Asian Journal of Water, Environment and Pollution, Vol. 14, No. 3 (2017), pp. 49–55.
DOI 10.3233/AJW-170025

Ground Water Quality Assessment through Index Method and Health Status: A Case Study of Firozabad City (India)

Nikhat Bano
Department of Geography, Aligarh Muslim University, Aligarh-202002, Uttar Pradesh (India)
✉ nikhatamu@gmail.com

Received July 31, 2016; revised and accepted March 19, 2017

Abstract: This paper assesses the status of ground water quality of Firozabad city through index method in order to assess the qualitative aspect of drinking water supply of the city by comparing it with existing standards for important parameters. The main components of the study include a field sampling analysis of groundwater collected from three different sites. Water Quality Index is calculated from physico-chemical analysis of eight parameters taken together, which ranges from 235.56 to 576.59 indicating the heavy pollution load in water. The result of this study indicate that the drinking water supply of the city do not conform the recommendation standards, which is a major cause of various health problems in the city, and hence it is suggested to take all necessary precautionary measures before it is sent to public consumption to avoid adverse health impacts and to prevent various intestinal epidemics. It is concluded that WQI is a useful tool and can be used in comparing the water quality of different sources.

Key words: Physico-chemical analysis, water quality index, qualitative aspect, drinking water, health problems.

Introduction

Water comprising over 70% of the Earth's surface, is undoubtedly the most precious natural resource that exists on our planet. Subsequently, we are slowly but surely harming our planet to the point where organisms are dying at a very alarming rate. In addition to innocent organisms dying off, our drinking water has become greatly affected as is our ability to use water for recreational purposes (DWAF, 1991). The term "water quality" was coined with reference to the quality of water required for human use: "good quality" water is "clean" and unpolluted and suitable for drinking as well as for agricultural and industrial purposes. Although scientific measurements are used to define the quality of water, it's not a simple thing to say that "this water is good," or "this water is bad". The quality of water that is required to wash a car is not the same quality that is required for drinking water. Therefore, when we speak of water quality, we usually want to know if the water is good enough for its intended use, be it for domestic, farming, mining or industrial purposes, or its suitability to maintain a healthy ecosystem (DWAF, 1996).

Lack of safe drinking water supply, basic sanitation and hygienic practices is associated with high morbidity and mortality from excreta related diseases (WHO, 2004). In general, the quality of water is equally important as the quantity. Therefore, water quality is considered as an important factor to judge environment changes which are strongly associated with social and economic development (Darapu et al., 2011). According to WHO, about 80% of all the diseases in human beings are caused by water. Once the groundwater is contaminated, its quality cannot be restored by stopping the pollutants from the source. It therefore becomes imperative to regularly monitor the quality of groundwater and to device ways and means to protect it. Contamination of groundwater by domestic, industrial effluents and agricultural activity is a serious problem faced by developing countries. The industrial waste water, sewage sludge and solid waste materials are currently being discharged into the environment indiscriminately. These materials enter subsurface aquifers resulting in the pollution of irrigation and drinking water (Girija et al., 2007). Therefore, the assessment of water quality is very important for knowing its suitability for various purposes.

Water quality index (WQI) indicates the quality of water in terms of index number for any intended use. It is defined as a rating reflecting the composite influence of different water quality parameters taken for calculation of water quality index (Rao et al., 2010). The concept of indices to represent gradations in water quality was first proposed by Horton (1965), then developed by several researchers like Brown et al. (1970) and improved by Deininger (Scottish development department, 1975). The index results represent the level of water quality in a given water basin, such as ponds, lake, river or stream (Srinivas, 2013). Many researchers in India have studied water quality for different purposes. Dakad (2008) studied to know the ground water pollution and its suitability for drinking and domestic purposes in Jhabua town of Madhya Pradesh. Rao (2010) calculated water quality index in order to assess the suitability of water collected from different areas in Guntur district of Andhra Pradesh. Srinivas (2013) determined water quality index in Kakinada industrial areas of Andhra Pradesh.

Objectives

The specific objectives of the study are to investigate the water quality status and water quality index (WQI) at selected monitoring sites of Firozabad city, to assess the intensity of household water pollution and incidence of associated diseases in the respondent's house and to study the impact of household water pollution on the health of people of the city.

Study Area

Firozabad, the glass city, is located in north central India, in the western Uttar Pradesh state 40 km away from Agra and 218 km away from Delhi at the northern edge of the Deccan Plateau, at 27° 15′ N and 78° 42′ E (Figure 1). Firozabad city is spread in 21.35 sq.km area bounded by river Yamuna from southern and western side with 603,797 persons as per 2011 census. It has an average elevation of 164 metres (540 ft). The city has got the monopoly of glass production and producing 70% of the total glass production in India due to which it is also called as *Suhag Nagri.* Firozabad city is facing an acute problem of water pollution because of old rusted and leaking water pipe lines and a large gap between demand and supply of water by the jal nigam. The core part of the city has no aquifer left and is declared as dark zone by jal nigam. Underground water is the only source of water available to the city whereas the city suffers from poor water quality, chocked sewer lines, poor drainage system and waterlogging problem etc.

Material and Methods

Water samples were collected in pre-cleaned plastic bottles of two litres and were analyzed for water quality parameters like pH, electrical conductivity, total dissolved solids, total hardness, total alkalinity, calcium, magnesium and chlorides as per standard method 2002. Water samples of bore well were collected from three selected sites namely Agra Gate (S1), Suhag Nagar (S2) and Raja Ka Tal (S3). In this study, for the calculation of water quality index, eight important parameters were chosen. The WQI has been calculated by using the standards of drinking water quality recommended by the Indian Council of Medical Research (ICMR) and Bureau of Indian Standards (BIS). Further, quality rating or sub index (qn) was calculated with weighted arithmetic index method using the following expression.

$$qn = 100\,(Vn - Vio)/(Sn - Vio)$$

(Let there be n water quality parameters and quality rating or sub index (qn) corresponding to n^{th} parameter is a number reflecting the relative value of this parameter in the polluted water with respect to its standard permissible value).

qn = Quality rating for the n^{th} water quality parameter.
Vn = Estimated value of the n^{th} parameter at a given sampling station.
Sn = Standard permissible value of the n^{th} parameter.
Vio = Ideal value of n^{th} parameter in pure water (i.e., 0 for all other parameters except the parameter pH and Dissolved oxygen (7.0 and 14.6 mg/L respectively).

Unit weight was calculated by a value inversely proportional to the recommended standard value *Sn* of the corresponding parameter.

$$Wn = K/Sn$$

where *Wn* = Unit weight for the n^{th} parameters, *Sn* = Standard value for n^{th} parameters and K = Constant for proportionality.

The overall Water Quality Index calculated by aggregating the quality rating with the unit weight linearly (Brown et al., 1970).

$$WQI = \sum qn\ wn / \sum wn$$

In this study, the computed grads of WQI values were categorized into five types for human consumption according to Ramakrishniah et al. (2009), as they are revealed in Table 1. WQI indicates the quality of water in terms of index number which represents overall quality of water for any intended use.

Table 1: Water quality index grades (WQI) and status of water quality

Water quality index levels	*Description*
<50	Excellent
50-100	Good water
100-200	Poor water
200-300	Very poor (bad) water
>300	Unsuitable and unfit for drinking

Source: Ramakrishniah et al., 2009

To examine the household water quality and its impact on the residents health the *Karl Pearson's Coefficient of Correlation technique* has been used whereas to measure spatial variations the statistical technique i.e. *Z score* has been used to develop a *composite score* for each set of indicators in order to arrive at the general housing and environmental condition of the study area as a whole. It is a linear transformation of the original data in such a way that its mean becomes a zero and its standard deviation becomes unity. For observation '*i*' on any variable, the standard score is obtained with the help of the following formula:

$$Zi = \frac{Xi - \overline{Xi}}{\partial i}$$

where Zi = Standard score of i^{th} variable, Xi = Original value of i^{th} variable, $\overline{Xi}$ = Mean of i^{th} variable and ∂ = Standard deviation of i^{th} variable.

The composite score is obtained with the help of the following formula.

$$CS = \frac{\Sigma Zij}{n}$$

where *CS* = Composite mean Z-score, *Zij* = Standard score of i^{th} variable at j^{th} unit of study and *N* = No. of variables.

Result and Discussions

The water samples taken from various locations of the Firozabad city for physico-chemical analysis reveal that all the parameters of Agra Gate (S1) except pH is beyond the permissible limits ICMR and BIS. While Suhag Nagar (S2) and Raja ka Tal (S3) lies within the maximum prescribed limit. The analysis of experimental investigation on quality of groundwater using physico-chemical parameters of the study area indicates that the quality of water in terms of index number is very poor to unsuitable or unfit for drinking purpose. Those index values (Table 2) reveal that the status of water at Agra Gate (576.59) is unfit according to WHO guideline standards (Ramakrishniah et al., 2009). Contrary to this, the WQI values for the sampling sites S2 (Suhag Nagar) and S3 (Raja ka Tal) is 284.78 and 235.56 respectively, indicating very bad water (200-300). The high WQI values are due to increase in pollution due to the discharge of various domestic and industries wastewater and also other anthropogenic hazardous waste. Thus, it can be inferred from the results of the present study that water of Firozabad city is severely contaminated. Therefore, it is recommended that the municipal board of the city should take into account this serious issue of water quality degradation. Moreover, there should be a regular monitoring for the quality of water, because this could increase the risk of direct threats to human health and environment.

Table 2: Water quality index of selected sites

Sl. No.	*Sites*	*Water quality index value*
1	Agra Gate (S1)	576.59
2	Suhag Nagar (S2)	284.78
3	Raja ka Tal (S3)	235.56

Source: Computed by author on the basis of physico-chemical analysis

Impact of Household Water Pollution on Health

To examine the household water pollution on health of the people some diseases have been taken into consideration. There are sixteen independent variables of water supply and sanitation conditions (X) and thirteen dependent variable of disease (Y) have been considered in this study as follows:

X1	Non-regular water supply	Y1	Diarrhoea
X2	Non-sufficient water supply	Y2	Dysentery
X3	Poor quality of water	Y3	Malaria
X4	Public source of water supply	Y4	Fileriasis
X5	Un-satisfied water quality	Y5	Hepatitis
X6	Storage of water in open containers	Y6	Jaundice
X7	Bathroom and toilet facility not present	Y7	Cholera
X8	Open toilet facility	Y8	Round Worm infection
X9	Manual toilets	Y9	Typhoid fever
X10	Discharge of flush latrin in open drains	Y10	Gastroenteritis
X11	Disposal of feacal matter with garbage/open drain/in field	Y11	Amoebiasis
X12	Absence of drainage around the house	Y12	Dengue fever
X13	Disposal of waste water around the house	Y13	Joint pain
X14	Open drainage		
X15	Water logging around the house		
X16	Waste and rain water logging		

Table 3 exhibits that all the variables X and Y are positively correlated at 1% significant level except X1 & Y5, X2 & Y1, X6 & Y4, X10 & Y4, X14 & Y4, X15 & Y2, Y4, X13 with Y7, Y8, Y9, Y11, Y12, Y13 and X12-Y13 which are significant at 0.05 level.

The analysis reveals that although their relationship is significant at 1 per cent or 5 per cent, they are correlated with varying degree of '*r*' value. Highest correlation is observed in between public source of water supply and typhoid fever ($r = 0.945$), public source of water supply and gastroenteritis ($r = 0.881$), poor quality of water and diarrhoea ($r = 0.872$), public source of water supply and dysentery ($r = 0.843$), public source of water supply and hepatitis ($r = 0.840$) whereas lowest correlation is seen among open drainage and Joint pain ($r = 0.396$), discharge of flush latrin in open drain and Joint pain ($r = 0.403$), manual toilets and Joint pain ($r = 0.405$), water logging around the house and Joint pain ($r = 0.407$) and non-sufficient water supply and fileriasis ($r = 0.415$).

Therefore, it becomes clear that water supply and sanitation condition of the city is affecting the health of the people. The resident of the city are mostly dependent on the municipal supply of water for all of their needs and the water distribution system of the city has become old due to which the rusted pipeline running parallel to the drains suck sludge and contaminated water of the drain and furthermore multiple connection into single supply line makes the condition more worst, when people consume this contaminated untreated water their health is affected.

It becomes evident from Figure 1 that high intensity of pollution and high intensity of diseases are found in central southern and eastern peripheral areas of the city because here mostly low income group people and labour class resides and this part is also having maximum number of slums who are devoid of municipal supply and therefore fulfill their need of water from roadside connections, along sewer connections. Medium intensity of pollution and low incidence of diseases are seen in newly added outer wards of the city because still rural character prevails in these areas and pollution is due to absence of municipal services. Low intensity of pollution and medium incidence of diseases are found in western peripheral and north eastern parts of the city because these are basically occupied by medium income group people and here commercial activities are carried out having accessibility of municipal supply. Medium intensity of pollution and medium incidence of diseases are seen in eastern and central parts of the city because of old and leaking supply system. Low intensity of pollution and low incidence of diseases are seen in core and north western wards of the city because here high income group people reside having good services as well as are aware of health outcomes of contaminated water intake.

Table 3: Relationship between water pollution and associated disease in Firozabad city

Independent variables	*Dependent variables*												
	Y1	*Y2*	*Y3*	*Y4*	*Y5*	*Y6*	*Y7*	*Y8*	*Y9*	*Y10*	*Y11*	*Y12*	*Y13*
X1	.562**	.529**	.499**	.429**	.323*	.534**	.449**	.350*	.446**	.493**	.475**	.483**	.365*
X2	.552**	.530**	.454**	.415**	.324*	.524**	.442**	.354*	.427**	.488**	.458**	.452**	.370*
X3	.872**	.792**	.769**	.676**	.630**	.821**	.653**	.626**	.732**	.794**	.682**	.656**	.643**
X4	.793**	.843**	.708**	.735**	.840**	.824**	.812**	.737**	.945**	.881**	.648**	.714**	.729**
X5	.744**	.835**	.565**	.490**	.548**	.663**	.550**	.559**	.618**	.663**	.649**	.671**	.490**
X6	.646**	.490**	.635**	.361*	.463**	.586**	.370*	.426**	.475**	.563**	.470**	.494**	.331*
X7	.793**	.745**	.657**	.499**	.678**	.625**	.539**	.538**	.692**	.654**	.487**	.609**	.416**
X8	.714**	.643**	.623**	.511**	.667**	.676**	.554**	.520**	.651**	.701**	.540**	.519**	.405**
X9	.703**	.666**	.619**	.525**	.495**	.709**	.572**	.468**	.646**	.665**	.572**	.683**	.555**
X10	.645**	.708**	.633**	.377*	.555**	.666**	.491**	.674**	.527**	.599**	.627**	.683**	.403**
X11	.715**	.728**	.695**	.587**	.629**	.769**	.730**	.539**	.732**	.729**	.618**	.653**	.610**
X12	.711**	.602**	.590**	.412**	.632**	.589**	.415**	.518**	.535**	.623**	.442**	.424**	.378*
X13	.563**	.398**	.524**	0.22	.487**	.444**	0.294	.382*	.371*	.452**	.348*	.387*	0.238
X14	.709**	.551**	.792**	.381*	.563**	.634**	.601**	.480**	.553**	.618**	.507**	.682**	.396**
X15	.715**	.593**	.727**	.305*	.487**	.615**	.596**	.450**	.518**	.604**	.554**	.670**	.407**
X16	.804**	.647**	.782**	.415**	.553**	.619**	.615**	.452**	.588**	.665**	.511**	.600**	.432**

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).
Source: Calculated from data collected from field survey (2012-2013).

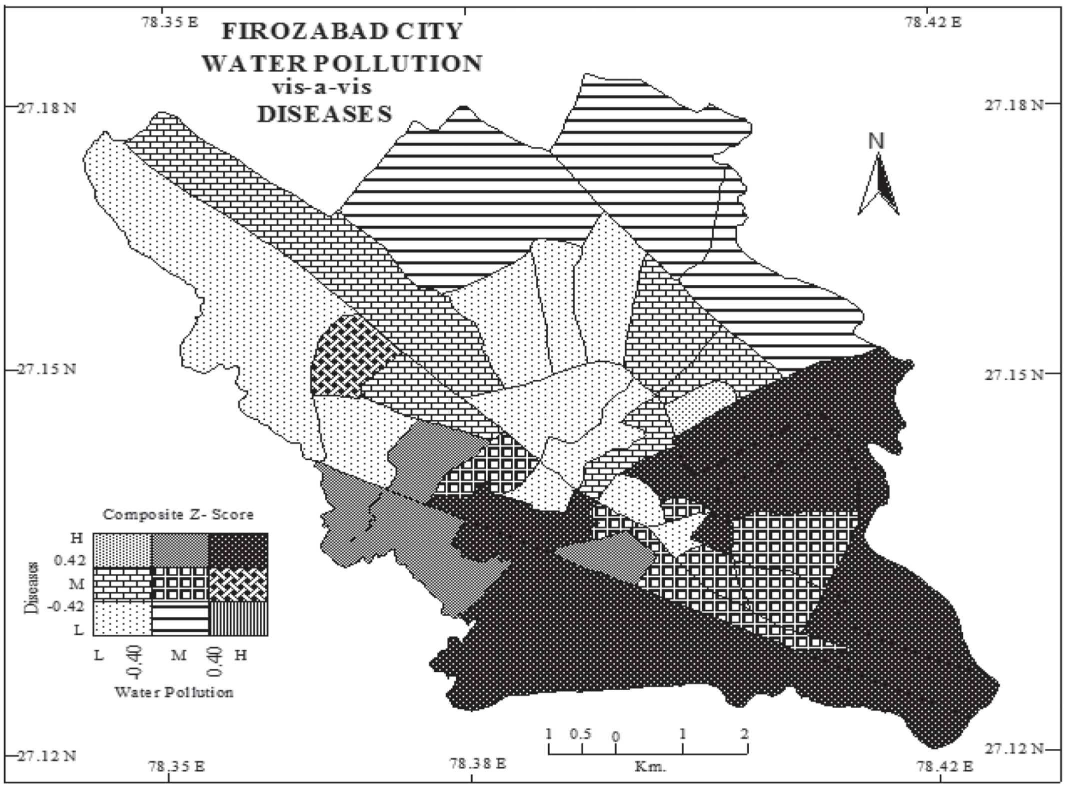

Figure 1: Composite map of household water pollution and sanitation condition and incidence of diseases.

Conclusion

The above discussion makes it clear that high household water supply and sanitation problem is mainly found in the eastern outer and adjoining areas which is the main cause of outbreak of diseases because in these wards labour class resides and are slum areas. Medium household pollution is seen in north eastern outer wards of the city because in these areas still good quality underground water is available. While north central parts have low water-related problems and hence occurrences of disease because these wards are inhabited by high status people, majestic house, good and closed drainage system, no water logging problems and use RO water for drinking as well as good cleaning facility by municipality. Low intensity of pollution but medium to high incidence of disease are due to the contaminated water supply system as the water pipelines are moving through the drains and are damaged from several points thus sucking slug with it. After foregoing discussion regarding water pollution and its impact on health of the city residents it is recommended:

- To replace the old pipe network with new one.
- Cleaning of underground reservoirs and overhead tanks.
- Strict action against using of boosters for sucking water.
- There should be closed drainage system.
- Transparency of municipal body in providing sanitary services to lower income wards and slum areas.

Acknowledgements

I would like to express my sincere gratitude to my supervisor Prof. Ateeque Ahmad for providing me with excellent guidance and technical advice in the various phases of the present work. I am grateful to senior scientist Mr. Gautam of Firozabad Pollution Control Board for assisting me to carry out the experimental work. I am also grateful to Moazzam Irfan, for his intellectual support and helping me to complete such an extensive household survey.

References

Brown, R.M., McClelland, N.I., Deininger, R.A. and R.G. Tozer (1970). A water quality Index—Do we dare? *Water & Sewage Works*, **117(10):** 339-343.

Dhakad, N.K., Shinde, D. and P. Choudhary (2008). Water Quality Index of ground water (GWQI) of Jhabua Town, M.P. India. *J. Environmental Res. Dev.*, 2(3): 443-446.

Darapu, S.S.K., Sudhakar, B., Krishna, K.S.R., Rao, P.V. and M.C. Shekhar (2011). Determining Water Quality Index for the Evaluation of Water Quality of River. *International Journal of Engineering Research and Applications (IJERA)*, **1(2):** 174-182.

Department of Water Affairs and Forestry (DWAF) (1991). Water Quality Management and Strategies in the Republic of South Africa. Pretoria, South Africa. 216 pp.

Department of Water Affairs and Forestry (DWAF) (1996). South African Water Quality Guidelines (2nd edn), Vol 1: Domestic Use; and Vol 2: Agricultural Use.

Girija, T.R., Mahanta. C. and V. Chandramouli (2007). Water Quality Assessment of an untreated effluent impacted urban stream: The Bharalu Tributary of the Brahamaputra River, India. *Environmental Monitoring and Assessment*, 221-236.

Ramakrishniah, C.R., Sadashivaiah, C. and G. Ranganna (2009). Assessment of Water Quality Index for the Groundwater in Tumkur Taluk. *E-Journal of Chemistry*, **6(2):** 523-530.

Rao, C.S., Rao, B.S., Hariharan, A.V.L.N.S.H. and N.M. Bharathi (2010). Determination of water quality index of some areas in Guntur district Andhra Pradesh. *International Journal of Applied Biology and Pharmaceutical Technology*, **1(1):** 79-86.

Srinivas, J., Purushotham, A.V. and K.V.S.G. Murali Krishna (2013). Determination of water quality index in industrial areas of Kakinada, Andhra Pradesh, India. *Int. Res. J. Environment Sci.*, **2(5):** 37-45.

WHO/UNICEF (2004). Meeting the MDGs water and sanitation: A mid term assessment of progress. WHO/UNICEF, Geneva. ISBN 9241562-1.

Asian Journal of Water, Environment and Pollution

Volume 14 Number 1 **January – March, 2017**

Contents