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The bacteriological quality of traditional water sources in north-eastern Imo State, Nigeria

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SUMMARY

Monthly bacteriological water testing of traditional water sources (ponds, rivers, unprotected springs and traditional wells) used by five villages in north-eastern Imo State, Nigeria, was conducted during the period January 1983 to August 1985. The membrane-filtration technique was used to detect faecal coliforms (FC) and faecal streptococci (FS). Evidence of faecal pollution was seen throughout the year for all water sources. During the study period, the monthly geometric mean counts per 100 ml of water (all sources combined) ranged from 760 to 17877 for FC and from 678 to 17394 for FS. The peak period of faecal pollution occurred during the transition between the dry and wet seasons and in the early wet season. During this peak pollution season (February–May), the geometric mean counts were 2·5–7·2 times higher than in the remaining part of the year for all source types except rivers, with ponds being the most heavily polluted. Preliminary findings on the sensitivity and specificity, in this tropical environment, of the standard membrane-filtration technique for enumerating FC are presented. The implications of the findings of this study for the environmental control of waterborne and hygiene-related diseases are discussed.

INTRODUCTION

The seasonality of traditional water source quality in developing countries (typically surface water) is well recognized. This seasonality varies by geographical area and the accompanying pattern of rainfall, temperature, type of water source and human behaviour. Generalizations about the peak pollution period cannot be made (Wright, 1986), as demonstrated by the contradictory findings of a number of studies from different countries (Feachem, 1974; Feachem *et al.* 1978; Muhammed & Morrison, 1975; Barrell & Rowland, 1979; Bagde & Varma, 1982; Wright, 1986). Some studies have examined the transition periods between seasons and found a peak in the level of contamination at the start of the rains (Moore, de la Cruz & Vargas-Mendez, 1965; Feachem, 1974; Barrell & Rowland, 1979; Wright, 1986).

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The seasonality of many infectious diseases is also well recognized, although the nature of the relationship between climatic factors and disease is complicated by numerous other interactions (Chambers, Longhurst & Pacey, 1981). For some diseases, such as typhoid fever and diarrhoeal diseases, the seasonality of disease transmission and the seasonality of water quality may be related. Contaminated drinking water is one of the ways in which these diseases can be spread. The extent to which transmission occurs through waterborne as opposed to other routes in developing countries is unclear and controversial (Feachem, 1981). If, however, waterborne transmission is important in a given setting, it follows that people are at greatest risk during periods of greatest water pollution. One possible important determinant of the quality of water, particularly surface water, is rainfall.

The Imo State Drinking Water Supply and Sanitation Project in south-eastern Nigeria began in early 1982. The project provides boreholes with handpumps, promotes the construction of ventilated improved pit latrines, and trains village-based workers as health and hygiene educators. A health impact evaluation, focussing particularly on childhood diarrhoea, was conducted in five villages in north-eastern Imo State – three villages in which the project was implemented during the course of the evaluation (intervention villages) and two villages which will receive the intervention package at a later date (control villages).

A longitudinal examination of the quality of traditional water sources was conducted in the five villages in north-eastern Imo State in conjunction with the health impact evaluation. These water quality results, and their possible relationship to rainfall, are presented here.

MATERIALS AND METHODS

Water sampling

The bacteriological quality of traditional water sources (excluding rainwater) was investigated monthly during the period January 1983 to August 1985, and then quarterly until the end of the evaluation in June 1986; the quarterly results are not presented here. During the earlier part of this period all villages were entirely dependent on traditional water sources for their water needs. Excluding rainwater, there was a total of 37 water sources used by the five study villages. These sources comprised 21 ponds, 3 rivers, 9 unprotected springs and 4 traditional wells. During 1984 the intervention villages gradually gained access to boreholes.

Water samples were collected in sterile plastic bottles from all available water sources (excluding rainwater and boreholes) used by the five villages. The number of sources tested varied according to the season. After a sample was collected, the temperature of the water was taken. The water samples were then transported in a cold box containing freezer packs to the field laboratory, where they were processed within 3 h of collection.

Bacteriological testing

Tests were conducted in the field laboratory for the presence of faecal coliforms (FC) and faecal streptococci (FS), using the membrane-filtration technique (APHA, 1981; DHSS, 1983). M-FC broth (Difco) was the only media

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used for FC from January to May 1983; Membrane Lauryl Sulphate Broth (MLSB; Oxoid and BDH) was introduced and used as the sole media for FC in June and July 1983; both M-FC and MLSB were used during the period August–December 1983, and MLSB was used alone for the remainder of the study. KF streptococcus agar (Gibco) was used for FS throughout. FC plates were incubated in a warm-air incubator at 37 °C for 4 h and then transferred to a water-bath incubator at 44·5 °C for 20 h, except during the period January–May 1983, when the plates were incubated in the water-bath incubator at 44·5 °C for the entire 24-h period. Plates for FS were incubated for 48 h at 37 °C in a warm-air incubator.

Two filtration volumes were used for each sample, both for FC and for FS. Yellow colonies on MLSB or blue colonies on M-FC were counted as FC, and dark red or reddish-brown colonies on KF agar were counted as FS. Filtration volumes were selected so as to produce up to 200 colonies on each plate. Where the number of colonies on both plates was in the range 10–100, the counts from the two filtrations were averaged to produce a count per 100 ml. If only one of the counts was in this range, that single count was used. If both counts were outside the 10–100 range, but one (or both) counts was (were) in a range of 5–200, that count (or the average of the two counts) was used. No counts below 5 or above 200 were used, even if that meant discarding all results for a sample in a given month.

Plastic containers, MLSB media and the distilled water were sterilized in an autoclave at 121 °C and 15 lb per square inch pressure for 15–30 min, depending on the material used. Glassware was sterilized in a hot-air oven at 170 °C for 1 h.

Quality control

Two quality control measures were carried out. First, a 'blank' in which distilled sterile water (used in media preparation) was filtered was run with each set of specimens. There was no growth on any of the blanks. Secondly, during the final round of testing in June 1986 a random sample of 10 typical and 15 atypical colonies from the MLSB plates were streaked on to nutrient agar in the field laboratory and transported to London for identification. All slopes were then subcultured on to nutrient agar plates and held at room temperature for 72 h. Identification of faecal coliforms was made using the API rapid identification method.

Rainfall measurement

A rain gauge, located at the field laboratory, was used to measure rainfall. Beginning in April 1983, measurements were taken three times per day and totalled at the end of the day. At weekends, measurements were not always done on individual days and the volume in the gauge was apportioned to individual days according to retrospective verbal accounts of the relative amount of rain falling on those days.

RESULTS

The total monthly rainfall, the percentage of days on which rain fell and the mean monthly water temperature of the sources examined are shown in Fig. 1. A clear seasonal pattern of rainfall is observed, with transition periods February–

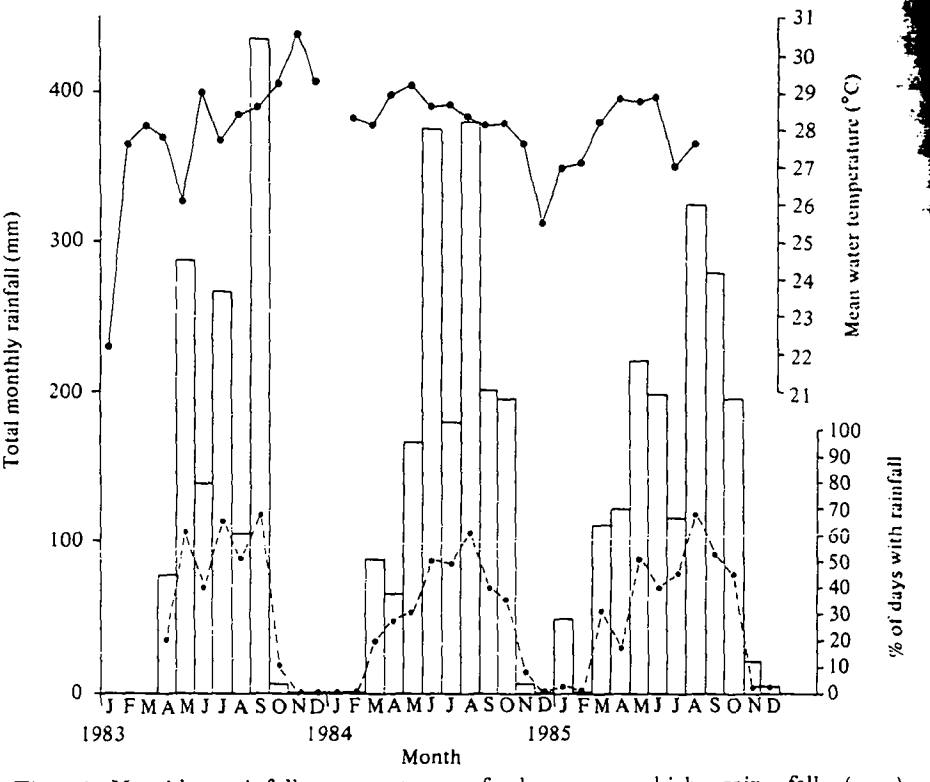

Fig. 1. Monthly rainfall, percentage of days on which rain fell (---) and mean water temperature (—), January 1983 to December 1985.

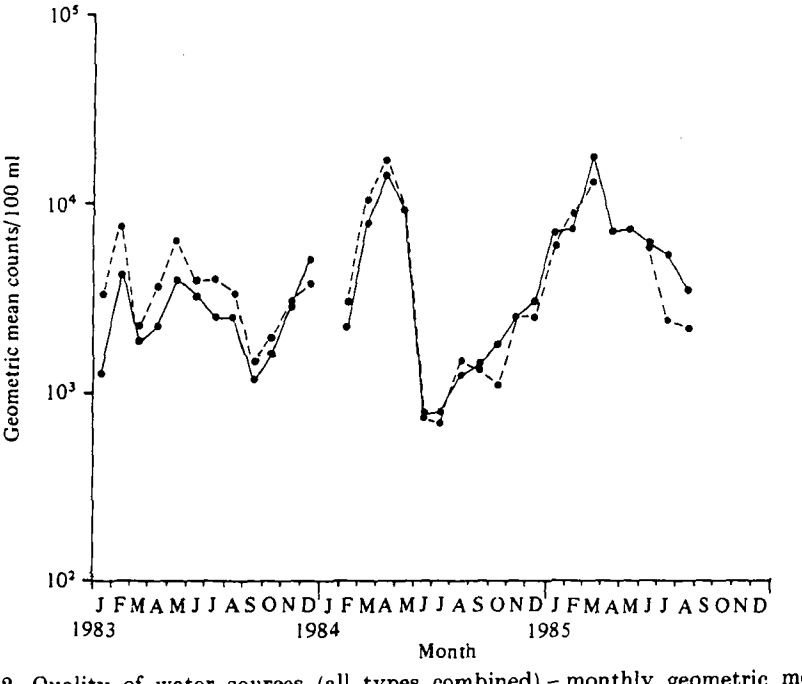

Fig. 2. Quality of water sources (all types combined) – monthly geometric mean faecal coliform (—) and faecal streptococci (---) counts.

Fig. 3. Wat

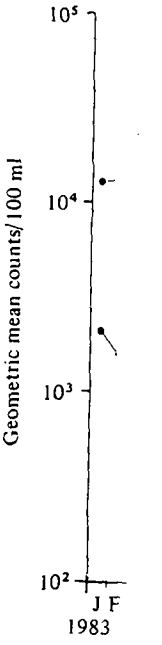

Fig. 4. Water

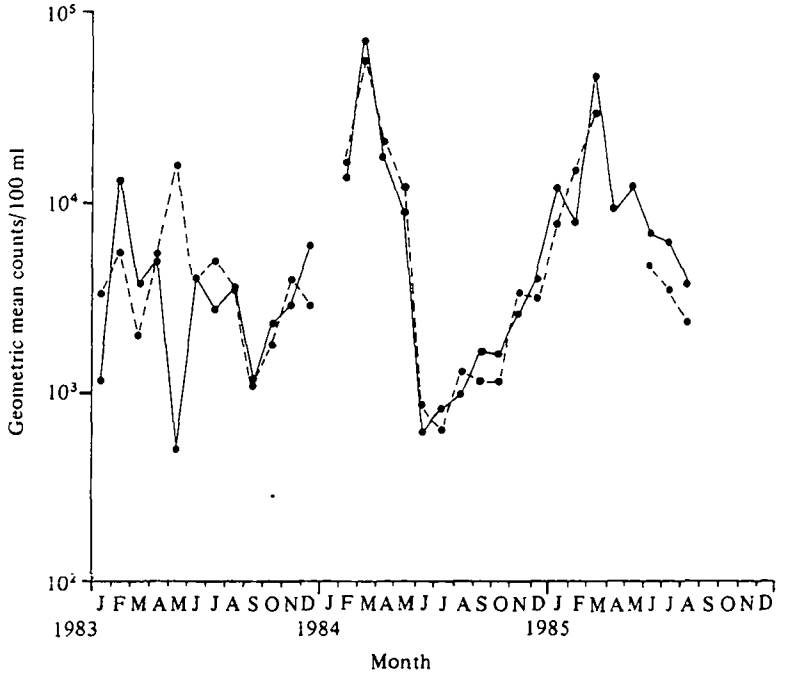

Fig. 3. Water quality of ponds – monthly geometric mean faecal coliform (—) and faecal streptococci (---) counts.

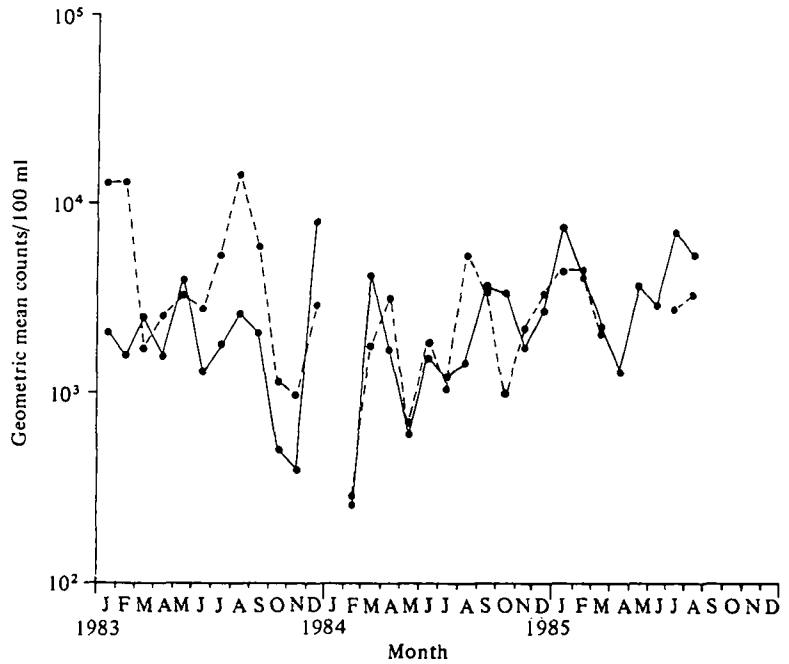

Fig. 4. Water quality of rivers – monthly geometric mean faecal coliform (—) and faecal streptococci (---) counts.

Table 1. *Geometric mean and range ($\times 10^{-3}$) of faecal coliform and faecal streptococci counts during the peak (February–May) and low (June–January) bacteria seasons, according to different source types**

Water source	Faecal coliforms		Faecal streptococci	
	Low	Peak	Low	Peak
Ponds				
Geometric mean	2·5	12·9	2·3	16·6
Range	0·05–120·2	0·5–151·3	0·08–41·7	0·6–141·2
No. of samples.	291	67	282	55
Rivers				
Geometric mean	2·2	2·1	3·2	2·0
Range	0·4–8·9	0·2–22·4	0·4–39·8	0·2–12·9
No. of samples	33	21	32	18
Unprotected springs				
Geometric mean	1·9	5·6	1·4	5·8
Range	0·05–67·6	0·3–169·8	0·1–43·6	0·3–195·0
No. of samples	139	72	129	63
Traditional wells				
Geometric mean	3·5	8·7	5·0	13·5
Range	0·3–39·8	0·2–85·1	0·4–67·6	0·3–125·9
No. of samples	42	13	44	11

* All counts are expressed as bacteria per 100 ml of water sample ($\times 10^{-3}$).

March (dry to wet season), and October–November (wet to dry season). The mean water temperature ranged from 22·2 to 30·5 °C and showed no definite seasonal pattern.

Geometric mean counts of FC and FS per 100 ml of water are shown by month in Fig. 2 for all sources combined, in Fig. 3 for ponds and Fig. 4 for rivers. The monthly geometric mean count (all sources combined) ranged from 760 to 17877 for FC and from 678 to 17394 for FS. The overall pattern shows that, in each year, peak counts occurred during the transition from dry to wet seasons and in the early wet season (February to May). Counts were generally lowest at the height of the wet season. In the transition period from wet to dry seasons, counts began to rise. This rise continued as the dry season progressed, culminating in the dry-to-wet-season transition peak. A similar but more pronounced seasonal pattern of bacterial counts was observed for pond sources. For rivers, however, little seasonal variation was seen.

FC and FS counts were of similar magnitude and seasonal pattern. No consistent FC/FS ratio was found.

Defining the peak bacteria season as February to May and the low bacteria season as June to January, Table 1 shows the range and geometric mean counts of FC and FS, by source type, in these two seasons. During the peak bacteria season, both FC and FS counts were significantly higher in ponds, unprotected springs and wells than in rivers ($p < 0·01$); ponds were more heavily contaminated than springs ($p < 0·01$). During the low bacteria season, significantly higher counts for FC were found in wells than in springs ($p < 0·01$); significantly higher FS counts were found in wells than in springs or ponds ($p < 0·001$). For ponds, unprotected springs and traditional wells, the mean counts were 2·5–7·2 times

higher in the peak season than in the low season. For rivers, however, the mean counts were similar in the two seasons (FC), or lower in the peak than the low season (FS).

A strong correlation between logarithmic FC counts obtained using the media M-FC and MLSB was found ($r = 0{\cdot}81$, $p < 0{\cdot}001$), and the media produced very similar counts ($\log(\text{MLSB}) = 0{\cdot}15 + 0{\cdot}96 \log(\text{M-FC})$).

Twenty-five colonies from MLSB plates (10 typical yellow colonies counted as FC, and 15 atypical blue, pink, brown or red colonies not counted as FC) were tested in London using the API system. Of the 10 typical colonies, all were found to be *Klebsiella pneumoniae* (9) or *Escherichia coli* (1). Of the 15 atypical colonies, 10 were species not generally regarded as FC (species of *Enterobacter* (7), *Chromobacterium* (1), *Acinetobacter* (1) and *Serratia* (1)), 1 colony did not survive transport to London, and 4 colonies were FC (*K. pneumoniae*).

DISCUSSION

The confirmatory tests on colonies grown on MLSB must be interpreted cautiously because of the small sample. MLSB proved to be a reliable medium for the detection of faecal coliforms in this tropical area of Africa and gave similar counts to M-FC broth. A specificity of 100% is suggested, and 10 out of 14 colonies regarded in the field as non-FC, and subsequently tested in London, were confirmed as such. Most of the faecal coliforms identified in confirmatory testing were *K. pneumoniae*, rather than *E. coli*. The predominant faecal coliform type appears to vary according to geographical location. Mara & Oragui (1985) also found a higher proportion of *K. pneumoniae* than *E. coli*. in water samples in north-eastern Imo State, but the reverse in similar studies in Zimbabwe.

These results confirm the findings of other studies which have found highest bacterial counts in the transition between the dry and wet seasons (Moore, de la Cruz & Vargas-Mendez, 1965; Feachem, 1974; Barrell & Rowland, 1979; Wright, 1986). In countries with pronounced dry and wet seasons, many of the sources available in the wet season dry up completely as the dry season progresses. In this situation, the first rains wash faecal matter into newly created small bodies of water, resulting in highly polluted water sources. As the wet season progresses, there is a rain-induced dilution effect. With the onset of the dry season, bodies of water again begin to shrink and counts rise.

The usual way in which water quality data are presented is by rainfall season, often defined arbitrarily rather than on the basis of the specific rainfall pattern observed in a given year. However, as we have seen, the peak period of water pollution may actually fall between rainfall seasons, and this may be missed in the usual analysis. For this reason we examined the relationship between counts in the peak pollution period and in the lower pollution period and then related these periods to specific months of the year, which did in fact cross traditional seasonal definitions.

The importance of studies that examine rainfall–water quality relationships is dependent on their ability to shed light on the rainfall–water quality–disease interaction. A striking finding in this study is that all traditional water sources were polluted, often very heavily, throughout the year (Table 1). Based on the

pattern of water pollution found in this study one can, however, predict that the period of highest risk of waterborne disease is likely to be during the dry- to wet-season transition period and early in the wet season.

Indeed, we have found in the baseline cross-sectional studies in these villages that diarrhoea prevalence rates were higher in this transition period than in the peak wet season for certain age groups (Huttly *et al.* in press). These relationships are, however, exceedingly difficult to demonstrate since some diseases (including all the diarrhoeas) have more than one transmission route, and other factors in addition to, or more importantly than, increases in water pollution may be responsible for observed seasonal variations. In the study area, the period of peak water pollution also corresponds to the period of least water availability for personal hygiene, and one would expect that the transmission of hygiene-related diseases, including all the diarrhoeal diseases, would be greatest at that time.

Despite these complications, this study has highlighted poor water quality as a potential contributor to disease throughout the year, but particularly in the transition period from the dry to wet seasons and in the early wet season. It is important for environmental health officers and health educators working with water supply and sanitation projects to understand the seasonality both of water pollution and disease, and to intensify their efforts in promoting proper water collection and handling before the high-risk pollution period. In areas such as Imo State where the seasonality of water pollution and water scarcity coincide or overlap, the potential for achieving an improvement in health through improving water-seeking or water-handling behaviours can be increased by concomitant promotion of personal hygiene.

The Imo State Project evaluation study, of which this survey was a part, was supported by the United Nations Children's Fund (UNICEF), the Imo State government and the Diarrhoeal Diseases Control Programme of the World Health Organization. We are grateful for the valuable work done by all members of the field team in Nigeria. Special thanks are due to the previous UNICEF Nigeria representative, Mr R. Reid, and to his succesor, Mr R. N. Tuluhungwa, for their co-operation. We would also like to thank Mr Nigel Cox for conducting the confirmatory bacteriology.

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