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DETERMINATION OF WATER QUALITY INDEX OF DRINKING WATER IN VARANASI DISTRICT, UP, INDIA

Rajesh Prajapati[1] and Ram Bilas[2]
Junior Research Fellow and Professor, Department of Geography,
Institute of science, Banaras Hindu University, Varanasi - 221005,
Corresponding author: Ram Bilas, Email ID: rajeshgeo90@gmail.com, dr.rbyadav@gmail.com

Abstract

The availability of water both in terms of quality and quantity is essential for the very existence of mankind. There is heavy extraction of water for domestic, industrial and agricultural purposes leads to more than 50 per cent of water wastage in the domestic, agriculture and industrial sectors. Water pollution is rendering much of the available water unsafe for consumption. In India, Most of the population are depend on surface water as the source of drinking water supply. Water Quality Index (WQI) provides a single number that expresses overall water quality at a certain location and time, based on several water quality parameters. The calculation of Water Quality Index using standard method given by the Bureau of Indian Standards and the Indian Council of Medical Research applied in this paper. This research work is based on the secondary data and aims to assessing the Water Quality Index (WQI) of the drinking water of Varanasi District. The analysed data are compared with standard values recommended by BIS and ICMR. Among various parameters, few are considered in the present paper for calculating the WQI such as pH, Total alkalinity, Calcium, Magnesium, Chloride, Sulphate, Nitrate and also calculated the seasonal variations of physics- chemical parameters of water quality of Varanasi District.

Key Words: Water quality index, Physico-chemical parameters, Water quality standards.

Introduction

The history of man has always been marked by an intimate relationship with water; it is well known that the earliest Palaeolithic implements of human existence have been traced in the river gravels. This situation clarifies the essential need of water even for the most primitive man while it is true that the water is the basis of all life and an absolute necessity for all varied activities like domestic, agricultural and industrial for which no substitute can be devised. One can seldom fully aware of these implications of this truth and of the countless direct and indirect ways in which we have to depend on water even in the modern scientific era (Bilas, 1981). Along with all the intensive activities in promoting hydrology and water resources, there has been a tremendous increase and expansion in the scientific and technological knowledge about water, and there is great need for an authoritative compilation of such knowledge. Since water is related to so many things in nature as well as in human society, this knowledge is extremely broad and interdisciplinary (Chow, 1964).

The present study treats quality of water resources and its utilization framework for drinking purpose. India is endowed with a rich and vast diversity of natural resources, water being one of them. Without food, human can survive for a number of days, but water is such an essential that without it one cannot survive. Water is not only essential for the lives of animals and plants, but also occupies a unique position in industries. Among the all water sources, the ground water is an important and most reliable source of water supply throughout the world. In some areas of the world, people face serious water shortage because groundwater is used faster than it is naturally replenished. Human development and population growth exert many and diverse pressures on the quality and the quantity of water resources and on the access to them. Water quality monitoring and assessment is the foundation of water quality management; thus, there has been an increasing demand for monitoring water quality of many rivers and ground water by regular measurements of various water quality variables. The groundwater is believed to be comparatively much clean and free from pollution than surface water. But prolonged discharge of industrial effluents, domestic sewage and solid waste dump causes the groundwater to become polluted and created health problems. In recent years, because of continuous growth in population, rapid industrialization and the accompanying technologies involving waste disposals, the rate of discharge of the pollutants into the environment is far higher than the rates of their self purification capacity.

Water is essential to sustain life, and a satisfactory (adequate, safe and accessible) supply must be available to all (WHO, 2008). Improving access to safe drinking water can result in tangible benefits to health. Safe drinking water, as defined by the Guidelines, does not represent any significant risk to health over a lifetime of consumption, including different sensitivities that may occur between life stages. Those at greatest risk of waterborne disease to infants and young children, people who are debilitated and the elderly, especially when living under unsanitary conditions. Every effort should be made to achieve drinking water that is as safe as practicable. Those who are generally at risk of waterborne illness may need to take additional steps to protect. Adequate safe water supply is an indispensable ingredient in promoting economic development and betterment of human welfare in every nation. Water is the basic resource essential for the survival of mankind on earth and it is the greatest gift of nature (Abebe,2013).

Water is necessary for all forms of life, either human beings or plants or animals and may be either surface water or ground water. But by increasing population of the countries and also industrializations, the water qualities are affected now a day. The polluted water is affecting the public health and aquatic ecosystems. Both the natural process and human activities influence the quality of surface and ground water resources. Water naturally contains dissolved substances, non-dissolved particulate matters and living organisms; indeed, such materials and organisms are necessary component of good quality of water, as they help to maintain vital biogeochemical cycles. There are few exceptions where naturally occurring substance trigger, water quality challenges detrimental to human health (Van etal., 2009). Lakes and tanks are known to be ecological barometers of the health of the city as they regulate the micro-climate of any urban centre (Benjamin et al., 1996). The quality of surface water in an inland water bodies have a profound effect on the ground water table and ground water quality of the nearby aquifers due to existence of direct interaction between surface and ground water. The environmental conditions of any lake ecosystem depend upon the nature of that lake and its exposure to various environmental factors. Hence, surface and ground water quality depend not only on natural process (precipitation inputs, erosion, and weathering of crustal materials etc.) but also on anthropogenic influences (urban, industrial and agricultural activities etc.) (Papatheodorau et al., 2006). The fragile ecosystem must maintain the state of environmental equilibrium with the existing surroundings particularly from a special prospective of human encroachment and pollution. However, in recent decades, population growth, agricultural practices and sewage runoff from urban areas have increased nutrient inputs many folds to the level of their natural occurrence, resulting in accelerate eutrophication (Chaudhary et al., 2010). Aquatic organisms need a healthy environment to live and adequate nutrients for their growth, the productivity depends on the physico-chemical characteristics of the water body. The pollution of water is increased due to human population, industrialization, use of fertilizers in agriculture and many other manmade activities. Water parameters such as temperature, turbidity, nutrients, hardness, alkalinity, etc. are some other important factors that determine the growth of living organisms in the water bodies (Smitha, 2013). Hence, water quality assessment involves the analysis of physico-chemical, biological and microbiological parameters that reflect the biotic and abiotic status of the ecosystem.

Table 1: Water standards and recommending agencies

S.No.	Parameters	Standards	Recommended Agency
1	pH	6.5-8.5	ICMR/BIS
2	Magnesium (mg/l)	30	ICMR/BIS
3	Calcium (mg/l)	75	ICMR/BIS
4	Sulphate (mg/l)	150	ICMR/BIS
5	Chloride (mg/l)	250	ICMR
6	Nitrate (mg/l)	45	ICMR/BIS
7	Electrical Conductivity (EC μS/cm at 25°C)	300	ICMR

Source: ICMR, 1975 and BIS, 1993.

Poor water quality has a direct impact on water quantity which is available for drinking in a number of ways. Polluted water that cannot be used for drinking, bathing and industry or agriculture purpose effectively reduces the amount of usable water within a given area. Notwithstanding, the use of low quality water (for example saline or brackish water) may have important and direct impacts on productive water such as irrigated agriculture, with important effects on land degradation, crop production and consequently on rural income and food security. Around 700 million people in 43 countries suffer today from water scarcity, a situation there are not sufficient water resources to satisfy long-term average requirements of mankind (Falkenmark, et al., 2001). Unsafe domestic use, agriculture production, mining activities, industrial production, power generation and other factors can alter the physical, chemical and biological characteristics of water in ways that can threaten ecosystem integrity and human health. The major sources of water pollution are human settlement, industrial and agricultural activity. A negative factor related to these activities includes unhygienic disposal and inadequate treatment of human and livestock wastes, deficient management and insufficient of industrial residues, inappropriate agricultural practices and unsafe solid waste discharge. Over the 80 percent sewage in developing countries is discharged untreated directly into water bodies (WHO, 2008).

Study Area

Varanasi district, extending between the latitudes 25˚ 10′ 30″ to 25˚ 35′ 15″N and longitude 82˚ 40′ 50″ to 83˚ 12′ 18″E which are rounded by Bhadohi district west side, Jaunpur north and north west, Ghazipur is in the north and north- east, Chandauli in the east and Mirzapur district in the south (Fig.1). River Ganga forms its natural boundary in the east and south-east while northern boundary is marked by the river Gomti. On the basis of relief variations, geology and drainage characteristics, the study area has been divided in to three physiographic divisions:

1. Upper Ganga -Varuna Plain
2. Varuna-Gomti interfluves and
3. Ganga-Varuna interfluves.

The Varanasi city one of the most important urban centre of the study area is an ancient city of India which is located on the left bank (west bank of river) of the most sacred river Ganga. Varuna and Assi are two streams bounded it from north and south. This is characterised as the religious and cultural capital of India. Administratively, the district comprises two tehsils namely, Varanasi and Pindara, which are further divided in to Baragaon, Pindara, Cholapur, Chiraigaon, Harahua, Sevapuri, Araziline and Kashi Vidyapeeth development blocks. The southern and southern- eastern part of Harahua development block has extended in Varanasi tehsil but major part of this block is extended in Pindara tehsil. Total area of study is 1535 km² (total rural area 1371.22 km² and total urban area 163.78 km²), density of population is 2395 and total number of cultivators is 197952 (16.22 % of total population of Varanasi) (Census of India, 2011).

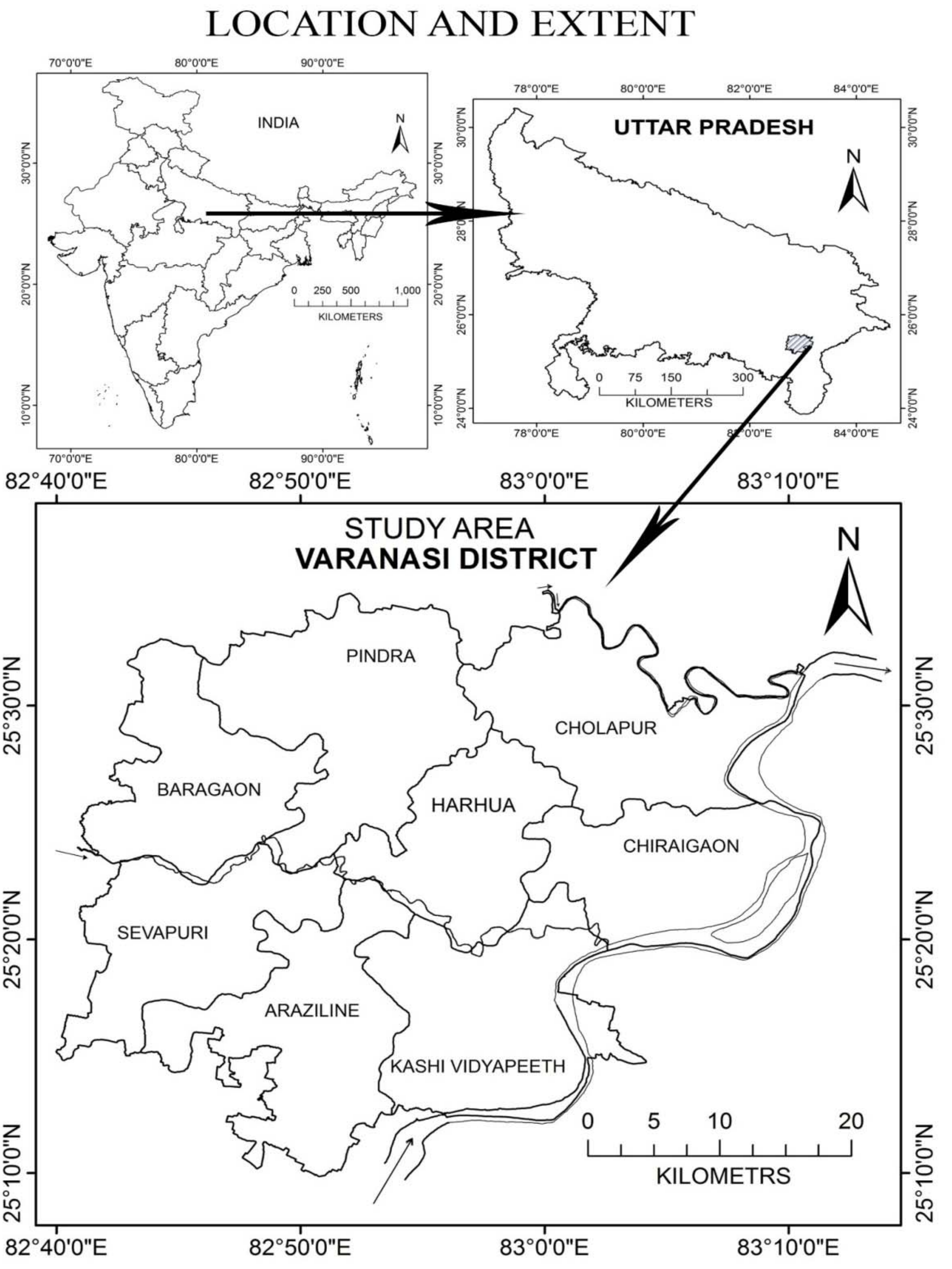
LOCATION AND EXTENT
INDIA
0 250 500 1,000
KILOMETERS
70°0'0"E
80°0'0"E
90°0'0"E
30°0'0"N
20°0'0"N
10°0'0"N
UTTAR PRADESH
0 75 150 300
KILOMETERS
78°0'0"E
80°0'0"E
82°0'0"E
84°0'0"E
30°0'0"N
28°0'0"N
26°0'0"N
24°0'0"N
STUDY AREA
VARANASI DISTRICT
N
PINDRA
CHOLAPUR
BARAGAON
HARHUA
CHIRAIGAON
SEVAPURI
ARAZILINE
KASHI VIDYAPEETH
0 5 10 20
KILOMETRS
82°40'0"E
82°50'0"E
83°0'0"E
83°10'0"E
25°30'0"N
25°20'0"N
25°10'0"N

Fig. 1

Objective

Two objective have taken for this present research work:

1. To analyse the status of water quality and their quality index of various stations in Varanasi District.
2. To recognise the causes and source of water deterioration in the study area.

Materials and Methods

This research paper is based on the secondary data which is taken from the Executive Engineer, Department of Ground Water, Taktakpur Varanasi. Water samples have been analysed for 7 physico-chemical parameters such as pH, Calcium, Magnesium, Chloride, Sulphate, Nitrate and Electrical Conductivity in the laboratory as per the standard procedures of Bureau of Indian Standards (BIS). The WQI has been calculated by using the standards of drinking water quality recommended by World Health Organization (WHO, 2004), Bureau of Indian Standards (BIS, 1993) and Indian Council for Medical Research (ICMR, 1975). This research work has been completed with the help of MS Office 2013 and Arc GIS 10.1 Software. The weighted Arithmetic index method has been used for the calculation of WQI of the drinking water. Further quality rating or sub index (Qn) has been calculated by the using of the following equation:

Quality Rating (Qn) = 100* [Vn – Vo] / [Sn – Vo] ………………. **(i)**

Where,

Qn = Quality rating for the nth water quality parameter.

Vn = Estimated value of the nth parameter at a given sampling stations.

Sn = Standard permissible value of the nth parameter.

Vo = Ideal value of nth parameter in a pure water.

Ideal values in the most cases Vo = 0 except in some parameters such as pH.

Calculation of quality rating for pH is 7.0 for natural water.

Calculation of quality rating for pH

For pH the ideal value is 7.0 (for natural water) and the permissible value is 8.5

Therefore, the quality rating for pH is calculated with help of the following equation:

Qn = 100 [Vn (pH) – 7.0] / [8.5 – 7.0] …………….. **(ii)**

Where, (Vn pH) = observed value of pH

Calculation of Relative weight or Unit weight (Wn)

Unit weight has been calculated by a value inversely proportional to the recommended standards values Sn of the corresponding parameters.

Unit weight (Wn) k/Sn ………..…… **(iii)**

Where, Wn = Unit weight of the nth parameter.

Sn = Standard value of the nth parameter.

K = Constant for proportionality (K = 2.5)

The overall quality index (WQI) has been calculated by aggregating the quality rating with the unit weight linearly.

Water Quality Index (WQI) = ∑Wn Qn / ∑Wn

Where, WQI = Water quality index

Wn = Unit weight of the nth parameters.

Qn Quality Rating of the nth parameter.

Discussion and Results

WQI is established through the measurement of various important physico-chemical parameters of the drinking water (Table 2). The physico-chemical parameters of sixteen different stations (S1, S2, S3, S4, S5, S6…….S16) are summarized (Table 3). There are some remarkable variations of physico-chemical data are found at all the sixteen sampling sites in study area (District Varanasi). Some hidden forces like temperature changes in season to season which are sometimes more controlling to some parameters like electrical conductivity, pH etc. An example of calculation of WQI has been given in table 4.

Table 2 : Water Quality Status based on WQI.

S. No.	Water Quality Index	Status of Water Quality
1	0 – 25	Excellent Water Quality
2	26 – 50	Good Water Quality
3	51 – 75	Poor Water Quality
4	76 – 100	Very Poor Water Quality
5	> 100	Unfit for Drinking

Source: WHO, 2004.

pH : pH, quantitative measures of the acidity or basicity of aqueous or other liquid solutions.pH is helpful for the determination of acidity and alkalinity of water.pH of pure water is about 7 at 25° C which is known as pH is normal (Bates, 1973). Acidic water pH value is less than pure water. Excessive acidity or alkalinity is not good for drinking water uses. In Varanasi district highest pH value recorded is 8 at S16 (Cholapur block) while lowest is 7.2 at the station S14. There are no direct adverse effects on health of pH, higher values of pH has reduces the scale formation in water heating apparatus and also reduce germicidal potential of chloride.

Table 3 : physico-chemical parameters of Drinking water samples (mg/l) except pH and EC.

Parameters	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16
Potential of Hydrogen (pH)	7.30	7.60	7.50	7.60	7.46	7.50	7.61	7.68	7.24	7.35	7.88	7.48	7.55	7.28	7.80	8.00
Magnesium (Mg)	19.5	43.8	43.8	41.4	31.6	14.6	29.2	51.1	77.8	43.8	48.6	21.9	24.3	36.5	67.0	34.0
Calcium (Ca)	80.2	36.1	52.1	32.1	48.1	56.1	60.0	40.0	68.0	44.0	40.0	88.0	80.0	100	144	76.0
Sulphate (SO4)	22.0	41.0	58.0	38.0	7.1	2.3	2.0	1.6	95.0	48.0	38.0	8.0	7.0	20.0	102	31.0
Chloride (Cl)	21.3	63.8	70.9	28.4	14.2	7.1	21.3	28.4	113.6	120.7	92.3	28.4	28.4	49.7	163	50.0
Nitrate (NO3)	39.0	32.0	2.7	0.8	1.7	1.3	2.0	5.6	102.0	0.6	3.2	6.6	3.8	48.0	115	15.0
Electrical Conductivity (EC µS/cm at 25°C)	780	1205	1002	999	610	610	700	780	1550	1180	1220	750	730	1260	1739	952

Source: Office of the Executive Engineer, Ground Water Department Taktakpur, Varanasi.

Magnesium : Magnesium hardness particularlyassociated with the sulphate ion has laxative effect on persons who have unaccustomed to it (Khursid, 1998).Magnesium less than 150 mg/l daily are generally safe for most adult aging population. Very large amounts, magnesium is possibly unsafe for body.The observed average value of the magnesium is43.24 mg/l throughout the city. The highest magnesium concentration is 77.82 mg/l at station S9 and lowest value is 14.592 at station S4.

Calcium : This parameter of drinking water depending upon the types of rocks. Small concentration of calcium is reducing corrosion in water pipes.Calcium is one among the most abandon ions in fresh water and plays a pivotal role in shell construction, bone building and plant precipitation. In Varanasi district highest amount of calcium content in water was recorded 144mg/l at the station S15. Whereas the lowest amount of calcium is 32.064 mg/l at station S4 recorded during the same season due to calcium being absorbed by a large number of organisms.

Sulphate : Low concentration of sulphate does not affect the taste of water. Accepted limitation of sulphate concentration varied between 2 mg/l to 163 mg/l. Average concentration of sulphate ion is 36.9 and highest value has been recorded 102 mg/l at station S15 during the same season. The overall observed value of sulphate is near about equal compared to standard value.

Chloride : The concentration of chloride can be related to purity or impurity of water. The high chloride concentrations indicate the presence of organic matter presumably of animal origin (Tresh, et al., 1944). Average chloride concentrations in Varanasi district is founded 67.799 mg/l. The highest chloride concentration is163mg/ l which is below the standard value 300 mg/l at S15. The lowest value has been recorded 7.092 mg/l. Maximum value of chloride is within the permissible limit (Table 3).

Table 4 : Calculations of Water Quality Index for station one (S1).

Sr. No.	Parameters	Observed Value	Standard Value (Sn)	Quality Rating (Qn)	Unit Weight (Wn)	Qn*Wn
1	Potential of Hydrogen (pH)	7.3	6.5-8.5	20	0.2941	5.882
2	Magnesium (Mg)	19.456	30	64.8533	0.0834	5.4087
3	Calcium (Ca)	80.16	75	106.88	0.0334	3.5697
4	Sulphate (SO4)	22	150	14.6667	0.0167	0. 2449
5	Chloride (Cl)	21.276	250	8.5104	0.01	0.0851
6	Nitrate (NO3)	39	45	86.6667	0.5004	43.368
7	Electrical Conductivity (EC µS/cm at 25°C)	780	300	260	0.0208	5.408
				∑Qn =561.5771	∑Wn =0.9588	∑Qn*Wn =63.7215
Water Quality Index (WQI) = ∑Qn Wn / ∑Wn WQI = 63.7215 / 0.9588 = **66.4596**						

Source: Computed by author.

Nitrate : Nitrogen is important to all life. Nitrogen cycle is the main drawing force for distributing the nitrogen in nature. Nitrogen in the atmosphere or in the soil can go through many complex chemical andbiological changes. It can be combined into living and non- living materials and return back to the soil or air in continuing cycle called the nitrogen cycle. The highest amount of nitrate has been recorded 115 mg/l at S15 stations, due to the possible influx of nitrogen rich water into the lake water from the large amount of contaminated sewage water.

Electrical Conductivity (EC µS/cm at 25°C) : EC help to determine the strength of hydroponic solution. According to ICMR Standard value of EC is 300 µS/cm in drinking water. EC value founded between 610 to 1739µS/cm in study area which are more than standard value which is recommended by ICMR that is 300 µS/cm. Highest value of electrical conductivity 1739µS/cmat S15 station, whereas lowest value is 610µS/cm.Average EC value is 1005µS/cm in Varanasi district.

Table5: Result of Samples and their water quality index.

Block	Sampling Stations	Water Quality Index	Status of Water Quality
KASHI VIDYAPEETH	S1	66.4596	Poor Water Quality
	S2	61.5255	Poor Water Quality
BARAGAON	S3	36.6838	Good Water Quality
	S4	34.4113	Good Water Quality
ARAZILINE	S5	27.3318	Good Water Quality
	S6	23.0368	Excellent Water Quality
HARHUA	S7	31.2366	Good Water Quality
	S8	42.9254	Good Water Quality
PINDRA	S9	182.4882	Unfit for Drinking
	S10	32.1219	Good Water Quality
SEVAPURI	S11	38.6433	Good Water Quality
	S12	33.5796	Good Water Quality
CHIRAIGAON	S13	31.9409	Good Water Quality
	S14	86.2500	Poor Water Quality
CHOLAPUR	S15	190.2887	Unfit for Drinking
	S16	58.6868	Poor Water Quality

Source: Computed by author.

Water Quality Index (WQI)

It is a single number value which is able to describe the overall water quality at a certain location and time based on several water quality parameters. WQI is the simplest form of index which is knowable and used by the public. WQI values comprises various important physico-chemical parameters of drinking water presented in a Table 5. The values of WQI showed the higher per cent of good water quality category of drinking water has been found in the middle, east and southern part of the city i.e. varies from 28 to 65 WQI, it is largest water quality category among all the water quality status in the city. Lowest WQI is 23.036 at S6 station, whereas highest WQI is 535.32 at S6 station showing unfit for drinking. 182.48 WQI found at station S9 which is second largest number which is also showing unfit drinking water (Fig.2).

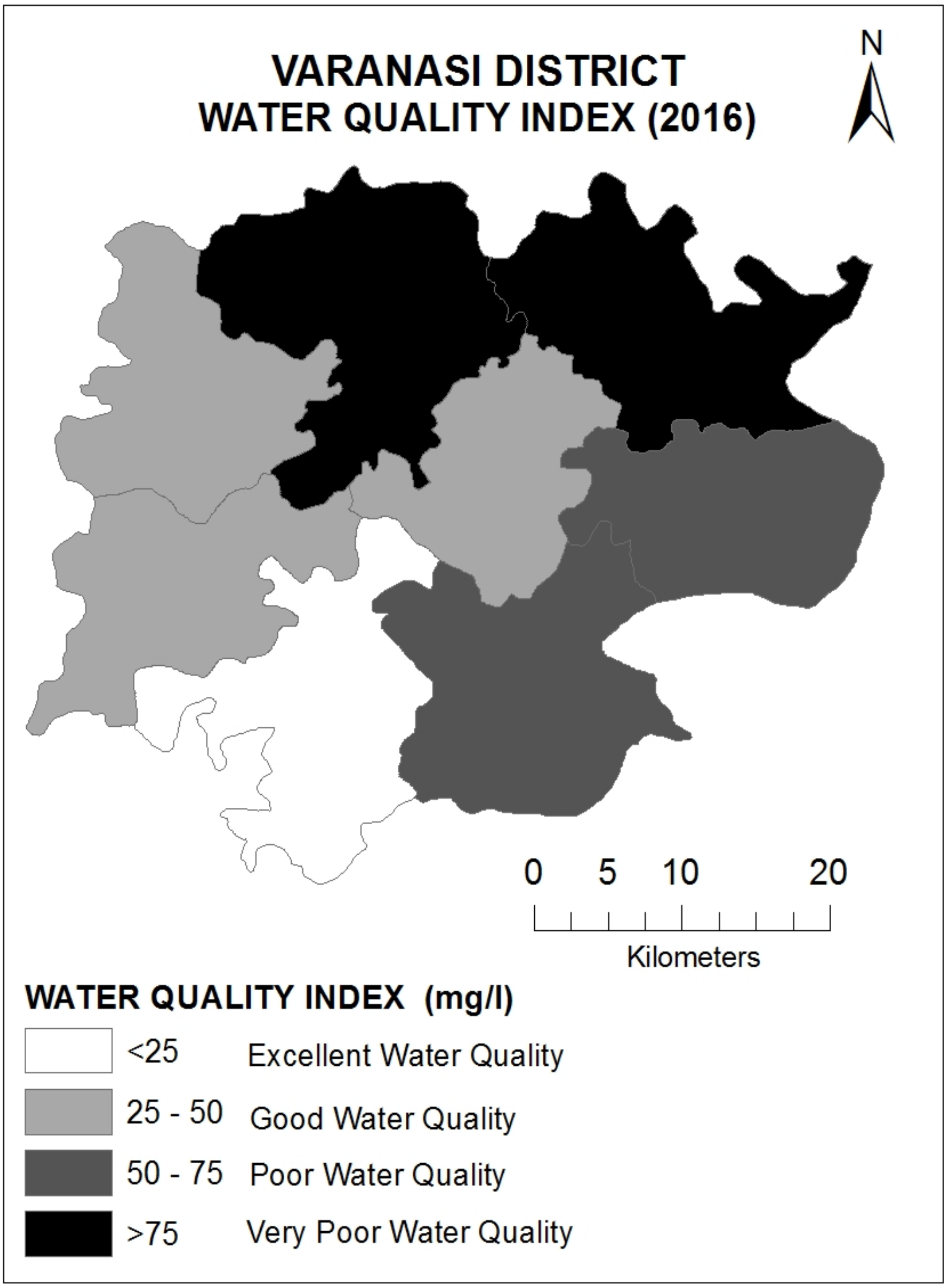
VARANASI DISTRICT
WATER QUALITY INDEX (2016)
N
0 5 10 20
Kilometers
WATER QUALITY INDEX (mg/l)
<25 Excellent Water Quality
25 - 50 Good Water Quality
50 - 75 Poor Water Quality
>75 Very Poor Water Quality

Fig. 2

Conclusions

The WQI method is more methodological and facilitates the comparative evaluation of drinking water quality of several sampling sites. It is found that the drinking water on 55.56 percentsampling stations are good inquality and 22.23 percent has been founded poor water quality. Only 11.12 percent of drinking water is unfit for drinking. It is clearly indicates thatmore than 50 percentwater samples is good and potable in quality. Total number of 7 station'sWQI values indicates that the status of water quality is not appropriate for drinking purposes and therefore prior treatment is required before use. S5 and S6 stations (Araziline development block) showing excellent water quality. Most of the part in the study area (Thee blocks namely Harhua, Bragaon and Sevapuri) found good water quality. InChirajigan and Kashi Vidyapeeth block showing poor water quality. Due to bad sanitation systems, lack of awareness for conservations and cleanliness of water resource in Karkhiaonv in development block of Pindra and Cholapur are of very poor at quality parameter.

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