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WATER, SANITATION, ENVIRONMENT and DEVELOPMENT

Nitrate pollution of groundwater sources at Oyarifa

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Introduction

An integrated community development programme comprising sufficient and safe water supply and sanitary facilities are necessary for ensuring an improvement in health conditions and living standards in rural communities.

Groundwater is the most cost-effective source of water supply in the rural areas and is exploited through the use of hand dug wells or boreholes depending on the depth at which it occurs. Though this source if properly developed and utilized, is generally safe for human consumption, natural or artificial contaminants in the water could seriously hamper its use. The main contaminants of concern include high salinity, excess iron and high nitrate levels. Whereas the first two are essentially naturally induced, nitrate contamination in groundwater is invariably caused by man's interference with the environment.

Oyarifa is a village in the Greater Accra region with a population of about 2000 persons (refer to Fig.1). The village had no reliable source of water supply and the situation was particularly critical during the dry seasons.

Two ponds were constructed to store storm runoff for domestic use but due to their poor quality the villagers are constrained to walk a distance of about 2km to fetch water from an abandoned quarry. Also, a hand dug well constructed under a UNICEF/GWSC assisted programme had not helped to alleviate the water problems facing the community because of poor water quality.

In consequence, the Water Resources Research Institute was contracted to provide a borehole fitted with a handpump for the Community in July 1992. The borehole was drilled to a depth of 64m in phyllite and yielded 5 litres per minute during air-lift (refer to Fig.1); the static water level was 4.8m.

Chemical analysis

Samples collected from the borehole source were analysed for chemical quality. Although most of the chemical parameters were within WHO limits the results revealed a serious nitrate-nitrogen problem in the order of 80 mg/l which is far in excess of the 10mg/l guideline value given by the World Health Organisation (WHO,1984) for potable purposes. Nitrate in water is of health significance since it is toxic when present in excessive amounts and it has been reported to cause methaemoglobinaemia in bottle-fed infants in some cases. For older age groups this problem does not arise but there is a possibility that certain forms of cancer might be associated with high nitrate concentrations.

Initial inferences were that the nitrate pollution was due to two unlined pit latrines, one located 200m south of the borehole and the other 150m to the north. Each pit latrine is located adjacent to one of the ponds in the village. In order to investigate the extent of the nitrate problem water samples were again collected from the borehole, hand dug well, two ponds and the quarry for chemical analysis. The results of chemical analysis for the 5 samples are given in Table 1.

Although the surface water sources showed low nitrate level, high levels were shown by the borehole and hand dug well. A preliminary explanation was that there was a single source of nitrate pollution, possibly the pit latrine adjacent to Pond I which was affecting the two sources. The intense plant activity observed through the excessive green colouration in the ponds suggest high intake of nutrients by the plants; leading to the low levels of nitrate in the surface water sources.

Geologic model and groundwater occurrence

The area falls within the Dahomeyan-Togo contact zone with granitic gneisses overlying phyllite or foliated schist. The overburden consists of lateritic clay and sandy clay. Existing borehole records reveal groundwater occurrence at the weathered rock and bedrock interface and in fractures in the bedrock.

The 64m deep borehole at Oyarifa intercepted a water zone at a depth of 53-54m in phyllite (refer to Fig.2). The borehole log shows the lithologic sequence; the interface between weathered rock and gneiss as well as the interface between gneiss and phyllite were dry.

The hand dug well is fed by a shallow unconfined overburden aquifer localised around Pond I. The overburden around the borehole was however dry. Site reconnaissance also revealed a topographic high between the borehole and hand dug well; this would provide a groundwater divide for at least the shallow unconfined flow system, ensuring that the flow around the hand dug well was in a direction away from the borehole. Considering the location of Pond I in an upper slope area underlain by shallow gneiss bedrock, there should have been good yielding

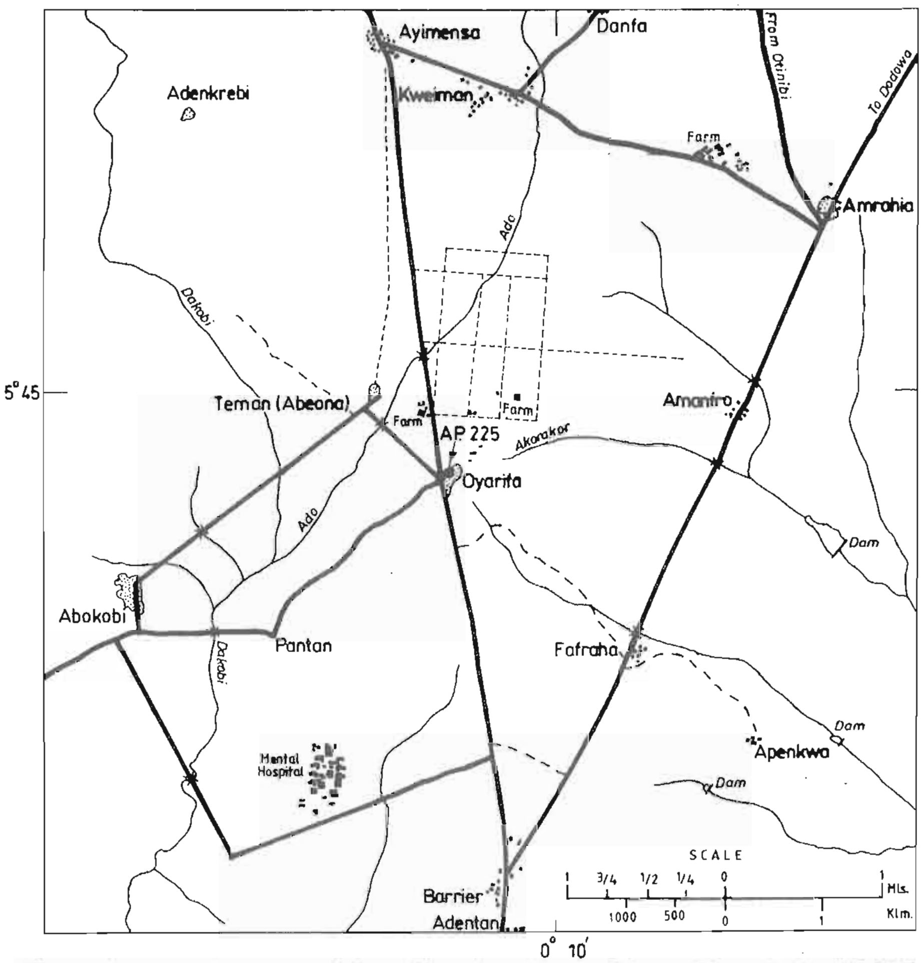

Figure 1. Location map of Oyarifa - showing position of borehole AP.225

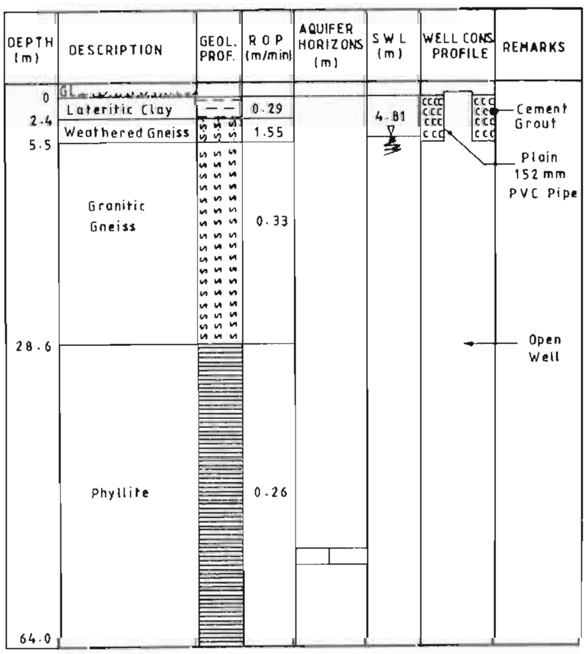

Figure 2. Borehole log of AP.225

fracture aquifers in the bedrock assuming it was sufficiently tectonised. This was not the case however.

Furthermore, the existence of hydraulic communication between the shallow unconfined groundwater flow system and the confined flow system in phyllite would have to be via fractures in the gneiss, ensuring that the gneiss-phyllite interface yielded some water to the borehole. This would have confirmed preliminary explanation of the nitrate pollution problem.

Since the gneiss-phyllite interface was dry, possibly indicating that there is no hydraulic communication as postulated above, it is suggested that the source of nitrate pollution in the borehole is different from that in the hand dug well. This implies a dual nitrate problem comprising a point source of pollution from the pit latrine in the water-bearing overburden and a larger scale diffuse source from an agricultural source. This postulation is partially borne out by the reported use of chemical fertilizer in a nearby farm complex in an area which is underlain mainly by phyllite (Fig. 1).

In contrast, chemical analyses of samples obtained from several boreholes in the granitic gneiss area gave acceptably low nitrate levels.

Conclusion

Results of chemical analysis of groundwater samples obtained from a new borehole and an existing hand dug well have revealed a serious nitrate pollution problem at Oyarifa.

The initial indications were that the nitrate pollution was due to a pit latrine. However, an evaluation of the geologic structure showed that the two groundwater sources were fed by separate flow systems.

It has therefore been suggested that there is a dual nitrate problem comprising a point source from the pit latrine and a diffuse agricultural source.

Despite the problem, controlled use of the borehole source for adults is possible provided a continuous monitoring of nitrate levels is carried out. The best option for improving the quality of the hand dug well source is to relocate the pit latrine.

The experience at Oyarifa confirms the need for a comprehensive investigation of such problems in the rural environment to ensure that large-scale problem sources are not masked.

References

1. Hiscock K.M., Lloyd J.W., Lerner D.N. and Carey M.A. (1989). An Engineering Solution to the Nitrate problem of a Borehole at Swaffham, Norfolk, U.K, Journal of Hydrology, 107, pp. 207-281, Elsevier.
2. Soil Survey and Land Research Centre, Cranfield (1987). Groundwater Vulnerability, Map 6 Mansfield, Severn-Trent Water.
3. Water Resources Research Institute (1992). Report on Groundwater Exploration at Oyarifa village, Ghana Organic Agricultural project, July 1992.
4. World Health Organisation (1984). Guidelines for Drinking-water Quality, Vol.1, Recommendations, WHO, Geneva.

Table 1.
Nitrate levels in water sources

Source	*Nitrate-nitrogen (mg/l)*
Borehole	84.6
Hand dug well	118.5
Pond 1	1.7
Pond 2	< 0.01
Quarry	1.5