Environmental Monitoring and Assessment (2006) **117:** 45–57
DOI: 10.1007/s10661-006-7675-5

ASSESSMENT ON SEASONAL VARIATION OF GROUNDWATER QUALITY OF PHREATIC AQUIFERS – A RIVER BASIN SYSTEM

C. M. LALURAJ[1,*] and GIRISH GOPINATH[2]
[1]*National Institute of Oceanography, Regional Centre, Cochin, India;* [2]*Department of Marine Geology and Geophysics, Cochin University of Science and Technology, Cochin, India*
*(*author for correspondence, e-mail: lalu@niokochi.org)*

(Received 8 March 2005; accepted 19 May 2005)

Abstract. Spatial distribution of pH, electrical conductivity (EC), total dissolved solids (TDS), fluoride and total iron content of ground water samples collected from the muvattupuzha river basin, Kerala, India, has been studied for pre monsoon and post monsoon periods of year 2001. Results showed the groundwater of the basin is acidic for which the pH values ranged between 5.5 and 8.0. Average EC was found to be less than 100 μS/cm, for most of the study region. The pre monsoon minimum and maximum TDS were found as 25.6 and 227.84 mg/L respectively, where as post monsoon values ranged between 16 and 162.56 mg/L. The relatively low EC and TDS values found both during the seasons in the lateritic terrain of the river basin signifies the lower residence time of ground water with the country rock. This makes the groundwater quality of this river basin as good. Pre monsoon season samples showed high total iron content than that during the post monsoon period. During the study period values of the fluoride contents were found to be within the permissible limits.

Keywords: groundwater quality, phreatic aquifers, pre and post monsoon periods, river basin

1. Introduction

Increased industrialization, urbanization and agricultural activities during the last few decades have deteriorated the surface water and groundwater quality of Kerala, the southern most state of India (Nageswara Rao and Ramadurai, 1970; CGWB, 2002). Understanding the special distribution of pH, electrical conductivity (EC), total suspended solids (TDS), fluoride and total iron content will help to identify the quality of ground water. Groundwater contamination can often have serious ill effects on human health. Groundwater with low pH values can cause gastrointestinal disorders, such as hyper acidity, ulcers, stomach pain and burning sensation. pH values below 6.5 cause corrosion of metal pipes, resulting in the release of toxic metals such as Zn, Pb, Cd, Cu etc. (Trivedy and Goel, 1986). Electrical conductivity (EC) of groundwater is considered as an important parameter for irrigation and industrial purposes. Total dissolved solids help to identify the potability of groundwater. Total iron content may not have direct effects on human health but is of importance due to aesthetic reasons. The excess presence of iron in groundwater causes stains to cloths and fixtures and has a bad taste and odour. These problems arise when iron concentration approaches more than 0.3 mg/L in groundwater. High concentration of fluoride in drinking water are also linked with cancer (Smedly, 1992).

Except a preliminary report (CGWB, 1989), no detailed study in terms of water quality of the Muvattupuzha river basin, Kerala have been carried out. Hence a detailed investigation of this dimension has been taken up in the present study.

2. Study Area

Kerala is characterised with forty-four rivers, which originates from Western Ghats, follows a meandering course before debouching into the coastal waters. Muvattupuzha, the major perennial river in central Kerala, drains through zones of highly lateritised crystalline rocks before finally entering into the Vembanad estuary and the Arabian sea. The river basin is bounded by the Periyar river basin on the north and the Meenachil river basin on the south. Geographically, the river basin is lying between latitudes 9°40′ and 10°10′ N and longitudes 76°20′ and 77°00′ E (Figure 1). For further discussion the basin is sub divided into four sub basins as illustrated in (Figure 2).

The basin consists of highly varied geological formations such as Pre–Cambrian crystallines, laterites and Tertiary sedimentary rocks. Charnockites,

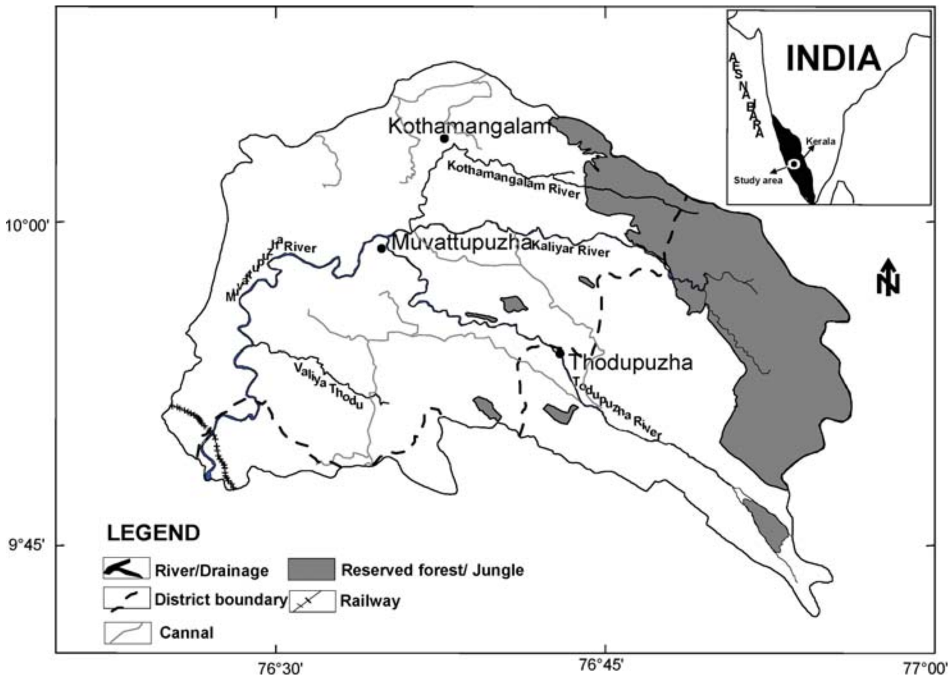

Figure 1. Base map of the Muvattupuzha river basin.

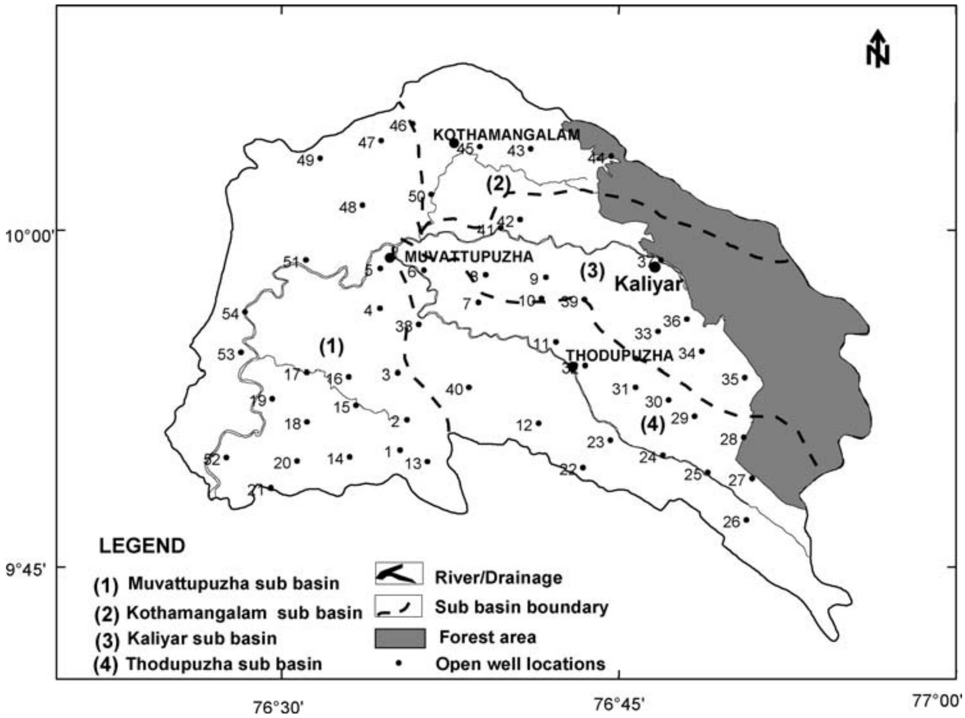

Figure 2. Sub-basins and location map of open wells in the Muvattupuzha river basin.

hornblende-biotite gneisses and other unclassified gneisses cover a major portion (~85%) of the drainage basin. These rock formations are often intruded by rocks of acidic (granite, pegmatite and quartz vein) and basic (gabbro and dolerite) types. Laterite is found almost in the entire basin as a cap rock, whereas Warkallai beds of Tertiary are found near the river mouth. The basin is also characterized by lateritic soil (over 70%) and the remaining as riverine alluvium and brown hydromorphic soil. The movement of groundwater in this basin is mostly controlled by numerous fracture systems and high gradient.

3. Materials and Methods

Groundwater samples collected from 55 dug wells from the river basin (Figure 2) during the year 2001 covering both pre monsoon and post monsoon periods were analysed for the present study. Samples were drawn with a pre cleaned plastic polyethylene bottle. Prior to sampling, all the sampling containers were washed and rinsed thoroughly with the groundwater. Water quality parameters such as, pH, EC and TDS were measured in the field itself. Samples of total iron were preserved by adding concentrated HCl, which were transported immediately to the laboratory following the standard guidelines (APHA, 1985).

The total iron and sulphate in samples were analysed using Spectrophotometer (Hitachi Model 2000, double beam UV-Visible Spectrophotometer). Fluoride concentrations in the samples were measured by colorimetric methods using SPADNS reagent (APHA, 1985).

4. Results

pH values of groundwater varied from 5.5 to 8.0 during pre monsoon and 5.6 to 8.1 during post monsoon season. EC values ranged from 40 to 356 μs/cm during pre monsoon whereas during post monsoon it was 27–254 μs/cm. Respective minimum and maximum TDS values observed were 16 and 160 mg/L during post monsoon season and 25 and 227 mg/L during pre monsoon. The total iron values ranged from 0–4.7 mg/L during pre monsoon and 0–1.2 mg/L during post monsoon. During both seasons fluoride concentrations were found within permissible limits ($<$0.5 mg/L). The highest value observed was 0.4 mg/L during pre monsoon season. Spatial distributions of pH, EC, TDS, total iron, fluoride in both seasons are presented in thematic maps (Figures 3a and b, 4a and b, 5a and b, 6a and b and 7a and b).

5. Discussion

5.1. pH

The pH of natural waters is often found slightly acidic (5.0–7.5). This may be due to the presence of dissolved carbon dioxide and organic acids (fulvic and humic acids), which are derived from the decay and subsequent leaching of plant materials (Langmuir, 1997). Waters with pH values above 10 are exceptional and may reflect contamination by strong base such as NaOH and $Ca(OH)_2$. The ranges for desirable limit of pH of water prescribed for drinking purpose by ISI (1983) and WHO (1984) as 6.5–8.5 while that of EEC (Lloyd and Heathcote, 1985) as 6.5–9.0.

Based on the pH distribution of the groundwater of the basin presented (Figure 3a and b), the region can be classified into five zones, viz. (i) 5.5–6.0, (ii) 6.0–6.5, (iii) 6.5–7.0, (iv) 7.0–7.5 and (v) $>$7.5. During the present investigation, pH value as low as 6.5 was recorded in most of the study region (almost 1/3 of the basin). In general, the distribution of pH did not show any specific trend within the basin. It's also found that at the eastern parts of sub basin, the pH distribution did not show any variation during both seasons. On the other hand, the north sub basin showed an increase in pH values during post monsoon, while the southern part of sub basin showed a decreasing trend during post monsoon. In an unconfined aquifer system (similar to the present study region) the pH was often found to be below 7

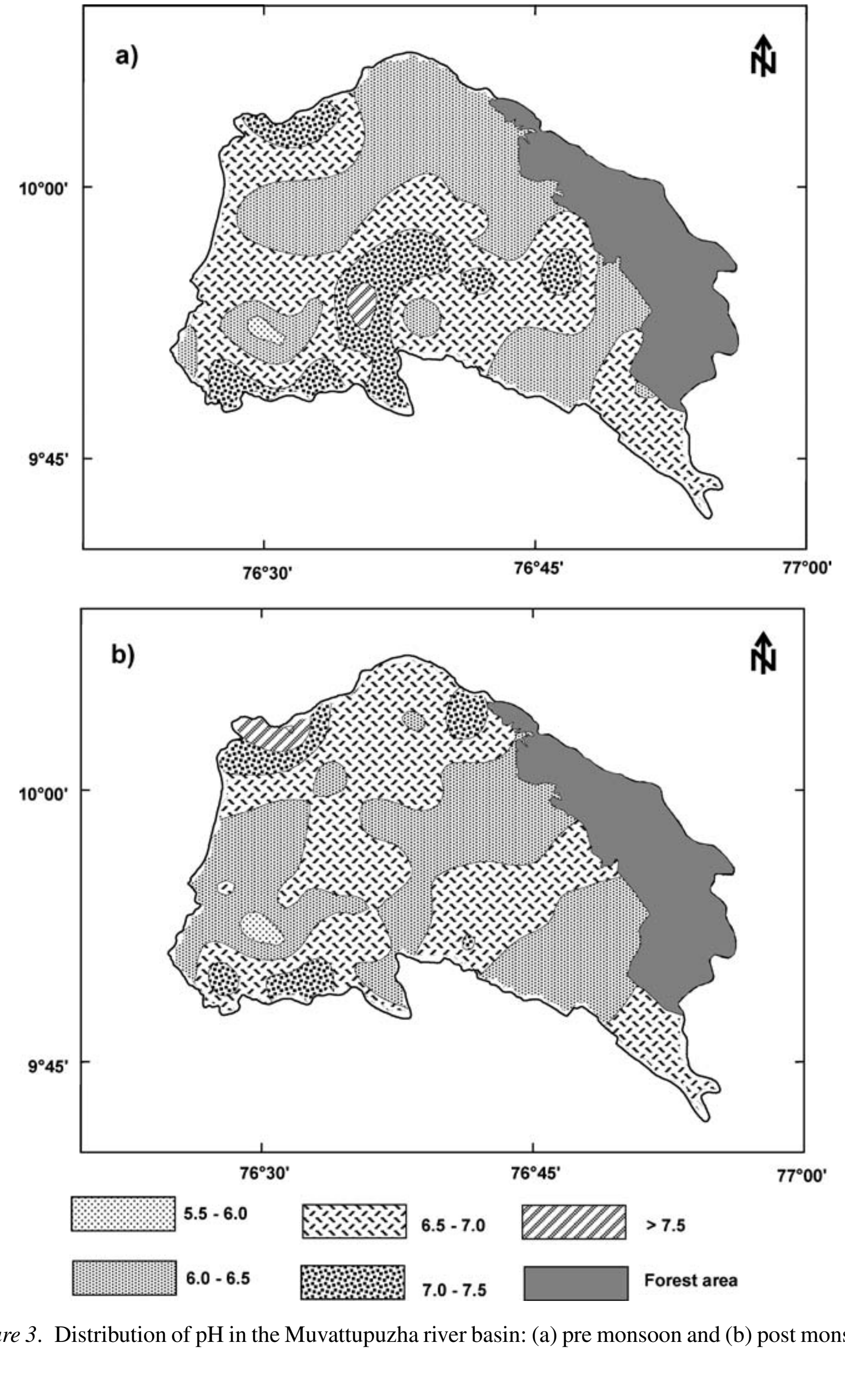

Figure 3. Distribution of pH in the Muvattupuzha river basin: (a) pre monsoon and (b) post monsoon.

(Langmuir, 1997). The low pH of the groundwater of the basin may be related to the wide distribution of lateritic soil whose pH is always acidic (CESS, 1984). Further, the study area also encompasses extensive agricultural fields. Another reason for the observed low pH values could be thus related to the use of acid producing fertilizers like ammonium sulphate and super phosphate of lime as manure for agriculture use (Rajesh *et al.*, 2001).

A low pH (below 6.5) can cause corrosion of water carrying metal pipes, thereby releasing toxic metals such as zinc, lead, cadmium, copper etc. (Trivedy and Goel, 1986). Davies (1994) while carrying out hydrochemical studies of Madhupur aquifer, Bangladesh has also found a moderately high concentration of zinc and attributed that to low pH of groundwater. Furthermore, low pH values in groundwater can cause gastrointestinal disorders like hyper acidity, ulcers, and stomach pain with burning sensation (Rajesh *et al.*, 2001).

5.2. Electrical conductivity (EC)

EC is measured in microsiemens/cm (μS/cm) and is a measure of salt content of water in the form of ions (Karanth, 1987). In the present study, EC values ranged from 40 to 356 μS/cm during pre monsoon period whereas it ranged from 25 to 254 μS/cm during post monsoon. The distribution of EC values is presented in Figure 4a and b. It is clear that a vast majority of the area showed EC values less than 100 μS/cm. During the pre monsoon period, low EC values were found in an east west stretch running at the centre of the basin while the northern, southern and southeastern parts of the basin showed higher EC values (>100 μS/cm). On the other hand during the post monsoon period, most of the basin (except the northern part) showed low EC values. The occurrence of high EC values (Figure 4b) on the northwestern part of the study area might also be due to addition of some salts through the prevailing agricultural activities. Comparatively zones with low EC values (<100 μS/cm) are found more during post monsoon than for pre monsoon period and are due to dilution of soluble salts by rainfall. As low EC values were recorded during the entire period, the water is found to be safe for drinking and domestic purposes. Moreover, a low EC value further signifies the anoxic condition of groundwater.

5.3. Total dissolved solids (TDS)

The quality of groundwater for drinking purpose can be expressed in terms of total dissolved solids (TDS). Groundwater with a TDS value less than 300 mg/L can be considered as excellent for drinking purpose (WHO, 1984). The distribution of TDS values for both seasons (Figures 5a and b) clearly showed that the entire basin falls within this range. During pre monsoon, values ranged between 25 and 227 mg/L, whereas it ranged between 16 and 162 mg/L during post monsoon period. Relatively high TDS values during pre monsoon were found on the northern and

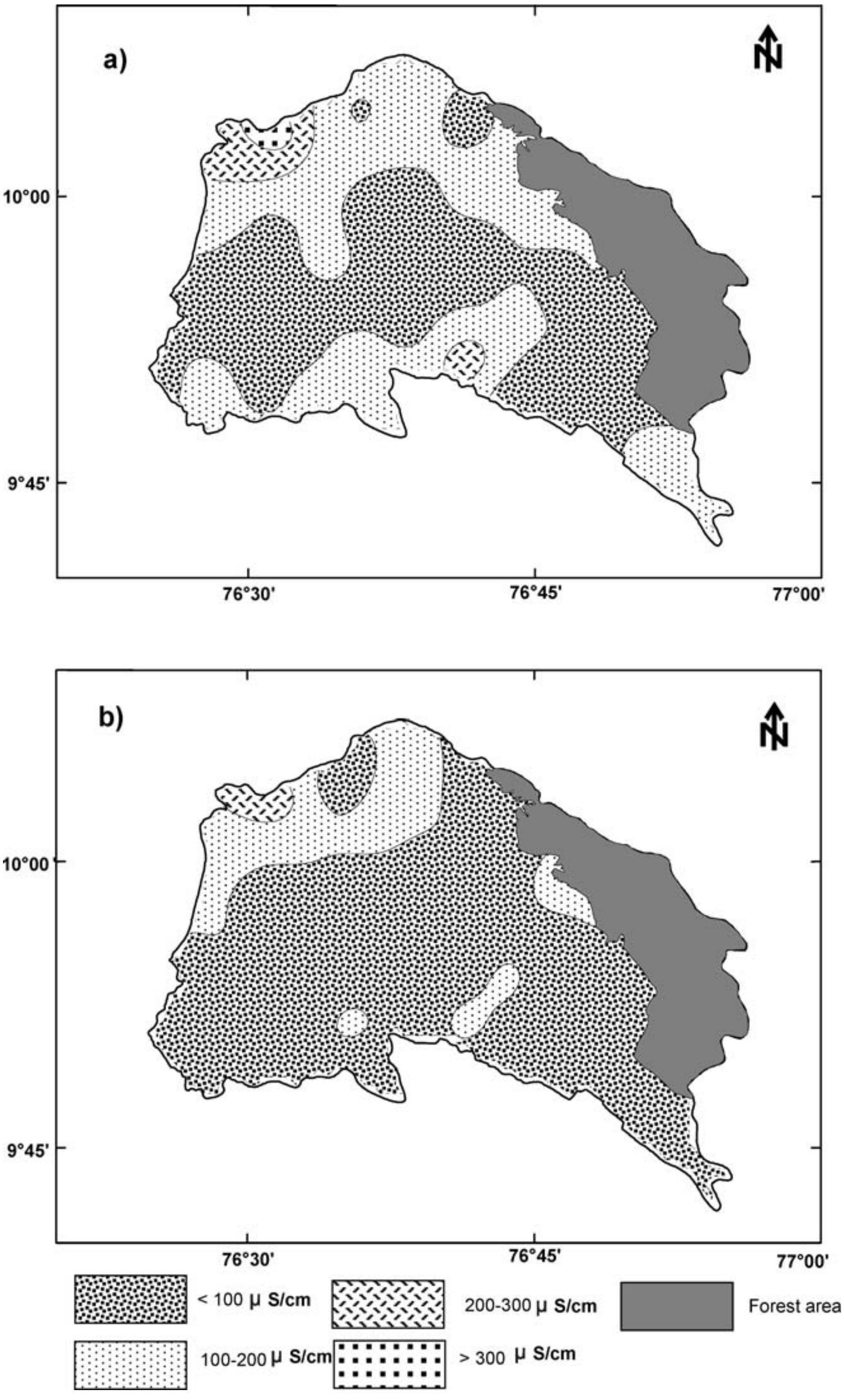

Figure 4. Distribution of electrical conductivity in the Muvattupuzha river basin: (a) pre monsoon and (b) post monsoon.

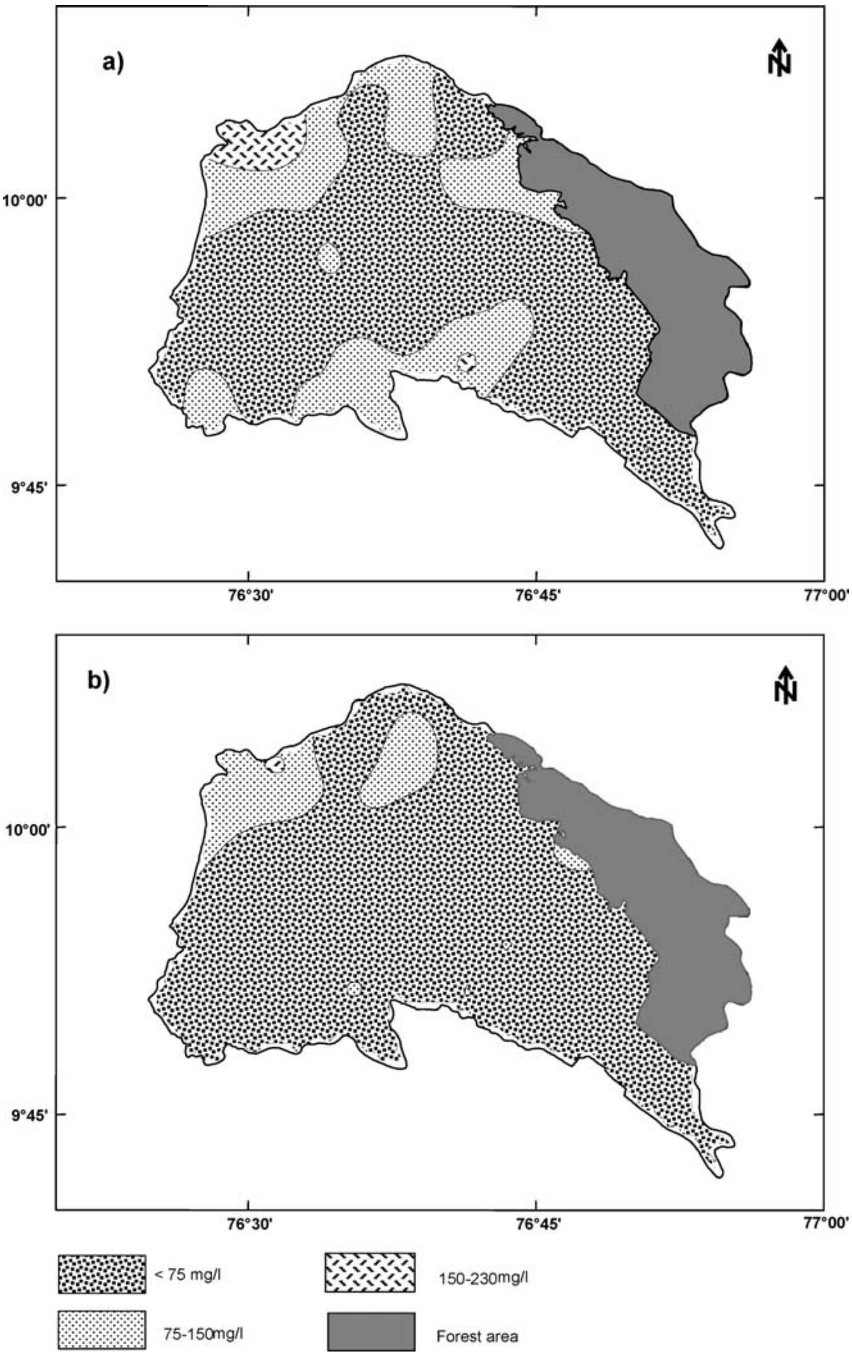

Figure 5. Distribution of total dissolved solids in the Muvattupuzha river basin: (a) pre monsoon and (b) post monsoon.

southern parts of the basin. On the other hand during post monsoon period only the northwestern parts of sub basins showed TDS values of over 75 mg/L. According to Venugopal (1998) and Aravindan (1999) the TDS values were higher during pre monsoon than during the post monsoon season. However, this basin is encountered with low TDS values which may be due to the prolonged leaching of topsoil under the existing anoxic condition.

Usually unconfined aquifer system has relatively low TDS (Langmuir, 1997). The hydrogeological properties of rocks will have a strong influence on the extent of water/rock reaction. Zones with high groundwater-flow velocities usually will have relatively low dissolved solids because of the shorter groundwater- rock contact time and high water/rock ratios, and vice-versa (Langmuir, 1997). Typical high groundwater velocities were found in highly fractured or weathered near-surface igneous and metamorphic rocks. Such conditions are usually found in shallow water table (unconfined) aquifers but not in deep, (confined) aquifers. The low TDS values found can be attributed to high rainfall prevailing, which causes significant dilution.

5.4. Total iron

Pre monsoon samples showed high total iron content than that during post monsoon period. During pre monsoon, the western part of sub basins and small patches in the southeastern part of the sub basin showed total iron values greater than 0.3 mg/L, whereas during post monsoon only the north western and south western parts of the sub basin showed more than 0.3 mg/L of total iron (Figures 6a and b). The concentration of iron in groundwater will be higher under more reducing conditions due to bacteriological degradation of organic matter which leads to the formation of various humic and fluvic compounds (Applin and Zhao, 1989; White *et al.*, 1991). Under reducing condition, the iron from biotite mica and laterites are leached into solution in ferrous state. According to Singhal and Gupta (1999) iron content in groundwater is mainly due to the dissolution of iron oxides. The common method for the removal of iron from water is by aeration followed by sedimentation. In high rainfall zones of India such as, Assam, Orissa and Kerala, it is reported that the total iron content ranges from 6.83 to 55 mg/L (Singhal and Gupta, 1999). As the study area is primarily covered with laterites (70%), leaching of iron can take place easily under the existing anoxic condition, which may be attributed to the high concentration of total iron in groundwater.

5.5. Fluoride

In groundwater, fluorine occurs mainly as simple fluoride ion. It is capable of forming complexes with silicon and aluminium, and is believed to exist at a $pH < 7$. Distributions of fluoride during pre monsoon and post monsoon periods of the river basin are shown in Figures 7a and b. During both seasons the fluoride contents were

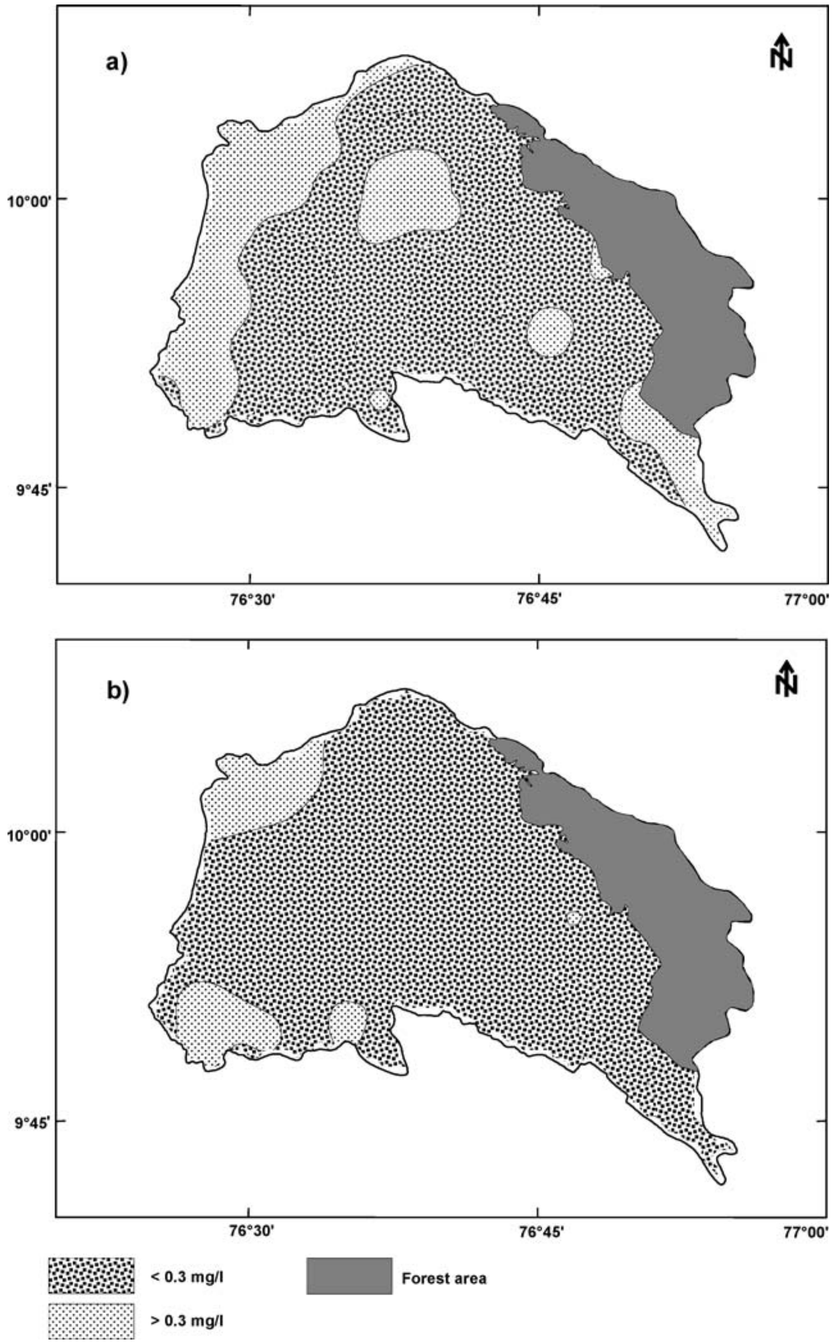

Figure 6. Distribution of total iron in the Muvattupuzha river basin: (a) pre monsoon and (b) post monsoon.

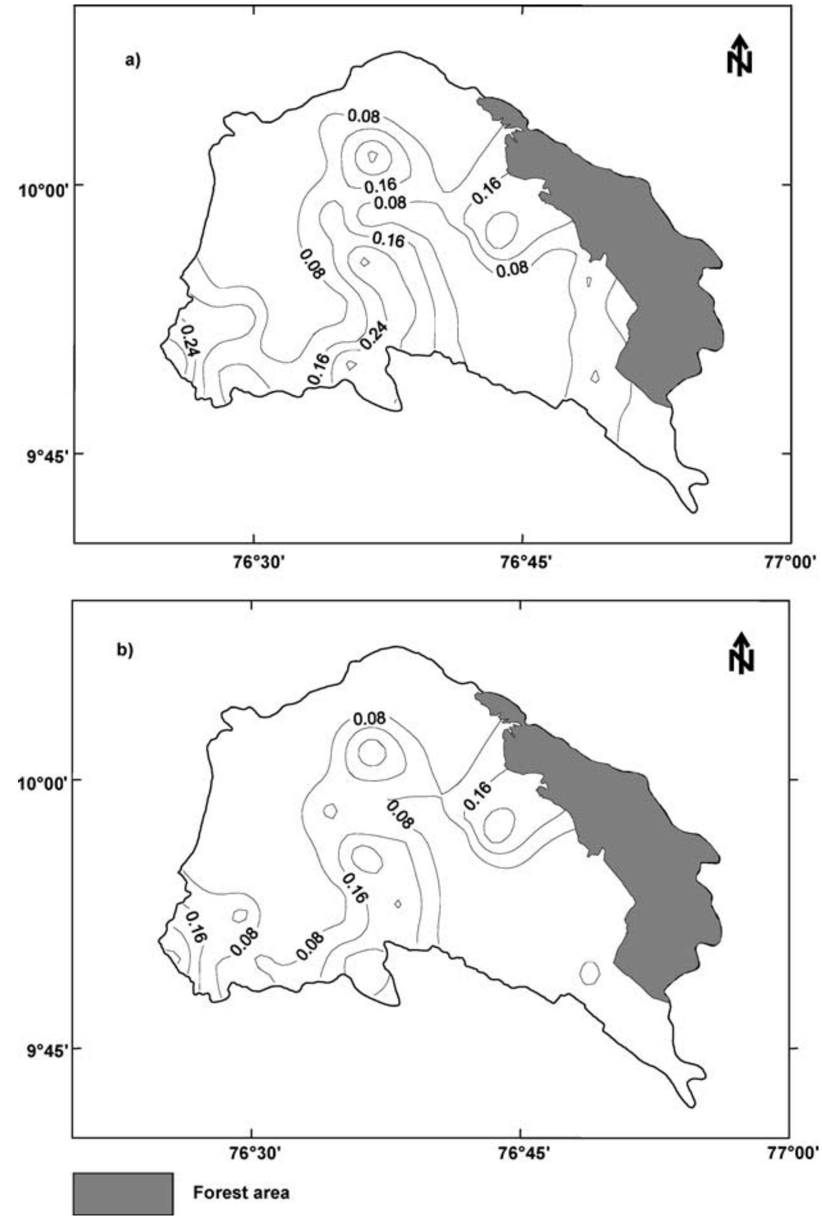

Figure 7. Isocone map of fluoride in the Muvattupuzha river basin: (a) pre monsoon and (b) post monsoon.

within permissible limits. The highest value (0.4 mg/L) is found recorded during pre monsoon season. The distribution of fluoride for both the seasons were showed more or less of an identical pattern.

Fluoride is beneficial when present in small concentrations (0.8 to 1.0 mg/L) in drinking water for calcification of dental enamel. However, it causes dental and skeletal fluorosis if high. Higher concentration of fluoride in drinking water is also linked with cancer (Smedly, 1992). A review of literature indicates that an abnormal concentration (>1.5 mg/L) of fluoride recorded in the Rift valley of Ethiopia due to calcium fluoride derived from bedrocks (Ashley and Burley, 1995). In Kerala too high concentration of fluoride (as high as 1.5 mg/L) was recorded in some parts of the coastal zones and is possibly due to the saltwater intrusion (CGWB, 2003). However, the fluoride concentration in the study area is found to be negligible.

6. Conclusion

The groundwater of the Muvattupuzha river basin, Kerala, India in general is found to be acidic in nature with an the average EC value of less than100 μS/cm. The total iron content is found to be more than 0.3 mg/L in certain areas of the basin. During the pre monsoon period the observed maximum TDS was 227.84 mg/L and 162.56 mg/L during post monsoon. In general, the low concentration of EC and TDS in the groundwater of the phreatic zone reveals the shorter groundwater-rock-contact time. Both during pre monsoon and post monsoon seasons the fluoride contents were found to be within the permissible limits. Based on these observations the groundwater in the study region in general can be considered good.

Acknowledgments

Authors thank Dr. S. R. Shetye, Director, National Institute of Oceanography (NIO) and Dr. K. K. C. Nair, Scientist-in-Charge, Regional Centre, NIO, Cochin for the encouragement and help. This is the NIO contribution number 3984.

References

APHA: 1985, *Standard Methods for the Analysis of Water and Waste Water*, 16th edn., American Public Health Association, Washington, DC.

Applin, K. R. and Zhao, N.: 1989, 'The kinetics of Fe (II) oxidation and well screen encrustation', *Ground Wat.* **27**(2), 168–174.

Aravindan, S.: 1999, 'Integrated hydrogeological studies in hard rocks aquifer system of Gadilam river basin', Tamil Nadu, India, Ph.D Thesis (unpublished), Bharathidasan University, p. 110.

Ashley, R. P. and Burely, M. J.: 1994, 'Controls on the occurrence of fluoride in the groundwater in the Rift Valley of Ethiopia', in: H. Nash and G. J. H. McCall (eds), *Groundwater Quality, 17th Special Report*, Chapman and Hall, pp. 45–54.

CESS: 1984, Resource Atlas of Kerala, Centre for Earth Science Studies, Thiruvananthapuram, Kerala.

CGWB: 1989, 'Basic data of borewells drilled in Meenachil and Muvattupuzha river basins', *Technical report*, FSP 1988–1989.

CGWB: 2002, 'Groundwater balance. Mass awareness programme in Ernakulam district on January 5th 2002 by CGWB, Kerala region', Thriruvananthapuram, Kerala.

CGWB: 2003, 'A study on seawater ingress in the coastal aquifers in parts of Alleppey and Ernakulam districts', Kerala, *Technical report*, AAP 2000–2001, p. 29.

Davies, J.: 1994, 'The hydrogeochemistry of alluvial aquifers in central Bangladesh. Groundwater Quality', in: H. Nash and G. J. H. McCall (eds), *17th Special Report*, Chapman and Hall, pp. 9–18.

ISI: 1983, *Indian Standard Methods of Sampling and Test (Physical and Chemical) Methods for Water Used in Industry*, p. 122.

Karanth, K. R.: 1987, *Groundwater Assessment Development and Management*, Tata Mc Graw-Hill, New Delhi, p. 720.

Langmuir, D.: 1997, *Aqueous Environmental Chemistry*, Prentice-Hall, Inc., New Jersey, p. 600.

Lloyd, J. W. and Heathcote, J. A.: 1985, *Natural Inorganic Hydrochemistry in Relation to Ground Water – An Introduction*, Clarendon Press, Oxford, p. 296.

Rao, N. and Ramadurai, S.: 1970, 'Systematic geo-hydrological survey of the coastal plains in Malapuram, Trichur and Ernakulam Districts, Kerala state', *GSI report*.

Raghunath, R. Sreedhara Murthy, T. R. and Raghavan, B. R.: 2001, 'Spatial distribution of pH, EC and total dissolved solids of Nethravathi river basin, Karnataka state, India', *Pollu. Res.* **20**(3), 413–418.

Singhal, B. B. S. and Gupta, R. P.: 1999, *Applied Hydrogeology of Fractured Rocks*, Kluwer Academic Publishers, The Netherlands, p. 400.

Smedly, P. L.: 1992, 'Relationship between trace elements in water and health with special reference to developing countries'. *Interim Report* 1992 BGS. Tech., Report WD/92/39, p. 33.

Trivedi, R. K. and Goel, P. K.: 1986, 'Chemical and biological methods for water pollution studies', Environmental Publication, Karad.

Venugopal, T. N.: 1998, 'Hydrogeological investigation in the Arkavathi river basin – A tributary of Cauvery river', Karnataka, Ph.D Thesis (unpublished), Mysore University, p. 224.

White, A. F., Benson, S. M., Yee, A. W., Woiienberg, H. A. and Flexser, S.: 1991, 'Groundwater contamination at Kesterson reservoir, California: geochemical parameters influencing selenium mobility', *Wat. Resource Res.* **27**, 1085–1098.

WHO: 1984, 'Guidelines for drinking water quality', Recommendations, Geneva.