Available online at **www.joac.info**

ISSN: 2278-1862

Journal of Applicable Chemistry

2016, 5 (5): 1191-1198

(International Peer Reviewed Journal)

Physico-Chemical Analysis of Packaged Mineral Water Bottles Floating In And Around Central Karnataka

Veena Kumara Adi*, Jayalatha N. A and Veena D.V

*P.G Department of Environmental Engineering, Civil Engineering Department
Bapuji Institute of Engineering and Technology, Davangere 577004, Karnataka, **INDIA**

Email: drveena.adi@gmail.com

Accepted on 20th August 2016

ABSTRACT

Water the natural resource for survival; occur in pure or impure form. Good health of humans depends upon the quality of water. Due to rapid urbanization and industrialization quality of drinking water is deterioted by toxic substances, which are very dangerous to the health even though in small amount. Mineral water is the purified water in which required amount of minerals are added and are very beneficial to human body. These mineral water bottles are supposed to be manufactured and packed under good manufacturing practice. Different industries adopt different water purification such as Activated carbon filter, Reverse osmosis, UV treatment, Ozonisation thus making it accessible at economical prices to the common man. To assess the water quality of bottled drinking water floating in the south part of the country, the physico-chemical analysis was conducted. Parameters like pH, acidity, alkalinity, total dissolved solids, electrical conductivity, chloride, hardness, Calcium and Magnesium (Ca^{2+} & Mg^{2+}), Sodium and Potassium (Na+ and K+), fluoride were analyzed. From the results it is evident that pH of 23% samples measured a pH less than 6.5. Approximately 15% of samples had absolutely no hardness. However the hardness measures of the remaining 85% of samples were within the limit. Alkalinities of 99% samples were within the desirable limit. The Total Dissolved Solids and Electrical Conductivity of all samples were within desirable limit. Acidity of all samples were within permissible limit. 100% samples were following under desirable limit for chloride and fluoride. It was a striking observation that same brands manufactured at different station differed in their physico chemical parameters. Water the natural resource for survival; occur in pure or impure form.

Keywords: Bottled water, Mineral water, Chemical analysis.

INTRODUCTION

Water is an essential element to life on planet Earth. Life needs water to survive, approximately 60% of the human body is composed of water. Although 75% of the earth's surface is covered by water, it is known fact that only 1% of that is drinkable. Shortage of drinking water worldwide is becoming very acute nowadays about 25% of earth's water is fresh and potable for human use. The ground water represents 13% of this water [1]. The degradation of water quality has become a major societal issue due erratic anthropogenic activity, besides natural factors. Entry of toxic heavy metals and minerals in human system mainly through contaminated water, food, and air, has lead to overt and insidious health problems. Therefore clean drinking

water is not as abundant as it may seem [3]. The decision of WHO's 29th session (May 1976) emphasizes that water delivered to the consumer should meet the high requirements of modern hygiene and should at least be free from pathogenic organisms and toxic substance [5]. With water as a limited available resource, and not as plentiful in some regions as it is in others, it has recently become common for water to be bottled and sold.

Table: 1 Details of the Mineral bottled water samples and collected place

Sample Name	Suffix	Collected Place
A1		Bangalore
A2		Goa
A3	a	Bangalore
A3	b	Hubli
A3	c	Kolhapur
A4		Kolhapur
A5		Mangalore
A6		Mangalore
A7		Goa
B1	a	Davangere
B1	b	Kolhapur
B2		Durga
B3	a	Kolhapur
B3	b	Hubli
B4		Kolhapur
B5		Mangalore
C1		Mangalore
C2		Kolhapur
C3		Suratkal
D		Chennai
E1		Kolhapur
E2		Mangalore
F1		Mangalore
F2		Davangere
F3		Davangere
F4		Davangere
G		Davangere
I		Mangalore
J		Goa
K1		Bellary
K2	a	Manglore
K2	b	Kolhapur
K2	c	Davangere
K3		Davangere
M		Mangalore
N		Bangalore
O1		Davangere
O2		Mangalore
O3		Kolhapur
P1		Goa
P2		Mangalore
P3		Kolhapur
Q1		Hubli
Q2		Bangalore
R		Mangalore
S1		Goa
S2		Mangalore
S3		Davangere
S4		Mangalore
S5		Hubli
S6	a	Davangere
S6	b	Mangalore
Y		Goa

MATERIALS AND METHODS

Materials: A total of 53 Mineral water bottle samples from different parts of South India (Bangalore, Bellary, Davangere, Durga, Hubli, Mangalore, Surathkal, Hubli, Chennai, Goa and Kolhapur) were collected. 10 samples were collected from Davangere, 4 samples from Bangalore, 15 samples were collected from Mangalore, 4 samples from Hubli. 1 sample is collected from Durga, Surathkal, Bellary respectively. 6 samples from Goa and 10 samples from Kolhapur were collected. The Brand name of the mineral water bottles were represented as A1 to Y. Total of 46 brands were analyzed , the brand names of mineral water bottles were represented as A1 to Y and suffixes a,b,c are used to indicate the samples of same brands manufactured at different places. Fifty three Mineral Water Bottle samples were collected from different places as mentioned in Table No.1. The physico-chemical analysis was conducted using the lab equipments viz., pH meter, Nepheloturbidometer, conductivity meter, ion meter, flame photometer, glassware, and chemicals.

Methodology: Standard protocols were adopted to determine different parameters. All the parameters were analyzed as per NEERI manual (1986). pH of the samples was determined using electrometric method. The mineral water bottle samples were titrated against standard acid and alkaline solution using phenolphthalein and methyl orange indicator to determine alkalinity and acidity. The chloride content of the samples was determined by Mohr's method. The hardness of the samples was determined using titrimetric method. Calcium & Magnesium are important contributors of the hardness of water. These parameters were determined by titrimetric method. Turbidity of the samples was determined by digital Nepheloturbidometer. Conductivity and Total dissolved solids were determined by conductivity meter. Fluoride content of the samples was determined using ion meter. Sodium and Potassium content of the sample were determined by flame photometer method.

RESULTS AND DISCUSSION

The results of physico-chemical parameters of collected samples are presented in table 2a; list of mineral water bottles in 2b, drinking water quality standards (BIS) in 2c and Guidelines for Evaluation of Quality of Irrigation Water in 2d.

Table 2a: Results of physico- chemical analysis of the mineral bottled water samples

Sample Name	pH	Acidity (P)	Alkalinity (M)	EC µS/cm	TDS	TH	Ca	Mg	Cl	F	Na	K
Desirable Limit	6.5-8.5	50	-	250-2000	500	300	75	30	250	1.0	Nil	
A1	6.68	18	42	107.7	68	20	4.8	1.9	19.85	0.078	9.09	0.08
A2	6.36	20	40	88.9	58	30	3.2	5.4	14.18	0.187	10.34	0.06
A4	6.81	12	24	81.2	62	26	5.6	2.9	22.69	0.009	6.04	0.07
A5	5.87	12	20	25.9	17.5	14	0	0	17.02	0.014	1.37	0.05
A6	8.12	40	118	261.9	173	138	44.8	6.3	24.11	0.208	8.59	0.1
A7	5.48	46	30	76.8	56	30	7.2	2.9	22.69	0.229	5.01	0.04
B2	7.48	50	124	273	184	120	25.6	13.7	21.27	0.880	15.53	0.34
B4	6.34	10	20	38.3	25	0	0	0	17.02	0.082	3.28	0.09
B5	7.91	8	42	53.8	30	14	4.8	0.5	15.59	0.025	3.66	0.03
C1	7.83	8	34	127.1	82	46	13.6		25.52	0.011	7.2	0.11
C2	6.55	12	40	203.6	142	0	0	0	38.29	0.090	20.81	0.05
C3	6.95	8	40	117.6	82	48	10.4	5.4	21.27	0.115	3.27	0.15
D	6.85	12	34	68.7	56	18	4	1.9	17.02	0.120	4.57	0.01
E1	6.87	10	22	80.6	54	0	0	0	22.69	0.011	8.9	0.07
E2	7.84	30	650	68.8	13	0	0	0	21.27	0.017	-	-
F1	6.87	8	22	105.3	69	18	4.8	1.5	35.54	0.090	8.34	0.01
F2	6.46	20	60	84	54	56	5.6	10.2	22.69	0.349	4.42	0.03
F3	6.60	38	50	236.1	156	14	4	0.9	41.12	0.431	26.56	0.06
F4	6.64	34	40	50	28	28	6.4	2.9	14.18	0.502	2.17	0.03
G	6.45	24	34	91.9	58	14	4.8	0.5	18.43	0.273	8.21	0.05
I	7.21	8	68	45.2	36	20	5.6	1.5	17.02	0.096	5.26	0.05
J	6.28	10	28	40.9	28	32	4	5.4	19.85	0.204	2.99	0.04
K1	6.71	16	52	159.6	107	44	10.4	4.4	22.69	0.048	7.92	0.03
K3	7.09	18	58	113.8	71	32	6.4	3.9	18.43	0.363	11.09	0.01
M	7.09	48	44	72.9	45	20	6.4	0.9	19.85	0.278	5.67	0.06
N	6.48	12	22	67.4	53	20	3.2	2.9	25.52	0.040	4.6	0.06
O1	7.89	24	50	111.9	79	16	1.6	2.9	19.85	0.363	11.96	0.03
O2	6.83	10	38	103.2	67	28	8.8	1.5	17.02	0.093	3.53	0
O3	7.03	8	28	218	147	26	8.0	1.5	42.54	0.017	16.93	0.04
P1	6.35	20	40	129.3	87	66	12.8	8.3	17.02	0.491	3.75	0.21
P2	7.06	14	48	99.9	62	44	8.8	5.4	18.43	0.348	3.32	0.07
P3	6.01	12	12	78.3	52	34	6.4	4.4	17.02	0.008	2.89	0.09
Q1	7.40	24	68	150	102	30	5.6	3.9	18.43	0.437	16.93	0.12
Q2	6.30	10	26	34.3	23	20	4	2.4	17.02	0.063	2.17	0.02
R	6.63	12	42	81	52	42	7.2	5.8	17.02	0.188	2.17	0.02
S1	6.52	18	56	78.8	58	30	3.2	5.4	12.76	0.470	10.46	0.06
S2	6.28	12	30	84.6	59	28	7.2	2.4	19.85	0.126	4.04	0.04
S3	6.94	14	30	212	154	40	7.2	5.4	48.21	0.403	19.31	0
S4	8.42	6	32	93.4	51	26	5.6	2.9	89.34	0.372	1.62	0.03
S5	7.40	28	94	168.3	154	24	7.2	1.5	21.27	0.243	18.43	0.05
Y	6.59	12	48	42.3	30	42	3.2	8.3	11.34	0.218	3.97	0.08

Table 2b: Physico-chemical analysis of the mineral water bottles (same brands manufactured at different places)

Parameter	A3			B1		B3		K2			S6	
	a	b	c	a	b	a	b	a	b	c	a	b
pH	6.82	6.97	7.82	7.04	6.58	8.13	6.75	7.45	6.94	6.94	6.77	7.76
Acidity	8	6	8	12	10	8	30	16	6	14	16	8
Alkalinity	14	24	26	68	26	48	46	22	30	28	20	28
EC	21.75	26.1	16.16	148	110.1	128.6	209.1	460.6	59.7	50.1	53.7	57.7
TDS	28	16	19	103	88	88	136	31	44	38	34	38
TH	10	0	0	40	0	0	28	32	16	42	16	20
Ca	32	0	0	12.8	0	6.4	5.6	7.2	5.6	5.6	0	3.2
Mg	0.5	0	0	1.9	0	0.9	3.4	3.4	0.5	6.8	1.9	0
Cl	19.85	17.02	14.19	22.69	26.94	15.59	25.52	17.02	19.85	17.02	25.52	21.27
F	0.361	0.070	0.068	0.237	0.006	0.075	0.875	0.0484	0.006	0.158	0.030	0.080
Na	0.98	1.30	0.59	8.15	9.15	9.09	18.43	1.41	1.04	2.80	2.53	1.63
K	0.08	0.07	0.01	0.02	0.03	1.09	0.02	0.09	0.08	0.06	0.03	0.04

Table 2c: Drinking Water Standards of BIS (IS: 10500: 1991)

Sl.No	Parameters	Desirablelimits mg/l	Permissible limits mg/l
Essential Characteristics			
1	Colour Hazen unit	5	25
2	Odour	Unobjectionable	-
3	taste	agreeable	-
4	Turbidity (NTU)	5	10
5	pH	6.5-8.5	No relaxation
6	Total Hardness, CaCO3	300	600
7	Iron (Fe)	0.3	1.0
8	Chloride (Cl)	250	1000
9	Residual Free Chlorine	0.2	-
10	Fluoride (F)	1.0	1.5
Desirable Characteristics			
11	Dissolved Solids	500	2000
12	Calcium (Ca)	75	200
13	Magnesium (Mg)	30	100
14	Copper (Cu)	0.05	1.5
15	Manganese (Mn)	0.1	0.3
16	Sulphate (SO4)	200	400
17	Nitrate (NO3)	45	100
18	Phenolic compounds	0.001	0.002
19	Mercury (Hg)	0.001	No relaxation
20	Cadmium (Cd)	0.01	No relaxation
21	Selenium (Se)	0.01	No relaxation
22	Arsenic (As)	0.05	No relaxation
23	Cyanide (CN)	0.05	No relaxation
24	Lead (Pb)	0.05	No relaxation
25	Zinc (Zn)	5.0	15
26	Hexavelant Chromium	0.05	No relaxation
27	Alkalinity	200	600
28	Aluminum (Al)	0.03	0.2
29	Boron (B)	1.0	5.0
30	Pesticides	Absent	0.001

NTU = Nephelometric Turbidity Unit

Table 2d: Guidelines for Evaluation of Quality of Irrigation Water

Water class	Sodium (Na %)	Electrical Conductivity µmhos/cm at 25°C	SAR	RSC (meq/1)
Excellent	<20	<250	<10	<1.25
Good	20-40	250-750	10-18	1.25-2.0
Medium	40-60	750-2250	18-26	2.0-2.5
Bad	60-80	2250-4000	>26	2.5-3.0
Very bad	>80	>4000	>26	>3.0

pH: pH measures the hydrogen ion activity in the water. It indicates the acidic or alkaline nature of water. It was determined by Electrometric method. Most of the processes involved in water supply and treatment are pH dependent. Potable waters if acidic lead to health problem. As per IS 14543, the desirable limit under FDA for Packed Drinking Water is 6.5 to 8.5. According to the World Health Organization, health effects are most pronounced in pH extremes. Drinking water with an elevated pH above 11 can cause skin, eye and mucous membrane irritation. On the opposite end of the scale, pH values below 4 also cause irritation due to the corrosive effects of low pH levels. A3, B1, B3, K2, S6 sample, even though the bottles of same brands got different pH values which were manufactured at different places. Out of 53 samples, 23% of samples are out of range.

Acidity: Most of the natural waters are buffered by a carbon dioxide-carbonate system since carbon dioxide is a natural component of all natural waters. It is caused due to the presence of minerals acids and free carbon dioxide in water. It results interferes in treatment of water, carbon dioxide is important in determining whether removal has to be done by aeration or simple neutralization with lime or sodium hydroxide. As per BIS the desirable limit for drinking water is 50mg/l. A3a and A3c sample have the same values but there was a variation in the value of A3b sample. Also B1, B3, K2, S6 samples have different values which were manufactured in different locations. However, all samples are within the limit.

Alkalinity: Alkalinity is the capacity of water to neutralize hydrogen ions. In natural waters, alkalinity is caused due to the presence of bicarbonates, carbonates and hydroxylated compounds of calcium, magnesium, sodium and potassium. It is important for aquatic life; it protects against rapid pH changes. As per IS 14543, the desirable limit under FDA for Packaged Drinking Water is 200mg L^{-1}. There was a considerable variation in the results of A3, B1 and S6 samples of same brand but manufactured in different places. E2 sample showed the range of 650mg/l which was above the desirable limit. Rest all the samples were within the limit.

Electrical Conductivity: The measurement of EC gives the concentration of soluble salts in the sample at any particular temperature. The EC results are useful in determining the suitability of water and waste water on disposal on land and also to find out quantity of inorganic dissolved solids. The health problems can occur where the EC exceeds 370 µS cm^{-1}, disturbance of the salt and water balance in children and in the blood pressure of heart patients and renal patients. Laxative effects when sulphate concentrations are high. Aesthetic problems of water with an EC as high as 150 µS cm^{-1}, are that it tastes salty and water with an EC higher than 300 µS cm^{-1}, fail to quench your thirst. Sensitive groups are, children under the age of 1 year, patients on salt-restricted diets, such as heart and kidney patients and individuals with chronic diarrhea. As per BIS IS10500-1991, the desirable limit under FDA for Packaged Drinking Water is 250 µS $cm^{-1}$to 2000 µS cm^{-1}. As in table no.2b there was a considerable variation in the results of B1, K2 and S6 samples of same brand but manufactured in different places. 95% samples showed excellent range and rest of the samples are good in range (as referred in table 2d)

Total Dissolved Solids: TDS are the dissolved inorganic mineral matter in water. The term total solids applied to the material completely dissolved in water. The determination of TDS gives the effectiveness of sedimentation process, also effectiveness of disinfection process. Higher the TDS in water lesser will be the passage of light through water. Hence adversely affects the photosynthesis by aquatic plants. As per IS 14543, the desirable limit under FDA for Packaged Drinking Water is 500mg/l. Again here there was a considerable

variation in the results of B1, K2, S6 samples of same brand but manufactured in different places. All the samples tested were within the limit.

Total Hardness: High mineral content water is known as hard water. Absolute soft water corrodes and dissolves the metals. Hard water is useful in the growth of children due to the presence of Calcium. Hard water is not a health hazard. In fact, the National Research Council (National Academy of Sciences) states that hard drinking water generally contributes a small amount toward total calcium and magnesium human dietary needs. In most water nearly all of the hardness is due to calcium and magnesium. As per IS 14543, the desirable limit under FDA for Packed Drinking Water 300mg/l as $CaCO_3$. A3b, A3c, B1b, B3a sample showed absence of hardness as $CacO_3$ where as A3a, B1a, and B3b sample showed the presence of hardness. 12 samples had no hardness and rest all samples are within the limit.

Calcium and Magnesium (Ca^{2+}& Mg^{2+}): In natural water, higher concentration of Calcium is found. The presence of Calcium results from deposits of lime stone, gypsum. As per IS 14543, the desirable limit under FDA for Packaged Drinking Water needs to be 75mg L^{-1} for calcium and 30mg L^{-1} for magnesium. Of the tested samples, 12 are absorbed to be free of hardness and the rest samples are within the limit. For one of the sample the data mentioned on the sample bottle for calcium was zero and the observed value during the analysis was 0.9mg L^{-1}. A3a, B1a and S6b sample showed the presence of Calcium whereas the same branded bottles showed the absence which were manufactured in different places. Of the 12 tested sample A3a, B1a and S6b sample showed the presence of magnesium whereas the same branded bottles showed the absence which were manufactured in different places.

Chloride (Cl^-): Chlorides are distributed as salts of Ca, Na, K in water and waste water. A normal adult human body contains approximately 81.7 g chloride. On the basis of a total obligatory loss of chloride of approximately 530 mg day^{-1}, a dietary intake for adults of 9 mg of chloride per kg of body weight has been recommended (equivalent to slightly more than 1 g of table salt per person per day). For children up to 18 years of age, a daily dietary intake of 45 mg of chloride should be sufficient .A dose of 1 g of sodium chloride per kg of body weight was reported to have been lethal in a 9-week-old child .Chloride toxicity has not been observed in humans except in the special case of impaired sodium chloride metabolism, e.g. in congestive heart failure and hypertension. High Chloride content may harm metallic pipes and concrete structures and affect the potable natural water. Presence of Magnesium Chloride in water forms a hydrochloric acid when water is heated. Hence it is highly corrosive in boilers. Healthy individuals can tolerate the intake of large quantities of chloride provided that there is a concomitant intake of fresh water. Little is known about the effect of prolonged intake of large amounts of chloride in the diet. Chlorides being highly soluble are present in all waters but the amount is often very low in natural waters. In mineral water bottles all the samples were within the limit.

Fluoride: As per BIS IS10500- 1991 fluoride concentration between 0.5 to 1.5 mg L^{-1} is desirable .Excessive fluoride (greater than 2.4 mg L^{-1}) may lead to fluorosis. Natural sources contribute to the bulk of environmental load of fluoride. In India, 19 out of 35 states and Union territories have ground water highly contaminated with fluoride, with levels exceeding 1.0 mg L^{-1} and going up to 48mg L^{-1}. Fluoride content varied amongst the brands and within the brands at different places. However all samples were within the threshold limit.

Sodium and Potassium (Na+ and K+): Sodium is essential to human life there is no agreement on the minimum daily requirement. However, it has been estimated that a total daily intake of 120–400 mg will meet the daily needs of growing infants and young children, and 500 mg those of adults. Sodium is permitted to a maximum level of 150mg L^{-1} in drinking water. In general, sodium salts are not acutely toxic because of the efficiency with which mature kidneys excrete sodium. However, acute effects and death have been reported following accidental overdoses of sodium chloride. Acute effects may include nausea, vomiting, convulsions, muscular twitching and rigidity, and cerebral and pulmonary edema. Excessive salt intake seriously aggravates

chronic congestive heart failure, and ill effects due to high levels of sodium in drinking-water have been documented. Adverse health effects due to potassium consumption from drinking-water are unlikely to occur in healthy individuals.

Potassium intoxication by ingestion is rare, because potassium is rapidly excreted in the absence of pre-existing kidney damage and because large single doses usually induce vomiting. The A6, K2a, K2b sample, the sodium range mentioned on the sample bottle was 0, 0.3, 0.3mg/l and the observed range during the analysis was 8.59 and 2.8, 1.04 mg L^{-1} respectively. For the B3a, B3b and M1 sample, the K range mentioned on the sample bottle was 0.1, 0.1, 0.1mg L^{-1} and the observed range during the analysis was 0.02, 1.09 and 0.03 mg L^{-1} respectively. We have no idea whether error in the data or is it in the printing of the data. B3a, B3b sample showed considerable variation in the results whereas A3, B1 and S6 showed slight variations.

APPLICATIONS

This report on the analysis of 53 samples collected from different places seems to be safe. Our analysis showed that almost all the samples were under the desirable limit of respective parameter given by IS 14543 Packaged Drinking Water and IS13428 Packaged Natural mineral water. There seems to be contradiction regarding the prescribed standards and details mentioned by the manufacturer on their supplied water bottles.

CONCLUSIONS

In the industry of soft drinks, bottled water is the product with the fastest growing rate of consumption. Bottled water industry colloquially called Mineral water industry, is a symbol of new life style emerging in India. Corporate control over water and water distribution in India is growing rapidly; the packaged water business is worth rupees thousand crores and growing at a huge 40-50% annually. Around 1200 bottling plants and 100 brands of packaged water across the country are battling over the market. There are more than 200 brands in the unorganized sector. According to International Bottled Water Association (IBWA) drinking water has become extremely popular not just in India but also in USA with a current US market of more than 11 billion American dollars. Inspite of the fact that one in six people globally live without access to clean drinking water, it needs to be readdressed whether the answer lie in the bottled water that's out of reach for a majority of the India population. Initially pitched and promoted at clubs, fitness centers, cinemas, department stores, malls, ice-cream parlors and retail sports outlet, besides restaurants, hotels and supermarket. Bottled mineral water brands have surfaced in larger middle class and lower middle class markets. Ironically bottled water that claims to be safe alternative to ordinary tap water is itself suspect, as was revealed in a lists profile exposed by the Center for Science and Environment. Due increased demand and consumption of bottled water, there has been a growing concern about the quality of water.

REFERENCES

[1] Alimuddin "Analysis of Ground Water Quality Using Physico-Chemical Parameters in Nagarbhavi Village of Bangalore", *J. Applicable.Chem.,* **2014**, 3 (4), 1727-1731.
[2] Bureau of Indian Standards, Preparation & Review of Product Manuals for Product Certification, 2013WHO Library Cataloguing-in-Publication Data, "Guidelines for Drinking-water Quality" First addendum to third edition Vol.1Recommendations.
[3] E. Danso-Boateng , Frimpong, "Quality analysis of plastic sachet and bottled water brands produced or sold in Kumasi, Ghana", *International Journal of Development and Sustainability*, 2(4), 2222--2232.
[4] Guidelines for Evaluation of Quality of Irrigation Water.
[5] Kaza Somasekhara Rao "Quality of Water", *J. Applicable. Chem,* **2016**, 5 (2), 308-314.
[6] IS 10500 (1991), Drinking Water Quality Standards prescribed by Bureau of Indian Standards.
[7] Manual for packaged Drinking Water", first Issue by Bureau of Indian Standards Manak Bhavan, Bahadur Shah Zafar Marg, New Delhi – 110002, Jan **2005**.

[8] Manual on Water and Waste Water Analysis (1986) NEERI (pub.), Nagpur.
[9] Standard Methods for the Examination of water and waste water, APHA, American water works Association, **1991**.

AUTHOR ADDRESS

1. **Dr. Veena Kumara Adi**
Associate Professor, P.G Department of Environmental Engineering, Civil Engineering Department
Bapuji Institute of Engineering and Technology, Davangere- 577004, Karnataka, India
E-Mail: drveena.adi@gmail.com