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The River Water Pollution in India & Abroad-A Critical Review to Study the Relationship among Different Physico-chemical Parameters

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Abstract Water is the elixir of life as there is no life without water and the rivers are the life line of our economy and culture. The river water pollution in India and abroad is a gigantic problem as it has affected not only of human and animal health but also the economy of the society as a whole. This work reviews a large number of research papers published by different researchers on river water pollution in India and abroad by critically analyzing and interpreting data on the different physico-chemical parameters and finds that the river water in India and abroad is highly polluted in respect of physically, chemically and bacteriologically with different hazardous pollutants including both chemical and microbial, coming from various sources such as industries, mines, agriculture, urban and domestic. Besides, this work finds and outlines the interrelationship among different physico-chemical parameters after careful analysis and interpretation of data and discussions published in different research papers. The dissolved oxygen (DO) and the pH are inversely related with temperature and turbidity and it is directly related with photosynthesis by autotrops. Further, biological oxygen demand (BOD) and free carbon dioxide are directly related with temperature. This review work gives opinions and suggestions to explain the experimental results by applying the standard concepts and outlines a brief guide line for the assessment of water pollution of river water.

Keywords: *river water pollution, physico-chemical parameters, bacteriological parameters, relationship among different parameters*

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1. Introduction

There are five basic elements, central to ecology, as described in Upanisada such as Kshiti, Aup, Tweja, Byoma and Marut ; pancha tatwa yah adhar sharira. This means Kshiti (Soil), Aup (Water), Tweja (Fire), Byoma (Sky) and Marut (Air) are integral part of our living world as well as ecology [1,2]. Water is the most important one among these basic elements and it is elixir of life. The hymn IX of Book 10 of Rig Veda recognizes the ability of water to give life both in physical and spiritual senses from ancient times. Water is used as principal requirement for worships of God, Goddess, spiritual curses and in any spiritual donations and hence it finds a paramount place in socio-cultural and economic affairs of human beings. Out of many fresh water resources, the rivers are the lifeline of our economy and culture. Natural resources are the important wealth of our universe and water is one of them. According to the eminent Greek philosopher, Pindar, water is the best of all things. The importance of water has been observed since ancient times.

The people on globe are under tremendous threat due to undesired changes in the physical, chemical and biological characteristics of water. As a result of increased human population, industrialization, use of fertilizers, pesticides, herbicides and other anthropogenic activities, water is highly polluted with different harmful contaminants including microbiological, which pose a great challenge on the very existence of the living world. It is worth mentioning that agriculture sector, industrial sector and domestic sector consume 89%, 2% and 9% of the surface water available [3,4] respectively.

It is because of use of contaminated drinking water, human population suffers from various types of water borne diseases. Natural water containing different types of impurities are introduced into aquatic system by different ways such as weathering of rocks and leaching of soils, dissolutions of aerosol particles from the atmosphere and anthropogenic activities such as mining, processing and use of metal based materials [5]. The increased use of metal based fertilizer in agricultural revolution of the Government resulted rise of concentration of metal pollutants in fresh water reservoir due to water run-off. The fecal pollution of water causes water borne diseases which has led to the death of millions of people [6].

Approximately, 30% of the garbage generated is not collected, remaining 70% collected is dumped in landfills or the space available in nearby habitants which are washed away and mixed with nearby water bodies at the time of heavy precipitations during monsoon season [7]. Out of collected garbage, only 18% is treated and the amount of sewage generated every day is 38 billion liters and installed capacity to treat waste water is around 12 billion liters and thus remaining 26 billion liters of sewage are dumped into rivers on daily basis [8].

According to the recent report, released by Comptroller and Auditor General of India (CAG), sewage and industrial waste discharged constitute the main polluting sources of aquatic systems in India and of all waste water generated, only about 10% is treated before being discharged into the water bodies [8].

According to the latest report of World Bank, safe drinking water and good sanitation system is essential for the country so as to check the infant mortality rate and to protect the health. According to Mr Guang Jhe ,the senior Director of World Bank, the universal safe drinking water and sanitation management is not only ensures the public heath but also enhances the economic growth rate. He opines that millions of peoples are suffering from poverty due to lower quality water supply and poor sanitation management. Water is our most abundant resource covering about 71% of the earth surface. About 97% of water is in Ocean as salt water and remaining 3% constitutes fresh water and out of these 3%, 2.5% is stored in Antarctica in the form of ice and 0.5% is in the rivers, lakes and underground and only 0.26% of water is available for human consumption [9].

he quality of water can be changed with the change of season and geographical area as there are several anthropogenic factors such as agricultural, domestic and socio-cultural which contribute to change water quality are changed with the change of season [10]. The gravity of pollution is more in rainy and post-rainy than winter seasons due to the large scale agricultural activities that discharge more agricultural effluents containing fertilizer and pesticide residues to the river.

Besides, anthropogenic activities such as open defecation in the river bed discharge of biomedical wastes and excretion of animals enhances the amount of pathogenic bacteria and protozoa in the river. Lack of toilets and sanitation facilities causes open defecation in the rural and urban pill areas of India, which leads to the pollution of surface water [11]. According to statistical data that more than 14,000 people die daily, 700 million Indians have no access to proper toilet and 1000 Indian children die of diarrhea every day [12].

India is the second largest population after China which is expected to put excess strain on water resources as the number of people grow. Water availability in India is strongly influenced by number of climatic and geographical factors. The rivers in both developing and developed countries in the world are polluted physically, chemically and bacteriologicaly, the review report concludes. In a survey, conducted in 1980, around 25 million people die every year as a result of diseases caused due to unsafe drinking water and poor sanitary conditions, the World Health Organization (WHO) estimates [13]. Now the picture of water pollution in India and abroad is really grim. Approximately 70% of available water in India is polluted and eleven man days are lost per year due to the water related diseases, the estimate report of the scientists of National Environmental Engineering research Centre, Nagpur envisage [14]. According to the report of World Commission on water, more than half of World's major rivers are polluted and they affect the human health, surroundings and ecosystem significantly [15]. In India 36% of urban and 65% of rural population is without access to safe drinking water and they are using contaminated drinking water [16]. The present study reviews a large number of papers on river water pollution in India and abroad published by different research scholars and it not only highlights the sources and factors responsible for pollution but also the methodology required to study pollution as well as the interrelationship among different parameters. The qualitative characteristics of water can be evaluated by assessing the physico-chemical and bacteriological parameters.

Evaluation of Water Quality: Water quality of any water body can be evaluated by applying the methods, as described hereunder.

1. Physical assessment
2. Chemical assessment
3. Bacteriological assessment

1.1. Assessment of Physical Parameters

Following physical parameters are to be evaluated in order to study the physical status of water body under investigation.

1. Turbidity
2. Total dissolved solids (TDS)
3. Conductance
4. Temperature

Turbidity: It measures the transparency and cleanness of any water body. In general, turbidity is higher in rainy season than winter and summer seasons. The higher value of turbidity in rainy season is due to the erosion of soil and floating of particles while lower value during summer and winter may be due to silt and settling of floating materials [17,18]. Panda et. al. while studying the water quality of the river Salandi have observed higher value of turbidity in rainy and lower value in summer season. High turbidity can absorb more heat and thus rise the temperature of water body but it can decrease photosynthesis and dissolved oxygen of the aquatic system [19].

TDS: TDS is a measure of total solids including inorganic salt, organic materials and other soluble substances present in water body. [20,21]. The principal components of TDS are generally Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, HCO_3^{-}, Cl^{-}, SO_4^{2-} and NO_3^{-}. The permissible range is 500mg /L [22].

According to WHO guidelines the stratification is [23].

i) Excellent (< 300mg/L)
ii) Good (300-600 mg/L)
iii) Fair (600-900 mg/L)
iv) Poor (900 – 1200 mg/L)
v) Unacceptable (> 1200 mg/L)

In general, TDS is higher in rainy and post-rainy seasons than the summer and winter seasons. The lower value of TDS in summer season is due to the silt and settling of dissolved materials [17,18] while higher value

of TDS in rainy and post-rainy seasons is due to the entering of agricultural wastes, forest run off, mining wastes, industrial wastes, domestic wastes and after all erosion of soil [19,21,24,25,26,27]. Panda et al. and Wani et al. while studying the water quality of the river Salandi and Dal lake respectively have observed the lower TDS in summer season than winter and rainy seasons [27,28]. Masood K.M, while studying the water quality of Oyun reservoir, Ofla, Nigeria has observed same result of TDS in summer season [17].

Electrical Conductance: The electrical conductance (EC) is a direct measure of the number of ions present in water. Higher the conductance more is the number of ions present and vice-versa. The ions include both anions and cations. Hence TDS and EC are complementary to each other and have a correletionship between two parameters.

Temperature: It is the temperature that holds a key position in study of water quality as it has a direct effect on pH and dissolved oxygen (DO) and regulates the self purification capacity of the river [29]. Temperature of water can affect the metabolic and biological activities of organisms and at higher temperature metabolic activities of organisms increases requiring more oxygen for respiration [30]. Further, if the temperature is above 35°C, then denaturation of certain enzymes take place which can reduce the metabolic function of enzymes [31]. Besides, the temperature can affect the respiration and photosynthesis. At higher temperature photosynthesis of algal increases, though different species require different temperature for optimum photosynthesis [32]. Photosynthesis increases the concentration of dissolved oxygen and decreases the concentration of dissolved CO_2. The respiration, on the other hand increases the concentration of CO_2 and decreases the concentration of dissolved O_2 [8]. But at higher temperature solubility of oxygen in water decreases (10.15 mg/l at 15 degree centigrade to 7.1mg/l at 35 degree centigrade) and decomposition of organic matters takes place liberating acids and carbon dioxide.

Hence, temperature has profound effect on various important parameters such as pH, conductivity, dissolved oxygen and free carbon dioxide [33,34,35]. Panda et al. and Sing et al. while studying the water quality of the river Salandi and three major rivers in Imphal respectively have observed lower pH in the month of May due to the liberation of CO_2 from the decomposition of organic matters at high temperature [27,36].

Moza et al. while studying water quality of the river Beas in Talwara and Mukerian stations during pre-monsoon, monsoon, post-monsoon and witner seasons have reported data, presented in the Table 5. From the data, it is evident that, both in Talware & Mukerian station DO is highest during winter (9.0 mg/L and 8.6 mg/L), when temperature is lowest (18°C and 17.5°C) respectively. Further it can be emphasized that DO is lowest (7.9 mg/L and 6.0 mg/L) when temperature is highest (28°C and 29.2°C) in Talware and Mukerian stations respectively. Hence it leads to conclusion that higher the temperature lowers the DO value and vice-versa.

1.2. Assessment of Chemical Parameters

In order to study the presence of chemical pollutants in the river, following chemical parameters are to be considered.

1. pH
2. TH, Ca & Mg hardness
3. Heavy metals
4. River bed sediment analysis
5. DO
6. BOD
7. COD
8. Cl^-,
9. SO_4^{2-}, NO_3^-, PO_4^{3-}
10. F^-
11. Cd^{2+}
12. Hg^{2+}
13. free CO_2

pH: The p^H is a crucial parameter required for promotion, maintenance and management of both abiotic and biotic ecological system. The corrosive nature of water is measured by p^H and it is inversely proportional to p^H. The p^H of any water body is not constant throughout the year; rather it is changed due to several factors which alter the pH value either directly or indirectly with the change of season [19,37].

The p^H of surface water increases with the increase of photosynthesis by autotrops as they use dissolved CO_2 and release O_2 to the surface water and low pH at the bottom of the water surface is the consequences of decomposition of organic matters at high temperature releasing CO_2 and acids [19,38,39,40]. The dissolution of CO_2 and Cl_2 in the surface of water body form carbonic acid and hypochlorous acid respectively which decrease the pH of surface water [10,18,27]. According to Hutchinson (1975), the water body is neither highly alkaline nor highly acidic, the pH of water body is generally governed by CO_2, CO_3^{2-} and HCO_3^-. According to Saikh & Yarangi, (2003), the p^H during rainy season is due to dissolution of atmospheric CO_2 and dilution of alkaline substances [29].

Hence, it leads to conclude that the pH of any water body can be correlated directly with photosynthesis, temperature, dissolved CO_2 and Cl_2 in the water body. Panda et al. while studying the water quality of the river Salandi has noticed that there is comparatively lower mean value of pH at Hadagada (6.972) and Rajghat (6.954) and this lower pH, according to their opinion is due to comparatively higher value of chloride at Hadagada (22.27mg/L) and Rajghat (23.18 mg/L) [27]. Further the same authors have observed that the lower value of pH (6.5-6.9) during summer season (May) and according their opinion, it is due to the decomposition of organic matters at high temperature [27].

Sing et al. while studying the river quality in three major rivers in Imphal have observed lower value of pH (7.16-7.5) and higher value of free CO_2 (5.67-21.16 mg/l) during summer [39]. Masood K.M., while studying the water quality of Oyun reservoir, Offa, Nigeria, has observed the lower pH (6.8) in the summer due to higher CO_2 concentration from organic decompositions at high temperature [17]. Samantray et al while studying the water quality of the river Mahanadi, Atharabanki and Taladanda have observed the comparatively lower value of p^H during summer season than post-monsoon and winter season, presented in the Table 1, Table 2 and Table 3 respectively and it is due to the decomposition of organic matters at high temperature and low flow of water during summer. [41].

Table 1. Water quality of the river Mahandi with respect to three parameters in three seasons

Location	Season	pH	BOD	DO	Remarks
M1	Post monsoon	7.07	4.7	6.3	1) The DO is low & BOD is high in summer than winter & post-monsoon season. 2) pH is low during summer than winter & post – monsoon season.
	Winter	7.0	4.8	6.1	
	Summer	6.85	5.0	5.9	
M2	Post monsoon	8.08	2.6	6.3	
	Winter	7.81	2.7	6.1	
	Summer	7.66	3.0	6.0	
M3	Post monsoon	7.07	3.8	6.1	
	Winter	6.95	3.9	5.9	
	Summer	6.81	4.0	5.8	
M4	Post monsoon	6.89	5.7	5.9	
	Winter	6.82	5.8	5.7	
	Summer	6.67	6.0	5.5	
M5	Post monsoon	7.20	4.6	5.9	
	Winter	7.12	4.7	5.7	
	Summer	6.97	5.0	5.5	
M6	Post monsoon	6.94	5.8	5.9	
	Winter	6.89	5.9	5.7	
	Summer	6.74	6.0	5.5	
M7	Post monsoon	7.05	2.7	6.1	
	Winter	6.96	2.8	5.9	
	Summer	6.84	3.0	5.8	
M8	Post monsoon	6.98	3.8	6.0	
	Winter	6.89	3.9	5.9	
	Summer	6.78	4.0	5.7	
M9	Post monsoon	7.25	4.8	5.9	
	Winter	7.16	4.9	5.8	
	Summer	7.01	5.0	5.6	
Except pH, BOD & DO are expressed in mg/L					

Table 2. Water quality of the river Atharabank with respect to three parameters in three seasons

Location	Season	pH	BOD	DO	Remarks
T1	Post monsoon	7.17	11.7	5.7	1) The DO is lower & BOD is high during summer than winter & rainy. 2) pH is low during summer than winter & rainy season.
	Winter	7.10	11.8	5.5	
	Summer	6.95	12.0	5.3	
T2	Post monsoon	6.45	17.6	5.0	
	Winter	6.18	17.7	4.8	
	Summer	6.03	18.0	4.7	
T3	Post monsoon	6.63	9.8	5.5	
	Winter	6.51	9.9	5.3	
	Summer	6.37	10.0	5.2	
T4	Post monsoon	6.92	10.7	5.5	
	Winter	6.85	10.8	5.3	
	Summer	6.70	11.0	5.1	
Except pH, BOD & DO are expressed in mg/L					

Table 3. Water quality of Taladanda Canal with respect to three parameters in three seasons

Location	Season	Parameter	BOD	DO	Remarks
T1	Post monsoon	7.38	2.7	6.4	1) The DO is low & BOD is high during summer than winter & rainy season ii) pH is low during summer than winter & rainy season.
	Winter	7.31	2.8	6.2	
	Summer	7.16	3.0	6.0	
T2	Post monsoon	7.27	3.6	6.0	
	Winter	7.0	3.7	5.8	
	Summer	6.85	4.0	5.7	
T3	Post monsoon	7.18	4.8	5.8	
	Winter	7.06	4.9	5.6	
	Summer	6.92	5.0	5.5	
T4	Post monsoon	7.53	3.7	6.0	
	Winter	7.46	3.8	5.8	
	Summer	7.31	4.0	5.6	
Except pH, BOD & DO are expressed in mg/L					

Mosummath et al while studying the seasonal variation of temperature dependent physico-chemical parameters of river Bhadra, Bangladesh, have reported highest value of pH during rainy season (7.68 ± 0.28) and lowest value of ph during summer season (7.09 ± 0.11) [42]. However it may be due to higher rate of photosynthesis and dilution of pollutants due to high flow of water during rainy season and on the other hand lower pH during summer season may be due to liberation of acids and CO_2 as a result of the decomposition of organic matters at high temperature and low flow of water in the river.

1.3. Ca, Mg and Total Hardness (TH)

Calcium and magnesium are essential elements for the metabolic function and these are present commonly in natural water bodies. Total hardness is due to the presence of calcium, magnesium, iron, aluminum, manganese etc. The permissible limit for $Ca^{2+,}$ Mg^{2+} and total hardness (TH) is 75 mg/L, 45mg/L and 300 mg/L respectively according to standard fixed by BIS-IS-10500 [22]. The natural source of Ca and Mg is the mineral rocks from which these are leached. The concentration of Ca & Mg if more than the permissible limit then water for drinking purpose can't be used. According to Campbell and Wildberger (2001), water with calcium level of less than 10 mg/L are usually oligotrophic, while those above 25mg/L are eutrophic [43].

Panda et al., while studying the water quality of the river Salandi have found that, concentration of Ca increases in rainy and post-rainy season than summer and winter season. The higher value of Ca in rainy & post-rainy season, what the authors opine is due to the excessive use of calcium containing fertilizers such as calcium ammonium nitrate, basic calcium nitrate and calcium superphosphate by the farmers during rainy and post-rainy season [26,27,44,45]. The same authors have observed the higher concentration of Mg than Ca in summer season (April & May) in certain monitoring stations and it can be due to the fact that magnesium hardness increases in summer than calcium hardness as higher concentration of CO_2 in the summer season, resulted due to the decomposition of organic matters at high temperature forms soluble magnesium bi-carbonate from insoluble magnesium carbonate. The same thing may not occur in case of Ca due to its lower solubility as magnesium compounds are more soluble than calcium compounds [27,46].

Panigrahi et al., while studying the water quality of river Mahanadi, Cuttack city in the downstream (Kaliaboda) have observed the higher value of Mg^{2+} (6.40 mg/L) in summer season than Ca^{2+} (6.33 mg/L) [46].

1.4. Fe (> 0.3.) & Cr^{6+} (> 0.05)

Iron is an important element required for plants and animals and insoluble Fe^{3+} can be reduced to soluble Fe^{2+} in water by bacteria [37]. The soluble Fe^{2+} is inhabitable for human and animal as Fe^{2+} in hemoglobin carries out oxygen. Chemical weathering of geological materials is the major source of Fe in natural water. Besides, mining runoff from iron mines, industrial effluents from iron extraction industries, pigment and paint industries together with agricultural wastes, when mixed with natural water bodies increases the concentration of Fe in natural water. The permissible limit of Fe in natural water is 0.3 mg/L and when the concentration of Fe increases this value, the water is treated as polluted.

Chromium is a redox active element that exists in water as Cr^{3+} and Cr^{6+}. Cr^{3+} is essential for human body as it discharges vital role for the maintenance of metabolism of glucose, lipid and protein where as Cr^{6+} has been reported to be toxic and carcinogenic due to its oxidizing potential [47,48]. The drinking water also contains Cr^{6+} due to the oxidation of Cr^{3+} by manganese. Cr^{6+} has been reported to accumulate mainly in the root of plants where it is reduced to Cr^{3+} in vacuole [49,50,51].

The permissible limit of Cr^{6+} in drinking water is 0.05 mg/L [22,52] and water is unfit for drinking when concentration of Cr^{6+} exceeds this value due to the mixing of chromite mining discharges, industrial discharges containing Cr^{3+} or Cr^{6+} as well as agricultural discharges containing pesticide and fertilizer residues [27,53-58].

Besides, the dust contaminated with heavy metals in the mining and industrial areas pollute the natural water bodies when comes to the surface of earth through rain water precipitations and it is mixed with water bodies as rain water runoff. [57,59,60,61].

Kar et al, Ishaq et al and Panda et al while studying the water quality of river Ganga, Yamuna and Salandi respectively have observed the higher concentration of heavy metals such as Cr and Fe in the river water. Further, Panda et al. have observed the higher concentration of Cr in the river water in rainy and post rainy season than summer and winter seasons in an irregular manner. Further it is observed that concentration of Cr^{6+} is higher in the month of May than April. This higher value of Cr^{6+} in rainy season according to the author can be due to the excessive use of chemical fertilizer and pesticides by the farmer in rainy season that might contain Cr^{6+} and mixing of mining run off, industrial run off with the river water and after all rain water precipitations of contaminated dusts containing Cr^{6+}. Further the higher concentration of Cr^{6+} in the month of May is due to the low flow of water in the river [26,27,53,62].

Cadmium (Cd^{2+}) & Lead (Pb^{2+}):- In river water, cadmium is found to be as Cd^{2+}. Now-a-days Cd^{2+} is found in the river water due to its vast applications and hence it enters to the river from different sources such as industries, mines and atmospheric deposition as a result of combustion of fossil fuels [63,64,65]. Besides, Cd is used in making rubber, pesticides, semiconductors and nuclear reactors. The permissible value of Cd^{2+} is 0.003 mg/L for drinking water and when the concentration of Cd^{2+} exceeds this value, water is treated as polluted [22]. Reza et al while studying the water quality of the river Brahmani in Talcher area, Angul (Odisha) have noticed that higher concentration of Cd^{2+} (4mg/L) in summer season. The higher value, according to the authors, is due to the combustion of coal in thermal power station [57].

Fourzia et al while studying water quality of the river Yamuna have observed the presence heavy metals including Cd^{2+}. The presence of heavy metals in the river water, according to the authors' opinion is due to the deposition of particulate matter in the sediments of water bodies and remobilization of these substances from the sediments to aquatic environments [19].

Lead is found in water as +2 oxidation state and comes from the sources such as industries, mines, smelting plants, pesticides ,etc. It is used in large scale in lead acid batteries, rust inhibitors etc. [66,67,68]. The permissible limit of Pb^{2+} is 0.01 mg/L [22].

Reza et al while studying the water quality of river Brahmani have noticed the higher concentration of Pb^{2+} in summer season (27µg/L) [57]. Kar et al while studying the water quality of river Ganga have recorded the higher value (mean) of Pb^{2+} in winter season (0.14 mg/L) [56].

1.5. Nickel

Commonly nickel is available in water as +2 oxidation state. Nickel is released to the environment from natural sources and anthropogenic activities. Natural sources include weathering of rocks and soils. Nickel and its compounds find vast applications such as for the preparation of stainless steel. Nickel enters into water bodies due to the atmospheric deposition from combustion of coal, fuel oil and diesel. Besides, domestic waste water containing Ni also increases concentration of Ni in the water bodies. The permissible limit for Ni, according to WHO guide lines is 70 µg/L in the drinking water [69] or 0.02 mg/L for drinking water [22].

In addition to this the presence of As and Hg should be done as As and Hg are poisonous metals and in drinking water if present in higher concentration (> 0.01 and > 0.001 / mg/L respectively) can cause serious health hazard. [22].

1.6. Sulphate, Nitrate and Phosphate

SO_4^{2-}, NO_3^- & PO_4^{3-}: Sulphate enters into natural water from different sources such as weathering and dissolution of minerals such as gypsoum, epsomite, barite, [70] oxidation of elemental sulphur and sulphides, decomposition of animal and plant residues [66]. Besides, industrial wastes from the industries such H_2SO_4 plants, dyes, textile mill, insecticides, fungicides preparation units and fertilizer plants. Further, municipal wastes, domestic wastes and sulphate containing fertilizer residues, when disposed off to the water bodies increases the concentration of sulphate. The permissible limit of sulphate in drinking water is 150 mg/L [22] and when the concentration of sulphate exceeds this limit, water is treated as polluted.

Kalavaty et al while studying the water quality index of the river Cauvery in Tiruchirappali district, Tamilnadu have observed that sulphate values are from 13. 2 – 31. 1 mg/L and according to the author, the higher value of sulphate is due to mixing of untreated domestic sewage with the river water [25].

Nitrogen species including NO_3^-, NO_2^-, etc are essential nutrients for growth of plant and other organisms. The permissible limit is 45 mg/L for NO_3^- and causes harmful effect when the concentration of NO_3^- exceeds this value [22]. It is observed that nitrate pollution in the surface water is mainly due to industrial, municipal and domestic waste disposal to the surface water bodies along with agricultural runoff containing nitrogen species and atmospheric deposition of industrial emissions contribute significantly [19,27,58,71,72]. Phosphorous is predominantly present in water and waste water as phosphates and classified as orthophosphates, phosphates and organic phosphates. These compounds are available in the organisms and plant residues [73,74]. Besides, ferric and calcium phosphate present in rocks are a major source for the supply of phosphate to aqcuatic system. Another sources of phosphate are the specific bacterial action that release phosphate from organic phosphorus compounds present in plant residues [75], sewage [76], animal manures, detergents such as sodium tripolyphosphate used for washing purposes [74] and phosphate containing fertilizers used by the farmers for agricultural purpose. [19,25,27,58,71,72].

Masood, K.M., while studying water quality of Oyun reservoir, Offa, Nigeria has observed that higher value of nitrate (6.4 mg/L), phosphate (2.2 mg/L) and sulphate (16.9 mg/L) during rainy season [17]. Panda et al, while studying the water quality of the river Salandi have observed the similar findings i.e. higher value of sulphate (15 mg/L), nitrate (5.5 mg/L) and phosphate (4.3 mg/L) during rainy season. It is due to the mixing of mining effluents, agricultural effluents, industrial wasters, urban wastes along with the forest run off containing biological residues with the river water [19,25,26,27,71,72]. The agricultural residues contribute significantly in rising the concentration of above parameters as during rainy season the farmers use fertilizers and pesticides in large scale that contain SO_4^{2-}, NO_3^- and PO_4^{3-} and in ideal conditions the plants use only 50% of the nitrogenous fertilizer applied, 2 -20% is lost due to evaporation, 15-25% react with the organic compounds of the soil and remaining 2-10% interfere with surface and ground water [17,18,27,58,77,78].

Mishra et al while studying the seasonal variation of physico-chemical and bacteriological parameters in the river Ganga in Varanasi have reported the higher value of NO_3^- and PO_4^{3-} during summer than rainy and winter seasons, shown in the Table 4. It may be due to low flow of water during the summer season [71].

1.7. Chlorides

Chlorides are normally available in the form of soluble salts. The principal sources of chloride are domestic sewage, industrial discharges, urban waste materials, fertilizer and pesticides, use of bleaching agents, septic tank effluents and animal feeds [19,25,27,79].

Panda et al, while studying the water quality of the river Salandi, have observed the higher value of chlorides during summer season (25-30mg/L) [25,26,45]. Kalavathy et al while studying the water quality of the river Cauvery have also observed the higher values of chloride during the summer season (94-100mg/L) in comparison to winter season. The authors have mentioned no reason for it. However, it may be due to low flow of water during summer season that rises the concentration of chloride. Further Panda et al have observed the excessive high concentration of chloride at Tinitaraf ghat irrespective of the season (1745-1760 mg/L). It is due to the back flow of sea water to the river from the sea as a result of tide, what the authors opine [27,56]. Mishra et al while studying the variation of physico-chemical and bacteriological parameters of the river Ganga in Varanasi have observed higher values of chloride during summer season than rainy and winter seasons, presented in the Table 4. It may be due to low flow of water [71].

Table 4. Water quality of the river Ganga in Varanasi in three seasons with respect to seven parameters in five sites

Parameters	Site-1			Site-2			Site-3			Site-4			Site-5			Inference
	S	R	W	S	R	W	S	R	W	S	R	W	S	R	W	
Temperature (^{0}C)	27.6	24.5	20.3	26.1	23.4	20.1	20.9	21.8	21.7	25.1	23.2	22.2	19.5	19.6	19.1	1.BOD is highest & DO is lowest during summer due to highest temperature. ii) Cl^- & NO_3^- & PO_4^{3-} are higher during summer due to low flow of H_20
pH	8.3	8.1	8.2	7.8	7.7	7.7	7.3	7.2	7.2	7.5	7.6	7.4	7.4	7.3	7.2	
BOD	589.0	560.0	490.0	389.0	325.0	320.0	310.0	210.0	205.0	310.0	300.0	295.0	100.5	98.5	95.6	
DO	1.8	1.9	2.1	2.2	2.4	2.6	3.4	3.8	3.9	2.3	2.5	2.6	5.1	5.8	5.9	
Cl^- (mg/L)	46.7	43.5	42.3	42.2	41.9	41.0	36.2	33.5	32.5	42.6	41.5	40.0	31.6	30.2	30.3	
NO^-_3 (mg/L)	2.6	2.5	2.3	2.2	2.1	2.1	1.5	1.49	1.4	2.0	2.1	1.9	1.3	1.1	1.0	
PO_4^{3-}(mg/L)	5.9	5.8	5.6	5.4	5.2	5.3	5.1	5.1	5.0	5.0	4.9	4.9	4.5	4.6	4.3	
S- Summer, R-Rainy, W - Winter																

1.8. Fluorides

Fluoride causes fluorosis, if concentration is more than the permissible range (0.6 – 1.5 mg/L) in drinking water [22,80]. The principal sources of fluoride are soluble compounds of fluorine such sodium fluoride (NaF), fluorosilisic acid (H_2SiF_6], sparingly soluble compounds of fluorine such as CaF_2 and cryolite (Na_3AlF_6] present in the soil and rocks [81,82]. The phosphate fertilizers also contain an average amount of 3.87% of fluoride which can be released into the river water as agricultural residues. Water, when passes through and over the soil containing fluoride dissolves it and carries to the nearby water bodies. [81]. Panda et al, while studying the occurrence of fluoride in ground water of Patripal Panchayat in Balasore district, Odisha, have observed much higher concentration of fluoride at the downstream of Sono river, especially at Kuanrpur station during the summer season (5.83 mg/L) than rainy (3.92 mg/L) and winter season (5.81 mg/L). According to the author's view, the higher concentration of fluoride in the water sample in the downstream of the Sono river in the summer season is due to the mixing of treated or semi-treated effluents containing high fluoride content of different industries [83] and higher value during summer may be due to low flow of water during the summer season.

Mishra et al while studying the occurrence of fluoride in ground water in Ganga alluvial plains in India, have observed the higher concentration of fluoride in many parts of India [84].

1.8. Dissolved Oxygen (DO)

The dissolved oxygen (DO) is a crucial parameter required for maintenance, management and promotion of aquatic system as DO plays a vital role in chemical and biological functions. Higher the DO for any water bodies, less the pollutants and vice-versa. The major governing factors affecting the concentration of DO are input sources such as dissolution of atmospheric oxygen in water, photosynthesis by autotrops, aeration and output sources such as respiration, decomposition of organic matters by micro-organisms and evaporation at high temperature [10,19,27,40,71,85]. Hence, DO concentration of any water body increases if input sources are higher than the output sources and minimum requirement of DO is 6 mg/L for drinking purpose and 4 mg/L is for fish culture. The concentration of DO of any river water changes over 24 hours and with the change of season as respiration, photosynthesis, temperature, aeration and turbidity are changed with the change of season. The DO values of any river can be affected due to the discharge of mining, Industrial, agricultural and after all domestic wastes to the river system as dissolved oxygen is used in redox reaction process to stabilize the pollutants [27,86]. Further anthropogenic activities such as open defecation in the river bed, picnic and other socio-cultural activities also affect the DO value of any river system [25,71]. As reported by Reporter, 2008, 700 million Indians have no access to a proper toilet [12].

Samantray et al while evaluating the water quality of the river Mahandi, Atharabani and Taladanda Canal have observed the lower value of DO during summer season in comparison to rainy and winter seasons in all monitoring stations as cited in the Table 1, Table 2 and Table 3 respectively [41].

Panda et al, while studying the water quality of the river Salandi, have observed the lower value of DO during summer season (6.0 – 6.8 mg/L) except the monitoring stations at Hadagada and Akhandalmani. It is due to the high rate of evaporation, low dissolution of atmospheric oxygen and high biological oxidation at higher temperature and after all low to flow of water [25,27,45,71,79,87,88,89,90].

Further same authors have observed the higher value of DO (7.1 mg/L) during rainy and post rainy seasons. It is due to the high flood in the river that dilutes the pollutants, aeration and after all dissolution of more atmospheric oxygen in the river water [27,36,37,45]. Masood, K.M. while studying the water quality of Oyun Reservoir, offa, Nigeria [17] and Tape, et al while studying physico-chemical characteristics of Hatay Harbiye (2005) [76] spring water, Turkey have observed higher DO value during rainy season. According to the authors view, it might be due to low temperature and high water flow during rainy season.

Sing et al while studying water quality of three major rivers in Manipur, Imphal have also observed the higher value of DO during rainy seaon i.e. 6.04 ± 0.74 mg/Lin the Irii river and 4.76 ± 0.66 mg/L in Nambul river [36]. Mishra et al while studying the seasonal variations of physico-chemical parameters of the river Ganga in Varanasi have reported higher value of DO in winter and lower value of DO during summer, cited in Table 5 [71]. The authors have mentioned no reason for it. However, it may be due to highest temperature during summer season and lowest temperature during winter season that promotes the rate of evaporation during summer and lowest temperature during winter season promotes the rate of dissolution of atmospheric oxygen in the river water.

Pardeshi et al while studying the water quality of the Waldhuni river, Ulshanagar, Thane have also recorded the same findings highest value of DO in rainy season (2-6 mg/L) and lowest value of DO in the summer season (0.4 – 1.0 mg/L) [10]. Mosummath et al ,while studying seasonal variation of temperature dependent physico-chemical parameters of river Bhadra, Bangladesh, have reported highest value of DO during winter (5.38 ± 0.62) and lowest value during summer season (4.40 ± 0.46 mg/L) [42]. However higher value during winter season may be due to more dissolution and low evaporation of atmospheric oxygen due to low temperature (21.56 ± 0.84) °C and low value of DO during summer season is due to high rate of evaporation and more decomposition of organic matter at highest temperature (32.12 ± 0.79)°C.

1.10. Free Carbon Dioxide

The free carbon dioxide is an important parameter required to study water pollution as it is directly related with pH. The sources from which free CO_2 is generated are atmospheric dissolution, respiration by autotrops and decomposition of organic matters by micro organisms at high temperature. It is generally observed that during the summer season concentration of CO_2 is high due to the decomposition of organic matter at high temperature. Higher the concentration of CO_2 in the river water, lower the pH and vice versa as the former forms carbonic acid with water [10,33,34].

Pardeshi et al while studying the water quality of Waldhuri river Ulhasnagar, Thane have reported the higher concentration of CO_2 and lower pH during summer than winter and rainy season. The values of pH and CO_2 for the year 2010 & 2011 have been presented in the Table 6 & Table 7 respectively. It is observed that during two year of study the highest concentration of CO_2 in summer (May), when temperature is highest and lowest concentration of CO_2 in rainy (August) when temperature is lowest. It is due to the decomposition of organic matters at high temperature and low flow of water. During the rainy season, it is diluted and stabilized in the river bed in due course of flow and decomposition of organic matters is insignificant as the temperature is lowest.

Ishaq et al while studying the concentration of heavy metal in the river Yamuna and their relationship with some physico-chemical parameters have reported that the concentration of free CO_2 in mg/L at the site S1, S2 and S3 are 1.632 ± 0.219, 1.73 ± 0.324 and 1.68 ± 0.173 respectively and the value of pH at the above corresponding sites are 8.3 ± 0.293, 8.13 ± 0.30 and 8.28 ± 0.17 respectively. It is observed that in above three sites S_1, S_2 & S_3 free CO_2 & pH correlate accordingly, but in sit S_3 there is non-significant increase pH in comparison to S_2 though the concentration of CO_2 is less in S_3 than S_2. The authors are silent on the issue. However, it may be due to increase in concentration of chloride in site S_3 (43.46 ± 4.92) in comparison of site S_2 (36.0 ± 3.33), which forms more hypochlorous acid. [10]. The seasonal variation of temperature dependent physico-chemical parameters was studied by Mosummath et al and had reported the highest value of free CO_2 during summer (9.85 ± 1.18) mg/L and lowest value during rainy (3.89 ± 1.13) [42]. However the highest value of free CO_2 during summer may be due to decomposition of organic matters liberating CO_2 at highest temperature (32.12 ± 0.79)°C.

2. Biochemical Oxygen Demand (BOD)

Like DO, BOD is an important parameter required to study water pollution. The higher BOD value of any water body, more the water polluted by the organic pollutants. On the basis of five days BOD test the quality of water has been classified as following [66].

1. Very clean, if BOD Level is < 1mg / L
2. Clean if BOD Level is 1.1 – 1.9 mg/L
3. Moderately polluted if BOD Level is 2-2.9 mg/L
4. Polluted if BOD is 3-3.9 mg/L
5. Very polluted if BOD Level is 4-10 mg/L
6. Extremely polluted if BOD Level is > 10mg/L

Water is generally treated as polluted if BOD value is more than 3 mg/L [22]. The value of BOD of any water body increases due to the mixing of industrial, mining, agricultural, urban and domestic effluents with the water. In general the higher the value of DO for any water body, lower the BOD and vice versa, ie, the DO and BOD of any surface water body are inversely related. However there are also deviations observed, as cited hereunder.

Samantray et al while studying the water quality of the river Mahandi, Talandanda Canal and Akharbanki river during different season have reported the results presented in the Table 1, Table 2 & Table 3 respectively. From the result, it is construed that DO and BOD are inversely related and emphasizing observation is that BOD is higher during the summer season than winter & post monsoon. It may be due to the low flow of water during summer and decomposition of organic matter at higher temperature that consumes more oxygen [41].

Panda et al while studying the water quality of the river Salandi during different seasons have observed an interesting fact, i.e, during rainy and post rainy season both DO and BOD increase simultaneously. The higher value of DO during the aforesaid season, what the authors opine, is due to the high flood, aeration, photosynthesis by autotrops as myxophyceae bloom is observed in the river bed and after all dissolution of more atmospheric oxygen in the river water and on the other hand higher value of BOD can be attributed to high flood and rain water that carries forest run off containing biological residues as Similar reserve forest is very nearest to it, mixing of mining, industrial, domestic and urban wastes with the river water [26,27,45].

Moza et al while studying the water quality of the river Beas in Talawar and Mukerian stations during pre-monsoon, monsoon, post-monsoon and winter seasons have reported the following data presented in the Table 5.

Talwara (pre-monsoon), DO (8.7 mg/L), BOD (9.0 mg/L), monsoon – DO (7.9 mg/L), BOD (3.83 mg/L), Post-monsoon) – DO (7.3 mg/L), BOD (6.4 mg/L), Winter - DO (9.0 mg/L), BOD (12.0 mg/L).

It is evident from above data that, in Talwara station both DO & BOD decrease in monsoon and increase in winter in comparison to pre-monsoon. But during post-monsoon, DO decreases and BOD increases. The authors are silent on the cause. However it may be due to the increase of hardness (133.50 mg/L) as compared to

monsoon (118.3 mg/L) and pre monsoon (131.7 mg/L), Mukerian (Pre-monsoon) – DO (8.1 mg/L), BOD (12.7 mg/L), (Monsoon) – DO (6.0 mg/L), BOD (7.70 mg /L), (Post-Monsoon) – DO (8.5 mg/L), BOD (8.2 mg/L), (Winter) – DO (8.6 mg/L), BOD (16.8 mg/L).

It is evident from above data, during monsoon both DO & BOD decrease and in other three seasons increase. Further it is construed from analysis of data that variation of DO and BOD are directly proportional to each other.

Table 5. Water quality of the river Beas with respect to three parameters in four seasons

Station	Season	Water quality parameters	Content	Inference
Talware	Pre-monsoon	Temperature	25°C	
		DO	8.7 mg/L	
		BOD	9.0 mg/L	
	Monsoon	Temperature	28°C	Highest
		DO	7.9 mg/L	Decreases
		BOD	3.83 mg/L	Decreases
	Monsoon	Temperature	22°C	
		DO	7.3 mg/L	Decreases
		BOD	6.4 mg/L	Increases
	Winter	Temperature	18°C	Lowest
		DO	9.0 mg/L	Increases(Highest)
		BOD	12.0mg/L	Increases
Mukerian	Pre Monsoon	Temperature	26.3°C	
		DO	8.1 mg/L	
		BOD	12.7 mg/L	
	Monsoon	Temperature	29.2°C	Highest
		DO	6.0 mg/L	Decreases
		BOD	7.7 mg/L	Decreases
	Post-monsoon	Temperature	19.3°C	
		DO	8.5 mg/L	Increases
		BOD	8.2 mg/L	Increases
	Winter	Temperature	17.5°C	Lowest
		DO	8.6 mg/L	Increases(Highest)
		BOD	16.8mg/L	Increases

Table 6. Water quality of waldhuni river, Thane with respect to five parameters during the year, 2010

Name of station	Temperature in May, 2010	Temperature in August, 2010	pH in May, 2010	pH in August, 2010	CO_2 in May, 2010	CO_2 in August, 2010	DO in May, 2010	DO in August, 2010	BOD in May, 2010	BOD in August, 2010	Remarks
Kakola Lane	34.1	27.5	6.5	7.4	85	35	1.0	6.0	3.0	1.0	1) Lower DO, pH & higher BOD & CO_2 during summer season; when temperature is higher 2) Higher BOD at the petrol pump station during summer is due to higher decomposition of organic matter as concentration of CO_2 is highest.
Amp gate	33.4	27.1	6.3	6.5	359	176	0.5	3.0	115.0	163.0	
CHM gate	33.2	27.4	5.5	6.2	385	190	0.4	2.0	191.0	20.0	
Petrol Pump	32.9	27.5	2.5	6.1	388	195	0.4	2.0	248.0	30.0	

Except pH & temperature all the concentration have been expressed in mg/L.

Table 7. Water quality of Waldhuni river, Thane, with respect to five parameters, 2011

Name of station	Temperature in 0^0 May, 2011	Temperature in 0^0 August, 2011	pH in May, 2011	pH in August, 2011	CO_2 in May 2011	CO_2 in August, 2011	DO in May, 2011	DO in August, 2011	BOD in May, 2011	BOD, August, 2011
Kakola Lake	33.5	27.2	6.5	7.5	75	29	1.5	5.6	4.0	1.2
Amp gate	33.8	27.5	4.1	6.3	361	185	0.4	3.5	125.0	18.0
CHm gate	33.5	27.1	2.4	6.2	381	189	0.3	2.4	250.0	21.0
Petrol Pump	33.7	27.2	2.1	6.1	395	198	0.2	2.2	206.0	33.0

Except pH and temperature, all the concentrations of CO_2 have been expressed in mg/L.

Sing et al while studying the seasonal variation of some physico-chemical parameters of three major rivers in Manipur, Imphal have observed the higher value of BOD (5.74 ± 1.03) and (8.44 ± 1.70) along with higher value of DO (6.04 ± 0.74) and (4.76 ± 0.66) during rainy season in the river Iril and Nambul respectively than summer and winter season [36].

Pardeshi et al while assessing physico-chemical parameters of river Waldhuni, Ulhasnagar, Thane [10] have reported higher value of BOD during summer season (3-291 mg/L) than rainy (1-30 mg/L) and post-rainy season (1.2-35 mg/L) presented in Table 6 & Table 7. The lower value of BOD during rainy and post rainy seasons may be due to dilution of pollutant by the large volume of water and self purification capacity of the river. Further, it is observed that DO and BOD are reciprocal to each other.

Kalavathy et al while assessing water quality index of the river Cauvery in Tiruchirapalli district, Tamilnadu during winter season (January – March) have reported mean values of BOD in three station, viz., S_1 (1.47mg/L),S_2 (1.5 mg/L) and S_3 (1.5 mg/L). The authors are remained silent on the result. However the higher mean value of BOD in the station S_2 and S_3 may be due to the higher mean value of chloride (81 mg/L), sulphate (24.5mg/L) as compared with station S_1 (chloride – 77 mg/L, sulphate – 22.13 mg/L) [25].

Mishra et al while studying the seasonal and tamporal variation in physico-chemical and bacteriological characteristics of the river Ganga in winter season have reported highest value of BOD (589.0 mg/L) and lowest mean value of DO (1.8 mg/L) in site – 1 during summer and lowest mean value of BOD (956 mg/L) in the site-5 with highest mean value of DO (5.9 mg/L) during winter [71]. From the analysis of result, it concludes that the DO and BOD are reciprocal to each other normally. Further it is observed that the DO values are always lower in summer season than rainy and winter seasons in all sampling stations i.e., (1.8 mg/L, 1.9 mg/L, 2.1 mg/L), (2.2 mg/L, 2.4 mg/L, 2.6 mg/L), (3.4 mg/L, 3.8 mg/L, 3.9 mg/L), (2.3 mg/L, 2.5 mg/L, 2.6 mg/L), (5.1 mg/L, 5.8 mg/L, 5.9 mg/L) are in site S_1, S_2, S_3, S_4 and S_5 during summer, rainy and winter seasons respectively. The authors have mentioned no reason to account for it. However, it may be due to high rate of evaporation and law rate of dissolution of oxygen, lower photosynthesis and more decomposition of organic matters at high temperature during the summer season. Further it is worth mentioning that lowest value of DO and highest BOD during the summer season in the site S_1 as it has highest temperature during summer season (27.6°C) in comparison to other four stations. The values are presented in Table 4.

3. Chemical Oxygen Demand (COD)

It is defined as amount of oxygen required for oxidation of both organic and inorganic pollutants and hence COD for a particular water sample is higher than the BOD. For oxidation purpose of both organic and inorganic materials $K_2Cr_2O_7$ is used. It measures the degree of water pollution and self purification capacity of the river. The COD study is very rapid and result can be obtained within few hours and value of COD for water sample must be within 20 mg/L [91]. Pardeshi etal while assessing the physico-chemical parameters of Waldhuri river, Ulhasnagar, Thane have reported highest value of COD at petrol pump sampling station (740 mg/L and 722 mg/L) in the both the years, 2010 & 2011 respectively. It is due to the fact that all the pollutants (TH = 399 mg/L & 405 mg/L), TDS – 1005 mg/L & 1015 mg/L,) are highest in this sampling station during the year 2010 and 2011 respectively [10].

4. Analysis of Bed Sediments

The analysis of river bed sediments gives the important information regarding the toxic pollutants present in the water body and toxicants include Pb, Cd, As etc [92,93,94]. The recent work finds trace elements in the river bed due to their persistent and non-degradable properties and are likely to enter into the human body through food chain. The presence of Fe, Zn, Cu, Pb, Cd, Mn, Cr and Ni in the bed sediments of the river Gomati in Uttar Pradesh was found [95]. The most important pollution sources of the river Gomati were its tributaries which carried raw effluents and waste water discharged from industries and towns. The status of water quality of the river Damodar was studied and the result found confirmed the presence of pollutants such as Mn, Cr, Pb, As, Hg, Cd, Cu and F^- in the river sediments [96].

5. Bacteriological Assessment

The bacteriological assessment of any water body is highly essential because the presence of pathogenic bacteria in water can create several water borne diseases in both human and animals. It includes fecal coliform and total coliform. The possible sources of coliform contamination in the river water are excretion of animals, open defection in the river bed, burning and throwing of dead bodies to the river, mixing of urban waste water, domestic waste water and biomedical wastes [27,45]

Mishra et al while studying the bacteriological contamination of the river Ganga in Varanasi have observed the presence of following bacteria and the amount of bacteria is more in rainy season than summer and winter seasons. According to the authors view, the higher amount of bacteria during rainy season may be due to presence of organic matters that enhance the bacterial growth and multiplication [71]. E. coli is prevalent in every season. The bacterial contaminations of the river Ganga in Varanasi have been presented in the Table 8. The once upon a time water of the river Ganga, considered as most sacred, now is unfit for domestic use without proper treatment for which Government. of India has taken “Ganga Udhar Jojna” to purify the river Ganga.

Panda et al while studying the bacterial contamination of the river Salandi have observed bacteria in all monitoring stations irrespective of nature of season. But exact nature and amount of bacteria was not performed. According to the authors view, it is due to the mixing of biomedical wastes, open defecation in the river bed, excretion by animals and disposal of urban and domestic waste water to the river [27,45].

Table 8. Bacterial species isolated from Ganga water in Varanasi

Bacteria	Summer	Rainy	Winter	Disease caused
Actinomycetes SP	+	+++	+	Actinomycosis of mouth, lungs
Streptococcus	++	+++	++	Pharyngitis, Vaginitis
Shigella sp	+	++	+	Bacillary dysentery
Salmonella paratyphi	-	+++	-	Typhoid fever
Salmonella typhi	++	++	-	Typhoid fever
Clostridium perfirgens	+++	+++	++	Necrotic enteritis, food poisoning
Escherichia coli	+++	+++	++	Cholecystitis, Cholangitis
Psuedomonos aeruginosa	+	+++	+	Respiratory system infections, bone & joint infection
Kiebsiella pneumoniae	+	++	-	Pneumonia, meningitis
Bacillus anthracis	-	++	+	Anthrax
Aerobacter aerogenes	+	+++	-	Produce gas and acid from sugars and responsible for souring of milk.

6. The Other Polluted Rivers in India and Abroad

Most of the rivers in urban areas of the developing countries are at the ends of effluents discharged from the industries. The quantum water pollution of Tigris river was studied and the result showed a significant degradation of water quality of the river due to receive of liquid and solid wastes discharged from sewage system. [97].

The effect of storm on the water quality and pollution load in Kanda river, a small urban tidal river in Tokyo, Japan was studied and the result found indicated that organic pollutants and suspended solids were present during flood phase. Further the fluctuations of DO is due to run off and intrusion of hypoxic water from downstream [98,99]. The bacteriological and physico-chemical analysis of Alierodom in Nigeria was carried out and it was concluded most of the physico-chemical parameters were found within the range while the level of nitrate and DO indicated high level of biological activity in the water due to the discharge of uncontrolled municipal effluents and animal wastes leading to eutrophication [100].

Gebreyohannes et al investigated the physico-chemical parameters and its pollution implications in Elala river in Ethiopia. The result established that though it might be useful for agricultural purpose, yet it is not at all potable without appropriate treatments which arise due to improper disposal of sewage, agricultural runoff and waste water from different domestic activities [101].

The water quality of Narmada river and its reservoirs was investigated by analyzing the various physico-chemical parameters. It has been observed that water quality of the river is deteriorated due to discharge of domestic, industrial effluents, various human and animal activities along the bank of the river [102,103]. The picture of Damodar river was studied and it was found that water contains heavy metals like Mn, Cr, Pb, As, Hg, Cd, Cu and non-metals such as F^- in the sediments [96].

The water quality of Sabaramati river, a source of irrigation, drinking water and a sink for urban and industrial waste water was evaluated. It was found that the levels of nutrients of water are being adversely affected due to higher rate of anthropogenic activities, illegal discharge of sewage and industrial effluents, lack of proper sanitation, unprotected river sites and urban run off. [104,105].

The analysis of important physico-chemical parameters of Satluj river and Gobinda Sagar lake in Himachal Pradesh shows higher value of turbidity, COD, BOD and chlorides as compared with Bureau of Indian standard (BIS). It reveals that the pollution in Satluj river is due to siltation, domestic, municipal sewage, industrial effluents and surface run off [106,107,108].

The physico-chemical analysis of Ayad river water Udayapur, Rajasthan was studied by Rathore et al and the results reveal that the fairly high values of fecal coliforms and BOD which are indicative of increasing pollution load of the river by organic means, particularly through discharge of sewage and domestic effluents into the river. [109] Evalution of physico-chemical parameters of river Krishna and Sangli, Maharastra was done by Sarwade et al and the result highlighted a significant alterations in physico-chemical parameters, which may be due to immersion of idols, discharge of domestic wastes, mixing of sewage and sand dredging [110]. Sahu et al studied the physic-chemical analysis of Mula-Mutha river at Pune. It was observed that the river was highly polluted because of its role in carrying out municipal and industrial sewage and run offs from agricultural lands in their vast drainage basins leading to enormous damages to the environment directly putting the lives at risk [111].

The assessment of water quality of Saank river at Morena, Madhyapradesh was studied by Kevat et al and the result shows that the water quality of river Saank is deteriorated very badly due to the addition of domestic sewage, anthropogenic activities, rapid industrialization and dumping of solid wastes which make the water unfit for drinking purpose [112].

Water pollution and its effects were studied by Sing` et al and the result obtained showed that the water in lentic and lotic system has tremendously deteriorated due to rapid unplanned industrialization, human interventions and also toxic effects of pesticides like organochlorides and organophosphates [113].

An estimation of seasonal variation of human pathogenic bacteria in different sites of the Barak river was carried out and the result concluded that of most of sites were not suitable for domestic purpose with respect to fecal coliform and total coliform as per standards of National River conservation Directorate, India [114].

Water quality assessment of river Ganga and Gomati, a tributary of Ganga, was carried out by many researchers to assess the impact of sewage, industrial pollution

and human activities on the water quality of the river. The important parameters such as biological oxygen demand (BOD), chemical oxygen demand (COD), total hardness (TH), total suspended solid (TSS) and fecal coliform were determined which shows a high value [115-121].

7. Conclusion

The river water pollution is a gigantic problem not only in India but also for the entire world. Both developed and developing countries are suffering from river water pollution, though the gravity of pollution differs from place to place. The present work concludes that the river water in India and abroad is largely polluted with respect to physically, chemically and bacteriologically due to the entry of pollutants from various sources such as industry, mines, agriculture, urban, domestic and medicals. Besides, this work establishes a relationship among different physico-chemical parameters. The DO is related with temperature, photosynthesis, respiration and turbidity [19,27,41,42,45,71]. The pH is related with temperature, photosynthesis, dissolved carbon dioxide and chloride. Further, the work found that, the value of DO is lower during summer season due to high temperature and higher during winter season due to low temperature. Hence temperature and DO are inversely related. It is also found that in certain cases, the value of DO increases during rainy season due to flood and aeration [10,27,36,45]. The review also finds that the DO and BOD are reciprocally related with certain deviation [10,41,42,71]. The deviation highlights that DO and BOD increase due to simultaneous rise of concentration of pollutants and dissolved oxygen [36,122].

The dissolved free carbon dioxide is directly related with temperature and during summer season, when temperature is high free CO_2 is high and during winter season, when temperature is low, free CO_2 is low [10,62,42]. Also, there exist a relationship among pH, temperature, photosynthesis, dissolved carbon dioxide and dissolved chlorine. The pH is low during summer season when temperature is high and high pH is observed during rainy and post-rainy season. [17,27,36,41,42]. The photosynthesis by autotrops in the river water is a principal factor to govern pH because when photosynthesis increases pH increases [17,42,123]. Besides photosynthesis, as and when the concentration of dissolved cabron dioxide and chlorine decreases, pH increases and vice-versa [10,17,42].

Thus, the review work gives an overall picture on river water pollution in India and abroad and interrelationship among different physico-chemical parameters so as to study and check the water pollution for the benefit of the society as a whole.

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