Impacts of Urban Growth on Surface Water and Groundwater Quality (Proceedings of IUGG 99 Symposium HS5, Birmingham, July 1999). IAHS Publ. no. 259, 1999.

Hazards due to migration of septic tank leakages in peri-urban settlements

H. K. RAMARAJU, M. VENKATACHALAPPA, G. RANGANNA
UGC-DSA Centre, Department of Mathematics, Bangalore University, 560001 Bangalore, India
e-mail: dsamath@blr.vsnl.net.in

C. SADASHIVAIAH & N. MANAMOHAN RAO
Department of Civil Engineering, Bangalore University, Jnanabharathi, 560056 Bangalore, India

Abstract Whilst it is widely accepted that a healthy environment is essential for human survival and sustainable development, two thirds of people living in developing countries still do not have adequate sanitation facilities. A field study carried out at three selected sites within the three southern districts of Karnataka has been undertaken to assess the contamination status of domestic well waters. The two-year study revealed that water quality of the domestic wells is deteriorating fast as partly indicated by very high nitrate levels. Thirteen wells out of 19 were found to be severely contaminated, five wells are marginally contaminated with only one well being considered fit for use. In some cases the nitrate level of the well waters has reached 495 mg l^{-1} during summer months, which is far in excess of WHO stipulations. Based on the two years of field data, certain measures are suggested for safe domestic waste disposal in the study areas in order to achieve a congenial groundwater environment and to provide long term protection for the health status of the local population.

INTRODUCTION AND STUDY SITES

Urbanization in many countries has resulted in widespread peri-urban expansion which whilst being "linked" to a developed urban core, does not enjoy common sanitation or safe water amenities on which continued human health is dependent. Septic tank systems have traditionally performed a vital function for environmental sanitation within both rural and peri-urban areas in developing countries. The septic tank system is a complex physical, chemical and biological system with performance being a function of design, construction type, characteristics of the wastes, climate, areal/regional geology, topography, physical and chemical composition of the soil mantle and the care extended to periodic maintenance. Efficient functioning of the septic system mainly depends upon the hydraulic loading and effective soil absorptive capacity. Otherwise, these systems may contaminate ground and surface water and result in sanitary nuisances and health hazards. Contaminants identified include bacteria, viruses, ammonia, nitrates, chlorides, phosphates and sodium (Miller & Scalf, 1974). An extensive literature study by Lewis *et al.* (1978) concluded that high levels of nitrate found in domestic well waters are mainly due to near proximity of pit latrines to the wells.

The newly developing suburbs around already developed urban centres lack protected water supply and sewerage systems. The migrants from rural areas depend on piped water supply from borewells (and rarely, open dug wells) and resort to septic tanks for disposal of domestic wastes. However, the majority of these are incorrectly designed and their working performance is far from satisfactory. The field investigation reported here is limited to the following three study sites (Fig. 1), which were selected on criteria based on the requirement for different hydrogeological features, terrain, soil types and meteorological aspects:

(a) the Bangalore peri-urban area, i.e. Nagarabhavi and Papareddypalya;
(b) well developed areas of the Chikballapur Taluk headquarters in Kolar district, i.e. Subbarayanapete; and
(c) the Mandya district headquarters where a sewerage system is absent, i.e. Chamundeswarinagar and Kaverinagar.

THE PROBLEM

Most urban areas in the developing world lack facilities for proper collection and disposal of domestic and industrial wastes. In many areas sewerage systems are non-existent, with human faeces and other wastes being deposited directly into surface drainage. Many suburban households not connected to the sanitary sewer system use individual septic-soil absorption systems for wastewater disposal. The septic system effluents are rich in nitrogen and phosphorus as well as sulphate, chloride, coliform organisms, viruses and organics. The environmental effects of septic tank sludge (septage) disposal are also of concern (Ramaraju *et al.*, 1998). Phosphorus in wastewaters entering the soil is not considered to be a potential water pollution problem because it is rapidly sorbed by the soil and hence there is no mobility. Nitrates, primarily from septic tanks, sanitary landfills, leaking sewers and fertilizers, migrate through the vadose zone and reach the water table. Nitrogen reactions in soil are well defined comprising ammonification, nitrification and denitrification (Lewis *et al.*, 1978). Nitrate contamination of drinking water is the subject of extensive research because of its potential health hazard, i.e. incidence of "blue baby" disease (Methaemoglobinemia), gastric and oesophageal cancer (Siddiqi *et al.*, 1992) and diabetes (Kostraba *et al.*, 1992).

Pit latrines are known to have a major build-up of nitrogenous material in the surrounding soil from which nitrate is leached intermittently by infiltrating rainfall. The presence of high groundwater nitrate concentration, if derived from organic sources, may be associated with intermittent bacterial pollution (Jiwan *et al.*, 1998). According to WHO guidelines, the safe level of nitrate content in drinking water is 50 mg l^{-1}. Groundwater contamination by pathogenic bacteria and viruses has been recognized as a serious hazard to human health (Keswick & Gerba, 1980). Studies have revealed that large numbers of viruses may be removed from wastewaters by percolation through soils, i.e. adsorption on soil particles, with clays enhancing the adsorptive process. As groundwater is often consumed without prior conventional treatment or perhaps after inadequate treatment, it is necessary to understand fully the mechanisms governing the transport and fate of these micro-organisms in groundwater systems so that the health risk to groundwater can be evaluated.

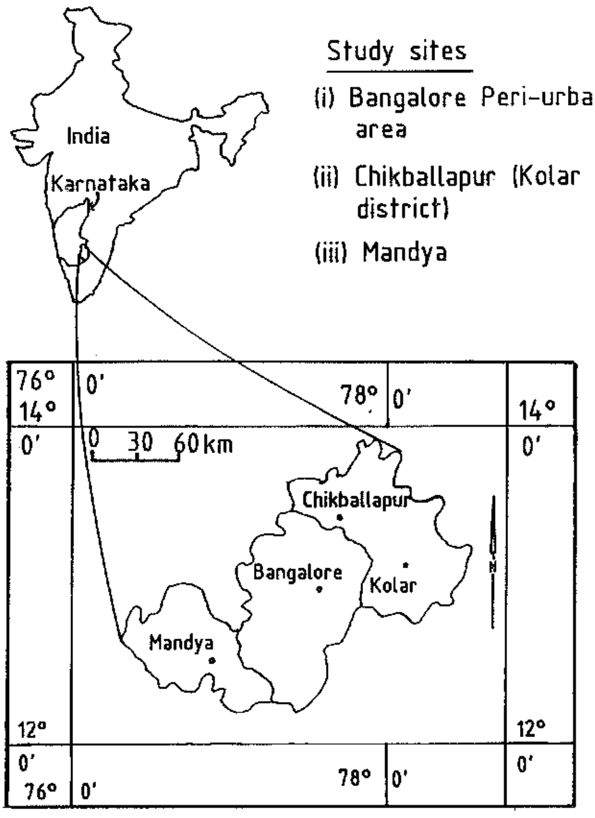

Fig. 1 Location map of study sites.

Research relating to the migration of organic compounds in the subsurface soil-water matrix has also gained importance in recent times.

METHODOLOGY

Reconnaissance survey was a prerequisite for selection of the study areas. A sample survey of user opinion was also carried out to quantify the type of pit latrines, proximity to family wells, the number of persons using such facilities, duration of use etc. The questionnaire was prepared in both English and local Kannada languages and distributed in the study area to selected individuals and isolated houses. Based on the information procured (Table 1), study sites for collection of water and soil samples were finalized. Samples of water from wells (monthly) and soil from two sites (seasonally) within each of the three study sites were collected. Standard sampling procedures were used (APHA, 1995). Bacteriological analysis was carried out for the presence of total coliform organisms and faecal coliforms. The entire study commenced in September 1996 and continues through to the present time. Soil and water samples have also been analysed for their physico-chemical properties as per standard methods and procedures.

Table 1 Field survey data.

Study site	Pop. density (People km^{-2})	Av. annual rainfall (mm)	Surface geology	Soil type	Study points moni-tored	No. users per family		Age of tank		Type of construction	Distance of tank (m) from:		
											Drinking water source		Agricul-tural field
						Max	Min	Max	Min		Max	Min	
1 Bangalore peri-urban (Nagarabhavi & Parapeddy Palya)	2200	830	Amphibolite & pelitic schist, perinsular gneisses, granites of different phases	Red loamy soil, red sandy soil, laterites & laterite gravelly soils	6	12	4	18	4	Sized stone masonry with/without mortar	5	1.5	500
2 Chikballapur town (Subbaraayana Pete)	263	744	Granites of different phases, green stones, dolerite & amphibolite dykes, charnock sites	Red sandy soil, lateritic soil, red loamy soil	7	21	4	16	12	Dug pit without lining with only squatting platform	9	1.5	150
3 Mandya town (Chamundes-warinagar & Kaverinagar	535	633	Granite, gneisses landscape with gently sloping to undulating middle and lower pediments forms major portion of area	Fine loamy mixed, iso hyperthermic udic rhodusalts	6	18	4	7	2	Sized stone masonry with slab/rubble/ dry masonry	11	3.0	270

RESULTS AND DISCUSSION

According to the results obtained, it is clear that high nitrate contents in groundwater originate from human organic wastes as well as from animal and plant wastes which are deposited in the settlements and their surroundings. The nitrate concentration varied form 41 to 495 mg l^{-1} during the summer season and during the monsoon period was reduced to between 7 to 418 mg l^{-1}, perhaps due to high rainfall dilution effects (Table 2). The monthly variation of nitrate levels is presented in Fig. 2. The permeability in the study areas varied from 0.14 to 0.39 m day^{-1}. Other factors that may certainly be of importance in view of the relatively high nitrate concentrations include the biological decomposition of organic matter and the poor characteristics of the local shallow aquifers. High nitrate content and coliform density in the sites are the most readily detectable due to leakage from septic tanks, cattle sheds and waste disposal sites. As is well known, nitrate in drinking water can cause methaemoglobinemia especially in infants as well as carcinogenic nitrosamines. There is little or nothing known about the occurrence of cases of methaemoglobinemia in the study areas. This is understandable because breast feeding is the normal diet for infants under three months of age. These aspects of potential groundwater pollution have to be considered, however, in future development schemes especially with respect to siting of shallow dug wells and drilled bore wells.

To indicate the degree of microbiological contamination of groundwater, the detection and enumeration of indicator organisms rather than of pathogens has been used in this study. Overseas studies have established the significance of the coliform group density as a criterion for faecal pollution. The summary of results from 19 samples (one year's data of maximum and minimum concentrations) is given in Table 2. The microbiological investigations have shown that there are problems of

Table 2 Nitrate concentration and bacteriological content of well waters at the study sites.

Location	Nitrate and rainfall: Max (mg l^{-1})	Month	(mm)	Min (mg l^{-1})	Month	(mm)	Bacteriological parameters: Max MPN count	DC test	Min MPN count	DC test
Bangalore peri-urban area (Nagarabhavi and Papareddy Palya)										
B27*	133	July 1997	Nil	68	Dec 1997	Nil	180	–	120	–
B28**	64	July 1997	Nil	28	Jan 1998	Nil	>1800	+	80	+
B29*	318	July 1997	Nil	147	Jan 1998	Nil	180	+	20	–
B30*	41	July 1997	Nil	15	Jan 1998	Nil	Nil	–	Nil	–
B31*	78	July 1997	Nil	30	Dec 1997	Nil	Nil	–	Nil	–
B32*	314	July 1997	Nil	217	Sept 1997	157	130	–	Nil	–
Chikballapur town (Subbarayana Pete)										
C51**	154	Mar 1998	Nil	104	Dec 1997	31	>1800	+	120	+
C53**	148	Aug 1998	112	89	Dec 1997	31	>1800	+	180	–
C54**	270	Mar 1998	Nil	207	Apr 1997	23	>1800	+	160	+
C55**	304	Aug 1997	112	214	Sept 1997	238	>1800	+	160	–
C58**	364	Mar 1998	Nil	264	Apr 1997	23	>2300	+	160	–
C59**	495	Aug 1997	112	418	Dec 1997	31	>2300	+	120	–
C60**	317	Mar 1998	Nil	204	Dec 1997	31	>1800	+	120	–
Mandya town (Chamundeswaarinagar and Kaverinagar)										
M2*	42	Mar 1998	Nil	7	Sept 1997	217	Nil	–	Nil	–
M8*	212	Mar 1998	Nil	164	Apr 1997	39	>1800	–	120	+
M9**	207	Mar 1998	Nil	99	Dec 1997	55	>2300	+	180	–
M12**	144	Aug 1997	89	92	Oct 1997	312	>1800	+	160	+
M14**	202	Aug 1997	89	101	Sept 1997	217	>1800	+	180	+
M17**	76	Mar 1998	Nil	36	Sept 1997	217	>2300	+	160	+

* Borewell; ** open well; + presence of *E. coli*; – absence of *E. coli*; bacteriological concentrations refer to the months of extreme nitrate levels.

bacterial contamination of groundwater at the sites studied. As indicated in Table 2, thirteen samples showed positive results (i.e. presence of *E. coli*) under the Differential Coliform (DC) test. Most Probable Number (MPN) per 100 ml of water varied from 130 to over 2300 and between 20 to 180 during the monsoon and summer seasons respectively. Bacterial contamination is high during the monsoon season and water characteristics are almost similar to the septic effluent characteristics at times.

CONCLUSIONS

It is evident from the findings that the causes and sources of water pollution in the study area are due to on-site waste disposal systems (human activities, cattle sheds, agricultural land uses and other waste disposal activities). The results presented here show that nitrate and microbiological contamination in groundwaters in the vicinity of septic tanks and a sewage treatment works are of concern. Measures to minimize and/or to eliminate such contamination should be adopted in areas of potentially high beneficial use, so that groundwater aquifers are protected. This may include changing traditional practices of wastewater disposal from conventional septic tanks to more

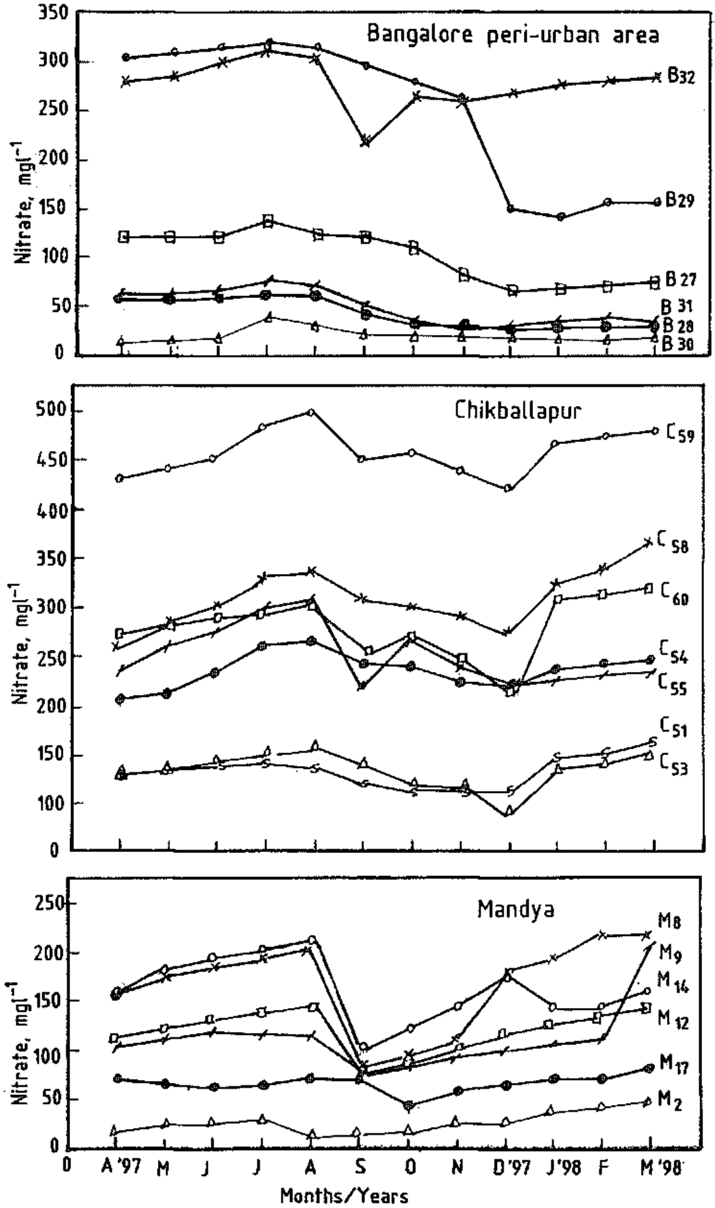

Fig. 2 Variation of nitrate content in well waters of the study sites between April 1997 and March 1998.

environmentally friendly designs, or alternatively increasing the number of blocks/wards that are sewered together in order to improve final effluent quality. Appropriate legislation on specifications, siting, design, education, construction and maintenance of septic tank systems is needed. It is also likely that if more deep-rooted vegetation such as shrubs and trees could be introduce into the areas, the situation could also be improved.

Acknowledgements The research work was funded by the Rajiv Gandhi National Drinking Water Mission, Government of India, New Delhi. The authors also thank the chemists of Zuari Agro Chemicals Laboratory, Bangalore and officials of the State Pollution Control Board Laboratory, Bangalore for their help with soil and water analysis.

REFERENCES

APHA (1995) *Standard Methods For The Examination Of Water And Wastewater* (nineteenth edn). APHA, Washington DC, USA.

Jiwan, S. J. & Gates, G. (1998) Microbiological contamination of groundwater in New South Wales, Australia. In: *Proc. Int. Groundwater Conference, University of Melbourne, Australia* (ed. by T. R. Weaver & C. R. Lawrence), 473–478. IAH, Australia.

Keswick, B. H. & Gerba, C. P. (1980) Viruses in groundwater. *Environ. Sci. Tech.* **14**, 1290–1297.

Kostraba, J. N., Gay, E. C., Rewers, I., Siddiqui, M. & Hamman, R. F. (1992) Nitrate level in community drinking waters and risk of IDDM. *Diabetes Care* **15**, 505–508.

Lewis, J. W., Foster, S. S. D. & Drasar, B. S. (1978) *The Risk Of Groundwater Pollution by On-Site Sanitation in Developing Countries: A Literature Review.* BGS Monograph, British Geological Society, London.

Miller, D. W. & Scalf, M. R. (1974) New priorities for groundwater quality protection. In: *Proc. Second Nat. Groundwater Quality Symp., Denver, Colorado, USA*, 7–19.

Ramaraju, H. K., Manamohan Rao, N., Venkatachalappa, M. & Ranganna, G. (1999) Bacteriological contamination of groundwater in per-urban areas (Mandya town). In: *Proc. INDO-US Workshop on Applications of Biotechnology for Clean Environment and Energy*. Bangalore University, India (in press).

Siddiqui, M., Kumar, R., Haldar, B. S., Fazali, Z. & Preussmann, R. (1992) Increased exposure to dietary amines and nitrate in a population at high risk of oesophageal and gastric cancer in Kashmir (India). *Carcinogenesis* **13**, 1331–1333.