Gastroenteritis Epidemic in the Area of the Itaparica Dam, Bahia, Brazil[1]

MARIA DA GLÓRIA LIMA CRUZ TEIXEIRA,[2]
MARIA DA CONCEIÇÃO NASCIMENTO COSTA,[3]
VERA LÚCIA PIRES DE CARVALHO,[4]
MANUEL DOS SANTOS PEREIRA,[4] & EDUARDO HAGE[4]

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Dam construction and associated flooding along rivers can alter ecosystems and pose serious threats to the welfare and health of local populations. This article describes a severe gastroenteritis epidemic in the Paulo Afonso region of Brazil's Bahia State related to flooding of the newly constructed Itaparica Dam's reservoir in 1988. Some 2 000 gastroenteritis cases, 88 of which resulted in death, were reported over a 42-day period.

Responding to the outbreak, clinical data and water sample test results were reviewed; blood and fecal specimens from gastroenteritis patients were subjected to bacteriologic, virologic, and toxicologic testing; and drinking water samples were examined for microorganisms and heavy metals. The results revealed that the source of the outbreak was water impounded by the dam and pointed to toxin produced by cyanobacteria as the responsible agent. Proliferation of these microbes, present at concentrations of 1 104 to 9 755 standard cyanobacterial units per milliliter in untreated water, appears to have been encouraged by the decomposing biomass and other conditions prevailing in the newly flooded reservoir area.

INTRODUCTION

Acute childhood diarrhea is highly endemic in the State of Bahia, with repeated epidemics occurring each year in different regions. Because of this high endemicity and lack of compulsory notification, it is often hard to determine the existence of epidemic outbreaks of childhood diarrhea except through unusually high numbers of deaths. Such epidemics, often associated with climate changes favoring source contamination of water supplies, compound the distress and chronic nutritional problems confronting a large share of the population.

Besides these recurrent natural outbreaks, others are being induced by human tampering with nature, principally along rivers, as when large dams are built to produce electricity. Typically, these hydroelectric projects are carried out without any thought to conducting further studies of changes in the area ecosystem that could have adverse social impacts on the riverbank population. As a result, towns, villages, forests, and plantations have been flooded without any regard for saving animals, preventing deforestation, containing sewage, or re-

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[2]Department of Internal Medicine, Medical Faculty, Federal University of Bahia; and Epidemiologic Surveillance Administration, Bahia State Health Secretariat, Bahia, Brazil. Correspondence should be addressed to Nova Colina, Bloco G apto 203, Brasília DF, Brazil CEP 70910.

[3]Department of Preventive Medicine, Medical Faculty, Federal University of Bahia; and Health Information Center, Bahia State Health Secretariat, Bahia.

[4]Epidemiologic Surveillance Administration, Bahia State Health Secretariat, Bahia.

moving cemeteries, fuel tanks, or toxic materials. In these circumstances, there is sometimes failure to technically and scientifically assess possible repercussions on the population's physical and mental health.

Few works have been published on this primarily health-related subject, either in Bahia or elsewhere in Brazil. Those that have are usually contained in technical reports by institutions involved with the project or with providing medical and social assistance during disease outbreaks, and they generally fail to adequately describe or investigate the events cited. Consequently, there is little epidemiologic or laboratory information about the etiologic agents of the diseases that most commonly occur during and after flooding.

Therefore, this appears an opportune time to describe a gastroenteritis epidemic that occurred in the Paulo Afonso region of Bahia, an area of some 213 000 inhabitants, from March to May 1988, a period coinciding with initial flooding of the reservoir behind the Itaparica Dam on the São Francisco River flowing through this region.

METHODOLOGY

Epidemiologic Profile and Institutional Action

In mid-March 1988, health professionals in Paulo Afonso Municipality began to see an increase in diarrhea cases among both children and adults. They immediately implemented a system designed to provide health care for diarrhea cases and commenced epidemiologic surveillance.

Among other things, they promoted and reinforced health measures directed at seeing that the affected population received care and that the effects of the outbreak were minimized. A mass distribution of oral rehydration salts was made to the populace through health units and organized social groups. Communities were alerted to the epidemic and advised to filter and boil drinking water through meetings of public organizations, participation in local radio programs, distribution of educational material, and talks given at churches, union halls, and other centers. Transmission of educational material emphasizing the importance of using oral rehydration salts was intensified through televised announcements.

Epidemiologic Research

Records of daily diarrhea treatments provided by municipal health units of the region from 10 February to 31 May 1988 were analyzed to confirm the epidemic's existence, characterize it, and guide control efforts. Hospitalizations and deaths at the Nair Alves de Souza Hospital (the only hospital in the area) from January 1985 through May 1988 were also reviewed.

Epidemiologic data cards were filled out for 76 individuals who contracted diarrhea and were treated as outpatients at the hospital. Among the items of information sought were the individual's age, residence, most frequent signs and symptoms, foods eaten before the illness, origins of water drunk, participation in group events, and travel. At the same time, a fecal specimen was collected from each subject for bacteriologic and virologic testing, and blood and urine specimens were obtained for cholinesterase and heavy metals analysis.

Concurrently, with the help of the Bahia Sanitation Enterprise (Empresa Baiana de Saneamento—EMBASA) and the Center for Environmental Resources (Centro de Recursos Ambientais—CRA), a survey was made of water at different collection points along the São Francisco River and within water supply systems for purposes of bacteriologic, hydrobiologic, and heavy metals analysis. Also, the São

Francisco River Hydroelectric Company (Companhia Hidroelétrica do São Francisco—CHESF) provided information about the filling curve of the Itaparica Dam, and local health professionals were interviewed.

RESULTS

The Epidemic

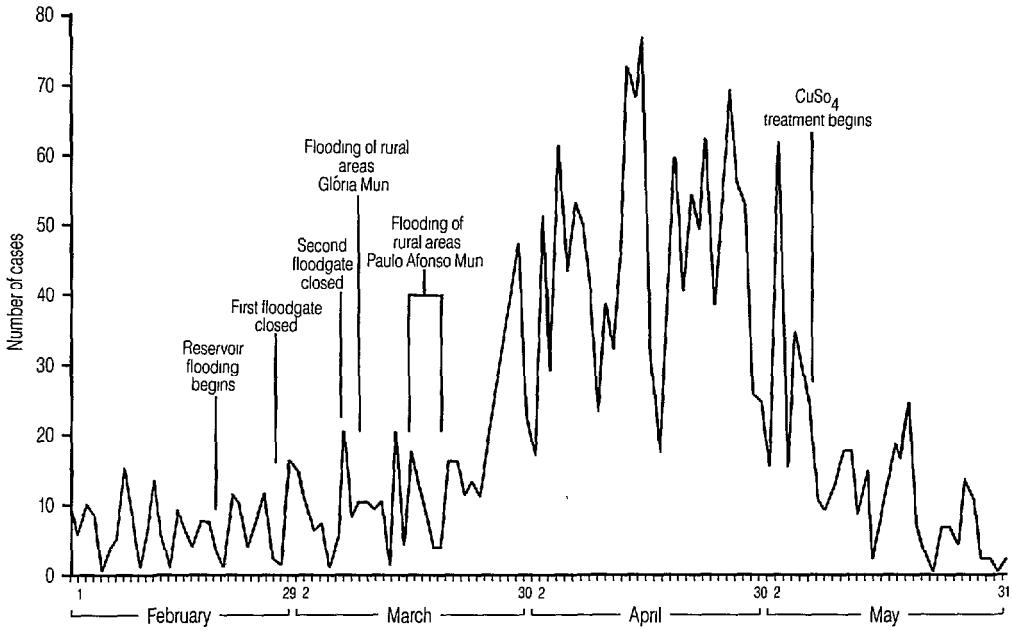
As indicated in Table 1 and Figure 1, the number of diarrhea cases treated at Paulo Afonso health units increased sharply in the last week of March 1988, peaked in April, and subsided in early May. The average number of cases treated daily (and the average variation) were 6.6 (±4.3) in February, 45.7 (±16.7) in April, and 4.5 (±3.9) from 19 through 31 May. Although both adults and children were affected, pediatric cases predominated, with 70.6% of the 1 118 cases treated at the health units occurring in children under 5 (Table 2).

Table 1. Numbers of patients treated for gastroenteritis at Paulo Afonso health units of the 10th Regional Health Directorate from 1 February through 31 May 1988.

	Month			
Day	February	March	April	May
1	9	15	17	15
2	6	10	50	61
3	10	6	29	15
4	9	7	61	35
5	0	1	43	28
6	4	10	53	23
7	5	5	50	10
8	15	20	40	9
9	8	8	23	12
10	1	10	38	17
11	5	9	32	17
12	13	1	45	8
13	5	10	72	14
14	1	20	68	1
15	9	4	76	7
16	6	12	33	12
17	4	9	17	17
18	7	17	42	16
19	7	4	59	24
20	3	4	40	6
21	1	16	54	3
22	11	16	49	0
23	10	11	62	6
24	4	13	38	6
25	8	11	53	4
26	11	19	69	13
27	2	26	56	10
28	1	33	52	2
29	16	40	25	2
30	—	47	24	0
31	—	22	—	2
Total	191	436	1 370	395

Source: Daily reporting bulletins of the centers, health posts, and clinics of the 10th Regional Health Directorate and records of the Nair Alves de Souza Hospital.

Figure 1. A distribution chart of patients treated for gastroenteritis at Paulo Afonso health units of the 10th Regional Health Directorate from 1 February through 31 May 1988 showing the number treated each day, the timing of events related to flooding of the Itaparica Dam's reservoir, and the date of the first copper sulfate treatment of drinking water.



Of the 76 hospital outpatient cases investigated, 71.0% affected young children (44.7% occurring among infants and 26.3% in the 1–4 age group) (Table 3). Nearly all these 76 patients (94.7%) complained of diarrhea, and nearly all the individuals for whom information was available (40 out of 44) had three or more evacuations a day. In addition, the clinical findings indicated that many patients had colic-like abdominal pain (72.4%), vomiting (55.3%), and fever during the initial phase of the disease (33.3%). No neurologic alteration was observed in any of the 76 subjects during the clinical examination. Most of the 76 patients (at least 76.3%) came from urban areas. Imbibing of well water was reported in only 17.1% of the cases, although in 25.0% of the cases the person reporting said there had been piped water available and gave no indication as to whether it was treated. No information was available about the water consumed in 22.4% of the cases.

Table 2. Age distribution of 1 118 gastroenteritis patients treated at Paulo Afonso health units from 26 March through 31 May 1988.

Age group (in years)	Patients	
	No.	%
<1	439	39.3
1–4	350	31.3
5–14	120	10.7
≥15	209	18.7
Total	1 118	100.0

Source: 10th Regional Health Directorate, Paulo Afonso.

The 1985–1988 data in Table 4 show higher rates of hospitalization from diarrhea-related illness during the first 4 months of each year than during the last 8 months except in 1987. In April 1988, of course, the number of such hospital-

Table 3. Data on the 76 study subjects treated for gastroenteritis at the outpatient clinic of the Nair Alves de Souza Hospital in 1988.

Item	Patients	
	No.	%
Age group (in years):		
< 1	34	44.7
1–4	20	26.3
5–14	9	11.8
≥15	13	17.2
No. of daily evacuations:		
2	4	5.3
3	26	34.2
4	3	3.9
5–7	0	0.0
≥8	11	14.5
Unknown	32	42.1
Clinical data:		
Fever at onset of illness[a]	7	33.3
Diarrhea	72	94.7
Vomiting	42	55.3
Abdominal pain/colic	55	72.4
Water source:		
Well	13	17.1
Piped water supply, treated	27	35.5
Piped water supply, no information about treatment	19	25.0
Unknown	17	22.4
Hospitalization:		
Yes	6	7.9
No	64	84.2
Unknown	6	7.9
Patient residence:		
Urban	58	76.3
Rural	5	6.6
Unknown	13	17.1

Source: Interviews with patients or accompanying responsible persons at the outpatient clinic of the Nair Alves de Souza Hospital.

[a]The patient's temperature was recorded in only 21 cases.

izations was high—well over twice that of April 1987. Also, despite considerable fluctuation in mortality among diarrhea patients at this hospital, mortality in May 1988 (45.1%) stands out as the highest monthly rate during the 4-year period covered.

Geographic Case Distribution

In addition to the noteworthy concentration of diarrhea cases in Paulo Afonso during the epidemic period, another concentration of cases was observed in the adjoining municipality of Glória (see Figure 2). Other nearby municipalities in adjoining states, including Delmiro Gouveia and Olho d'Água do Casado (in the state of Alagoas) and Petrolândia (in the state of Pernambuco), were also affected.[5] Other municipalities in the Paulo Afonso region that did not receive water from areas flooded by the Itaparica Dam (such as the municipalities of Jeremoabo, Macururé, and Chorrochó shown in Figure 2), did not exhibit an unusual increase in diarrhea cases.

The Epidemic Curve

Lack of charts or any other type of data register in nearly all of the region's health units prevented analysis of diarrhea case distributions in previous periods. However, the data charted in Figure 1 indicate that the 1988 epidemic began toward the end of March, persisted throughout April, and declined after the first week in May. Its onset was sudden, quickly affecting a large number of individuals, and during its long (more than a month) duration it covered a broad but well-defined geographic area. It could thus be characterized as a significant and prolonged epidemic, possibly with a common source.

The Flooding of Lake Itaparica

The process of flooding Lake Itaparica began on 19 February 1988 when the floodgates of the Sobradinho Dam were

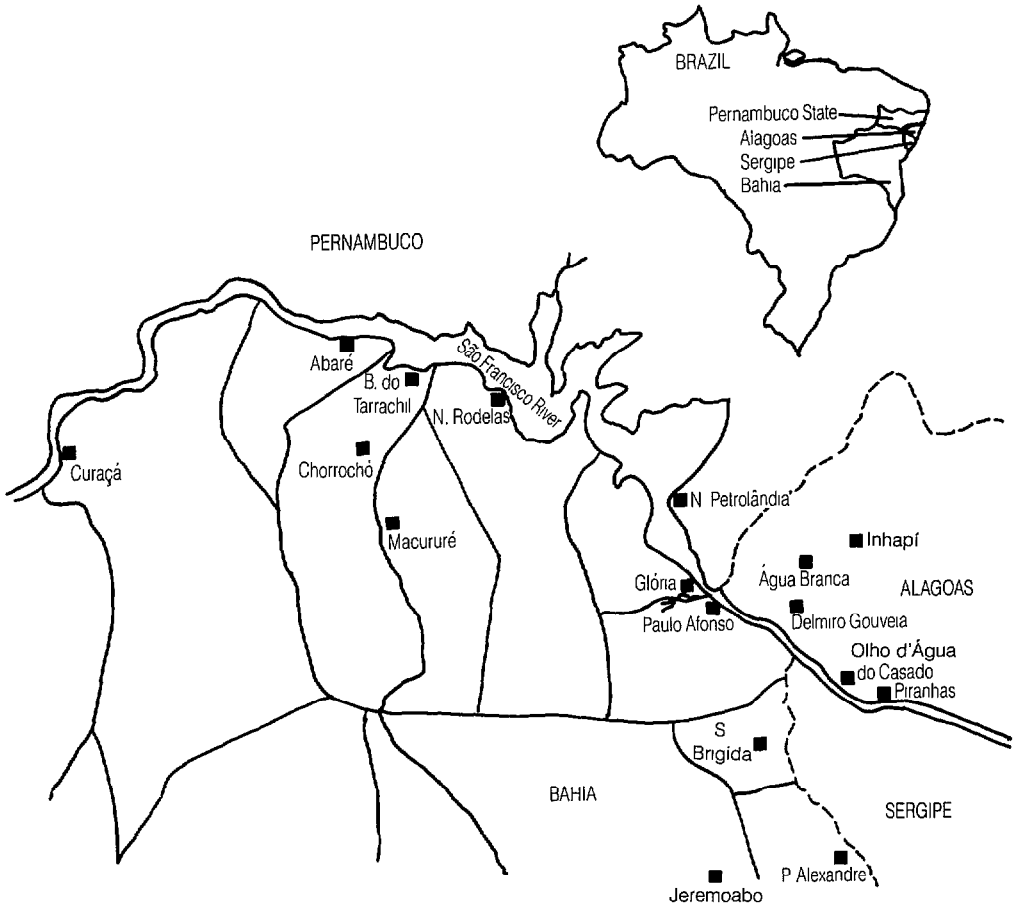
[5]Most of the cases studied were obtained from Paulo Afonso hospital data, but a number of others were reported by the state health secretariats of affected states.

Table 4. Hospitalizations, deaths, and % hospital mortality among gastroenteritis patients admitted to the Nair Alves de Souza Hospital from January 1985 through May 1988, by month.

	1985			1986			1987			1988		
Month	Hospitalizations	Deaths	% Mortality	Hospitalizations	Deaths	% Mortality	Hospitalizations	Deaths	% Mortality	Hospitalizations	Deaths	% Mortality
January	33	4	12.1	43	15	34.9	34	7	20.6	56	7	12.5
February	53	9	17.0	30	7	23.3	31	9	29.0	65	9	13.8
March	70	20	28.6	20	2	10.0	36	1	2.8	44	8	18.2
April	38	11	28.9	34	13	38.2	49	8	16.3	131	31	23.7
May	26	4	15.4	35	7	20.0	53	15	28.3	72	33	45.1
June	21	5	23.8	26	3	11.5	16	4	25.0	...	...	...
July	20	4	20.0	22	4	18.2	32	8	25.0	...	...	...
August	16	2	12.5	26	2	7.7	36	7	19.4	...	...	...
September	18	2	11.1	27	—[a]	—	33	11	33.3	...	...	...
October	21	2	9.5	34	5	14.7	27	3	11.1	...	...	...
November	30	1	3.3	27	5	18.5	37	5	13.5	...	...	...
December	41	5	12.2	25	2	8.0	19	2	10.5	...	...	...
Total	387	69	17.8	349	65	18.6	403	80	19.9	368	88	23.9

Source: Medical records of patients at the Nair Alves de Souza Hospital.
[a]— = No data.

Figure 2. A map of the affected area, including portions of the states of Pernambuco, Alagoas, and Bahia, showing the location of towns and municipalities cited in the text.



opened. This dam, which has a large reservoir, is the next dam upstream from Itaparica. The first and second floodgates of the Itaparica Dam were closed between 26 February and 7 March. From 8 March onward, flooding of the Itaparica reservoir was observed.

On 24 March the incidence of gastroenteritis cases began to rise in rural communities of Glória Municipality and in certain downstream communities (Delmiro Gouveia and Olho d'Água do Casado) served by the reservoir. In addition, it appears that rains during this period (*1*) could have facilitated the mixture of flood waters, potentially rich in decomposing organic material, with those of the São Francisco riverbed.

Possible Transmission Mechanisms

The signs and symptoms presented by the patients were sufficient to characterize the gastroenteritis picture. The geographic distribution of cases, the many individuals affected, the duration of the outbreak (indicating continual exposure to the causative agent), and a lack of indicators pointing to a common source of contaminated food indicated that water

was serving as a vehicle or causative agent of the disease in question.

Research on Etiologic Agents

Because water was the probable vehicle, the following hypothetical agents were considered:

- Agricultural toxins. Because local inhabitants said the flooded region had contained plantations that were sprayed with toxic agricultural chemicals, as well as depositories where pesticides were stored, possible poisoning by such chemicals was investigated.
- Proliferating bacteria or viruses. Such microbial proliferation might have been encouraged by degradation of the submerged biomass.
- Cyanobacteria (formerly called blue-green algae). Proliferation of these toxin-producing organisms could likewise have been stimulated by biomass degradation and the consequent increase in suspended organic material.

Laboratory Tests

Toxicologic analyses of specimens from the study subjects showed that levels of cholinesterase and heavy metals (2) were within normal limits. Enzyme and toxicity tests of water collected at various points from the reservoir behind the Itaparica Dam failed to detect organophosphate agrotoxins, carbamates, or heavy metals (2).

Coprocultures and viral tests of fecal specimens did not detect *Salmonella spp., Salmonella arizona, Shigella,* rotavirus, or adenovirus (2).

EMBASA performed biologic and bacteriologic analyses on water samples from the São Francisco River collected during the epidemic. These water samples were obtained at various collection points in the Itaparica and Glória Basin and at the water treatment facility (including samples that were untreated, decanted, filtered, chlorinated, and outgoing for residential use) (2). This analysis showed that the samples of treated water distributed from March to May 1988 did not contain significant levels of fecal coliforms and were therefore fit for human consumption; however, the samples of untreated water contained high levels of fecal coliforms and did not meet the established bacteriologic standards for drinking water.

After installation of a hydrobiology laboratory at the area's water treatment facility on 26 April, the presence of pigmented flagellated algae and cyanobacteria of the genera *Anabaena* and *Microcystis* were detected in untreated water at levels of 1 104 to 9 755 standard cyanobacterial units per milliliter. These levels were 3.7 to 32.5 times the maximum acceptable level of 300 units/ml established by the World Health Organization (WHO) for drinking water prior to its recommended conventional treatment (filtration, decantation, and chlorination) (3–5).

DISCUSSION AND CONCLUSIONS

Lack of data on reported diarrhea cases or their treatment in previous years made it hard to develop a control model capable of statistically characterizing the epidemic. However, the unexpectedly large number of cases, together with subsequent analysis of the history derived from hospital data, provided good grounds for recognizing an epidemic profile.

Treatment records showed a predominance of diarrhea cases among children under 5, possibly because they were more susceptible and ran a greater risk of contracting more serious forms of the dis-

ease. However, the outbreak also affected individuals of other age groups. In addition, the large number of cases, duration of the outbreak, use of the same water supply by most of those affected, and occurrence of cases in other municipalities of neighboring states that also received water from the dam reservoir, led us to conclude that the water was the vehicle of the disease agent. Although operational difficulties prevented our research from encompassing a representative population sample (including cases and unaffected individuals), the findings obtained nevertheless strongly support the foregoing conclusion.

The clinical picture, together with the negative toxicologic analyses of blood specimens and water samples and the absence of dead fish or other animals at the edge of the dam during the epidemic, made it appear unlikely that excess agrotoxins in the water could have been the causative agent. Therefore, it seemed likely that the epidemic was of infectious (bacterial or viral) origin or was caused by toxins produced by the cyanobacteria found in high numbers in untreated water samples.

Of the many infectious agents causing human gastroenteritis (*6, 7*), some (like the classic *Vibrio cholerae)* generate a very specific clinical profile while others (such as *Shigella, Yersinia,* and *Campylobacter*) produce rather similar symptoms. In the latter instance, this makes it difficult for an observer to identify the responsible agent by means of a clinical profile.

The clinical descriptions of treated cases, reflecting very severe diarrhea pictures, corresponded to the portion of ill people who procured health services, a portion that the literature suggests typically amounts to only 20% or so of the total cases in a gastroenteritis outbreak (*8*). This is partly because gastroenteritis is a common disease, familiar to the population, and one for which people are accustomed to finding their own remedies. In addition, the distribution of oral rehydration salts during the epidemic reported here may have contributed to home treatment and caused only part of the affected population (that part with the more serious clinical manifestations) to avail itself of health services. In all probability this made the disease appear more severe than it actually was and, at the same time, increased the possibility that the number of cases was underestimated.

The signs and symptoms described tended to rule out a common enteric disease such as that caused by *Salmonella* or *Shigella;* but they did not eliminate the possibility of a viral or *Escherichia coli* etiology in the absence of negative coprocultures. However, EMBASA tests during the epidemic showed that water in the reservoir, in the distribution network, and in kitchen faucets conformed to the recommended WHO drinking water standards.

In addition, if the outbreak was caused by increased levels of fecal coliforms in untreated waters of the São Francisco River, such coliforms would already have been present in the river before the onset of the epidemic (*1, 9*), a fact that could help explain the persistent stable rates of endemic gastroenteritis in the area. However, epidemic cases with this cause should only have come from rural areas using untreated river water, whereas in fact they came partly from such rural areas but primarily from urban areas served mainly with treated water.

We also observed that public health advice provided during the epidemic, which recommended that drinking water be filtered and boiled, did not prevent individuals who followed this advice from becoming ill. This made us suspect that the causative agent might not be neutralized by boiling water.

In sum, these findings led us to think that the agent responsible, whether of

bacterial or viral origin, was probably not sensitive to conventional water treatment methods; and this encouraged us to keep looking for other possible causes.

Because of the likelihood that the agent was not a common gastroenteritis pathogen, and because the clinical data suggested upper gastrointestinal irritation, we came to suspect that the agent might be a toxin producer. This suspicion was strengthened by identification of two kinds of cyanobacteria (*Anabaena* and *Microcystis*) in untreated waters of the São Francisco River that are toxic and capable of producing gastroenteritis. They are also resistant to conventional water treatment methods but sensitive to copper sulphate (*10*).

Accordingly, copper sulfate was used to treat drinking water on 6 and 7 May. This water was distributed through the urban supply network and was also provided to rural areas by water trucks filled at local water treatment facilities. Although the epidemic had declined sharply by then (see Figure 1), this action may have contributed to its termination.

The drinking water was again treated with copper sulphate on 19 and 20 May. This treatment was suspended on 21 May because of a decline in the concentrations of cyanobacteria observed in untreated waters (2). (The number of reported gastroenteritis cases had also diminished sharply by then.) Overall, the theory that the outbreak was associated with an abnormal proliferation of cyanobacteria in the river water induced by increased organic material (2) arising from biomass degradation in the area influenced by the Itaparica Dam was accepted as capable of providing an appropriate explanation for this serious epidemic.

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REFERENCES

1. Barros AC. Levantamento hidrobiológico. In: Companhia Hidroelétrica do São Francisco: relatório preliminar sobre monitoramento hidrobiológico na represa de Itaparica, no período de alagamento. Paulo Afonso: 1988:11–19. [Mimeographed document].
2. Bahia, Secretaria da Saúde. Relatório final do surto epidêmico de gastroenterite ocorrido na região de Paulo Afonso, Bahia, no período de março/abril/maio de 1988 (3 vol). Salvador: 1988. [Mimeographed document].
3. World Health Organization. *International standards for drinking water, third ed.* Geneva: WHO; 1971.
4. Pan American Health Organization. *Guidelines for drinking-water quality: health criteria and other supporting information.* Washington, DC: PAHO; 1987. (Scientific publication 506).
5. Pan American Health Organization. *Guidelines for drinking-water quality, vol 1: recommendations.* Washington, DC: PAHO; 1984. (Scientific publication 481).
6. Junqueira JCF. Diarréias. *Ars Curandis.* 1986;19(80):234–242.
7. Silva LR, Mota E, Santana C. *Diarréia aguda na criança.* Rio de Janeiro: Medsi; 1988.
8. Brasil, Ministério da Saúde. Programa de assistência integral à saúde da criança: a doença diarréica aguda. Brasília: 1986. [Mimeographed document].
9. Companhia Hidroelétrica do São Francisco. *Usina hidroelétrica de Itaparica: estudos ambientais: identificação, descrição e avaliação do impacto ambiental, vol 3.* 1987:362–363.
10. Branco SM. Algas. In: Companhia de Tecnologia de Saneamento Ambiental. *Hidrobiologia aplicada à engenharia sanitária, second ed.* São Paulo: 1978:248–274.