Water Quality Index in Municipal Distribution System for Solapur city, Maharashtra State, India

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***Abstract*- A study was conducted to assess water quality in the various zones of municipal distribution system for Solapur city (India) using water quality index technique. The variation in the water quality parameters was found to be pH (6.25-9.25), Total Alkalinity (88-408), Hardness (144-432), DO (1.48-9.8), Total solids (304.3-1011) and MPN (0-21).The WQI in various zones of distribution system for Solapur city varies temporally and spatially. The variation in WQI was found to be from 25.4 to 98. Such large variation in WQI was due to more variation in DO, TS and MPN. The TS and MPN exceeds the ICMR tolerance limits in many zones. It was observed that main cause of deterioration in water quality is due to regrowth of microorganisms in the distribution system and overhead tanks, non replacement of old pipes, corrosion of pipe material and reduction in the water treatment efficiency at water works against the population growth. The study reveals that out of twenty-nine zones in the study area, for Zones Two, Four, Twenty- three and Twenty-nine water quality was found to be critical and pose a serious threat to public health.**

Keywords- Water Quality Index; Municipal Distribution System; Twenty Nine Zones.

I. INTRODUCTION

Water distribution system plays a vital role in presenting a desirable life quality to the public. The welfare level of country is measured with the amount of water consumption for each person and the quality of the provided water [1]. A typical water supply system comprises the water source (aquifer or surface water source), transmission mains, treatment plant and distribution network. The water quality varies temporally and spatially at source, treatment plant and in the distribution network. The water quality in the distribution system deteriorates due to pipe age, corrosion of pipe material, intrusion of contaminants through leakage and cross connections, leaching of pipe material, formation of biofilm etc. Intrusion of contaminants in the water distribution systems can occur through pipes and storage tanks. Open water reservoirs are susceptible to microbial contamination from external non point sources such as feaces of infected animals, e.g. beaver, squirrels and rabbits, within the watershed. Microorganisms can be introduced into open reservoirs from windblown dust, debris and algae. Organic matter (leaves and pollens) are also of concern in open storage tanks [2]. Microorganisms can also be introduced into ground level storage through surface water (flooding) or groundwater infiltration. Bird droppings are commonly found in storage facilities with floating covers. A broken gasket that seals pipe joints can be a pathway for variety of heterotrophic bacteria in the distribution network [3]. The corrosion of metallic pipes and metallic devices increases metal compound in the water. Different metals go through different corrosion processes, but in general low pH water, high dissolved oxygen, high temperature and high levels of dissolved solids increases corrosion rates [4]. Leaching of pipe liners (plastic and epoxy lining) leads to contamination of water [5]. The objective of an index is to run complex water quality data into information that is understandable and useful by public. The water quality index is a unit less single dimensional number, varies from 0 to 100. A higher index value represents good water quality [6, 7].

In the literature various indices have been used to assess the water quality for surface and ground water sources. The WQI technique is still not being used for assessment of water quality in the municipal distribution system. In this study an attempt is made to analyse the water quality in the municipal distribution system for Solapur city using water quality index (WQI). This study may help the stake holders to get an idea about the critical zones in the city. These obtained results may be used for water quality management in the distribution system to avoid the epidemic. The water quality index (WQI) was determined according to index developed by Tiwari and Mishra [8].

II. STUDY AREA, MATERIALS AND METHOD

The municipal water distribution system of Solapur, India, is taken as a case study for prediction and analysis of water quality in the distribution system. Solapur relies mainly on surface water supply for drinking, industrial and other domestic purposes. There are three different sources of surface water supply: (1) Ujjani Dam Reservoir about 100 km west of the city (2) Bhima River at village Takli about 30 km south of the city and (3) Ekrukh Tank near village Hipparga about 3 km North of the main city. Arrangements have been made for direct supply of 90 million liters per day (MLD) of water to Solapur from Ujjani Dam, which is basically a hydro-electric-cum-irrigation project. Bhima River scheme at Takli is designed to supply about 120 MLD of water; it collects the released water from Ujjani Dam. Ekrukh Tank, constructed for irrigation purposes in

1871, can supply up to 27 MLD of water. There are three water treatment plants (water works) for these three different water sources. To meet the fluctuations in the demand of water, the water from Ujjani Dam and Ekrukh tank is mixed at Bhavanipeth water works and the water from all the three water sources is mixed at Hill service reservoir, Jule Solapur. Fig. 1 shows the location details of these sources of water. There are three water treatment plants (water works) for these three different water sources. To meet the fluctuations in the demand of water, the water from Ujjani Dam and Ekrukh tank is mixed at Bhavanipeth water works and the water from all three water sources is mixed at Hill service reservoir, Jule Solapur. The water quality at these three sources is not same. The mixing of water takes place at two locations in the city and mixing proportion is also not same, due to which the resulting water quality in the distribution system changes. The water is distributed to Solapur city by dividing the entire city into twenty-nine zones, the details of which are mentioned in the Table I. The water quality parameters pH, alkalinity, hardness, DO, total solids and MPN are used to develop WQI for various zones in the distribution system.

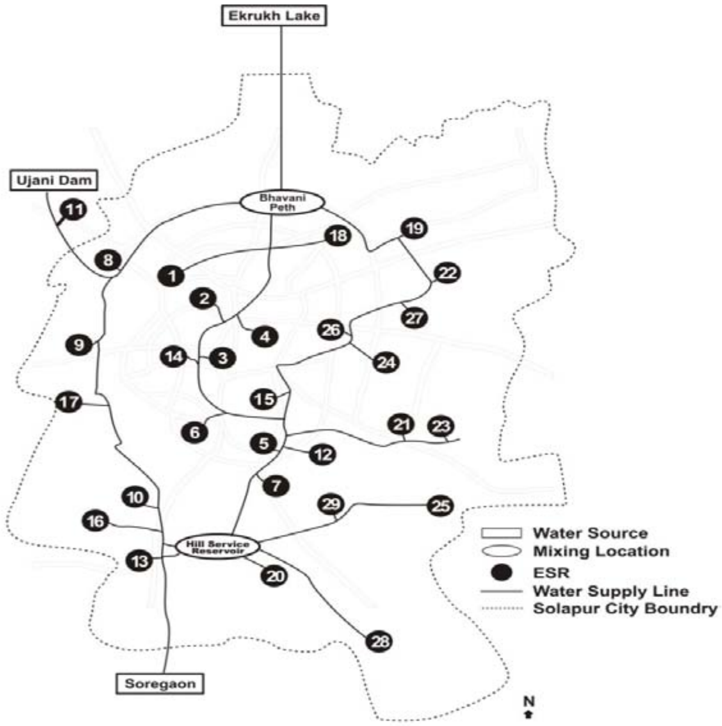

Fig. 1 Location Details of Water Sources

TABLE I ZONE DETAILS OF SOLAPUR CITY

Zone No.	Water Tank	Water Supply Area
1	Kasturba Budhwar Peth	Budhwar Peth, Balives Chowk , Budhle lane, Samrat Chowk, Bhavani Peth, Maratha Vasti, Tuljapur Ves, Kashi Kapde lane, Sarda Plot, Hanuman Nagar, Namdev Nagar, Homkar Nagar, Mantri Chandak Nagar, Sahir Vasti, Mukund Nagar, Ravji Sakharam Prashala.
2	Percival Area Near Zilla Parishad	South Kasba, North Kasba, Murarji Peth, Navi Peth, Datt Chowk, Mullababa Tekdi, Ramlal Chowk, Juni Mill Chawl, Zunje Lane, Tole Lane, Gavandi Area, Bakshi Lane, Mahalaxmi Milk Dairy, Panjrapol Chowk.
3	Siddheshwar Zilla Parishad Compound Area	Vijapur Ves, Foujdar Chawdi, Old Vitthal Mandir Area, Patva lane, Tilak Chowk Area, Mallikarjun Temple Area.
4	High level Civil hospital	Shanivar Peth, Telangi Pacha Peth, Rahul Gandhi Slum area, Jamkhandi Bridge, Rajendra Chowk, Jodbasavanna Chowk, Kanna Chowk, Sakhar Peth, Ganesh Peth, Budhwar Market, Vijapur Ves till Kontam chowk till Kumbhar Ves, Manik Chowk, Madhla Maruti Area, Shukurwar Peth, Jodbhavi Peth Area, Tilak Chowk Area, Guruwar Peth Area.
5	D.S.P Raised Area	Gandhinagar Area, Saat rasta Solapur Society, Gurunanak Nagar Chowk Area, Moulali Chowk, Qureshi lane, Darasha Hospital, Chuna Bhatti Area till Huma Hotel, Kumtha Naka Area, Milk Dairy.
6	D.S.P Lowered Area	Modi, Shoba Nagar, Saat Rasta Area, Soni nagar, Revan Siddheshwar Nagar, Morya Society, Yetiraj Hotel till Modi police Station, Chintalwar Vasti, Pankha Vihir, Municipal Colony, Akanksha Society, Uplap Vasti, Shindhi Khana.
7	Jule Solapur Raised Area	Jule Solapur Area, Mhada Colony, Dhonde Nagar, Dnyaneshwar Nagar, Waman Nagar, Kalyan Nagar, Kinara Hotel, ESI Hospital, Antrolikar Nagar.
8	Avanti Nagar Water Tank	Avanti Nagar, Abhimanshri, Hande Plot, Mote Vasti, Jai Malhar Chowk, Prabhakar Maharaj Road, Sathe Chawl, Mahesh Society, Bhagwati Society, S.T.Stand Area, Satyam Shivam Society.
9	Ujani Main Line Mariaai Chowk	Mariaai Chowk, Damani Nagar, Thobde Vasti, Gavali Vasti, Bhaiyya Chowk, Degaon Deshmukh Patil Vasti, Amrai Shete Vasti, Pratiksha Colony, Habbu Vasti, Mithila Nagar, Ashirwad Nagar, Lakshmi Vishnu Chawl, Dongaon Road Area.

10	Indira Nagar Statue	Indira Nagar, Garibi Hatao Slums, Koli Samaj Society, Iranna Vasti, Utkarsh Nagar, Bhushan Nagar and other areas.
11	Bale Village Ujani Crossroad	Bale, Kegaon, Ambika Nagar, Barshi Road Area.
12	D.S.P Raised Area	Area behind Taluka police Station, Ambedkar nagar, Shikshak Society, Bharat Society, Gurunanak Nagar, Shandar Chowk, Shastri Nagar Slum Area, Keshav Nagar, Vikas Nagar, Pandurang Vasti, Panchasheel Takshasheel Nagar.
13	Nehru Nagar Water Tank	Sundaram Nagar, Anand Nagar, Nirapam Society, Ashok Nagar, Nehru Nagar, S.T.Colony, Bennur Nagar, Mahalaxmi Nagar, Chatrapati Society, 22 Society Vijapur Road Area.
14	High Level	Railway line, Duffrin chowk, Employment Chowk Area, Railway Station Area.
15	High Level Round Tank	Bedarpool, Patrakar Nagar, Lodhi Lane Area.
16	Aditya Nagar	Sonamata Nagar, Mashal Vasti, Dwarka Nagar, Sushil Nagar, Kamala Nagar, Brhamachaitanya Nagar, Aditya Nagar, Nirmiti Vihar, Jai-Jui Nagar, Siddheshwar Nagar, Indira Nagar Area
17	Settlement Salgar Vasti Water Tank	Railway line, Duffrin chowk, Employment Chowk Area, Railway Station Area.
18	Dayanand Water Tank	Bhavani peth, Ghongde Vasti, Indira Resident, Satpute Vasti, Jodbhavi peth, Netaji Nagar, Maddi Vasti.
19	Mehtab Nagar Tank	Shelgi Village, Ramdev Nagar, Amarnath Nagar and Area, Vidi Gharkul Area.
20	Jule Solapur	Lokmanya Nagar, Mantri Chandak Nagar, Industrial Estate, Nai Zindagi Area.
21	Mitragotri Gentyal Tank	M.I.D.C Area, Neelam Nagar, Akashwani Area, Vinayak Nagar, Sunil Nagar, Asha Nagar.
22	Percival Area Near Parishad	Vidi Gharkul A.B.C group, Sagar Chowk, Rangraj Nagar, Rajeshwar Nagar, Sangameshwar Nagar.
23	Mitragotri Tank	Satyasai Nagar, Ashok Chowk, Sant Tukaram Chowk, Pacha Peth, Bapuji Nagar, Jawahar Nagar, Area Near Pathrut Chowk, Madhav Nagar, Kumtha Naka, Hudko.
24	Sadhu Waswani 175 H.P	Karnik Nagar, Ekta Nagar, Padma Nagar, Saibaba Chowk, Satter Foot Road Area, Kamtam Nagar, Paccha Peth, 33- 786 Flour Mill.
25	Sadhu Waswani 75 H.P Pump	Extended Area Near Kumtha Naka, Huccheshwar Math Area, Swagat Nagar, 1,2 Krushna Society, Balaji society, Hanuman Nagar, Tai Chowk.
26	Bhadravati Tank	Bhadravati Peth, Datta Nagar, Ravivar Peth, Jodbhavi Peth, Jodbassavanna Chowk, Daji Peth, Joshi Area, Kavita nagar, Gawai Peth, Market Yard 256 Area, Shanti Nagar.
27	High Level 150 H.P. Pump	Gandhinagar 1 to 6 , Vidi Gharkul, Rangrj Nagar, Mahesh Nagar, A.B. Group, Venkatesh Nagar, Vajreshwar Nagar, Shewta Nagar, Kalpana Nagar, Konda Nagar, Yatiraj Nagar.
28	Jule Solapur	Hotgi Road, Hatture Area, Majrewadi Area.
29	Low Level Round Tank	Lodhi Lane Area, Amarnath Nagar and Nai Zindagi Area.

III. COLLECTION OF SAMPLES AND WATER QUALITY INDEX (WQI)

The water is distributed to Solapur city by dividing the entire city area into twenty-nine zones. The water samples were collected from the various zones once in a month for three years i.e. January2008 to December 2010 and analysed in the laboratory.

The samples were collected, labelled and transported to the laboratory. Physico-chemical properties of water such as dissolved oxygen (DO), total alkalinity (TA), total solids (TS), total hardness (TH) and most probable number (MPN) were analysed by standard methods given in Trivedy and Goel [9] and Tandon [10]. Water quality index was calculated for each month by considering six important physico-chemical properties and using Indian Council of Medical Research (ICMR), 1975 standards. Water quality index was calculated by weighted index method to determine the suitability of water in the distribution system for drinking purposes. The index developed by Tiwari and Mishra [8] is used in the present study. Six input parameters viz. pH, Alkalinity, DO, Hardness, total Solids and MPN were considered for computing WQI and the unit weight Wi of each parameter is obtained depending upon its weightage, by using following expression

$$WQI = \sum \frac{Wiqi}{Wi} \tag{1}$$

Where q_i= Quality rating for the i water quality parameters (i=1, 2, 3 …), W_i = Unit weight of water quality parameter. The ICMR (Indian Council of Medical Research) Standards and unit weights for different quality parameters are shown in Table II and the rating scale for calculating WQI is given in Table III.

TABLE II WATER QUALITY FACTORS: THEIR ICMR STANDARDS AND ASSIGNED UNIT WEIGHTS

Water Quality Factor	ICMR Standards	Unit Weights(W_i)
pH	7-8.5	0.09
Total Solids	<500	0.13
Hardness	<300	0.05
Alkalinity	<120	0.01
Dissolved Oxygen	>5	0.12
MPN	<1	0.6

TABLE III RATING SCALE TO CALCULATE WQI

Physico-Chemical Factors	Ranges				
pH	7-8.5	8.6-8.7 6.8-6.9	8.8-8.9 6.7-6.8	9.0-9.2 6.5-6.7	>9.2 <6.5
DO	>7	5.1-7	4.1-5	3-4	<3
Alkalinity	21-50	16-20 51-70	11-15 71-91	5-10 91-120	>120
Hardness	0-150	150.1-300	300.1-450	450.1-600	>600
Total solids	<500	500-700	701-900	901-1000	>1000
MPN	<1	2-4	5-7	8-10	>10
Rating	100	80	60	40	0
Extent of Pollution	**Clean**	**Slight pollution**	**Moderate Pollution**	**Excessive Pollution**	**Severe Pollution**

IV. RESULTS AND DISCUSSIONS

The water quality analysis in the study area for all twenty nine zones is carried and the values of Mean, variance and standard deviations are given in Table IV. The physico-chemical parameters have shown temporal and spatial variations. The value of mean, standard deviation and variance indicates that there are large fluctuations in the values of MPN, DO and TS as compared to the other parameters such as alkalinity, total hardness and pH. The Table V shows comparison between average Value of water quality parameters and ICMR values.

TABLE IV SUMMARY OF BASIC STATISTICS OF WATER QUALITY PARAMETERS

ICMR Standards	Water Quality parameters	Observed Avg .Values
7-8.5	pH	7.612
<500	Total Solids	693.330
<300	Hardness	200.67
<120	Alkalinity	162.627
>5	Dissolved Oxygen	6.28
<1	MPN	3.508

(All units except pH and MPN are in mg/*l*)

TABLE V COMPARISION OF ICMR STANDARDS AND OBSERVED AVG. VALUES

Water Quality →Parameters	pH	Total Alkalinity	Hardness	DO	Total Solids	MPN
Minimum	6.25	88	144	1.48	304.3	0
Maximum	9.85	408	432	9.8	1011	21
Mean	7.612	162.627	200.67	6.28	697.330	3.508
Standard Deviation	0.270	20.125	18.12	1.069	142.82	6.921
Variance	0.0733	405.025	328.420	1.143	20398.44	47.902

(All units except pH and MPN are in mg/l)

A. *Effects of Total Solid*

The amount and nature of dissolved and undissolved matter present in water vary greatly. Waters with higher solids content have laxative properties and sometimes the reverse effect upon people whose bodies are not adjusted to them. Total dissolved solid (TDS) consists of oxygen–demanding wastes and disease–causing agents, which can cause immense harm to public health. The presence of synthetic organic chemicals (fuels, detergents, paints, solvents, etc.) imparts objectionable and offensive tastes, odors and colors to fish and aquatic plants even when they are present in low concentrations [11, 12 ,13].

In present investigations TS value varied from 304.3 to 1011 mg/lit. Average value is found to be 697.33mg/lit, which is more than ICMR standard. The reason for more TS in the distribution system could be higher concentration of TS in Bhima River, which collects the released water from Ujjani Dam. Higher concentration of TS in the river is probably due to discharge of industrial effluent in Bhima River in between Ujjani dam and Soregaon. The other reasons such as heavy deposits in distribution system, corrosion of metallic pipes and intermittent water supply also contributes to increase in TS.

B. *Effect of Microorganisms*

In drinking water micro–organisms can cause sensory defects (odour, colour, taste). Micro–organisms are an important cause of the corrosion of steel pipes. Various health related problems due to contaminated waters are diarrhea, abdominal cramps and vomiting due to salmonella, cholera is due to vibrocholerae, infection of lungs due to mycobacterium [11, 12, 13].

In present study MPN varied from 0 to 21 and the average is found to be 3.508, which is more than ICMR standard. The increase in MPN value is due to regrowth of microorganisms in the distribution system and overhead tanks. Iron pipes are commonly used in the distribution systems. Iron corrosion may cause taste, colour and also induce a chemical decay of the residual chlorine. Booster chlorination would have to be adopted, to ensure minimum residual chlorine in the distribution system. Soft deposits and biofilm in the drinking water pipelines have been found to consist mostly of bacteria, including pathogenic microbes [14]. Detachment of bacteria from biofilm has accounted for most of the planktonic cells present in drinking water.

C. Effect of pH

Since most of the human body consists of (50–60%) water, the pH level has profound effect on all body chemistry, health and disease. All regulatory mechanism (including breathing, circulation, digestion, hormonal production) serves the purpose of balancing pH. The fluids in our body have to be in the range 7–7.2 level. If pH is less than 5.3, assimilation of vitamins or minerals is not possible. When body pH drops below6.4, enzymes are deactivated; digestion does not take place properly. An acid pH of range 1–4 can result from an acid forming diet, for example soft drinks (pH 1.5–3), can cause emotional stress, toxic overload or any process that deprive the cells of oxygen and other nutrients. The rainwater has a pH range 5.5–6, as such may not be harmful if it is consumed. The rainwater may not contain minerals for the growth of the body. pH greater than 8.5 causes the water taste as bitter or soda like taste. If pH is greater than 11 cause eye irritation and exacerbation of skin disorder. pH in the range of 10–12.5 cause hair fibers to swell. pH in the range 3.5–4.5 affects the fish reproduction [12,13].

pH was found to be most stable parameter, which did not show drastic changes during the sampling period. Most of the water samples in this study recorded a pH of about 6.25-9.85.The average pH value is found to be 7.612., which is within ICMR limits. The normal range of pH has no immediate effect on human health .The variation in pH regulates most of the bio chemical and chemical reactions affecting water composition [15].

D. Effects of Dissolved Oxygen

Natural waters in equilibrium with the atmosphere will contain dissolved oxygen concentrations ranging from about 5 to 14.5 mg O_2per litre depending on the water temperature, salinity, and altitude. The dissolved oxygen (DO) concentration present in water reflects atmospheric dissolution, as well as autotrophic and heterotrophic processes that respectively, produce and consume oxygen.

DO is the factor that determines whether biological changes are brought by aerobic or anaerobic organisms. Thus, dissolved–oxygen measurement is vital for maintaining aerobic treatment processes intended to purify domestic and industrial wastewaters. The optimum value for good water quality is 4 to 6 mg/l of DO, which ensures healthy aquatic life in a water body [11, 12, 13]. In this study the value of DO at various zones ranges from 1.48 to 9.8 mg/lit. The average value is found to be 6.28.The reduction of DO was more frequently observed at Zones Two, Four, Twenty-three and Twenty-nine. The reduction of DO at these zones is due to presence of more microorganisms. High MPN value and low DO ultimately leads to decrease in WQI. From Figs. 2-5 it is observed that WQI fluctuates seasonally, which is due to seasonal fluctuation of DO. The DO is more soluble in cold water than warmer water, a trend that can typically be seen in annual WQI. From Figs. 2-5 it is observed that WQI is less during warmer months and more in colder months, this is because the colder months have higher mean DO concentrations than the warmer months. Other deficiencies of DO can occur when materials that exhibit an oxygen demand are introduced into a water distribution system through cross connections.

E. Effects of Alkalinity

Alkalinity is a measure of the presence of bicarbonate, carbonate or hydroxide constituents. Concentrations less than 100 ppm are desirable for domestic water supplies. A minimum level of alkalinity is desirable because it is considered a "buffer" that prevents large variations in pH. Alkalinity is not detrimental to humans. Moderately alkaline water (less than 350 mg/l), in combination with hardness, forms a layer of calcium or magnesium carbonate that tends to inhibit corrosion of metal piping [11, 13].

The total alkalinity at various zones varies from 88 to 408 mg/lit. The average is found to be 162.62 mg/lit. There do not appear to be serious adverse health effects from drinking water with alkalinity above or below the suggested levels by ICMR. However, many public water utilities try to maintain an acceptable alkalinity level in order to prevent low pH (acidic) water from damaging pipelines and other distribution equipment.

F. Effects of Hardness

Both calcium and magnesium are essential minerals and beneficial to human health in several respects. Inadequate intakes of calcium have been associated with increased risks of osteoporosis, kidney stones, colorectal cancer, hypertension and stroke, coronary artery disease, insulin resistance and obesity. Low magnesium levels are associated with endothelial dysfunction, increased vascular reactions, elevated circulating levels of C-reactive protein (a proinflammatory marker that is a risk factor for coronary heart disease) and decreased insulin sensitivity. Increased intake of magnesium salts may cause a temporary adaptable change in bowel habits (diarrhoea), but seldom causes hyper magnesaemia in persons with normal kidney function. Laxative effects have also been associated with excess intake of magnesium taken in the form of supplements, but not with magnesium in diet [16].The value of total hardness at various zones varied from 144 to 432 mg/lit. The average is found to be 260.67 mg/lit.

The quality of water is categorised from very bad to excellent based on water quality index (WQI) [8]. WQI ranges are as shown in Table VI. The water quality classification in the distribution system for solapur city is shown in Table VII, from this table it can be observed that out of twenty-nine zones in the study area, for Zones Twenty-two and Twenty-eight water quality is excellent, for Zones Four, Twenty-three and Twenty-nine water quality is medium, for Zone Two water quality is bad and for remaining twenty-three zones water quality is good. The water quality in Zones Two, Four, Twenty-three and Twenty- nine deteriorates due to increase in MPN and TS value. Hence these four zones are critical and pose a serious threat to public health. The variation in WQI for these critical zones from January 2008 to December 2010 is shown in Figures 2 to 5. From Figures 2-5 it is observed that WQI value for most of the months in year 2010 are comparatively less with respect to months in 2008 and 2009 this may be due to decrease in treatment plant efficiency against population growth. The low WQI at these zones suggests that serious efforts are needed by the stake holders and policy makers to improve the water quality in these critical zones. High MPN count at all critical zones further emphasizes the need of protecting the health of the persons staying in these critical zones. They should be trained to disinfect the water by boiling or by using bleaching powder before drinking.

TABLE VI WATER QUALITY CLASSIFICATION

Value of WQI	Quality of Water
91-100	Excellent
71-90	Good
51-70	Medium
26-50	Bad
00-25	Very Bad

TABLE VII AVERAGE WQI VALUE AT EACH ZONE

Zone	Avg.WQI Value	Classification
1	75.33	Good
2	35.85	Bad
3	77.95	Good
4	55.37	Medium
5	85.88	Good
6	84.37	Good
7	80.58	Good
8	87.29	Good
9	86.28	Good
10	86.79	Good
11	84.06	Good
12	73.20	Good
13	82.77	Good
14	70.24	Good
15	77.72	Good
16	87.904	Good
17	84.227	Good
18	72.57	Good
19	83.63	Good
20	83.86	Good
21	74.89	Good
22	90.64	Excellent
23	66.69	Medium
24	78.75	Good
25	78.995	Good
26	89	Good
27	73.29	Good
28	92.39	Excellent
29	62.14	Medium

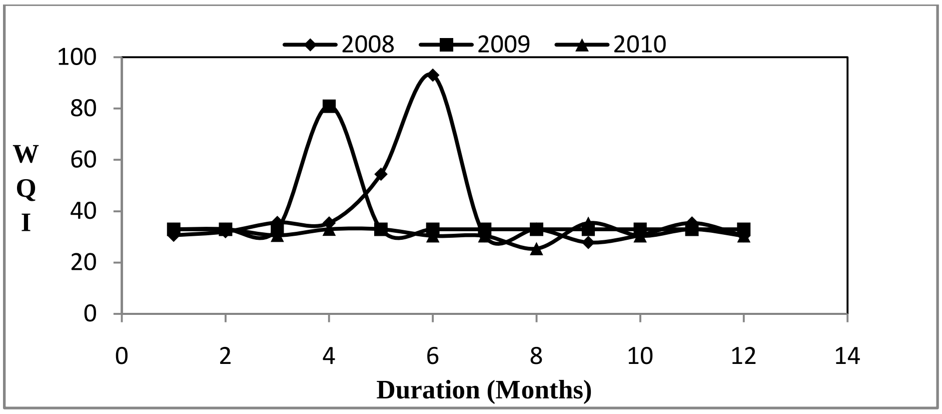

Fig. 2 Variation in WQI for Zone Second (Avg.WQI-35.85)

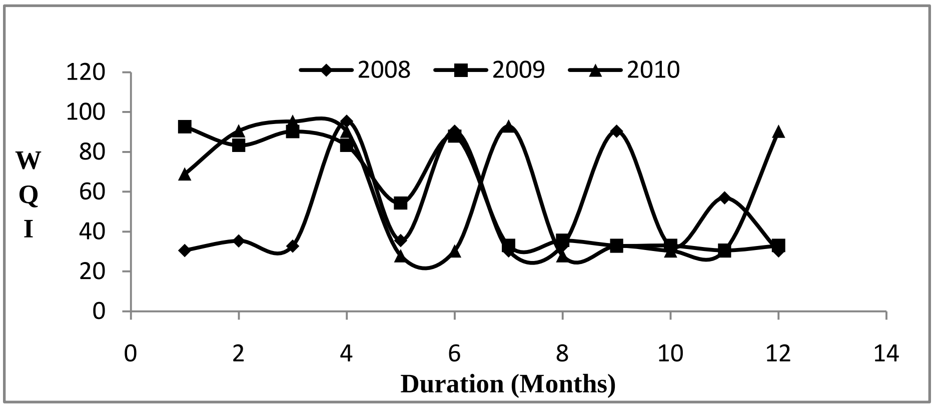

Fig. 3 Variation in WQI for Zone Four (Avg.WQI-55.37)

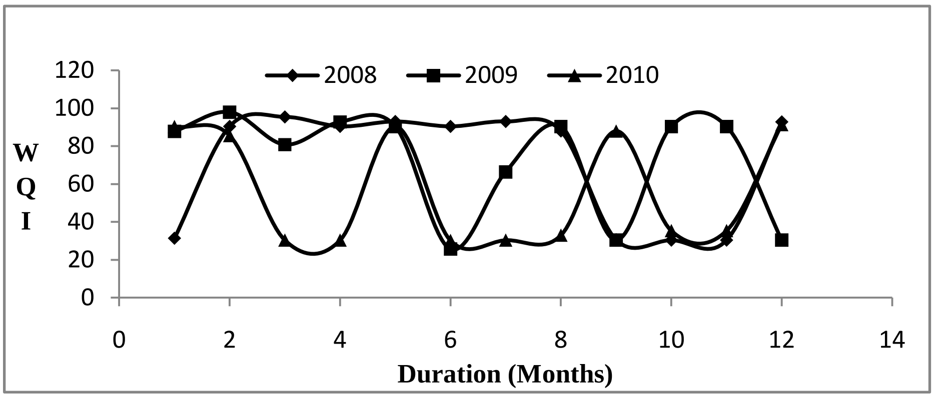

Fig. 4 Variation in WQI for Zone Twenty-three (Avg.WQI-66.69)

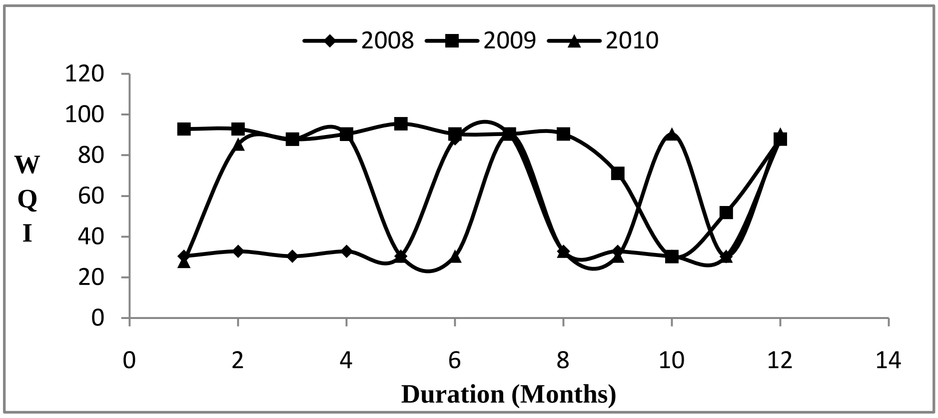

Fig. 5 Variation in WQI for Zone Twenty-nine (Avg.WQI-62.14)

V. CONCLUSIONS

The water quality parameters used for analysis shows spatial and temporal variations. The variation in the water quality parameters was found to be pH (6.25-9.25), Total Alkalinity (88-408), Hardness (144-432), DO (1.48-9.8), Total solids (304.3-1011) and MPN (0-21). The WQI varies from 25.4 to 98. The total solids and MPN were found to be most important parameters as they contribute the most for WQI calculation amongst six parameters. Out of twenty-nine zones in the study area, Zone Two was found to be most critical showing average WQI 35.85, followed by Zone Four (avg.WQI 55.37), Zone Twenty-nine (avg.WQI 62.14) and Twenty-three (avg.WQI 66.69). The developed WQI in the distribution system can be used as a tool by the policy makers or managers to avoid the epidemic.

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