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Assessment of Quality of Water through Physicochemical Parameters- A Review

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Abstract - *Water is most precious and essential need for survival of all the living beings on earth. Its availability as a natural resource is very significant for the flora and fauna. For sustenance of life water quality plays a vital role and hence its assessment becomes important to ensure its suitability for different purposes. Nowadays, anthropogenic activities and increasing industrialisation, use of fertilizers and pesticides for agriculture stand as a major source for rising pollution ultimately deteriorating water quality and affecting aquatic life greatly. Restoration of Quality of water resources is difficult once it gets contaminated. Hence, assessment of water resources' quality becomes essential to understand its present status considering physicochemical characteristics and to assert its usefulness for varied purposes. The present study aims at reviewing the various water quality assessment works carried out by authors and researches using different approaches including water quality Index method in different areas of study. The different physicochemical parameters considered for water quality assessment comprise pH, Electrical Conductivity, Total Dissolved Solids, Dissolved Oxygen, Total Hardness, Cations, Anions and heavy metals. The review amply makes clear that researchers observed water resources globally being affected extensively because of anthropogenic activities and increasing industrialization. Hence their assessment is essentially required alongwith regular monitoring and suitable water treatment practices.*

Key Words: Water resources, Physicochemical parameters, Water Quality, Pollutants

1.INTRODUCTION

The most important and basic need for mankind to sustain life on earth is Water. It is the most precious resource present on earth. Water sources are known to occur in the form of groundwater, surface water such as rivers, lakes and rain water. With the increasing human population and growing economies, global demand for freshwater has been increasing rapidly [1]. In addition, industrial and mining activities considerably affect the water resources quality further leading to its deterioration. Availability of water per person will be reduced due to increased consumption of water owing to population growth which in turn affects biodiversity in the ecosystem globally [2]. Disposal of agricultural, industrial, domestic wastes are the contaminants being introduced by human activities into the environment that adversely affect the water resources. Industrial activities and processes discharge various levels of pollutants directly or indirectly into the water bodies. Deforestation carried out on large scale for setting up industries further affects the water resources and their quality to a great extent. Chemicals present in the industrial effluents are toxic to aquatic life and poisonous to human life [3]. In order to protect the invaluable water resources, it is becoming imperative to focus on assessment of water resources in relation to human demand and impacts. Assessment of water resources can be carried out by measuring and analysing various physicochemical parameters pertaining to water quality which greatly helps for better management along with development of available water resources [4]. Further, in order to assess and monitor water quality certain national and international standards and criteria have been established. Researchers appreciated that now a days it is being observed rivers are considered as the main source for the dumping of regular waste (household waste) as well as the industrial waste. Thus, water quality in India has been deeply affected, especially in urban areas, due to improper waste disposal and overexploitation of water resources Many people die of water pollution related illness every day in India. So, in order to make the least used water bodies to put into use for water on regular basis suitable remedies and planned monitoring should be undertaken. For the assessment, Water Quality Index (WQI) serves as a simple mathematical tool which transforms the available composite data into a single numerical value to give an idea about the present condition of water along with its suitability for different usages.

Water pollution leads to worsening of water quality which in turn poses a big threat to living beings' health ultimately affecting economic development [5]. With the growing population and owing to limited availability of water resources, the problem of acute scarcity of water is being faced worldwide [6]. According to WHO, water is one of the major causes globally for about 80% of all the diseases in human beings [7]. Once the contamination of groundwater takes place, it becomes very difficult to stop the pollutants from the source and restore its quality. Different national and international organisations such as BIS, WHO, EPA, USEPA and EUC have therefore, set up guidelines for drinking water quality to safeguard human health. Hence, regular monitoring of the water quality and developing protective measures is very important to maintain the health of environment. Policies and strategies need to be envisaged for maintaining and assessing the water quality of the

resources available on earth. Many researches have undertaken studies for water quality assessment of different water resources in different areas across the globe. This review is being done to understand the state of the water quality of resources that had been assessed by different authors and researchers alongwith ways and means suggested by them to protect the resources. It becomes apparent that decision making for water related policies particularly can be better achieved through assessment of different water resources across the globe.

2. METHODOLOGY

The paper considers the various studies and research undertaken by authors and researchers on the subject of water quality assessment being conducted out in different areas of the world. It has taken into consideration related journal articles, academic papers and materials from internet. Water being vital for human life, several studies have been conducted and still continuing pertaining to assessment of water resources across the continents. Qualities of groundwater and surface water for different regions at national and international levels have been assessed through various ways and approaches including the well-known water quality index (WQI) method.

2.1 Overview of Studies Pertaining to Water Quality Assessment

Kavita Parmar et al. [8] carried out their study for river Subernarekha situated in east and west Singhbhum district to assess the drinking water quality in 2006. Four stations were selected for estimation of overall Water Quality Index by employing Bhargava method. The different parameters that were studied for analysis included pH, Turbidity, Dissolved Oxygen (DO), Biological Oxygen Demand (BOD), Most Probable Number (MPN) in accordance to the standards of APHA, 1998 [9]. It was observed that stations of downstream region reflected higher TDS than upstream ones. The pH values ranged between (6.6 -7.4) which were within desirable limits. Further, they observed a progressive decline in WQI values along downstream. Industrial effluent discharges and influence of anthropogenic activities were observed to be the main causes leading to the deterioration of water quality.

K. Yogendra et al. [10] in 2008 conducted their study in Shimoga town of Karnataka for an urban water body by determining Water Quality Index by means of physicochemical parameters like pH, Electrical Conductivity (EC), TDS, Total alkalinity, Total hardness, Total suspended solids, DO, BOD, Calcium, magnesium, chloride, nitrate and sulphate. Standard procedures of APHA were followed to carry out the analysis and WQI was evaluated following weighted arithmetic index method. Results obtained revealed low DO value, Higher EC, TDS, Nitrate, chloride, sulphate and high BOD concentration for the water body under consideration. The average values of pH for three seasons showed the water to be slightly alkaline. Concentration of DO was observed more during monsoon and least during summer period. The resulting WQI values 96, 101.7 and 106.3 for rainy, winter and summer seasons respectively indicated poor water quality. Further, the water body was found to be eutrophic and unsuitable for drinking and other domestic purposes.

Sharma et al. [11] underwent study for various physicochemical parameters of Narmada River water that covered pH, Electrical conductivity, Turbidity, Calcium, Magnesium, Chloride, Sulphate and Nitrate in Hoshangabad city of Madhya Pradesh in the year 2011. They observed that most of the parameters such as Calcium, Magnesium, Chloride and Sulphate were beyond permissible limits. The cause for the exceeding limits was a result of discharge of industrial effluents, anthropogenic activities and agricultural runoff. This was further resulting in ground water pollution in the adjoining area.

P. J. Puri et al. [12] had assessed the quality of surface water in Nagpur city, Maharashtra covering mainly lakes, in three different seasons and found them to be affected by industrial and urban wastes. For ascertaining water quality of the study area, National Sanitation Foundation, Water quality index (NSF, WQI) using parameters (pH, TDS, EC, Total Hardness, BOD, DO, Chloride, Faecal Coliform) was considered. Results depicted lower values of WQI which were mainly because of higher pH, TDS, hardness, Chloride, Nitrates. Hence, water quality found to be very poor and unfit for consumption. It was noticed that human activities such as washing, and surface runoff from resulting rainfall and idol immersion during festive seasons contributed to the pollution of various lakes in the city. This led to their recommendation for effective water quality management plan for surface water resources to further protect them from perils of contamination.

C. Sarala et. al. [13] carried out study in Jawaharnagar, in Ranga Reddy district of Andhra Pradesh covering the surrounding borewells in the area. Sampling was carried out for post-monsoon and pre-monsoon seasons in 2007 & 2008 respectively in the study area and Arc GIS was used for the study. Their study disclosed that majority of the parameters were lying within permissible limits of BIS exceptions being for Total hardness and Fluoride whose concentrations were exceeding in some cases. Further, groundwater in the study area was found to be acidic in nature, very hard and polluted. Responsible cause for pollution was cited out to be industrial and agricultural activities that were utilising groundwater and surface water enormously. This was eventually resulting in deterioration of human health also effecting livestock and soil nutrients in the area.

D. Mukherjee et al. [14] underwent study to assess water quality of Damodar river in West Bengal and Jharkhand region for drinking needs through evaluating Water Quality Index. Eighteen sampling stations were selected for study during pre-monsoon of 2009 and parameters considered for analysis comprised pH, TDS, DO, BOD and MPN to obtain Quality Index through APHA, 1998. Results disclosed most of

the samples were having DO values more than 6 mg/l while BOD values ranged between 0.7- 6.2 mg/l. Results also indicated none of the samples falling in the excellent category. Not only most of the sampling locations were highly contaminated with coliform bacteria but also unsuitable for taking baths. Study further revealed that river water was not potable at many sampling locations because of getting polluted through sources such as industrial effluents and anthropogenic activities. Hence, it was essentially suggested for routine monitoring of river water along with necessary water treatment practices. Tomar et. al. [15] carried out study for water samples in Karnal district, Haryana for the pre-monsoon and post-monsoon season in 2011. Samples collected for study from 67 different locations were analysed for different physicochemical parameters mainly Sodium, Magnesium, Calcium and Bicarbonate. Standard irrigation criteria were considered for the classification of water samples. This further led to study of the chemical changes in water quality brought about by the natural recharge and rain. Their study revealed that water type predominating during pre-monsoon season was of Na-Ca-HCO3 type whereas in post monsoon season it was Mg-HCO3. Sanjib Das et al. [16] in the year 2013 carried out study in Kolkata city of West Bengal, India for groundwater quality using Water Quality Index method. Collection of 18 groundwater samples for analysis was mainly done from tube wells spanning from January 2011 to December 2012. Physicochemical parameters mainly pH, TDS, Total hardness, Turbidity, chloride and iron were analysed as per APHA 2012 for calculating WQI. Standards for water quality on the guidelines of WHO & IS: 10500-1991 was considered for comparison of the obtained results of the analysis. The concentrations of TDS, Total Hardness and Chloride were found higher than the permissible limits. The minimum and the maximum value of WQI were found out as 34.67 and 100 respectively. Finally, it was concluded that 17% of the samples were falling under excellent category while 17% under good category. Remaining 66% of the samples with WQI lesser than 80 were found to be unfit for drinking purposes.

Samreen Ahmad et. al. [17] had studied the physicochemical properties of groundwater in Kanpur city for understanding the quality of groundwater at various locations in the area. Water sampling was carried out at twenty different locations of the city and collected samples were analysed for parameters such as pH, EC, TDS, Turbidity, Total hardness, Sodium, Potassium, Total alkalinity, Chloride, Fluoride and Nitrates. Results of the analysis were compared with recommended standards by BIS & WHO. pH values (6.8-7.5) revealed slightly alkaline nature of water. Most of the analysed parameters like TDS (236-876 mg/l), EC (450-1360 µS/cm), TH (138-650 mg/l), Turbidity (0.5-6.2 NTU), Sodium (6-55 mg/l), Potassium (2-11 mg/l), Chloride (19-92 mg/l), Fluoride (0.08-0.89 mg/l) and Nitrate (6-29 mg/l) were found within permissible limits. Significant correlation was observed for TDS, EC and Turbidity with most of the parameters. Finally, water quality was found to be poor in the area making it unfit for drinking purposes. V. Jena et al. [18] in 2017 carried out their study by analyzing the physicochemical parameters of groundwater samples of Raipur city in Chhattisgarh. Twenty groundwater samples were considered for study during 2015-16 and analysed for different physicochemical parameters mainly pH, EC, TDS, COD, sodium, potassium, sulphate and chloride through standard procedures and methods recommended by APHA. pH values (7.54 - 8.86) revealed alkaline nature of water while concentrations of EC and TDS were observed to be within permissible limits. The range of chloride (141.2 – 189.4 mg/l), sulphate (14.56 – 26.14 mg/l) contents were within permissible limits of WHO. They also calculated Correlation coefficient further applying T-test to check correlation for significance. It was observed that industrial effluents and sewages were the possible sources that affected the water quality in the study area. While concluding the study they suggested for regular chemical analysis to be done so as to prevent water from getting contaminated. Suman D. et al. [19] in 2017 carried out groundwater quality assessment in Baddi, Solan district of Himachal Pradesh to evaluate WQI based on weighted arithmetic index method. Twenty-two locations were selected for sampling points and 10 water quality parameters were considered for WQI. Results indicated Electrical conductivity having good correlation with sodium, alkalinity, nitrite and sulphate. Regression analysis was also done to find relation between different parameters. Resulting high WQI was due to high turbidity and high concentrations of iron. It was observed that only 32% out of the 22 locations exhibited good water quality; 27 % being very poor whereas 18% of them found unsuitable for drinking. The cause noticed for poor water quality was the growth of industries alongwith anthropogenic activities that had affected groundwater severely. They concluded with recommendation that before consumption, groundwater of the area was requiring treatment and protection from contamination.

L. Ngwira et al. [20] conducted study on the quality of industrial wastewater from SOBO factory together with its effect on water quality in river Nankhaka, Malawi in 2017. Physicochemical parameters like pH, TDS, Dissolved Oxygen, Nitrate, Phosphate, BOD, Chemical oxygen demand and Faecal coliform were considered for analysis of the effluents and river water samples using standard methods of APHA. pH values disclosed alkaline nature of water while TDS levels were increased due to industrial effluents discharge. The results revealed that the river water was getting polluted from the effluents of the factory and hence not suitable for human consumption. They suggested concerned authorities for enforcing laws to govern for disposal of effluents and mitigate the river pollution in order to protect the lives of the people. M. Gebrekidan et al. [21] carried out their study in Tigray

region in Northern Ethiopia. 106 water samples were collected from 16 densely populated urban areas. They studied six physicochemical parameters as pH, conductivity, TDS, turbidity, salinity, temperature and ten heavy metals that consisted Arsenic, Chromium, Cadmium, Nickel, Copper, Iron, Manganese, Cobalt, Lead and Zinc. They observed that many physicochemical parameters exceeded the permissible limits set by WHO (2008). Also, heavy metals mainly As, Ni, Fe, Cr, Cd and Pb exceeded the permissible limits of WHO (2008). Obtained results of the analysis revealed water being polluted in the area. They therefore suggested to the authorities for envisaging corrective measures and suitable treatment plan for alleviating water pollution.

D. K. Essumang et al. [22] conducted their study for groundwater in Lower Denkyira district in the central region of Ghana. They collected 15 groundwater samples in the study area and carried out physicochemical analysis. It was observed that most of the parameters, pH (5.89-7.86), EC, TDS, Total hardness, Sodium, Potassium ions were within standard permissible limits. However, Iron and Manganese concentrations were exceeding the permissible limits of 0.3 mg/l and 0.1 mg/l respectively which, they observed, could be due to natural sources. They concluded with their finding of water quality being good in the area while suggesting treatment of water for exceeded contents of manganese and iron. Olayiwola Oni et. al. [23] carried out their study in Nigeria centered around the major dumpsite wherein municipal solid waste produced in Ado Ekiti were disposed. Water samples were collected in pre-monsoon season of 2016 from both groundwater and surface water sources for study. Most of the parameters considered for analysis (TDS, Total hardness, calcium, magnesium, sulphate, chloride and Nitrate) revealed values within permissible limits of WHO guidelines. pH values ranged between 5.6 to 6.2 revealing acidic nature of water. WQI was estimated following the weighted arithmetic index method developed by Horton. They found out that the surface water quality at location 2 was poor whereas those of remaining locations including groundwater being good. The well water was unaffected by the leachate runoff due to higher ground elevation resulting in good quality.

3. SIGNIFICANCE OF PHYSICOCHEMICAL PARAMETERS FOR WATER QUALITY ASSESSMENT

The studies reviewed here were conducted for assessing the quality of water resources spanning across various parts of India and abroad in order to establish their suitability for different purposes such as drinking, industries and agriculture. To attain the objective of quality assessment of water resources and to understand their pollution status, the researchers analysed following water quality parameters mainly: pH, EC, TDS, DO, BOD, Total Hardness (TH), Cations and Anions. Their significant relevance concerning physicochemical analysis can be understood through the following discussion.

pH: It is one parameter representing the concentration of H+ ions and is of very significance in water analysis. It is also an indication of the alkalinity and acidity for the water. The limits desirable for pH is 6.5 to 8.5 as per BIS specifications for water. The water is found to be bitter in taste when the pH value exceeds 8.5 [14]. pH value of water is very useful in ascertaining its suitability for drinking, agricultural and various domestic uses. Several important water quality parameters such as ammonia toxicity's etc. behaviour is governed by concentrations of hydrogen ions [24]. As most of the above studies reveals, pH value plays a key role in assessing the water quality and suitability of different sources.

Electrical Conductivity (EC): Electrical conductivity stands as a significant parameter when water purity is concerned. Generally, it is understood as property representing the capability of water to transmit electric current. Conductivity varies with temperature. Also, the conductivity is known to be very low for pure water. However, rise in conductivity is observed when inorganic acid, salt or alkali is present in water. According to BIS and ICMR specifications, the desirable limit of electrical conductivity is 600 µS/cm. In most of the above reviewed studies, EC contents for water bodies were observed within permissible limits. Total Dissolved Solids (TDS): The presence of minerals of various types in dissolved form in water is signified by TDS. It is undoubtedly a significant parameter while studying water quality standards. The desirable limit in accordance to BIS and ICMR standards for TDS is 500 mg/l. The taste of water gets affected further degrading the quality of water on account of high concentrations of TDS in water. In some of the reviewed studies the cause for high values of TDS observed were the impact of anthropogenic activities. One of the significant classifications based on TDS values was put forth by Caroll (1962) (Table 1) for ascertaining water quality.

Table – 1: Classification of Water Quality based on TDS by Caroll (1962)

TDS (mg/l)	Water Quality
0 – 1000	Fresh Water
1000 – 10000	Brackish Water
10000 – 100000	Salty Water
>100000	Brine Water

Total Hardness (TH): Hardness to water is induced by the presence of cations mainly calcium and magnesium. Higher concentration of hardness above the desirable limit may lead to adverse effects on water supply system causing stomach disorders, urinary concretions and excessive soap consumption (CPCB 2008) [25]. Higher concentration of hardness observed in the above studies may be a result of anthropogenic activities, surface runoff or natural accumulation of salt. Sawyer and McCarthy in 1967 had

given an important classification for water based on hardness into four categories (Table 2).

Table- 2: Water Classification based on Hardness (Sawyer and McCarthy)

Hardness (mg/l)	Water Type
0 – 75 75 – 150 150 – 300 >300	Soft Moderate Hard Very Hard

Dissolved Oxygen (DO): Existence of oxygen in water may be due to dissolution from atmosphere. It is also produced and consumed through autotrophic and heterotrophic processes respectively [8]. Change in concentrations of oxygen may lead to obnoxious odour. For water quality to be good and ensuring aquatic life to be healthy the optimum value of DO is 4 to 6 mg/l. Low DO values as observed in some of the studies may weaken the respiration of aquatic animals in turn affecting their growth. It is thus an important physicochemical parameter as far as water quality maintaining is concerned.

Turbidity: Presence of different type of suspended particles in water leading to muddy appearance is Turbidity. It is measured in Nephelometric units (NTU). Acceptable limits for Turbidity as per IS:10500-2012 standards is 1 NTU while 5 NTU is the permissible limit. Excessive consumption of turbid water may lead to health risks.

Total Alkalinity: It depicts the water's ability to neutralize acid. Large part of alkalinity is the result of presence of carbonate and bicarbonate ions in water. As per the standards 120 mg/l is the desirable limit of alkalinity.

Cations (Sodium, Calcium and Potassium): They are the naturally occurring and most vital elements which are the outcomes of weathering of rocks besides the industrial effluents and sewages [26]. Human health is largely affected by presence of sodium for instance, hypertension may be caused due to intake of Sodium in higher amounts. It may also cause diseases related to kidneys and ailments related to heart. Calcium is an important element for development of cells, bones and nervous system. However, long exposure to higher concentration of Ca ions may lead to increased risk of Kidney stones. Potassium if present in excess quantity in water may lead to disorders in digestive and nervous systems [27].

Anions (Chloride, Sulphate, Bicarbonate): One of the major anions studied during water analysis is the Chloride ion. The prescribed limit for chloride in drinking water is 250 mg/l as per the standards of BIS and ICMR. If concentration of chloride is found higher then it is an indication of higher intensity of organic pollution [9]. In some of the reviewed studies, higher contents of chloride were observed in the water. This indicates existence of pollution occurring on account of domestic and industrial activities in the areas. There exists sulphate in nearly all natural water sources and its higher concentrations may be attributed to anthropogenic sources like industrial effluents and agricultural runoffs. Excess of sulphate produces laxative effect, particularly in combination with magnesium or sodium [18].

Bicarbonates are the result of weathering of carbonate minerals with a secondary contribution by dissolution of CO2 gases. However, the prescribed limits of bicarbonates should not be exceeded although its effect is not adverse when health issue is concerned. Some of the basic standard physicochemical parameters' values depicted in Table 3 have been recommended by different organisations for maintaining water quality and safeguarding the water resources.

Table- 3: Standards for Physicochemical parameters' values

Sr. No	Water quality parameters	Standard IS 10500: 2012		(WHO) (2006)
		Desirable Limit	Permissible Limit	
1	pH	6.5-8.5	_	7.0-8.5
2	Electrical Conductivity (µS/cm)	_	_	750
3	Total Dissolved Solids (mg/l)	500	2000	500
4	Total Hardness (mg/l)	200	600	500
5	Calcium (mg/l)	75	200	75
6	Magnesium (mg/l)	30	100	30
7	Sodium (mg/l)	200	_	200
8	Potassium (mg/l)	200	_	200
9	Chloride (mg/l)	250	1000	250
10	Nitrate (mg/l)	45	_	50
11	Sulphate (mg/l)	200	400	200
12	Bicarbonate (mg/l)	200	600	200
13	Iron (mg/l)	0.3	_	0.3
14	Manganese (mg/l)	0.1	_	0.1
15	Copper	0.05	1.5	1.5

3.1. Water Quality Index

The reviewed articles had used various methods for ascertaining Water Quality Index which is a simple tool to obtain a single score mathematically from combinations of different parameters. WQI concept was primarily developed by Horton (1965) in United States through selection of most common water quality parameters such as pH, Dissolved oxygen, chloride, alkalinity, conductivity etc. Later, this Weighted Arithmetic Water Quality index found improved version by Brown [28]. It was employed by researchers Yogendra et al. [10], Suman D et al. [19], Olayiwola Oni et al. [23] in their studies. Some of the other Water Quality indices that are widely followed for evaluating water quality index across the globe are: National Sanitation Foundation Water Quality Index (NSF WQI) developed in 1970 by US sanitation Foundation which was followed by Sharma S. et al. [11]. The Canadian Council of Ministers for the Environment Water Quality Index (CCME WQI) is also very significant method followed globally. Originally it was being expressed as Canadian Water Quality Index (CWQI). Its basic concept is comprised of three Factors sch as F1 (Scope), F2 (Frequency) and F3 (Amplitude). It produces single unit number representing overall water quality. This method was also employed by Sanjib Das et al. [16] and other researchers. Thus, WQI has been proving a very significant and simple mathematical tool for ascertaining quality of water resources in different areas of the world.

4. CONCLUSIONS

The different studies conducted pertaining to the impact assessment on water resources by respective researchers were carried out with standard procedures for sampling, analysis and results based on APHA, BIS and similar standard agencies. Studies reveal that depleting natural resources, primarily water are becoming a cause of concern for the existence of the human beings. With the advancement of civilisation, the utility of water has increased immensely which necessitates well-organized schemes for public water supply as the need of the current scenario. Most of the studies revealed that major causes responsible for the degrading water quality were discharge of industrial effluents, sewages, anthropogenic activities and agricultural runoff. In addition to the water quality assessment of different water sources there lies an essential need to regular monitor the water quality of those sources further being important for maintaining health of the ecosystem. For maintaining the quality of water, available water treatment processes need to be employed that include water softening and reverse osmosis mainly. State and local authorities should ensure for the pre-treatment of industrial wastes, mainly effluents before their discharge into the environment. This information in this review may also help the authorities involved in water quality management along with their control aspects.

REFERENCES

[1] UNEP [United Nations Environment Programme], 2003a. Water scarcity in the Middle East-North African region, General Assembly Resolution 53-21. (20 January 2003; www.skmun.freeservers.com/unep/unpres1.htm)

[2] Pimentel D. Berger et al., Water Resources, Agriculture and the Environment. Ithaca (NY): New York State College of Agriculture and Life Sciences, Cornell University, 2004, Report 04-1.

[3] World Health Organisation (WHO), Water pollutants: Biological Agents, Dissolved chemicals, Non-dissolved chemicals, Sediments, Heat, WHO CEHA, Amman, Jordan. 2002.

[4] GWP (Editor), Water Resources Assessmen, Stockholm: Global Water partnership, 2008.

[5] M. Milovanovic, "Water quality assessment and determination of pollution sources along the Axios/ Vardar River, Southeastern Europe," Desalination, 2007, 213: 159–173.

[6] UNEP (United Nations Environment Programme), Convention on Biological Diversity, United Nations, 2002.

[7] WHO, Water, sanitation and hygiene links to health—facts and figures, World Health Organization, Geneva, 2004.

[8] K. Parmar and V. Parmar, "Evaluation of water quality index for drinking purposes of river Subernarekha in Singhbhum district," Int. Journal of Environmental Sciences, 2010, 1. 77-81.

[9] APHA (American Public Health association), Standard Methods for the Examination of Water and waste Water, APHA, Washington, 1998, 20th edition.

[10] K. Yogendra & E.T. Puttaiah, "Determination of Water Quality Index and Suitability of Urban Water body in Shimoga Town, Karnataka," Proceddings of Taal 2007: The 12th World Lake Conference, 2008, 342-346.

[11] S. Sharma, R. Vishwakarma, S. Dixit, P. Jain, "Evaluation of water quality of Narmada river with reference to physicochemical parameter at Hoshangabad city, MP, India," Research Journal of chemical sciences, 2011, 1(3): 3155-3158.

[12] P. J. Puri, M.K.N. Yenkie, S.P. Sangal, et. al., "Surface water (Lakes) quality assessment in Nagpur city (India) based on water quality index (WQI)," Rasayan J. Chem., 2011, Vol 4(1), pp. 43-48.

[13] C. Sarala, P. Ravi Babu, "Assessment of groundwater quality parameters in and around Jawaharnagar, Hyderabad," International Journal of scientific and Research Publications, 2012, Vol. 2, Issue 10, pp. 1-6.

[14] D. Mukherjee et al., "Evaluation of water quality index for drinking purposes in the case of Damodar river, Jharkhand and West Bengal region, India," J. of Bioremed. Biodeg, 2012, Vol. 3. pp. 3-9.

[15] V. Tomar, S.K. Kamra, S. Kumar, et. al., "Hydro-chemical analysis and evaluation of groundwater quality for irrigation in Karnal district of Haryana state, India," International Journal of Environmental Sciences, 2012, Volume 3, No 2, pp.756-766.

[16] Sanjib Das, P. K. Roy, A. Mazumdar, "Development of Water Quality Index for groundwater in Kolkata City,

West Bengal, India," ARPN Journal of Engineering and Applied Sciences. 2013, Vol. 8. No. 12. pp. 1054-58.

[17] Samreen Ahmad, A. Mishra, "A Study on physic-chemical Properties of Groundwater Quality of various locations of Kanpur City," 2014, International Journal of Science and Research. Vol 3. Issue 3. Pp. 177-179.

[18] V. Jena et al., "Physico chemical analysis of groundwater of selected areas of Raipur city," Indian Journal of Science Research, 2017, 13(1): 61-65, ISSN- 2250-0138.

[19] Suman K. Dhaka, N. Bhaskar, "Assessment of groundwater quality in terms of water quality index and regression analysis of water quality parameters," J. of basic and Applied engineering research 2017, Vol. 4. pp. 339-342

[20] L. Ngwira, D. Lakudzala, "Assessment of the quality of SOBO industrial wastewater and its impact on water in Nankhaka River," Physics and Chemistry of the Earth, 2018, 108. 9-12.

[21] M. Gebrekidan, Z. Samuel, MEJS, 2011, Vol. 3 (1): 105-121

[22] D. K. Essumang et. al., "Groundwater quality assessment: A physicochemical properties of drinking water in a rural setting of developing countries," Canadian Journal on Scientific & Industrial Research, 2011, Vol. 2. No. 3.

[23] Olayiwola Oni, F. Olubunmi, "The use of water quality index method to determine the potability of surface water and groundwater in the vicinity of a municipal solid waste dumpsite in Nigeria," American Journal of Engineering research (AJER), 2016, Vol.5, Issue-10. pp. 96-101.

[24] WHO (World Health Organisation) and UNICEF (United Nation Children's Fund), Global Water Supply and Sanitation Assessment 2000 Report, WHO/UNICEF, Geneva/New York, 2000, pp. 80.

[25] CPCB 2008. Guideline for Water Quality Management. Central Pollution Control Board, Parivesh Bhavan

[26] A. K. Singh, S.I. Hasnain, "Environmental geochemistry of Damodar river basin, east coast of India," Environ Geol. 1999, 37:124–136.

[27] R. K. Tiwary, "Environmental impact of coal mining on water regime and its management," Water Air Soil Pollution, 2001, 132:185–199

[28] R. M. Brown, N. J. McClelland, et. al., "A water quality index crossing the psychological barrier," Jenkis, S. H. (ed.) Proc. Int. Conf. on Water Poll. Res., Jerusalem, 1972, 6. 187-197.