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Water quality assessment of open wells in and around Chavara industrial area, Quilon, Kerala

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Abstract: *Water quality of four open wells representing four localities around the Kerala Minerals and Metals Ltd industrial area, Chavara, Quilon district was studied for a period of six months from December, 2006 to May 2007 to assess the suitability of the well waters for domestic purposes. The well waters exhibited high BOD (average values from 12.87-15.96 mg l^{-1}), COD (666.67 - 796.67 mg l^{-1}), TDS (500-1466.67 mg l^{-1}), total hardness (110-835 mg l^{-1}), nitrate (1.12 -4.97 mg l^{-1}), calcium (30.59-271.22 mg l^{-1}), phosphate (0.19 -0.48 mg l^{-1}) and free CO_2 (49.13 - 102.47 mg l^{-1}) and low dissolved oxygen (2.63 - 3.13 mg l^{-1}). Heavy metal analysis revealed that the third and fourth wells are free from heavy metal pollution. Coliform test showed bacterial contamination in all the wells. The values of BOD, COD, TDS and phosphate exceeded the maximum permissible limits and the dissolved oxygen was much lower than the desirable limit in all the well waters. Hence all the four well waters are found unsuitable for domestic purposes as it is confirmed by water quality index. The use of waters of open wells in and around the industrial area may cause health hazards to nearby inhabitants.*

Key words: *Physico-chemical parameters, MPN coliform, Water quality index, Open wells, Pollution*
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Introduction

Ground water has long been considered as one of the purest forms of water available in nature and meets the overall demand of rural and semi-urban people. Large scale industrial growth has caused serious concern regarding the susceptability of ground water contamination due to waste materials. Waste materials near the factories which are subjected to reaction with percolating rain water and reach the aquifer system and hence degrade the ground water quality (Tyagi *et al.*, 2002). Heavy metals constitute a very heterogenous group of elements widely varied in their chemical properties and biological functions. They are persistant in nature, therefore get accumulated in soil and plants. Dietary intake of many heavy metals through consumption of plants and drinking water has long term detrimental effect on human health (Sharma and Agarwal, 2005; Farooqui, *et al.,* 2007; Sabal and Khan, 2008). The transmission of water borne disease has been a matter of concern for many years (Radha Krishnan *et al.,*2007; Roy, 2007). Hence bacteriological examination is also very important in the assessment of water quality.

Kerala Minerals and Metals Ltd. (KMML) located at Chavara, Quilon district is one of the major industries in Kerala. People around this industrial area mainly depend on ground water source, particularly the open wells for their domestic purposes. The quality of ground water is deteriorating at a faster pace due to industrial wastes being discharged into the surrounding areas. The people in the area suffer from health hazards. It is, therefore very important to maintain the ground water quality of this industrial area. For the effective maintenance of water quality one needs continuous monitoring of water quality. No specific work has been done so far to assess the ground water quality status of this area. The present study is designed for the physico-chemical and biological characterisation of the well waters around the KMML industrial area. The study also aimed to assess the suitability of the well waters for domestic purposes.

Materials and Methods

Study area : The present investigation was carried out by selecting four open wells representing four localities around the KMML industrial area, Chavara, Quilon district. KMML is located at 8°. 59698'N latitude and 70°31917' E longitude. The areal extend of KMML is about 210 acres. It is the only integrated plant with Mineral separation plant, Synthetic Rutile plant with acid regeneration facility and titanium dioxide pigment production plant in a single complex.

Selected open wells:

Well-1 located at Mekkadu, 400 m away from KMML industrial area towards south-west direction.

Well-2 located at Chitoor, 600 m away from the industrial area towards north - west direction.

Well-3 located at Panmana, 2 km away from the industrial area towards north - east direction .

Well-4 located at Kalari, 1 km away from the industrial area towards the south- east direction.

Water samples were collected from all the four wells during December, 2006 to May, 2007 at regular intervals of one month between 9.30 and 10.30 a.m.The samples were brought to the

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laboratory in polythene bottles of 2 litres capacity.The samples were kept cool in darkness until the analysis were completed. Water quality parameters *viz.* temperature, pH, phenolphthalein alkalinity, total alkalinity, free CO_2, dissolved oxygen (DO), BOD,COD,nitrate, phosphate, sulphate, total dissolved solids (TDS), chloride, total hardness and calcium were analysed as per the standard methods (APHA, 2005). Coliform count, fluoride and heavy metals such as lead, cadmium, copper, iron, zinc, nickel, chromium and mercury were estimated only once *i.e.* from the samples collected in May, 2007. Multiple tube test was used for the estimation of total coliform. The most probable number (MPN) of coliform in the sample was determined from the statistical table (Mackie and Mc Cartney, 1996). Fluoride concentrations was determined with the help of selective ion meter and heavy metal estimations were carried out using atomic absorption spectrometry (Perkin Elmer Model-300).

Eleven water quality parameters such as pH, TDS total alkalinity, total hardness, DO, BOD, chloride, sulphate, phosphate, nitrate and MPN coliform were selected for the calculation of Water quality index (WQI). The calculation of WQI was done using weighted Arithmatic index method (Brown *et al*., 1972).

Results and Discussion

The range and average values of various physico-chemical parameters of the four well waters are presented in Table 1, heavy metals in Table 2 and WQI in Table 3. Water temperature of all the four wells varied from 27.3 to 32°C and has a close relation to the variation of atmospheric temperature as observed by Sunkad and Patil (2004). According to Zajic (1971) water with temperature above 30°C is unfit for public use. The temperature of waters of all the four wells was above 30°C from March to May 2007. All the well waters except that of third well were alkaline in nature and their pH ranged from 7.09 to 8.94. The third well water was highly acidic and the pH raged from 3.0 to 4.37 and is much lower than the recommended limit (6.5 - 8.5) of WHO (1992).

Phenolphthalein alkalinity was completely absent in all the well waters. The total alkalinity was comparatively higher in the first well and it ranged from 80 to 300 mg l^{-1} with in an average value of 136.67 mg l^{-1}. It varied from 50-140 mg l^{-1} with an average value of 88.33 mg l^{-1}, 20-40 mg l^{-1} with an average of 27mg l^{-1} and 60-180 mg l^{-1} with an average value of 123.33 mg l^{-1} in second, third and fourth wells respectively. The average values of total alkalinity in the first and fourth wells exceeded the higher desirable limit given by WHO (1992). According to Nayak *et al*. (1982) and Ghosh and George (1989) the higher alkalinity indicates pollution. So, from the alkalinity point of view the water quality is poor in the first and fourth wells. Free CO_2 ranged from 22 to 167.2 mg l^{-1} with an average value of 102.47 mg l^{-1} in the first well; in the second well CO_2 varied between 17.6 and 88 mg l^{-1} with an average value of 45.47 mg l^{-1}; in the third well it varied between 22 and 86.4 mg l^{-1} with an average value of 63.53 mg l^{-1} and in the fourth well it ranged from 22.0 to 79.2 mg l^{-1} with an average value of 49.13 mg l^{-1}. Relatively higher concentration of free CO_2 in all the wells can be attributed to the presence of decomposable organic matter in the bottom as suggested by Unni (1972).

Dissolved oxygen (DO) ranged from 2.0 to 3.6 mg l^{-1} with an average value of 2.73 mg l^{-1} in the first well, 2.0 to 4.0 mg l^{-1} with an average value of 3.07 mg l^{-1} in the second well, 1.6 to 3.6 mg l^{-1} with an average value of 2.63 mg l^{-1} in the third well and in the fourth well it ranged from 2.4 to 4.6 mg l^{-1} with an average value of 3.13 mg l^{-1}.The DO values were very low and showed a gradual depletion towards the summer months in all the waters as observed by Kaushik and Saksena (1998). Its depletion is the most critical manufestation of pollution. The average values of BOD were 13.23, 13.67, 15.96 and 12.87 mg l^{-1} in wells 1,2,3 and 4 respectively. These higher values indicate that untreated organic wastes are being leaching to the ground water as observed by Adeleye and Adebiyi (2003). The permissible limit for BOD as per WHO (1992) is 5 mg l^{-1}. The waters from all the wells have BOD values much higher than the permissible limit. The COD values varied from 680 to 800 mg l^{-1} with an average of 716.67 mg l^{-1}, 620 to 800 mg l^{-1} with an average of 703.33 mg l^{-1}, 680 to 920 mg l^{-1} with an average of 796.67 mg l^{-1} and from 600 to 720 mg l^{-1} with an average of 666.67mg l^{-1} in the waters of wells 1,2,3 and 4 respectively. The higher values of COD indicate the persence of oxidizable organic matters (Garg, 1998; Chadrashekar *et al*., 2003). According to BIS (1991) the maximum permissible limit of COD for discharge of effluents into surface waters is 250 mg l^{-1}.However, all the observed values were much above the permissible limit.

The average values of nitrate were 1.55, 1.12, 4.97 and 2.62 mg l^{-1} in the wells 1,2,3 and 4 respectively. The average values of phosphate were 0.37, 0.48, 0.19 and 0.36 mg l^{-1} in the wells 1,2,3 and 4 respectively which are higher than 0.1 mg l^{-1}, an indication of pollution. The maximum permissible limit of sulphate for drinking water given by BIS (1991) is 400 mg l^{-1}. The values of all the samples were found within the maximum permissible limit. The average values of TDS were 666.67, 633.33, 1466.67 and 500 mg l^{-1} in the wells 1,2,3 and 4 respectively. Its values in the range of 50 to 150 mg l^{-1} make the water unfit for any use (Ranu *et al*., 1991). TDS values were very high in the wells and exceed the maximum permissible limit (WHO, 1992).

The estimated average values of chloride were 140.34 mg l^{-1} in the first well, 103.25 mg l^{-1} in the second well, 886.83 mg l^{-1} in the third well and 72.89 mg l^{-1} in the fourth well. Gopal and Durve (1989) recorded high chloride content of water with an annual average of 83.7 mg l^{-1} as an indication of organic pollution. The observed values were higher than this, except that of fourth well, with the highest in the third well which exceeded the drinking water limit of chloride. Total hardness ranged from 128 to 320 mg l^{-1} with an average of 220 mg l^{-1} in the first well; 104 to 200 mg l^{-1} with an average of 168.87 mg l^{-1} in the second well; 300 to 1200 mg l^{-1} with an average of 835 mg l^{-1} in the third well and 48 to 172 mg l^{-1} with an average of 110 mg l^{-1} in the fourth well. High concentration of total hardness in water

Table - 1: The range and average values (of six samples) of physico-chemical parameters of well waters during December, 2006 to May, 2007

Parameters	Well-1		Well-2		Well-3		Well-4	
	Range	Average	Range	Average	Range	Average	Range	Average
Temp. (°C)	28.2-31.9	30.28	27.8-31.8	29.75	28-32	29.88	27.3-31.9	29.72
pH	7.32-8.94	7.97	7.11-8.20	7.69	3-4.37	3.62	7.09-8.75	7.83
PA	0-0	0	0-0	0	0-0	0	0-0	0
TA	80-300	136.67	50-140	88.33	20-40	27.5	60-180	123.33
Free CO_2	22-167.2	102.47	17.6-88	45.47	22-86.4	63.53	22-79.2	49.13
DO	2-3.6	2.73	2.0-4.0	3.07	1.6-3.6	2.63	2.4-4.6	3.13
BOD	10.8-16	13.23	10.0-16.0	13.67	12.0-20.0	15.96	9.6-16.0	12.87
COD	680-800	716.67	620-800	703.33	680-920	796.67	600-720	666.67
Nitrate	0.77-2.50	1.55	0.53-2.42	1.12	3.12-5.86	4.97	0.504-7.10	2.62
Phosphate	0-1.43	0.37	0-2.468	0.48	0-0.64	0.19	0-1.352	0.36
Sulphate	0-56.78	27.48	9.52-107.78	42.95	3.4-18.7	9.29	5.78-39.1	14.64
TDS	400-1200	666.67	400-1000	633.33	800-2000	1466.67	200-1000	500
Chloride	71-220.1	140.34	28.4-241.4	103.25	289.68-1886	886.83	34.08-102.24	72.89
TH	128-320	220	104-200	168.67	300-1200	835	48-172	110
Calcium	44.89-80.16	62.47	36.87-64.13	53.04	73.13-400.08	271.22	16.03-52.10	30.59

All parameters are expressed in mg l^{-1} except temperature and pH, DO = Dissolved oxygen, BOD = Biological oxygen demand, COD = Chemical oxygen demand, TDS = Total dissolved solid, PA = Phenolphthaline alkalinity, TA = Total alkalinity, TH = Total hardness

Table – 2 : Heavy metals (mg l^{-1}) and fluoride content and coliform count in the water of wells

Heavy metals	Well - 1	Well - 2	Well - 3	Well - 4
Lead	0.2	0.3	BDL	BDL
Cadmium	BDL	BDL	BDL	BDL
Copper	0.1	0.1	BDL	BDL
Iron	1.4	0.8	0.5	0.5
Zinc	0.4	0.4	0.5	0.4
Nickel	0.2	0.2	BDL	BDL
Chromium	0.2	0.2	BDL	BDL
Mercury	BDL	BDL	BDL	BDL
Fluoride	BDL	BDL	BDL	BDL
Coliforms (100 ml^{-1})	280	80	80	230

BDL = Below detectable leve

Table - 3 : The calculated sub index ($q_n w_n$) values of different parameters and water quality index of wells

Parameters	Sub index ($q_n w_n$) values			
	Well – 1	Well – 2	Well – 3	Well – 4
pH	11.70	9.95	4.68	10.13
TDS	9.33	8.862	20.52	7.0
TA	1.71	1.104	1.145	1.54
TH	0.439	0.371	1.67	0.219
DO	9.28	10.404	8.84	10.74
BOD	29.10	29.92	35.11	28.51
Chloride	0.392	0.305	2.63	0.204
Sulphate	0.08	0.12	0.027	0.043
Phosphate	37.0	48.0	19.0	36.0
Nitrate	0.775	0.56	2.48	1.31
Coliform	49.7	14.2	14.2	40.8
Water quality index	149.49	123.69	111.93	136.48

TDS = Total dissolved solid, TA = Total alkalinity, TH = Total hardness, DO = Dissolved oxygen, BOD = Biological oxygen demand

may cause kidney stone and heart disease in human (Jain, 1996).

The average values calcium were 62.47 mg l^{-1} in the first well, 53.04 mg l^{-1} in the second well, 271.22 mg l^{-1} in the third well and 30.59 mg l^{-1} in the fourth well. According to Ohle (1955) any value above 25 mg l^{-1} indicates calcium rich water . As per this definition the water in all the wells were rich in calcium and the average value of the third well water exceeded the maximum permissible limit.

The deleterious effect of heavy metals in the environment is well known (Sharma and Agarwal, 2005). The lead contet in the wells 1 and 2 were 0.2 and 0.3 mg l^{-1} respectively. It was below the detectable limt in third and fourth wells. The concentration of lead in the first and second wells exceeded the maximum permissible limit of 0.1 mg l^{-1} for drinking water given by WHO (1992). The cadmium content in all the well water was below the detectable level. The recorded value of copper content is 0.1 mg l^{-1} in the first and second wells which is within the permissible limit (1.0 mg l^{-1}). The copper content was below detectable level in the waters of third and fourth wells. The concentration of zinc was 0.4 mg l^{-1} in the first, second and fourth wells, while it was 0.5 mg l^{-1} in the third well. All these values are within the permissible limit of 5.0 mg l^{-1} (WHO, 1992). The maximum permissible limit of chromium in drinking water is 0.05 mg l^{-1}. Chromium has potent carcinogenic effects on human beings (O'Brien *et al.*, 2003). Its concentration was 0.02 mg l^{-1} in the first and second wells, where as it was below the detectable level in the third and fourth wells. Nickel content was detected only in first and second wells with the same value of 0.2 mg l^{-1}. This value was within the maximum permissible limit. Mercury was below the dectactable level in all the four wells. The maximum permissible limit of iron is 1.0 mg l^{-1}. Its concentration was 1.4 mg l^{-1} in the first well; 0.8 mg l^{-1} in the second well and 0.5 mg l^{-1} in the third and fourth wells. Its value exceeded the maximum permissible limit in the first well. Fluoride was below the detectable level in all the four wells.

The observed MPN coliform were 280, 80, 80 and 230 per 100 ml in the waters of first, second , third and fourth wells. These values indicate bacteriological contamination in the well waters (Gupta and Kumar, 2002).

Water quality index (WQI): Eleven parameters *viz*., pH, TDS, total alkalinity, total hardness, DO, BOD, chloride, sulphate, phosphate, nitrate and MNP coliform were used for the calculation of WQI. The calculated values are given in Table 3. In the present study application of WQI gives a comparative account of water quality of the four wells. The WQI values were 149.49, 123.69,111.93 and 136.48 in the wells 1, 2, 3 and 4 respectively. The permisible value for drinking water is 100 (Sunilkumar and Ravindranath, 1998). The values of all the four wells are above 100, indicating unsuitability of the water for drinking purpose. The index value was maximum in the first well and minimum in the third well. In the first well it was the coliform bacteria which increased the value of WQI. This result is similar to that of Sinha (1991). The higher WQI values in the wells can be attributed to the continuous discharge of industrial effluent and a little amount of sewage in the study area.

All the four well waters exhibited high BOD, COD, TDS, total hardness, calcium, chloride, nitrate , phosphate and free CO_2 which are sourced to industrial wastes being dischaged into the surrounding areas. Heavy metal analysis revealed that the third and fourth wells are free from heavy metal pollution. The coliform test showed bacterial contamination in all wells. The values of TDS. BOD, COD and phosphate exceeded the permissible limit and the DO was much lower than the desirable limit in the well waters. Hence, all the four well waters are unsuitable for domestic purpose, as confirmed by water quality index. The consumption of the well waters around the industrial area may cause health hazards to the local residents. It is therefore, advisable that authorities should take appropriate steps to check the ground water contamination.

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