The Impact of Plastic Materials on Iron Levels in Village Groundwater Supplies in Malawi

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ABSTRACT

IRON IS NOT NORMALLY CONSIDERED to be a constituent of health significance, and recommended limits for iron in drinking water supplies are based on aesthetic considerations. Experience in Malawi has demonstrated that, even when present in only trace amounts, iron can influence the consumer's acceptance of an improved borehole supply. The effect of the use of plastic construction materials on the iron content of village groundwater supplies was investigated using a statistical approach. The majority of groundwater points using only plastic materials was found to supply water containing less than the WHO guideline value of 0.3 mg/l iron. In contrast, the use of ferrous materials increased the iron content of the water to unacceptable levels, sometimes causing the consumers to reject the borehole as a source of drinking water.

Bacteriological data show that the quality of the alternative, traditional supply is far inferior to the new improved supply. An otherwise perfectly safe supply may therefore be abandoned as a direct result of contamination introduced by 'down the hole' components. This frustrates efforts to improve the well-being of rural communities, and is a waste of precious development resources.

Key words: Iron; groundwater; plastic materials; bacteriological quality; rural water supplies; developing countries.

INTRODUCTION

Malawi is a small land-locked country, occupying the southernmost part of the East African Rift Valley. Farming is the basis of the country's economy, and only 8 per cent of the people live in towns. For a rural country Malawi is densely populated, with an estimated 1985 population of 7.06 million (75 per sq. km), and it is estimated that this population will double in the next 20 years. One of the prime objectives of the *International Drinking Water Supply and Sanitation Decade* is to give people access to a safe drinking water supply within a reasonable walking distance of their homes and, since independence in 1966, Malawi has made commendable progress towards achieving this goal.

The main supply sources are rural gravity-fed piped water schemes, protected boreholes and dug-wells fitted with handpumps. The piped-water schemes cover a defined area by a network of pipes, drawing untreated water mostly from protected forest catchments. The country has 47 schemes serving about 1.2 million people from about 8 500 taps, each tap serving 136–160 people with a maximum walking distance of 500 m at a design capacity of 36 l/hd/day. In 1985 the country as a whole had 5 100 boreholes and 3 200 wells serving an estimated population of 1.7 million.

WATER QUALITY CONSIDERATIONS AND IMPLICATIONS FOR SOURCE ACCEPTABILITY

Outside the towns and larger population centres, treatment of drinking water is considered to be unaffordable, and in many areas of the country a groundwater supply is often the only viable solution. Despite the fact that in rural areas sanitation is almost exclusively dependent upon pit latrines, the microbiological quality of groundwater is normally good. The overlying soils and unconsolidated strata are an effective pollution barrier, having the ability to remove faecal microorganisms from waste water percolating to the underlying aquifer. The unsaturated zone is the most important line of defence against pollution, and this defence makes possible the close association of groundwater-supply sources and pit latrines in a rural environment. A review of the literature concerning the risk of groundwater pollution by on-site sanitation in developing countries[1] showed that there was little risk of contamination, provided that there was a minimum of 2 m of relatively fine (<1 mm) continuous unsaturated soil (unconsolidated strata) between the water table and the base of any pit latrine. However, groundwater pollution is likely in areas where the water table is shallow and where fissured bedrock is overlain by shallow soils. Poor attention to sanitary construction will allow contaminants to by-pass this

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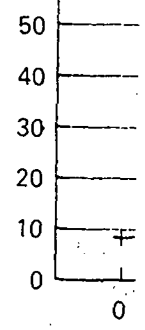

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protective barrier, resulting in water of unacceptable quality[2].

The superior water quality delivered by improved groundwater supplies is demonstrated in Fig. 1, which summarizes the microbiological data from over 300 boreholes and 60 unprotected dug-wells collected by the staff of the Central Water Laboratory from 1984 to 1987. About 60 per cent of boreholes can supply water complying with the World Health Organization guideline value of zero faecal coliform (FC) in a 100-ml volume of water[3]. Setting a more realistic guideline for untreated water of 25 FC/100 ml, around 97 per cent of boreholes will meet this criterion, whilst only 15 per cent of unprotected wells can achieve the same standard. Almost 20 per cent of the wells were found to contain in excess of 500 FC/100 ml. The risk of waterborne diseases to people consuming water of this quality is self-evident.

Water is considered to be safe to drink when it is free from harmful contaminants and chemicals. In assessing the quality of drinking water, however, the consumer relies completely upon his senses. Water constituents may affect its appearance, smell or taste, and the consumer will evaluate the quality and acceptability essentially on these criteria. The absence of any adverse sensory effects does not guarantee the safety of the water for drinking. Authorities on water quality matters are unanimous that the microbiological quality is of pre-eminent importance, and this must never be compromised to provide aesthetically pleasing and acceptable water.

Field observations in Malawi have shown that, irrespective of the microbiological quality, the rural consumer will often reject an improved supply if the water does not taste satisfactory, especially when there is an alternative source nearby. These alternative water sources are usually traditional unprotected water supplies, typically shallow wells or rivers and streams which are invariably polluted with contaminants of faecal origin. A frequent cause for rejection of borehole supplies has been the presence of objectionable quantities of iron in the water. Iron, when present in quantities above 1 mg/l, imparts a bitter taste to the water. The borehole may be used for other domestic purposes, but the traditional water source is still used for all drinking water supplies, thus frustrating the efforts of government to improve the wellbeing of rural communities, and is a waste of precious development resources.

USE OF PLASTICS IN BOREHOLE CONSTRUCTION

In 1980, the Department of Water embarked upon an accelerated rural groundwater supply programme. The significant difference between this

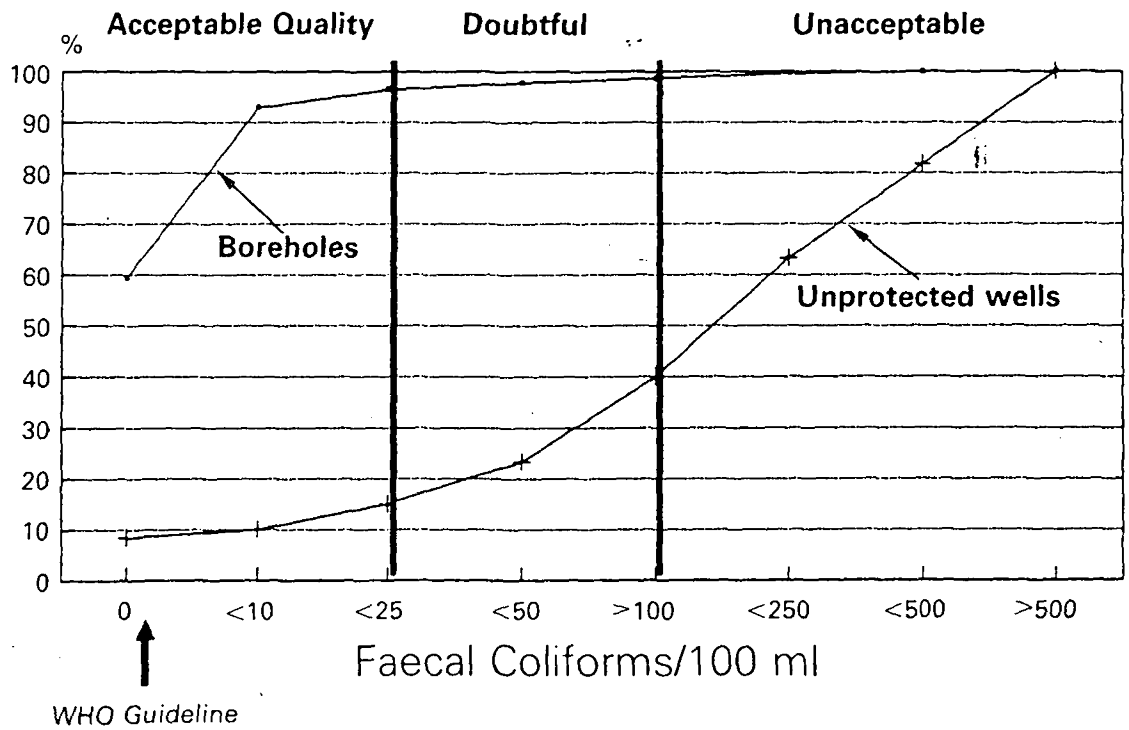


Fig. 1. Comparison of bacteriological quality of boreholes and unprotected wells

programme and earlier efforts was two-fold: (i) a parallel programme alongside the dispersed borehole programme, which concentrated provision of water points in specific areas, thereby greatly reducing transport costs, and (ii) a departure from using mild-steel borehole casing in favour of plastic. The use of plastic material as borehole casing and screen has been an established construction practice for some time, and has been rapidly gaining wider acceptance in developing countries in the last few years, particularly with uPVC.

In the rural water supply programme in Malawi, uPVC has been used extensively and for many years in the gravity-fed piped-water projects, and its adoption by the groundwater programme followed logically.

Since its introduction to the borehole programme in 1980, more than 500 boreholes have been completed with locally-produced uPVC casing and screen. The use of plastics and other polymer materials as pump components, cylinders, rods and rising main for boreholes is not so well established. Recent developments in handpump technology suggest that the use of plastics will become much more widespread in the future. Several recently-developed and now commercially-available handpumps make extensive use of plastics for the below-ground components, and current prototype development work being carried out by the UNDP/World Bank Rural Water Supply Project may lead to even greater use of such components[4]. The assessment of the impact of the use of plastic on iron levels and hence source acceptability is thus timely.

LIVULEZI INTEGRATED GROUNDWATER PROJECT

The Livulezi Integrated Groundwater Project was chosen as a study area. The project area is located in Ntcheu District and occupies about 200 km^2 north-east of Ntcheu town. It is bounded by the foot slopes of the Kirk mountain range in the west and the scarp zone of the Bilila fault in the east. The valley is a down-faulted part of the Central African plateau, composed of Precambrian crystalline basement rocks (Fig. 2). The weathered profile of these rocks provides a thin but extensive and continuous aquifer, which is of great importance as a source of village water supplies[5].

The project area proved to be an ideal testing ground to study the impact of plastic components on iron levels in the groundwater, due to the intermix of construction materials used for the various water points throughout the project area. These can be categorized as follows:

- *(a)* APC – All-plastic construction; plastic casing, rising main and pump components.
- *(b)* PCIM – Mixed uPVC/iron construction; plastic casing and galvanized iron rising main and pump rods.
- *(c)* AIC – All iron construction; mild-steel casing and galvanized-iron rising main and pump rods.

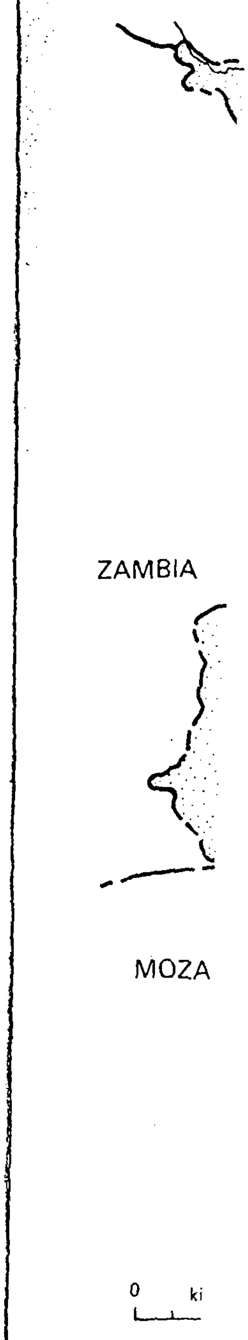
Over a four-month period, 33 wells and 13 boreholes of type APC, 111 boreholes of type PCIM, and 9 old boreholes of type AIC were sampled and tested for major, minor and some trace constituents. Standard methods of analysis were used for the determination of total iron[6]. The water point was pumped for a minimum of 5 mins before sampling but, in practice, all the water points are used heavily by the villagers and it is unlikely that a non-representative sample was taken. Two 1-l samples were collected in plastic bottles, and the portion used for determination of metals was filtered through a 0.45-μ membrane filter and acidified in the field. The chemical analytical data, together with details of sample location, source identity, type and construction, were fed into the computer data-base for subsequent analysis.

DISCUSSION OF RESULTS

Fig. 3 summarizes the statistical data on minimum, median, mean and maximum iron values for the various classifications of water sources and construction materials. The iron levels varied from 0.01 mg/l to 33 mg/l, and the figure clearly demonstrates that high concentrations of iron (>1.0 mg/l) are only associated with water which is drawn from water points employing iron in its construction. All the old (AIC) boreholes exceeded the recommended WHO value of 0.3 mg/l. The data suggest that the more ferrous materials are used in the construction, the greater the likelihood that iron will exceed this value. The median and mean values of the water points having no ferrous materials (APC) used in their construction are below the guideline.

The APC water points were randomly distributed throughout the project area. However, in order to ensure that the APC water points were not drawing water which was chemically different from the other types, and thus possibly lower in natural iron content, the chemistry of all the water samples was plotted on a tri-linear Piper diagram. This is a method developed by Piper[7], to graphically depict the chemical character of a water sample, by plotting points in three different fields. Piper's graphical treatment of the chemical analysis allows for an easy discrimination of distinct water types by their plottings in various sub-areas of the diamond field.

Fig. 4 shows the Piper plot of all the 166 water points within the project area (samples with similar chemistry overplot each other). Superimposed on the plot is the outline of the area containing all the APC-type water points. Virtually all the samples plot in a sub-area of the diamond field dominated by the alkaline earth metals, calcium and magnesium in the cation group, and by the carbonate/bicarbonate



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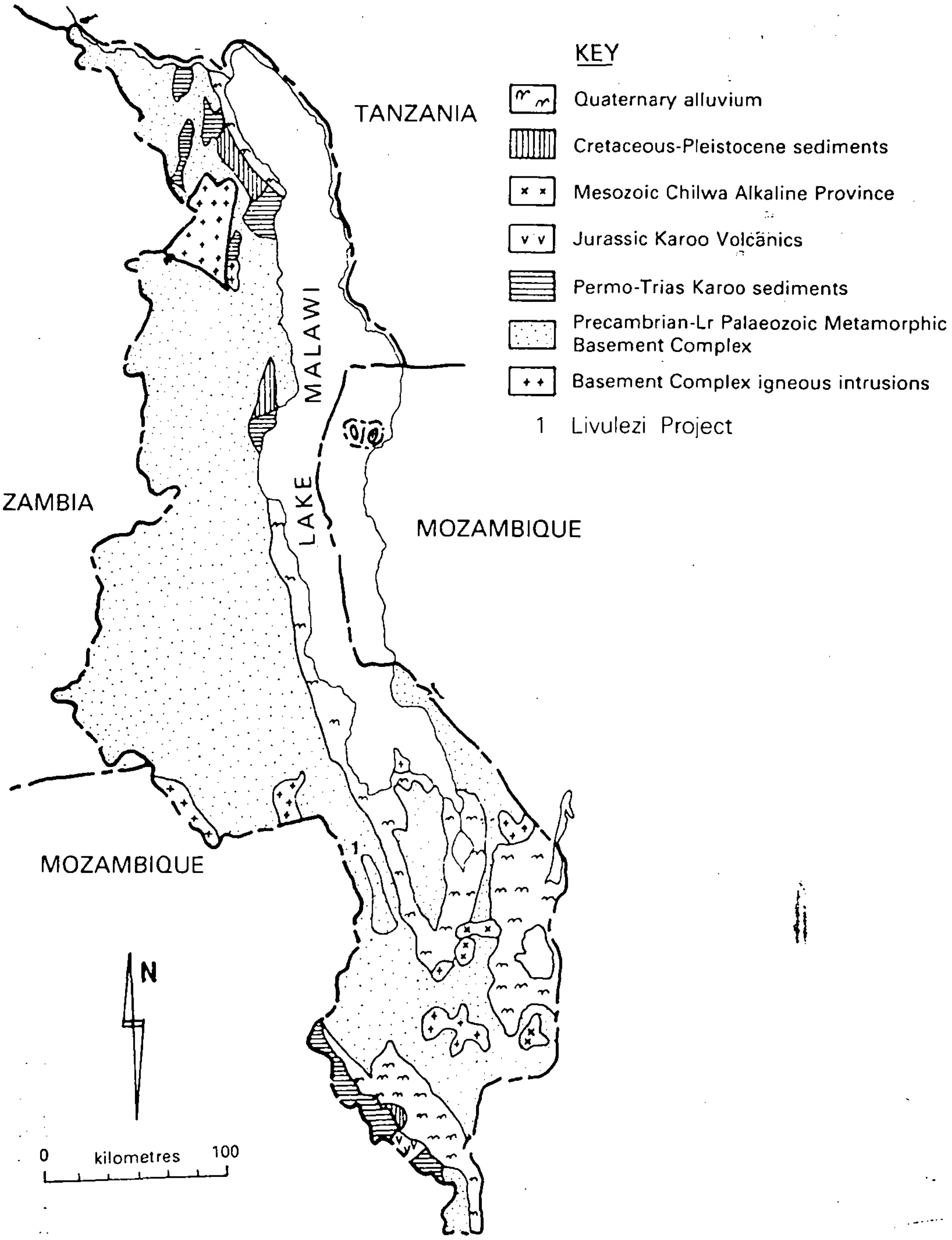


Fig. 2. Geological map of Malawi and location of study area

system, in the weak acids group. This is typical of the chemistry of samples from the basement aquifer underlying most of Malawi.

The outline of the APC plots is broad, and coincides with the general area of the other plots. This is considered strong evidence to support the supposition that the water supplied by these sources is not unique in character. It had been widely assumed that the iron was derived from ferromagnesian minerals during the weathering process.

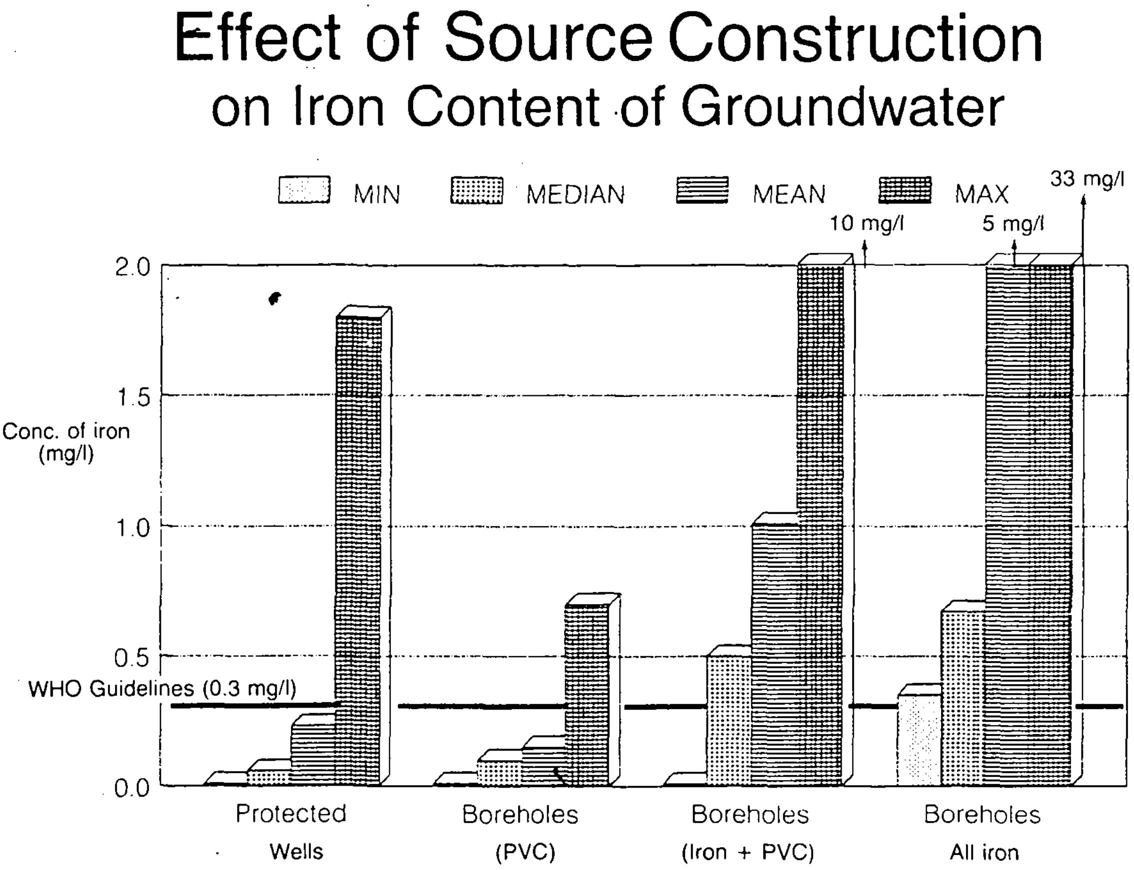


Fig. 3. Effect of source construction on iron content of groundwater

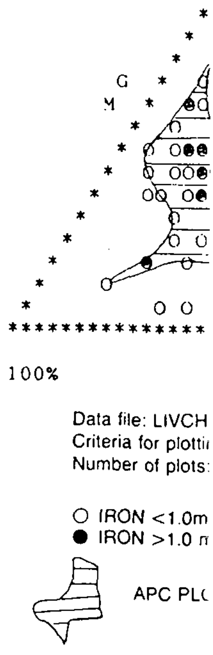
The implication of this study is that in many cases the unsatisfactory iron levels are due not to naturally-occurring iron minerals, but rather to contamination of the water by materials which were used in the construction of the borehole.

The results of two simple experiments clearly support this theory. In the first experiment, a borehole of mixed plastic and iron construction (PCIM) in another project area was sampled in the late afternoon during the peak time of water collection. A second sample was then collected at first light the following morning before any villagers had drawn water. The iron was found to have increased from 1.4 mg/l in the first sample to 11.8 mg/l in the subsequent sample.

In the second experiment, a new motorized borehole, supplying water to Madisi, a small town about 50 km north of Lilongwe, was sampled at commencement of pumping and at hourly intervals for a period of 7 h. The first sample, collected immediately after starting the pump, contained heavy rust deposits which would have been meaningless to analyse. Subsequent samples showed a gradual decrease in iron, from 0.87 mg/l after 1 h to 0.24 mg/l after 6 h, and thereafter remained constant.

CONCLUSIONS

1. Water engineers and hydrologists working on groundwater supply programmes in developing countries see their main priority as supplying water to people. It is therefore understandable that they are often preoccupied by numbers of water points installed or population served.
2. Water quality data, or the means to get that data, are not always readily available. It is clear, even without laboratory confirmation, that the traditional water supply is usually of inferior bacteriological quality, and it is often wrongly assumed that the intended recipients of a borehole will also perceive this difference in quality. As long as the water is clear in appearance, and reasonably palatable, the borehole is considered to be successful and the engineer moves on to tackle the next problem.



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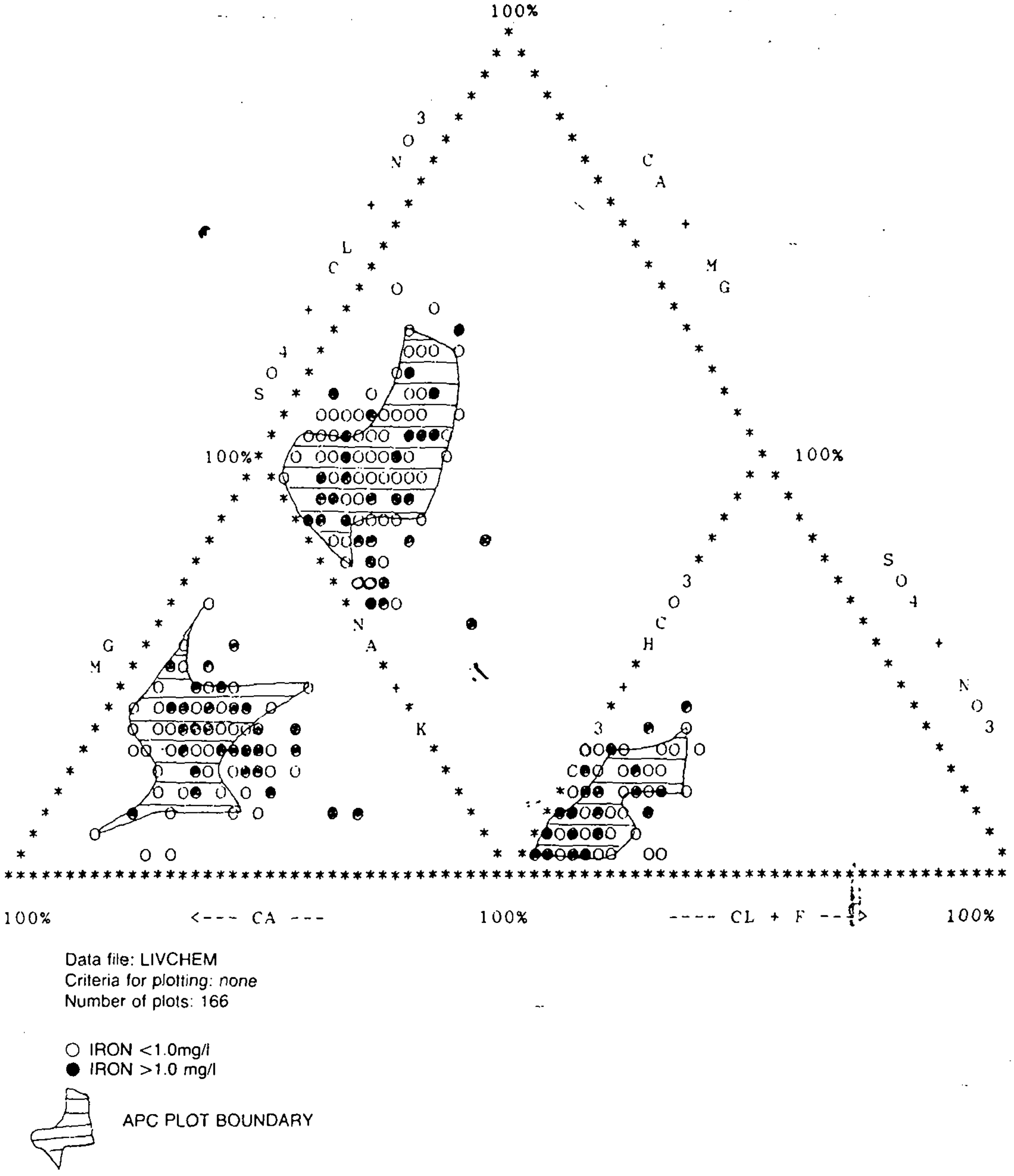

Fig. 4. Tri-linear Piper diagram

3. Limits for many constituents of natural waters are based on aesthetic considerations only, since they are not injurious to health. Iron, although itself not a constituent of health significance, and even when present in only trace amounts, can influence the consumer's acceptance of an improved borehole supply. It can cause the supply to be rejected in favour of an alternative which often poses a threat to health, thus defeating one of the main objectives of any water supply programme, i.e. the improvement of health of the community served. The study has demonstrated that, by avoiding where possible the use of ferrous materials in borehole construction, this problem can be minimized and in many instances eliminated.

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