data set and to eliminate redundancy in univariate analysis from a large set of data [200]. Traditionally, PAC reduces dimensionality of data by linear combination of original data through creating the uncorrelated set of variables from the original variables. The eleven variables of twenty sampling site in the Mohonpur subdistrict under Rajshahi District ascribed that the two principle components cover most (almost 72.53 %, considered eigenvalues ≥ 1) of the variables [70]. Bhuiyan and coauthors studied the surface water quality near Dhaka district through 10 sampling sites and for 16 variables. They executed varimax method with Kaiser Normalization for studding PC and found that five PC cover almost 88 % of variables [35].

2.7.3. Cluster Analysis

Cluster analysis (CA) studies allow us to find out the groups according to their similarities [201] like their sources, distribution and chemical behavior. The outcome of CA is expressed through dandrogram. Most generally, Hierarchical cluster analysis and Ward's linkage method used to classify the samples. CA performs a series of multivariate methods to determine the appropriate groups of data [202]. Hierarchical cluster analysis has been done for eleven samples from Mohonpur under Rajshahi District and the output shown in dendrogram falls into two main clusters like Cuslter A and B [70]. Cluster A showed a close association of As, Mn, Cd, Total hardness, Pb, TDS and EC and cluster B formed by Total alkalinity, NO_3^-, Cl^- and pH. Molla and coauthors also applied CA among ten sampling sites and find two major clusters. This study put forward a message that, only two sampling points are suitable enough for understanding the environment of Mohonpur area. Ten sampling points around Dhaka district has been grouped by CA and found into two main clusters [35]. Cluster 1 possesses three sampling sites those are more polluted and rest of the sampling sites are less polluted and comprise in cluster 2. Bhuiyan also implied CA for sixteen variables and grouped into two clusters. TDS, turbidity, DO, Cl^-, temperature, COD and SO_4^{2-} lie in cluster 1 and TSS, EC, alkalinity, pH, PO_4^{3-}, BOD, fecal coliform, and total coliform lie in cluster 2. Incorporation of coliforms and BOD in similar cluster means that the growth of bacteria enhances the raising BOD level.

3. Handicap in Sampling and Analysis

Surface water analysis does not carry any worthy value if the sampling, storing procedures and analysis do not follow appropriate method. Ascertaining the quality of surface water depends on the sampling site selection. A sample site is usually an infinitesimally small part of water body. Therefore, the chemical composition and quality of surface water is greatly influenced by the selection of sampling sites. The sample selection site should be representative of the water body being investigated. Sampling sites selection of Mouri river [64] did not explain well enough by providing information whereas the sampling sites selection in Buriganga river [20] industrial zone of Dhaka [97] were explained along with sufficient information. The study period for environmental research conveys a significant essence to evaluate the pollution status of water body. However, the surface and ground water evaluation study of Chittagonj region did not mention the time period [68]. Grab and integrated sampling methods are applied for representative sampling for surface water [203]. Depth of sampling is accounted in both of the aforementioned sampling processes to understand the hydrochemistry. Most of the surface and ground water evaluation studies did not disclose the sampling methods and sampling depth. This is one of the significant handicaps of water quality analysis. The geology is different in the different part of Bangladesh for example in northern part we have a flat land but in the east and northeast we have hill track area. The water level would differ from region to region. Consequently to realize the true facts authors should disclose the sampling depth. Sampling in nontransparent polyethylene bottle has been recommended by WHO and the collected sample must be stored at 4 °C [204]. A proper preservation process was followed by Islam and coauthors but they said the sampling bottles was washed by detergent solution whereas they did not mention the type of detergent [10]. The detergent which is used for washing purpose shold be nonionic [203]. Collected samples should be carried to the laboratory by using ice carrier and for microbial analysis the time interval of sample collection and analysis must not exceed 24 hours [204]. Microbial analysis was performed for the Burigang river [16] Turag river [12] but the authors did not mention about the analysis time as well as any standard procedure however, such study performed for Dhaka municipal water followed a standard procedure [170]. Some parameters must be measured in the spot whenever samples are collected for example, DO, pH, turbidity etc. but in some article authors did not mentioned about their analysis strategies [20, 39, 205]. Flowing water generally possesses unique character and demands special care in sampling. Obtaining consistent results and make them rationalize flowing stream water should be collected by isokinetic, depth-integrated or nonisokinetic process [206].

4. Environmental Policies in Bangladesh

The law for conserving environment in Bangladesh was first adopted in 1995 although achieved the independence in 1971. This delay does not really mean that there was no concern about environment in Bangladesh. The environment protection was reflected in national development policy [207] and Five year policy 1973-78 [1]. National Environment Policy 1992 was the first draft for conserving the environment and thereafter became law in 1995 under the name Bangladesh Environment Conservation Act 1995 [208] which is operated under Department of Environment (DoE). Permissible standard for 26 health hazardous substance in drinking water was fixed in March 1997 and another 27 substance was fixed as water quality monitoring parameters. The quality standard for industrial waste water has been also mentioned under the Environmental Quality Standard 1997 [209]. In 2003 the standard value for total zinc in drinking water has been established and other three substances added into the monitoring parameters. Environmental court Act 2000 was established to support the BECA 1995 and for the trial against offences regarding environmental pollution. In National Water Policy (NWP) 1999 have 50 clauses to augment the protection, restoration and preservation of natural habitats in wetlands, mangroves and other forests. All the policies, ordinances and acts are reviewed time to time for ensuring the safe and sound environment. However, inappropriate implementation and lack of observation due to administrative complexity, inadequate manpower and insufficient budget, above all lack of awareness, skill and seriousness the efficiency has questioned tremendously. As a result, the surface and ground water in industrial cities has polluted extremely.

Bangladesh is a low laying country beside Bay of Bengal. Most of the river generated from the upper riparian neighboring countries India and Nepal. To protect the water security, the Government of Bangladesh maintains the treaty and agreement with India, Nepal and Bhutan. During dry season (January-May) the water flow in Hardinge Bridge (a bridge on Padma river in Pabna, western part of Bangladesh) region decline tremendously after construction of Farakka barrage on Ganges river in India. The ecosystem of Padma river and the lifestyle of the people on the Padma catchment area affected extremely especially who are depended on fishing due to lack of certain water level. Also the agriculture has been hindered due to the decline of ground water level. An agreement on Ganges river water was signed between Bangladesh and India to preserve the navigation and a certain water flow during dry season (January-May) in 1996 [210]. Tista is the fourth transboundary rive between Bangladesh and India [211]. India have planned to construct at least 30 hydropower project by a series of cascade damn which will greatly decline the flow of Tista water [211]. Already India control the water flow by Tista barrage in Gazaldoba point and providing water in the northern part of West Bengal [212]. Government of Bangladesh diplomatically tried to make an agreement from 2000 to get sufficient water flow in Tista river.

5. Conclusion

Industries are the main culprit for both surface and groundwater pollution in Bangladesh. Groundwater arsenic pollution in northern and southeastern part of the country is due to the naturogenic reason. Although sufficient data is not available, the pharmaceutical and hormone pollution in surface water due to the increasing use of drugs for human, animal and aquaculture project is concerning and prone to creating bacterial resistant strain for human and animals. Surface water in industrial zone videlicet Dhaka and Chittagong are mostly polluted however, in remaining rural districts is till now pretty fresh. The peripheral rivers of Dhaka District are polluted by COD, BOD, dye and heavy metals (most commonly Cr, Cu and Zn) according to DoE and WHO. People are not aware enough to protect the hydrological balance. Although, every year people are suffering from water borne diseases but adequate data are not available. Government should raise the awareness throughout the country including rural part about the worthiness of fresh water in our daily life and at the same time should imply strictly the policies and law to protect the water for future generation.

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