FAECAL CONTAMINATION OF RURAL WATER SUPPLY
IN THE SAHELIAN AREA

FRANCIS GUILLEMIN1, PASCALLE HENRY2, NDIDI UWECHE2 and LOIC MONJOUR1•

1Département de Santé Publique, Faculté de Médecine, F-54505 Vandoeuvre-Les-Nancy Cedex,
2Département de Parasitologie et Médecine Tropicale, Hôpital Pitié-Salpêtrière, 83 Boulevard de
l'Hôpital, 75013 Paris Cedex and Organisation Non Gouvernementale EAST, France

(First received July 1988; accepted in revised form January 1991)

Abstract—The present expansion of water improvement programmes in developing countries is hardly
adapted to provide rural areas with an adequate supply of drinking water. Quality control measures
encounter many technical difficulties and are not often performed. A study of the microbiological quality
of 982 rural water points was undertaken in the Sahelian region of Burkina Faso. A mobile laboratory
was developed for this work. Bacteriological analyses were performed using the membrane filtration
method and the results measured according to WHO potability standards. Surprisingly, results showed
a faecal contamination in 7.7% of boreholes. Possible risk factors of pollution were analysed, leading to
recommendations for technical improvement. The responsibility for eliminating these risk factors, in the
main, lies with the consumers through health education. This study highlights the place of sanitary
education programmes as a priority among the objectives of health policies.

Key words—drinking water, faecal pollution, analytical method, risk factors, sanitary education,
West Africa

INTRODUCTION

As part of the Drinking Water Supply and Sanitation
Decade (1980-1990), a number of village water pro-
grammes are being implemented in developing
countries, particularly in West Africa. Systems
designed to exploit underground water resources are
progressively meeting the requirements of rural popu-
lations. However, the potability of this water has not
been well established, since bacteriological quality
control is hampered by the fact that laboratory
techniques are ill adapted for conditions in the field.

A survey was conducted to determine the microbial
quality of 982 water points in rural areas of Burkina
Faso (Guillemin, 1985). This was possible by way of
the development of a simple, low cost, analytical
technique, applicable in the field. Factors contribut-
ing to water pollution were consequently analysed.

MATERIALS AND METHODS

Critical Situation

The granitic subsoil in Burkina Faso presents a network
of faults often corresponding to underground ponds
or rivers. Recent borehole techniques have made these reserves acces-
sible (BRGM, 1985) and provide a permanent supply, un-
affected by seasonal droughts. Villages are generally
dispersed clusters of houses within a 10 km² area. Several
water supplies, not exceeding some 100 m from each cluster,
are available in this area, where cattle can graze freely. Wells
are usually dug near ponds and boreholes are constructed
on lines of faults often corresponding to underground ponds
or rivers.

Programmes for such boreholes were developed over the
decade. More than 10,000 boreholes have already been dug
in Burkina Faso. These will progressively replace the com-
mon traditional wells (Awad et al., 1985).

Scientific equipment and training

Due to transport difficulties (rough roads and tracks), the
analytical equipment had to be compact and sturdily built.
It had to withstand extreme temperature conditions (45°C)
and hygrometric variations (0-99%).

Since the equipment had to be of small dimensions,
analyses were limited to those required for determining
potability, according to the WHO standards (WHO, 1984).

We used culture media dried onto cardboard (Sartorius).
Hermetically sealed, they were protected from hygrometric
variations and stored, undamaged, at room temperature.
Media were rehydrated at the time of use.

The average cost of one test was assessed by taking into
account the following four items: logistics, scientific equip-
ment, personnel and operating expenses.

Technical staff from the Burkinabe Health Ministry were
trained, so that local technicians would be able to perform
water quality control tests. Training consisted of instruction
in analytical methods applicable in the fields and in the
determination and elimination of factors causing pollution
of boreholes.

Analytical methods

The membrane filtration technique was used as a basis for
most field analyses to detect indicators of faecal contami-
nation. The mobile analytical laboratory was either installed
in a village dispensary or in another building. Water samples
from all the neighbouring villages, stored in iceboxes, were
brought to the analytical unit in less than 6 h. All water
sources (boreholes, wells, etc...) within a 30 km radius were
examined. The equipment consisted of a filtering system
joined to a vacuum pump connected to a generator. Water
(100 ml) was filtered through membrane filters (pore size:
0.45 μm) which were then deposited on culture media already rehydrated with 2-3 ml of sterile water and placed in a portable incubator. The following four tests were carried out:

—Standard plate count (SPC) was made by the pour plate method after 24 h incubation at 37°C in nutrient agar (Institut Pasteur) inoculated with 1 ml water sample. When the water was highly contaminated, dilutions (1/10, 1/100 or 1/1000) were initially performed.

—Detection of total coliforms (TC) was made by the pour plate method after 24 h incubation at 37°C in nutrient agar (BCP agar—Institut Pasteur) incubated for 24 h at 37°C.

—Identification of faecal coliforms (FC) was carried out on Tergitol TTC medium incubated at 44°C for 24 h. Doubtful colonies were isolated on purple bromocresol lactose agar (BCP agar—Institut Pasteur) at 37°C for 24 h, followed by biochemical identification on API 20 E galleries (API System) after 24 h at 37°C.

—Identification of faecal streptococci (FS) was conducted on Azid medium (SM 14051 N-Sartorius) incubated for 48 h at 37°C. The morphological and biochemical characteristics of these bacteria facilitated their identification by Gram staining and catalase reaction.

These four tests were conducted for each water sample. After analysis, sampling vials were sterilized and the used material was destroyed in a portable autoclave (131.—Pros ciences).

**Laboratory checking of the dried media method**

The reliability of our method was confirmed at the Laboratoire d’Hygiène et de Recherche en Santé Publique in Nancy (France). Thirty water samples (11 drinking water, 11 bathing water and 8 wastewater) previously tested in the mobile laboratory were re-analysed using the membrane filtration method, and the Sartorius dried media were compared with usual agar media. Detection of TC was obtained on Tergitol 7 Agar (5471—Merck) medium, incubated for 24 h at 37°C. FC were detected after 24 h at 44°C using the same medium. Doubtful colonies were isolated on Hajna-Kligler medium (Institut Pasteur) after 24 h at 37°C. Their identification was obtained on Schubert medium—24 h, 44°C—(Institut Pasteur) and API 20 E gallery—24 h, 37°C—(API System). For detection of FS, membrane filters were deposited on Slanetz medium (5262—Merck) and incubated for 48 h at 37°C. Doubtful FS colonies were isolated on Esculine agar (Institut Pasteur) for the research of specific hydrolysis, after 24 h at 37°C. Incubation times and procedures were the same as those used in the field.

**Potability standards**

The drinking water standards adopted correspond to those of the WHO (1984). For unpiped water sources, the following is recommended: less than 10 total coliforms per ml of sample and the absence of faecal coliform and faecal streptococci per 100 ml.

**Water sampling**

The survey concerned 982 water sources distributed over four provinces: two in the Northern Sahel, one in the vicinity of the capital (Ouagadougou) and one in the south-west (Fig. 1).

This comprised an area of about 2/5 of the national territory. The bacteriological quality of drinking water from 688 boreholes was compared with that of 250 concrete wells and of 44 traditional wells. In attempt to identify the main polluting factors, each water source was examined for:

—existence and cleanliness of protective devices surrounding the base of the pump;

—the presence of leaks in the gasket at the base of the pump;

—the environmental sanitary conditions (i.e. proximity of latrines);

—systems designed to deter cattle from the water supply area;

—defects in the pump requiring re-priming with water of doubtful quality.

In addition, the influence of rainfall on the quality of subterranean water was studied in 76 boreholes from the Sahel region (Sebba), north of the 500 mm pluviometry line. Two series of analyses were conducted within a 6 month period. The first investigation took place during the dry season (March-April), the second at the end of the wet season (October).

**Statistical analysis**

The reliability of the dried medium method and rainfall effect were determined using chi² paired tests. The contamination rate of the different water sources were compared using the chi²-test. The correlation coefficient calculation was used to assess the relation between FC and FS levels for each water sample.

The study of each variable, as assumed risk-factors of pollution, was first conducted separately using the chi²-test, then analysed in a stepwise logistic regression adjusted to each survey area. All analyses were performed using BMDP software (BMDP, 1983).

**RESULTS**

**Validity of the dried media**

Water analysis results obtained using our method were comparable with those from the specialized laboratory—Nancy (Table 1). The number of contaminated waters detected by both methods did not differ significantly. Regardless of the bacteria involved, water pollution analysis revealed no statistically significant difference. Nor did the pollution levels assessed by both methods differ, as far as TC, FC or FS are concerned.
Faecal contamination of a rural water supply

Table 2. Results of the survey (982 water points): rates of pollution, according to the WHO standards, and details of bacteria counts for each type of contaminated wells and boreholes

<table>
<thead>
<tr>
<th>Faecal contamination (according to the WHO standards)</th>
<th>Boreholes</th>
<th>Concrete wells</th>
<th>Traditional wells</th>
</tr>
</thead>
<tbody>
<tr>
<td>(n = 688)</td>
<td>(n = 250)</td>
<td>(n = 44)</td>
<td></td>
</tr>
</tbody>
</table>

<p>| Total bacteria and contamination indicators levels in the polluted samples: |</p>
<table>
<thead>
<tr>
<th>Mean ± SE (range)</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPC/ml</td>
</tr>
<tr>
<td>48.5 ± 25.9 (3-500)</td>
</tr>
<tr>
<td>344 ± 97 (10-8700)</td>
</tr>
<tr>
<td>3500</td>
</tr>
<tr>
<td>TC/100 ml</td>
</tr>
<tr>
<td>17.3 ± 6.4 (1-380)</td>
</tr>
<tr>
<td>23.45 ± 3.23 (4-200)</td>
</tr>
<tr>
<td>830</td>
</tr>
<tr>
<td>FC/100 ml</td>
</tr>
<tr>
<td>4.2 ± 0.27 (0-15)</td>
</tr>
<tr>
<td>9.2 ± 1.24 (0-57)</td>
</tr>
<tr>
<td>527</td>
</tr>
<tr>
<td>FS/100 ml</td>
</tr>
<tr>
<td>3.8 ± 1.3 (0-11)</td>
</tr>
<tr>
<td>10.5 ± 4.2 (0-220)</td>
</tr>
<tr>
<td>454</td>
</tr>
</tbody>
</table>

SPC, standard plate count. TC, total coliform. FC, faecal coliform. FS, faecal streptococci.

Results of bacteriological analyses

Results for the 982 water samples were reported according to the different water sources (Table 2):

—92.3% of the boreholes met the WHO potability standards, leaving 7.7% polluted with an average of 17.3 ± 6.4 TC/100 ml, 4.2 ± 0.27 FC/100 ml and 3.8 ± 1.3 FS/100 ml.

—13.5% of the concrete wells were contaminated with an average of 23.45 ± 3.23 TC/100 ml, 9.2 ± 1.24 FC/100 ml and 10.5 ± 4.2 FS/100 ml.

—66% of the traditional wells presented a mean pollution level of up to 300 TC, FC and FS per 100 ml.

These data emphasize the expected high rate of unsanitary conditions in traditional wells. They also confirm the higher risk a faecal contamination of wells compared to boreholes (P < 0.05).

The FC identified were the following: Escherichia coli (85%), Citrobacter freundii (3.5%), Enterobacter agglomerans (1.7%), Enterobacter cloacae (1.7%), Klebsiella oxytoca (0.8%), Citrobacter diversus (0.8%) and 5.2% that could not be identified.

The other pollution indicators (SPC and TC) provided information concerning the importance of bacterial contamination drinking water points: traditional wells are the most exposed.

No correlation could be found between the FC and FS levels for each water source. In a large number of them, a higher level of FS than FC was present (boreholes: 38%; concrete wells: 48%; traditional wells: 100%).

Influence of rainfall

Seventy-six boreholes in the Sebba region were tested for bacteriological pollutants during the dry season (March–April). Nine of them (11.8%) contained FC contaminated water. At the end of the rainy season (October), 16 boreholes (21%) were found to be polluted (Fig. 2). Though the rate of pollution tended to increase at the end of the rainy season, the effect of rainfall as a factor leading to pollution was not statistically significant.

Risk factors of pollution

Analysis of the results shows a significant relation between water pollution and each risk factor assessed. After a stepwise logistic regression analysis, the link with each factor persisted independently, whatever the survey area (Table 3). The unsanitary conditions of the proximal environment (P < 0.001), the absence of protective devices (P < 0.001), hazards in re-priming (P < 0.001), leaks in the pump (P < 0.05) and the absence of efficient system to keep cattle away from the water supply area (P < 0.05) seem to contribute to the non-potability of water.

Although it was not possible to establish a strictly causal relation with these factors, their influence on the water quality of boreholes must be taken into consideration.

Table 3. Risk factors of pollution—stepwise logistic regression (688 boreholes)

<table>
<thead>
<tr>
<th>Risk factors</th>
<th>N</th>
<th>Odd-ratio</th>
<th>P value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unsanitary environment</td>
<td>E  = 348</td>
<td>2.46</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>NE = 318</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Absence of protective device</td>
<td>E  = 96</td>
<td>2.76</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>NE = 570</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hazards in re-priming</td>
<td>E  = 31</td>
<td>5.12</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td></td>
<td>NE = 635</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Leaks in the pumps</td>
<td>E  = 14</td>
<td>3.54</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td></td>
<td>NE = 652</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No system to keep cattle away</td>
<td>E  = 116</td>
<td>2.20</td>
<td>&lt;0.05</td>
</tr>
<tr>
<td></td>
<td>NE = 350</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

E, exposed; NE, non exposed.
DISCUSSION

This study shows that all drinking water sources in tropical Sudan–Sahel regions may be polluted. Traditional wells were invariably contaminated with very high levels of indicators of faecal contamination, similar to that found in ponds or rivers. Pollution in concrete wells was less frequent. Variations in contamination levels seemed to depend on the protective equipment utilized and on how carefully the technical finish was applied (Lewis and Chilton, 1984). Boreholes were found to be the best safeguard against the transmission of water-borne bacterial diseases (Monjou et al., 1984), since at least 80% of them were free of pollutants, representing a real improvement in drinking water supply. These results were consistent with prior reports on the quality of water in rural African areas (Essien and Osuhor, 1979; Lewis et al., 1980; Viens and Lavoie, 1982; Lewis and Chilton, 1984).

The difference between FS and FC incidence rates is a common finding. Three explanations are proposed for this. Firstly, FS have a longer life span and may indicate a semi-recent pollution (2–4 months previously), whereas FC indicate recent faecal contamination and survive for a shorter period. So, semi-recent contamination by FS is more likely to be detected. Secondly, a higher FS/FC rate is generally related to a pollution of non-human origin, especially if FS/FC exceeds 2.0 (Finstein, 1972). With the frequent proximity of domestic animals and deterioration of protective devices around the pumps, a large part of FS was probably due to livestock contamination. Lastly, the higher FS/FC frequently reported in African field studies may be related to injury of the more delicate coliform bacteria in the aquatic environment, where exposure to stress (i.e. time, nutrient availability) might have sublethal consequences for microorganisms (McFeters et al., 1984). However, according to McFeters et al. (1982), recovery of FC may be improved by using adapted time, temperature of exposure and media.

The relation between rainfall and pollution remains controversial. Under subtropical or guinean climates, like Ivory Coast or Malawi (Viens and Lavoie, 1982; Lewis and Chilton, 1984), the pollution increases with monthly rainfall level like the trend we observed. This is assumed to be a consequence of contaminants accumulated in the ground during the dry season being washed by rainfall. Conversely, in countries like Sierra Leone (Wright, 1986), faecal contamination indicators increase at the end of the dry season, possibly due to a concentration effect when water reserves are diminishing. This difference might be related to the filtering capacities of the various water ducts.

The water of boreholes is generally assumed to be potable. In fact, this survey showed that 7.7% of them contain low levels of indicators of faecal contamination. Therefore, boreholes should not be condemned as this would send consumers back to the much more polluted traditional wells. However, while using boreholes, other sanitary programmes must be initiated, since according to the threshold-saturation theory (Shuval et al., 1981) there is no improvement in health status even after further investments in water supply and sanitation as long as these remain below a certain socio-economic threshold.

Another objective was to determine the factors of borehole water pollution. Three factors were identified:

1. The quality of the equipment (hydraulic pumps or public fountains) should be the prime concern. This means that it should be robust and easy to use. It necessitates the organization of distribution networks for repairs and the training of operators and repair staff. It is essential to ensure that the manufacturer’s equipment guarantee is provided, and that it covers a period of at least 2 or 3 years. Indeed, mechanical defects in the pumps forces the users to prime them with water from traditional wells, thereby threatening the underground water with pollution. Another factor favouring contamination is neglect of the technical finish of boreholes and of the water supply area. The addition of a concrete annular gasket surrounded by a concrete base of at least 2 m in diameter supporting the pump would prevent pathogenic infiltration.

2. Safety is even further improved when supply areas are designed so as to prohibit the access of cattle to the pumps.

3. Finally, health education remains a priority. This is best prior to the installation of drinking water sources. It should be aimed at the application of simple hygiene in individual and familial life (Feachem, 1984), with greater responsibility of the community in the maintenance and cleanliness of boreholes and the surrounding areas (Roundy, 1985). Safer water supplies will eventually lead to improvement in the health of consumers via a decrease in morbidity and mortality (Monjou et al., 1984; Esrey et al., 1985; Esrey and Habicht, 1986). After the provision of boreholes, health education courses, conducted by health technicians, as part of the primary health care programme, are essential in order to sustain and reinforce their efficiency (Van Damme, 1985; Cyjetanovic, 1986; Briscoe, 1987). All programmes concerning rural water supplies should include investigations into possible causes of pollution. A 1 week instruction in our analytical method for health staff trained in bacteriology is sufficient for microbiological quality control of water. For field analyses of 100
Faecal contamination of a rural water supply

water points three times a year, the cost of one bacteriological assessment amounts to $20–30. Such expenditure is very low when considering that of setting-up a pump in granitic subsoil amounting to approx. $15,000.

Acknowledgements—This programme was supported by: Ministry of Health (Burkina Faso), Banque du Credit Agricole, Total Afrique, Embassy of Canada–Ivory Coast. We wish to thank the EAST organization for participation in the work and Professor P. Hartemann and J. L. Paquin (Laboratoire d’Hygiène et de Recherche en Santé Publique–Nancy) for their kind advice and fruitful contribution.

REFERENCES


