Applied Geography (1984), *4*, 247–254

Impact of different surface sources of pollution on the quality of ground water in Madurai, India

Anandavalli Mahadevan
School of Energy, Environment and Natural Resources, Madurai Kamaraj University, Madurai 625 021, India

and **S. Krishnaswamy**
School of Biological Sciences, Madurai Kamaraj University, Madurai 625 021, India

Abstract

Seepage of pollutants from surface and subsurface sources of pollution are known to occur. Here the effect of the type, number and the proximity of the visible surface sources of pollution on the extent and degree of pollution in the neighbouring water sources is investigated. In Madurai the pollution loadings are more or less continuous and hence there is no possibility of reducing pollution levels.

Introduction

Horizontal and lateral seepage of pollutants from surface and subsurface sources of pollution are known to occur (Reneau and Pettry 1975; Sherril 1975). Consequently, any programme to evaluate or protect groundwater quality must focus initially on measurements of specific details relating to sources and causes of pollution (Todd *et al.* 1976). Very few reports relating the sources of pollution to the extent of its influence on the quality of groundwater are available in India, though it has been argued that the presence of refuse dumps and sewage stabilization ponds is responsible for groundwater pollution (Olaniya and Saxena 1977; Olaniya *et al.* 1978).

In this study the extent of the effect of three factors – namely, the type of sources of pollution, the number of sources of pollution and the proximity of the polluting sources – on the extent and degree of pollution of the groundwaters was investigated in Madurai, South India. Here the Most Probable Number (MPN) of coliforms was taken as an index of the extent of pollution. Wells that have coliform counts exceeding the WHO (1971) standards were considered to be polluted.

Study area and the need for research

Madurai city is the second largest and most densely populated city of South India. Public water supply is abstracted from the River Vaigai though the supply is highly inadequate. There are thus 870 bore-wells installed throughout the city by the Corporation of Madurai to compensate for the inadequacy of the treated water supply. Apart from these, there are numerous private open wells that are being used. The bore-wells are in continuous operation and contribute significantly to the public water supply. The yield from ten bore-wells was found to be $4\text{-}5 \times 10^6$ l day^{-1} (Shivakumar and Ramamoorthy 1977).

Groundwater in Madurai district is assessed to occur at shallow depth ranging from 2 to 12 m below the ground level; especially in the alluvial aquifer of the River Vaigai valley the water table occurs nearer to the surface level (i.e. 2–4 m below ground level; Santhakumari 1980).

The provision of sewerage treatment and disposal facilities continues to remain a programme of low priority here (CUPS/1/1978–79). Only around 30 per cent of the city is provided with sewerage facilities. As a result, indiscriminate defecation of solid wastes occurs, and stagnant waste water pools and open drainages carrying waste water are commonly adopted for waste disposal. Because of the high population density, waste disposal often occurs close to water sources and considerable pollution pressures are exerted on the bore-wells. As these bore-wells are vital for the continuous supply of water to the public, and the water is not treated, it is imperative to study the effects of the different surface sources of pollution on the quality of the water obtained.

Methods

Of the 870 hand-operated bore-wells in Madurai, 184 bore-wells and 13 open wells were selected at random for this study.

The presence or absence of a paved platform around the well was noted. An area of 50-m radius around the well was surveyed for possible sources of pollution such as open drainage, solid waste dumping grounds, septic tanks, stagnant pools nearby, defecation and animal waste dumping. The distance of the well from the polluting source was then measured and the nature of the possible pollutant was identified.

The bore-wells were operated for ten minutes before collecting the samples so as to ensure that the samples represented the actual groundwater. Each well was sampled twice, the second sample being taken after a period of six months. Because Madurai is in a tropical region, the temperature and climatic conditions do not fluctuate widely. The sample was analysed within four hours of collection.

Present regulations use coliform organisms as an indicator of sewage contamination. The coliform group of bacteria includes all organisms that are gram negative, non-spore-forming rods which ferment lactose and occur in large numbers in the large intestine of warm-blooded organisms (Tate and Trussel 1977). The Most Probable Number (MPN) of coliforms was therefore computed in the collected samples by the multiple tube fermentation technique (APHA 1965).

Results and discussion

It can be seen from Table 1 that 10 per cent of the wells had no visible sources of pollution within a radius of 30 m. Some wells, however, were found to have more than one polluting source, the maximum number observed being three. 15·7 per cent of the wells had three sources of pollution (Table 2).

Type of sources of pollution

Groundwater pollution and bacterial contamination are known to be associated with many different sources: septic tank effluents (Jordan 1976), disposal of waste water (Sherril 1975; Johnson and Urie 1976) and landfill leachates (Goltzbecker and Novello 1975), leaks from sewers and sewage treatment plants (Schmidt 1975), urban runoff (McPherson 1973), man-induced faecal contamination (Doehring and

Table 1. Sanitary survey showing the distribution of the proximity of polluting sources

Proximity (distance in m from the nearest polluting source)	No. of wells (Total 197)	Percentage of wells
<1	71	36·0
1–5	40	20·3
5–10	40	20·3
10–20	13	6·6
20–30	13	6·6
>30	20	10·2

Table 2. Sanitary survey showing the distribution of the number of polluting sources

Number of visible sources of pollution (within 30-m radius)	No. of wells (Total 197)	Percentage of wells
Nil	20	10·2
1	84	42·6
2	62	31·5
3	31	15·7

Butler 1974), cesspool discharge (Smith and Myott 1975), refuse dumps (Olaniya and Saxena 1977) and sewage farms (Olaniya *et al.* 1978). No information is available, however, on the differential effects of pollution by the different types of sources of pollution.

In this study is was found that the different types of sources of pollution seem to affect the extent and the degree of pollution in the neighbouring water sources (Fig. 1). For uniformity the wells with one polluting source within a distance of 10 m were considered for this analysis. The highest percentage of wells (i.e. 76·8 per cent) were polluted when an open drain was nearby, while only 62·4 per cent of wells were polluted when located near a pool of stagnant waste water and just 32·3 per cent when a garbage dump was nearby. The highest average coliform count of 8000 coliforms 100 ml^{-1} was seen in the wells adjacent to an open drain, while the lowest average count of 98·4 coliforms 100 ml^{-1} occurred in the case of wells with a nearby garbage dump (Fig. 1). This can be due to two reasons. Firstly, an open drain may be the most potent polluting source because it carries all the domestic waste water, including raw sewage. Secondly, the amount of waste water in an open drain is subject to less fluctuation than garbage and stagnant water which are liable to be removed by the city corporation and evaporation respectively.

Number of sources of pollution

As the number of polluting sources near each well increases the percentage of polluted wells, as well as the MPN of coliforms, tends to increase. For example, when the wells had no polluting source within a 30-m radius, only 42 per cent of wells were polluted while all the wells which were affected by three polluting sources were polluted (Fig. 2). With an increased number of polluting sources, the pollution load tends to increase, as reflected in the higher level of pollution in the

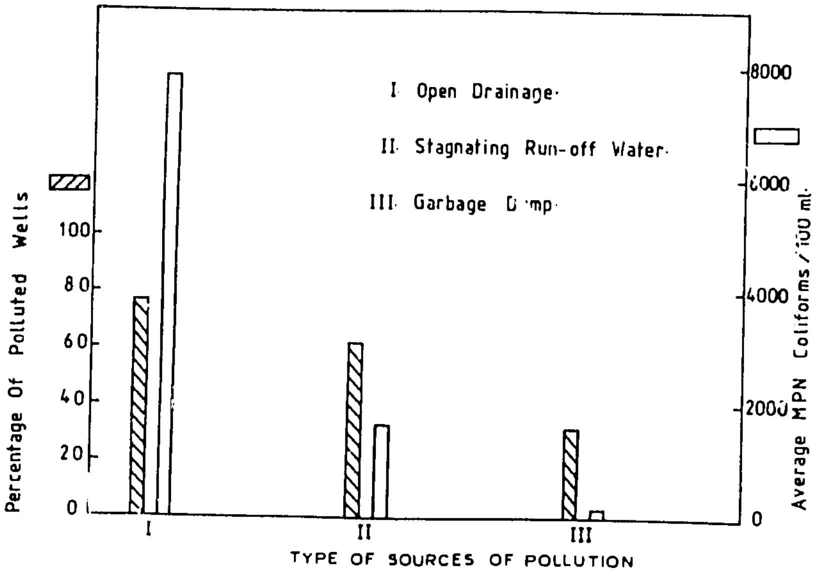

Figure 1. Effect of the type of source of pollution on the extent and degree of pollution of the wells.

wells (Fig. 2). Nevertheless, wells with two sources of pollution showed no significant increase either in percentage of wells polluted or in average MPN of coliforms when compared to the wells with one polluting source. This discrepancy could be attributed to the fact that open drains were shown to be the most potent source of pollution. A higher percentage (i.e. 67 per cent) of the wells with one polluting source had open drains as their source of pollution, while only 40 per cent of the wells with two polluting sources had open drains as one of the polluting sources.

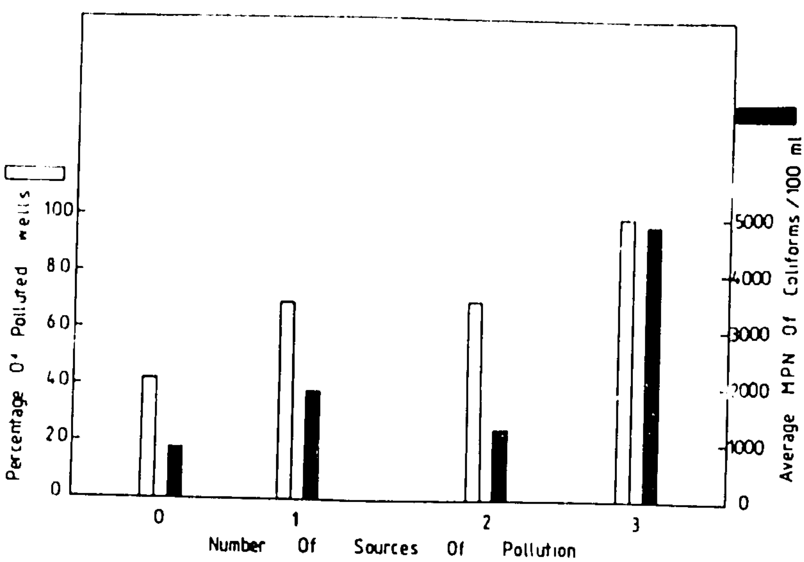

Figure 2. Effect of the number of sources of pollution on the extent and degree of pollution of the wells.

However, as already mentioned, 42 per cent of the wells, which have no visible source of pollution within a 30-m radius were also found to be polluted. This can be attributed to subsurface sources of pollution such as sewer leakages (Schmidt 1975). Pollution may also be caused by the tendency of some inhabitants to prime wells with waste water, and by contamination from the hands of well users (Snow 1855).

Proximity of sources of pollution

As the proximity of the source of pollution increases, the percentage of polluted wells increases significantly (Fig. 3). Of the wells which had a polluting source at a distance of 0·5 m, 84·2 were found to be polluted. The MPN of coliforms also decreased significantly with the increase of the distance from the polluting source (Fig. 4). For uniformity, the wells with an open drain as the only polluting source within a distance of 50 m were considered for this analysis. These wells were chosen because, as mentioned earlier, the open drain forms the most potent and common among the different sources of pollution due to the poor sewerage facilities available in Madurai. Statistically a negative product moment correlation coefficient (r) of $-0{\cdot}930$ was obtained between the logarithm of the distance of open drain from the well and the logarithm of MPN of coliforms, significant at the 99 per cent confidence level (degrees of freedom = 47). A regression equation of the form $Y = 3{\cdot}2957 - 1{\cdot}3744X$ was also derived, where X is the log. of the distance of the well from the source of pollution and Y is the log. of MPN of coliforms.

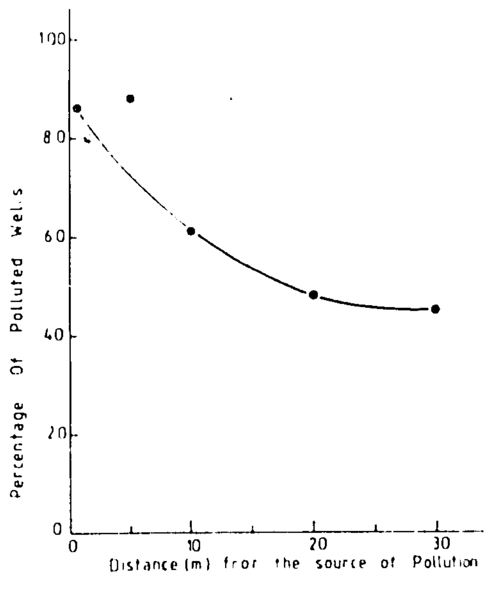

Figure 3. Effect of the proximity of the source of pollution on the extent of pollution.

The frequency distribution of wells with different MPN of coliforms varies as the proximity of the polluting source varies (Fig. 5). A higher percentage of wells tends to have low MPN of coliforms as the polluting source recedes from the vicinity of the well. This reflects the tendency of bacterial indicators to decrease significantly with horizontal distance (Reneau and Pettry 1975).

Natural purification of groundwaters is also evident from these observations. Any one of the factors such as the presence of a paved platform, a paved open

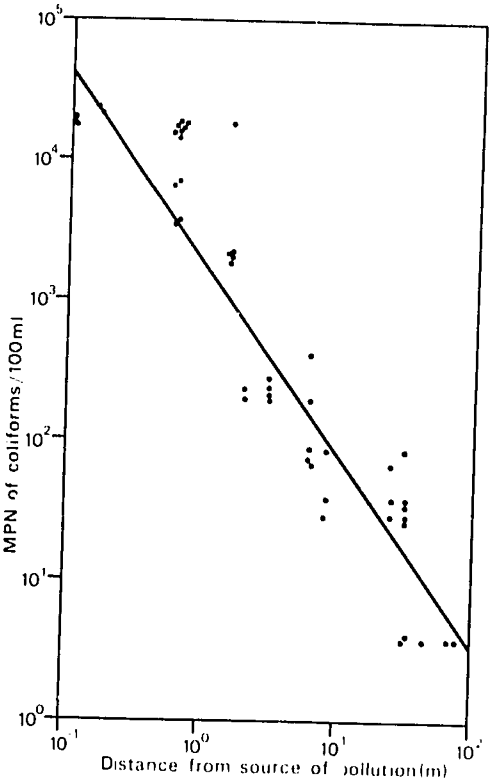

Figure 4. Effect of the proximity of the source of pollution on the degree of pollution (degrees of freedom = 93).

drainage, a dry garbage pit or increased depth of the well may account for the unpolluted nature of the rest of the bore-wells. Since all the waste water must pass through the vertical and horizontal layers of soil, purification occurs due to filtration, removing a significant amount of suspended matter including bacteria (Nichols 1955).

A travel distance of 30 m is found to be sufficient to reduce the pollution by 50 per cent. However, in Madurai the main sources of pollution are waste disposal sites and these are distributed more-or-less continuously. Natural purification only occurs to any extent in unsaturated soils (Viraraghavan and Warnock 1976), so it

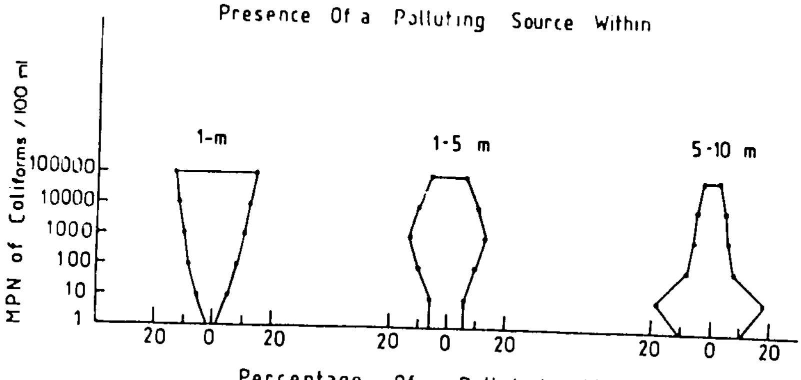

Figure 5. Distribution of coliforms in well waters with the sources of pollution at different distances.

6

might be expected that there is little opportunity for reducing further the levels of pollution. This is because the capability of soil filtration to remove bacteria tends to decline with increased duration of loading of pollution (Smith and Baver 1969). Also the coliforms in the solid waste leachates may survive from hours to months depending upon temperature and leachate quality (Blannon and Peterson 1974; Goltzbecker and Novello 1975).

Moreover, most of the observed wells were shallow (Madurai Corporation 1979) and shallow wells are more prone to contamination because the distance travelled by the surface water and waste water through the soil is insufficient to filter out the bacteria and other contaminants (Purdon 1971; Reneau and Pettry 1975; Viraraghavan and Warnock 1976).

The presence of a paved platform around the wells offers protection against the seepage of waste water and urban runoff that would otherwise accumulate around the well. It was found that all the wells without a platform were polluted (i.e. positive for faecal coliforms) whereas only 64 per cent of the wells with a protective platform show indications of pollution.

Sanitation and quality

India is a developing country where environmental hygiene and sanitation are poor. Most of the people defecate on the river banks, fields and waste ground. Hand- or cistern-flushed latrines connected to open drains, as well as septic tanks and cesspits, are also prevalent in many areas. Madurai city is only partially sewered, more than 70 per cent of its area lacking sewerage facilities. Similar low levels of groundwater quality are seen in other parts of the country also in Delhi (Kaushik *et al.* 1963; Phirke *et al.* 1969), Bhopal (Aboo *et al.* 1968; Sastry *et al.* 1969), Jaipur (Olaniya *et al.* 1969), Ajmer (Bhargava *et al.* 1978) and Nagpur (Pande *et al.* 1979), all of which are characterized by partial sewerage facilities and poor sanitation. Thus the problems of water quality noted in Madurai are likely to be typical of conditions prevailing in many other Indian towns.

References

Aboo, K. M., Sastry, C. A. and Alex, P. G. (1968) Study of well waters in Bhopal city. *Environmental Health 10*, 189.

Allen, M. J. and Geldreich, E. E. (1975) Bacteriological criteria for goundwater quality. *Groundwater 13*, 45.

Anandavalli, A. (1980) *Biological and physio-chemical indicators of polluted waters in and around Madurai*. Unpublished PhD thesis, Madurai Kamaraj University.

APHA (1963) *Standard methods for the examination of water and waste water. APHA, AWWA, WPCF*. 12th ed. New York: American Public Health Association.

Bhargava, R. K., Saxena, S. C. and Thergaonkar, V. P. (1978) Groundwater quality in Ajmer district. *Indian Journal of Environmental Health 20*, 290.

Blannon, J. C. and Peterson, M. L. (1974) Survival of fecal coliforms and fecal streptococci in a sanitary landfill. Solid and hazardous waste research news: April 12, Environmental research in Cincinnati: US Environmental Protection Agency.

CUPS/1/1978 1979. *Control of Urban Pollution Series*. Union Territory of Delhi (abridged). New Delhi: Central Board for the Prevention of Control of Water pollution.

Doehring, D. O. and Butler, J. H. (1974) Hydrogeologic constraints of Yucantons development. *Science 186*, 591.

Goltzbecker, R. A. and Novello, A. L. (1975) Poliovirus and bacterial indicators of fecal pollution in landfill leachates. *News of Environmental Research in Cincinnati*, EPA I.

Johnson, N. and Urie, D. H. (1976) Groundwater pollution aspects of land disposal of sewage from remote recreation areas. *Groundwater 14*, 403.

Jordon, D. G. (1976) Groundwater contamination in Indiana. *Journal of the American Waterworks Association 54*, 1213.

Kaushik, N. K., Prasad, D. and Bishnoi, C. N. (1963) A study of well waters in rural Delhi. *Environmental Health 5*, 128.

Madurai Corporation (1979) *Reports*. Madurai: Madurai Corporation.

McPherson, M. B. (1973) *Urban runoff*. American Society of Civil Engineers, Urban Water Resources Research Programme, Memo No. 181972.

Nichols, M. S. (1955) Quality of natural waters. In *Public water supplies – requirements, resources and the construction of works* (F. E. Turneasure and H. L. Russell, eds). New York: Wiley.

Olaniya, M. S. and Saxena, K. L. (1977) Groundwater pollution by open refuse dumps at Jaipur. *Indian Journal of Environmental Health 19*, 176.

Olaniya, M. S., Saxena, K. L., Dutta, N. and Bhargava, R. K. (1969) Well water quality in Jaipur City. *Environmental Health 11*, 378.

Olaniya, M. S., Nawlakhe, W. G., Sharma, H. C. and Saxena, K. L. (1978) Pollution studies of well waters in sewage farms at Jaipur. *Indian Journal of Environmental Health 20*, 398.

Pande, S. P., Narayanaswamy, V. S. and Hasan, M. Z. (1979) Quality of well waters of Nagpur with regard to Nitrates, Nitrites (Phase I). *Indian Journal of Environmental Health 21*, 25.

Phirke, P. M., Balasubramaniyan, R. and Verma, S. R. (1969) Studies on the quality of hand pump water in Delhi. *Environmental Health 11*, 323.

Purdon, W. (ed.) (1971) *Environment and Health*. New Delhi: Academic Press.

Reneau, R. B. and Pettry, E. D. (1975) Movement of coliform bacteria from septic tank effluent through selected coastal plain soils of Virginia. *Journal of Environmental Quality 4*, 41.

Santhakumari, A. (1980) A study of water resource potential of Madurai district. In *Proceedings of the Symposium on water resources of southern states*. Madurai: Madurai Kamaraj University.

Sastry, C. A., Aboo, K. M. and Rao, M. N. (1969) Incidence of coliforms and enterococci in natural waters. *Environmental Health 11*, 32.

Schmidt, K. D. (1975) Regional sewering and groundwater quality in the southern san Jaoquin valley. *Water Resources Bulletin 11*, 514.

Sherril, M. G. (1975) Groundwater contamination in the Silurian Dolomite of Door country (Wisconsin). *Groundwater 13*, 209.

Shivakumar, M. and Ramamoorthy, M. V. (1977) Quality of well waters in Madurai. *Indian Journal of Environmental Health 19*, 199.

Smith, S. O. and Baver, J. H. (1969) Report on nitrate pollution of ground water, Nassau country, Long Island. In *Bulletin of Water Resources*. Moneola, N.Y.: Nassau Country, Department of Health.

Smith, S. O. and Myott, D. H. (1975) Effect of cesspool discharge on ground water quality in Long Island, N.Y. *Journal of the American Waterworks Association 67*, 456.

Snow, J. (1855) In *On the mode of communication of cholera*. London: John Churchill.

Tate, C. H. and Trussel, R. R. (1977) Developing drinking water standards. *Journal of the American Waterworks Association 69*, 486.

Todd, D. K., Tinlin, R. M., Schmidt, K. D. and Everett, L. G. (1976) A groundwater quality monitoring methodology. *Journal of the American Waterworks Association 68*, 586.

Viraraghavan, T. and Warnock, G. (1976) Groundwater quality adjacent to a septic tank system. *Journal of the American Waterworks Association 68*, 611.

WHO (1971) *International standards for drinking water*, 2nd ed. Geneva: World Health Organisation.

(*Revised manuscript received 31 October 1983*)