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NITRATE POLLUTION OF GROUNDWATER AROUND A SEWAGE STABILIZATION POND, KERALA INDIA

K. VASU, A. SHAHUL HAMEED, K.T. VELAYUDHAN,
S. JACOB, M. MATHEW
Nuclear Hydrology Division,
Centre for Water Resources Development and Management,
Kerala, India

Abstract- *An investigation was carried out to determine the influence of the sewage stabilisation pond of the Calicut Medical College on the quality of water in the open dug wells which are situated in and around the stabilisation pond. The study revealed that domestic wells are becoming increasingly polluted with nitrate inspite of heavy rainfall in the region. The level of nitrate in the observation wells was found to be vary widely during different seasons: from 1.1 to 49.8, 0.7 to 19.5 and from 2.1 to 38.3 mg/l during pre-monsoon, monsoon and post-monsoon periods, respectively. One well had nitrate exceeding the maximum permissible limit specified for drinking water by Bureau of Indian Standards. The problem is more pronounced in summer when the level of nitrate is observed to be on the higher side.*

1. INTRODUCTION

Groundwater, which is generally thought to be well protected from what is happening at the surface of the earth is becoming increasingly contaminated by many pollutants. Water carries the pollutants when put to use for domestic, agricultural and industrial purposes. Urban areas with a high degree of industrial and domestic activity, together with agricultural operations in their immediate surroundings, have industrial effluents, domestic sewage and agricultural wastes discharged into streams or disposed on the land, thus encouraging the migration of pollutants to the underlying groundwater during recharge. Nitrate appears to be one of the major pollutants reaching groundwater from all the above mentioned activities. It is of major concern particularly for the health of infants [1,2].

In India, it is estimated that 20 to 50% of the wells in areas of high population density produce water with nitrate above 50 mg/l, thus causing health hazards [3,4]. As nitrate is soluble in water, its movement is fast in soil. Even soil rich in clay, nitrate is not greatly attenuated compared to water since the similarity of electrical charge between the clay fraction of the soil and the nitrate prevents its adsorption on to the clay surfaces.

Groundwater is the major source of drinking water in Kerala. The region has a population density of 750 persons per square kilometre and has about 250 open dug wells per square kilometre. Urban sewage, industrial effluents and agricultural residues are the major sources of pollutants of groundwater in the region. An investigation was carried out to determine the influence of the sewage stabilisation pond of a medical college and hospitals on the quality of groundwater sources.

2. DESCRIPTION OF THE STUDY AREA

2.1 General location

The study area falls within the Calicut Medical College Campus where the sewage stabilisation pond is situated. The site lies between 75 ° 49' and 75 ° 53' East longitude and, between 11 ° 16' and 11 ° 18' North latitude (Fig 1). It is a high rainfall region with humid tropical climate. The annual precipitation is around 3500 mm and the temperature varies from 22 to 33 ° C. More than 75% of the annual rainfall falls during the south-west monsoon months of June to August and about 15% during the north-east monsoon months of September to November. The rest of the precipitation occurs as summer or pre-monsoon showers during the months of December to May.

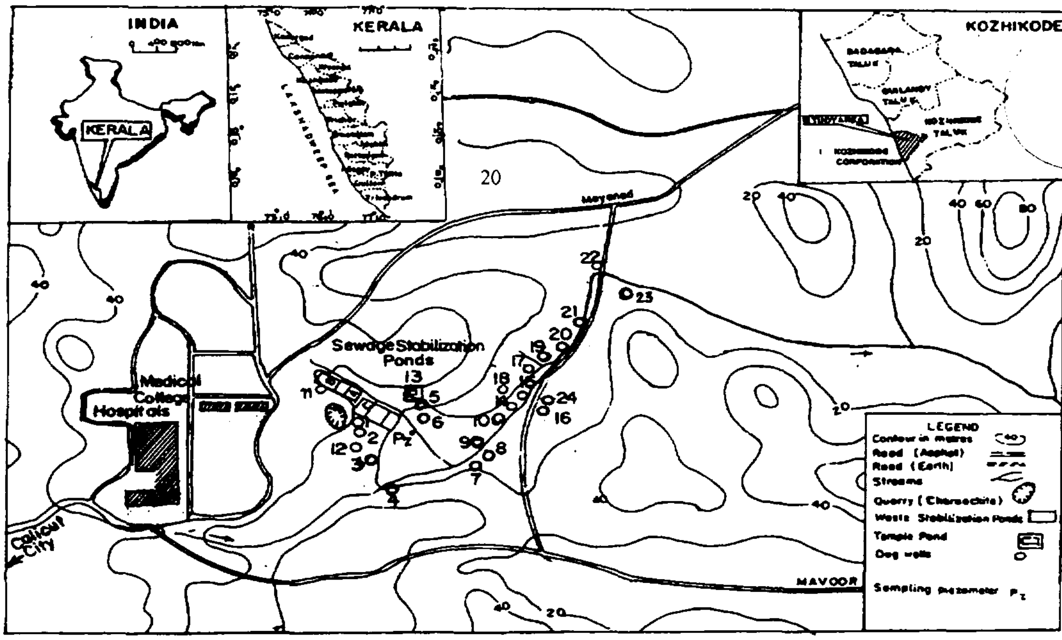

Fig. 1 Study area showing the source of pollutants and observation wells

The area is a part of high grade granulitic terrain of Precambrian age. It is covered with lateritic soil and crystalline bedrock which is exposed at a few places. The bedrock in the area is gneissic charnockites and exhibits medium grained granulitic texture. Observations made on the exposed bedrock show two sets of vertical and one set of oblique joints trending N 85 ° E and N 15 ° W, respectively. The mineral foliation in the rock trends NW-SE and has a dip of 80 ° E. The crystalline rocks are intensely deformed during more than one phase of orogeny. The overburden in the area is laterite formed by the weathering of crystalline basement rocks. The laterites are of residual and fairly mature type. The overburden thickness above the basement rocks varies from place to place owing to the irregular topography. On an average, it is about 9 m as observed from the existing open dug wells.

The study area forms part of the midlands region of Kerala with elevation between 7 and 75 m above MSL. The terrain is undulating in nature with gently sloping residual hills separated by valley fills. The sewage stabilisation pond is situated on the slope of a hillock and at the side of a seasonal stream course.

3. METHODOLOGY

Twenty four water samples comprising of 23 open dug wells and one from the pond in the area of investigation were collected to study the groundwater quality. Two samples were drawn from the sewage stabilisation pond to assess and quantify the different pollutants. Soil samples were drawn from the study site at different depths up to 1 m to determine their physical and physico-chemical properties. A suction type multilevel point sampler was installed 25 m away from the sewage stabilisation pond. For this, a borehole was drilled at the site to a depth of 10 m. A casing pipe made of PVC, having an outer diameter of 110 mm and holes of 4 mm made at regular intervals of 1 m was lowered. In order to draw water samples at different depths, nylon tubes of 4 mm OD were directly connected to the main pipe at the openings. The space between the soil and the outer surface of the casing pipe was filled with sand and the openings in the pipes were covered with nylon filter material to prevent the entry of sand and other solid soil particles into the nylon sampling tubes (Fig 2). Water samples were drawn at 1 m depth interval from the multilevel point sampler.

The effluents and water samples drawn from the observation wells during pre-monsoon, monsoon and post-monsoon periods and those collected at different depths from the multilevel point sampler were analysed for their chemistry. The analyses of their physico-chemical properties were according to methods reported in literature [6,7].

4. RESULTS AND DISCUSSION

4.1 Soils of the area

The area is underlain by the laterite formation which is separated from the basement rocks by a lithomarge zone (clay zone above the bedrock). The soils are red laterite type containing a high amount of gravels. Its clay content increases with depth. The soils in the upper valley portions are well-drained and are reddish brown in colour. In the middle and lower slopes, the water table is shallow, with poor drainage and the soils dry out less frequently. This is reflected in increasing degree of hydration of iron. These soils have brownish yellow colour. The lithomarge clay in the valley portion where the piezometers are located has an average thickness of four metres which is much higher than the clay horizons in the slopes.

The soil chemistry indicates that the soil at the site of the investigation is fairly rich in plant nutrients such as nitrogen, phosphorus and potassium. The influence of the sewage stabilisation pond on the nutrient level of soil cannot be ruled out. Elements like nitrogen, phosphorus and potassium are high compared to local soils.

4.2 Sewage stabilisation pond as a potential source of nitrate pollution

Different forms of nitrogen arise from the sewage stabilisation ponds. Ammoniacal, nitrate and nitrite are the most important forms of nitrogen expected. Due to high microbiological and biochemical reactions normally expected in a sewage stabilisation pond, many other intermediate organic forms of nitrogen such as amines and amides may also be present in appreciable quantities. However, these forms of nitrogen have little mobility in the soil unless they are biochemically and microbiologically converted into simpler oxidised inorganic forms of nitrogen. Stabilisation of the sewage ensures the conversion of organically bound nitrogen into the mobile form.

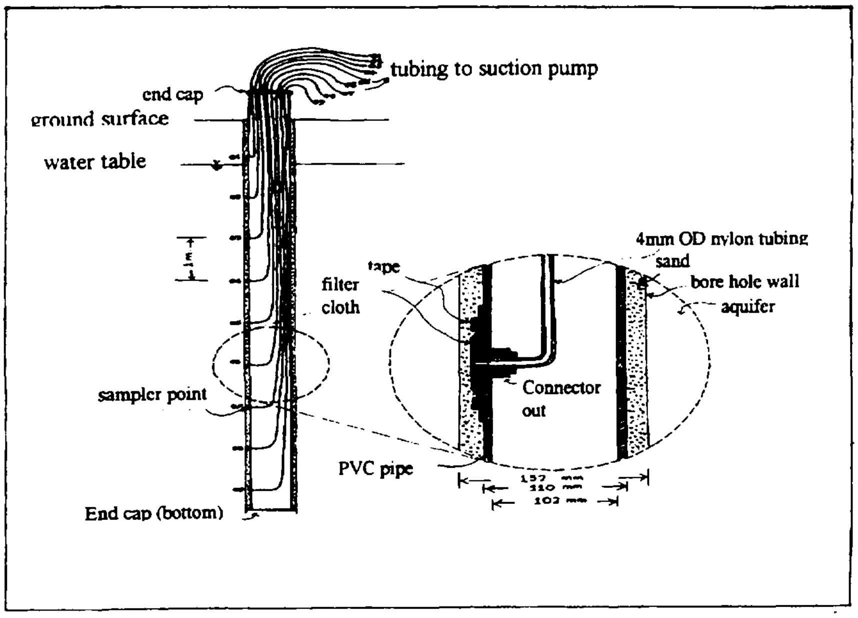

Fig. 2 Suction type multilevel point sampler for sampling groundwater from different depths.

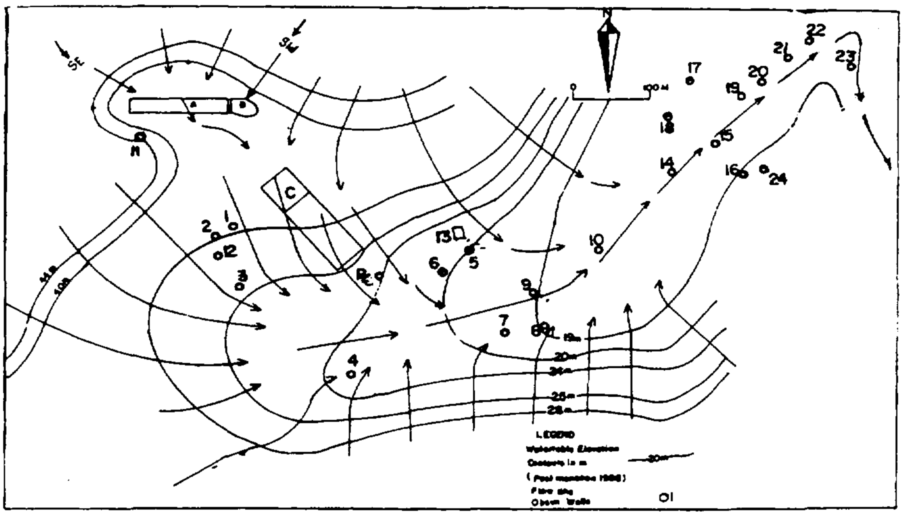

Fig 3: Groundwater table contours and flow direction in the area of investigation

TABLE I. Physico-chemical properties of a) a representative soil of the region and b) soils surrounding the stabilisation pond.

a) a representative soil of the region

Sl.No	Depth (cm)	pH	Organic carbon %	N %	P(P_2O_5) %	K(K_2O) %	Sand %	Silt %	Clay %
1	0-30	6.5	0.52	0.05	0.05	0.16	43.54	19.61	31.68

b) soils surrounding the stabilisation pond

Sl. No	Depth (cm)	pH	EC	Organic Carbon %	N %	P (P_2O_5)%	K (K_2O) %	Sand %	Silt %	Clay %
1.	0-30	4.5	90.22	1.00	0.10	0.18	0.16	49.8	22.8	27.2
2.	30-60	4.5	67.88	0.83	0.09	0.16	0.17	44.8	22.0	30.6
3.	60-90	4.5	60.12	0.63	0.06	0.14	0.16	36.0	25.0	36.6
4.	90-120	4.4	81.51	0.61	0.07	0.14	0.16	37.3	23.4	37.2

Table II. Chemistry of effluent in the sewage stabilisation pond

Period	pH	EC	Cl	SO_4	NO_3	PO_4	F	Ca	Mg	Fe
Pre monsoon 1995	6.6	550	55.7	10.2	204	5.4	0.7	13.8	6.7	0.5
Monsoon 1995	7.8	671	45.0	20.0	168	6.4	0.6	11.2	6.6	0.4

All parameters except pH and EC are expressed in mg/l
pH in pH units and EC in μScm^{-1}.

The sewage stabilisation pond receives as much as 50,000 litres/day of effluents from the medical college and the attached hospitals. The effluent comprises mostly of wastes of organic nature, human excreta, washings, residues of drugs and pharmaceuticals. The chemistry of the effluents indicates that except for nitrate, all other species like chloride and sulphate are present at very low concentrations. The nitrogen level found in the sewage stabilisation pond is of the order of 204 and 168 mg/l during the summer and monsoon periods, respectively. The nitrogen level is comparatively less during the rainy days.

4.3 Groundwater condition in the area and nitrate pollution in the observation wells

The groundwater in the area occurs under unconfined conditions. Most of the dug wells extend to the lithomarge zone. Some of the wells sited on the upper hill slopes have encountered hard rock. The depth of wells ranges from 5.5 to 10 m on upper hill slopes and between 1.3 and 3.5 m in valley bottoms. There is a high intra and inter seasonal fluctuation of water table in the upper slopes of hills, but in the valley bottoms, the fluctuation is considerably less. The depth to water level is between 1.8 and 8.7 m on the hill slopes and, between 0.05 and 2 m in the lower valley areas. The maximum water level rise in the aquifers is observed during the high rainfall months of July and August, whereas the lowest water levels are observed in the late summer months of April and May.

Figure 3 shows the general groundwater flow pattern in the study area. The groundwater flow is from the west, north and south hill slopes with respect to the stabilisation pond. It discharges into the central valley then drains to the north eastern direction which is the principal direction of groundwater flow in the area. The northwest part of the area has a major source of groundwater. The waste stabilisation pond is situated on the upper valley slope in the west where groundwater flow is towards south-west and south-east directions, finally draining towards north-east. The rock exposure near the stabilisation pond dips in southeast direction which may be the reason why the flow lines in the sewage stabilisation pond area deflect in the same direction near the rock exposure.

The spacing between the groundwater table contours in the lower area near the piezometer sites is wide which indicates that the hydraulic conductivity of the aquifer in the valley bottom is low. This observation is consistent with the fact that the thickness of lithomarge clays which have a low hydraulic conductivity is more in the valley bottoms than in the hill slopes. The twenty three open dug wells selected for the study of pollution from nitrate showed that there are 7 to 12 wells with nitrate of appreciable quantity during different seasons of observation. One of the wells (No.3) has nitrate concentration of 50mg/l during summer, which is exceeding the maximum permissible limit of 45 mg/l prescribed for drinking water [5]. In most of the wells, nitrate level appeared to be above 10 mg/l during pre- and post- monsoon seasons, showing that they are susceptible to nitrate pollution. However, during the monsoon period, all the observation wells have nitrate less than 20 mg/l (Table III). The temple pond (No.13)is not used for drinking.

4.4 Extent of nitrate pollution in the area of investigation

The extent of pollution is shown in Fig.4. Out of all the observation wells, 48% have nitrate less than 10 mg/l during the pre monsoon period. This increased to 70% during the monsoon period but decreased to 61% during the post-monsoon period. A nitrate range of 10-25 mg/l was observed in about 39, 30 and 26% of the observation wells during pre-monsoon, monsoon and post-monsoon seasons, respectively. 13% of the wells have nitrate above 25mg/l during the pre- and post- monsoon seasons. These wells have nitrate exceeding 50% of the maximum permissible limit specified for drinking water by the Bureau of Indian Standards.

TABLE III. GENERAL QUALITY OF WATER IN THE OBSERVATION WELLS DURING DIFFERENT SEASONS (1994-95)

	Pre-monsoon					Monsoon					Post-monsoon				
Well No.	pH	EC	Cl	SO_4	NO_3	pH	EC	CI	SO_4	NO_3	pH	EC	CI	SO_4	NO_3
1.	6.2	80	13.0	1.0	5.5	7.7	128	17.0	2.0	14.2	6.6	59	12.0	3.0	5.1
2.	6.6	105	18.5	ND	11.0	7.8	150	19.0	1.0	14.2	7.0	85	20.0	1.3	10.6
3.	5.0	140	24.5	ND	49.8	5.4	120	17.0	ND	17.7	6.2	90	18.0	0.5	38.3
4.	5.4	85	20.5	ND	21.0	5.6	104	18.0	1.0	4.4	6.7	67	18.0	6.0	13.7
5.	5.7	110	20.5	0.8	27.3	5.8	150	24.0	2.0	8.8	5.7	95	23.0	3.0	28.6
6.	6.0	175	36.5	3.3	25.8	5.9	204	29.0	5.0	16.8	6.6	130	30.0	6.5	9.0
7.	5.4	60	29.5	ND	17.1	6.8	92	16.0	0.5	9.7	6.6	55	16.0	0.8	18.8
8.	5.6	74	17.0	0.5	17.7	7.0	104	18.0	1.0	14.2	7.0	65	17.0	1.8	13.5
9.	6.7	230	34.0	1.0	8.4	7.4	244	29.0	4.0	8.8	7.3	235	20.0	9.0	4.9
10.	6.7	250	34.5	2.5	24.4	7.7	281	29.0	6.0	6.6	7.2	160	27.0	6.6	8.1
11.	6.0	93	21.5	ND	12.2	6.2	113	19.0	0.5	19.5	6.2	95	20.0	0.8	25.8
12.	5.9	90	22.5	ND	11.1	7.3	88	17.0	1.0	12.4	6.4	71	19.0	1.0	23.0
13*.	6.2	265	38.0	4.3	24.4	6.3	235	32.0	3.5	13.7	5.4	166	28.0	6.5	48.7
14.	6.7	135	22.5	2.5	6.6	7.0	214	25.0	10.0	4.9	7.6	113	16.0	4.1	4.5
15.	7.0	335	44.5	2.5	15.1	7.8	85	39.0	9.5	2.7	7.3	265	40.0	12.5	6.4
16.	5.7	55	14.5	ND	10.1	7.0	271	15.0	ND	5.8	7.1	63	18.0	1.3	7.3
17.	5.9	45	10.5	1.0	1.6	6.4	79	12.0	2.0	2.5	6.6	65	14.0	1.8	4.4
18.	6.0	45	11.5	1.0	4.7	6.6	79	13.0	2.0	3.3	7.1	48	13.0	3.3	4.0
19.	6.4	50	14.0	1.3	1.1	6.1	88	13.0	2.5	2.3	7.2	60	14.0	2.5	2.1
20.	5.9	60	12.0	0.5	6.4	7.2	85	14.0	1.5	6.6	6.9	80	16.0	2.3	13.6
21.	7.3	235	11.0	3.0	3.9	7.8	162	8.0	6.0	0.7	7.6	140	11.0	5.0	5.0
22.	6.3	100	14.0	4.5	2.4.	7.0	128	14.0	7.5	2.3	6.6	95	13.0	4.3	3.5
23.	6.5	115	16.5	1.0	1.1	6.4	73	19.0	2.5	1.4	7.2	73	15.0	2.3	ND
24.	6.2	40	14.0	ND	8.3	7.1	79	17.0	ND	4.9	6.8	48	18.0	1.0	5.0

All parameters except pH and EC are expressed in mg/l   ND : Non detectable
pH in pH units and EC in μScm^{-1}.   * : Temple pond

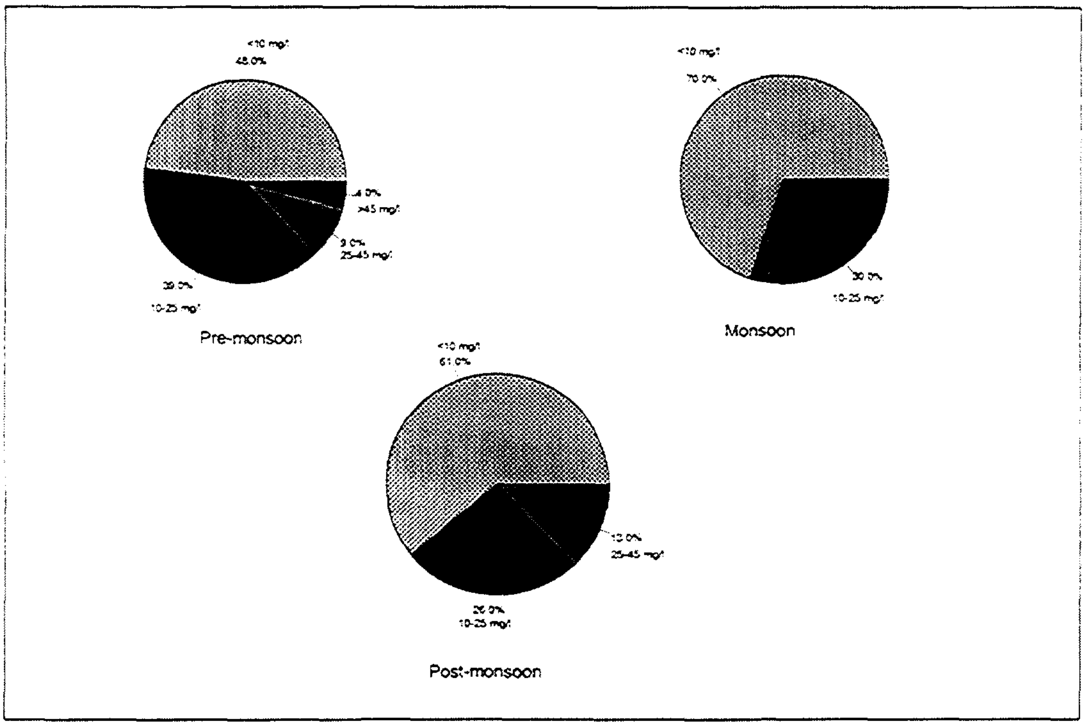

Fig. 4 Percentage distribution of wells and the extent of nitrate pollution

The variations observed in nitrate during pre-monsoon, monsoon and post-monsoon period are presented in Fig.5 in comparison with the maximum permissible limit of nitrate in drinking water. It is observed that most of the observation wells have considerably low nitrate during the monsoon months probably due to dilution.

4.5 Movement of nitrate in the soil

Though nitrogen compounds present in the sewage in the organically bound form do not directly pose any threat to groundwater, the stabilisation through enzyme catalysed biochemical transformation of these compounds into more water soluble inorganic forms like nitrite, nitrate and other similar oxidised forms of nitrogen can result in their fast movement downwards. Once the nitrogen is transformed to nitrate, the mobility of nitrogen is enhanced by its solubility in water, thus it moves easily with the medium. However, the influence of the soil organic matter, in fact, retards its downward movement by adsorption at the protonated sites of the organic matrix. Hence, in terms of quantity, nitrate level is always observed to be more in the surface or the immediate subsurface layers of the soil. In the deeper aquifer, it is virtually low. This is what is observed in the samples collected from the multilevel point sampler at different depths (Fig 6). Nitrate is observed to be high in the surface layers. However, in the areas where the soils are clayey and devoid of organic matter and humus, more and more nitrate can be expected in the groundwater. Compared to nitrate, other ions like chloride and sulphate do not show any significant decrease with depth. They almost remain at the same level.

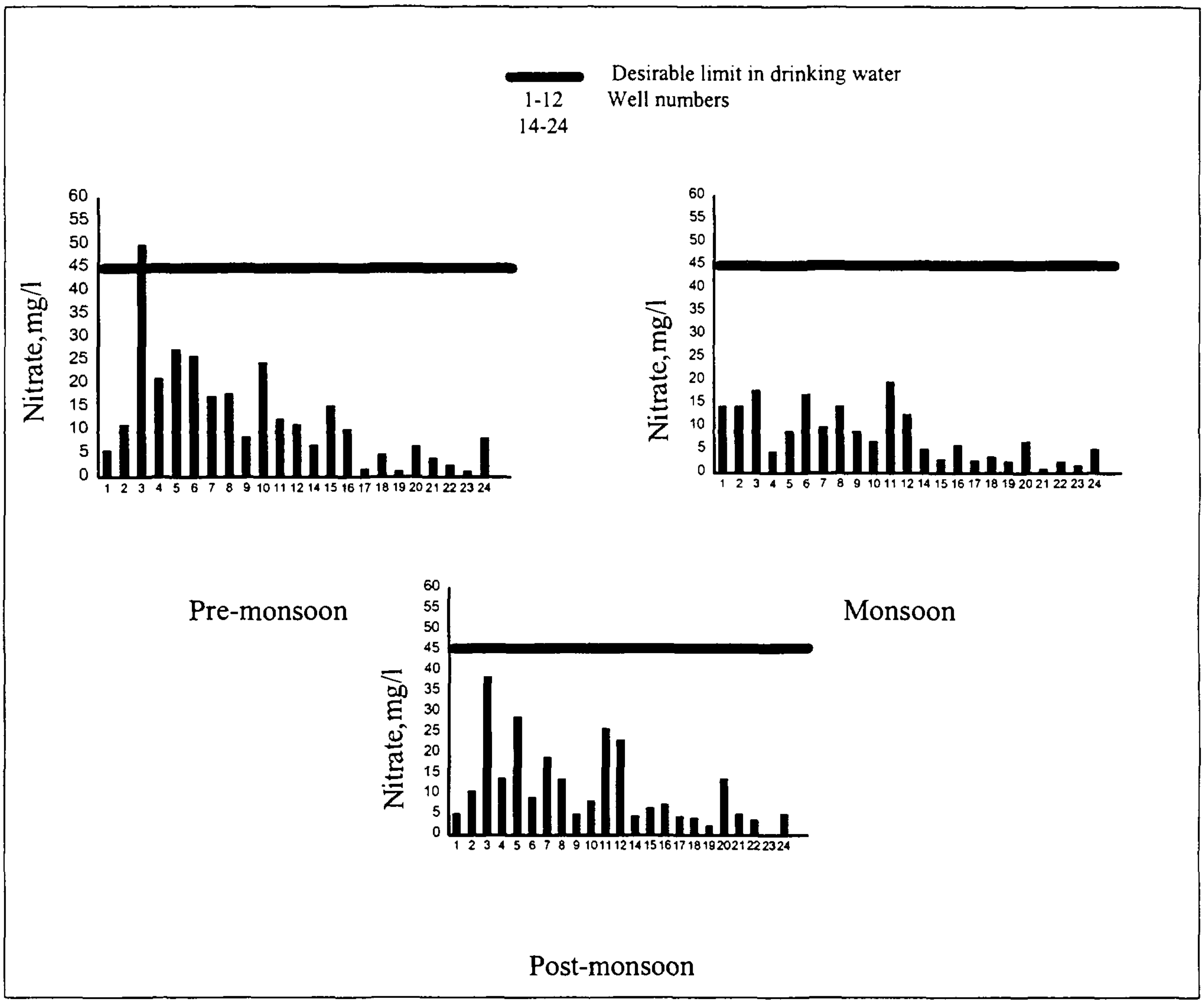

Fig. 5: Nitrate levels in the observation wells as compared to the maximum permissible limit in drinking water

5. CONCLUSIONS

The investigation carried out indicated that the sewage stabilisation pond can be a potential threat to groundwater quality. The level of nitrate in the observation wells varies widely during different seasons. Some of the wells in the immediate surrounding of the stabilisation pond are polluted with nitrate inspite of heavy rainfall in the region. A few more domestic wells in the area are likely to be polluted particularly during the dry months. The problem is more pronounced in summer when the level of nitrate is observed to be on the higher side.

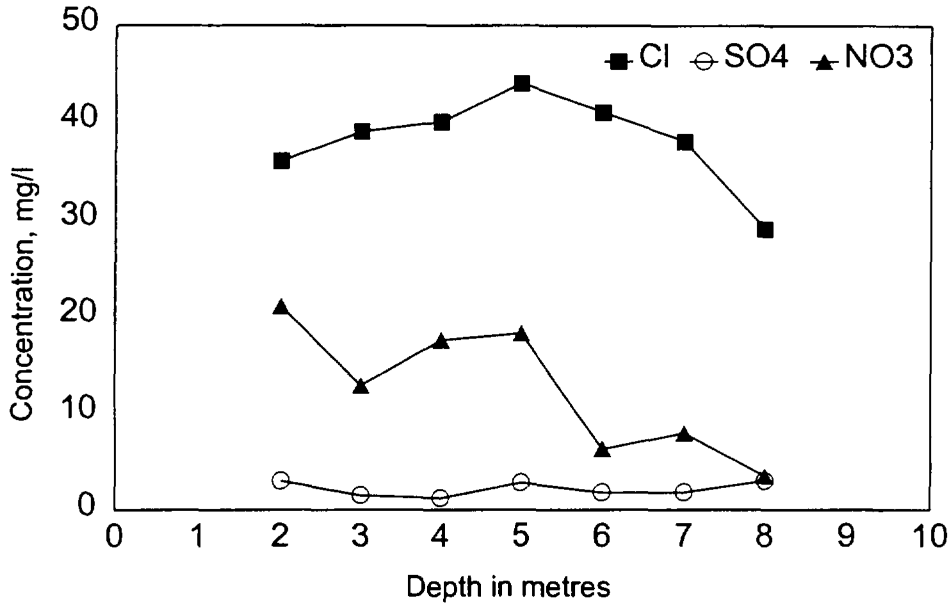

Fig.6: Distribution with depth of nitrate, chloride and sulphate in the site of investigation.

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