# The Recent Cholera Outbreak in the South African Gold Mining Industry

## A PRELIMINARY REPORT

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## SUMMARY

**A large-scale cholera surveillance programme was introduced in South Africa in November 1973 as a result of the progressive southward spread of cholera in Africa.**

**Moore's technique for the isolation of *Salmonella paratyphi* was modified for cholera detection. The method proved to be very sensitive and it was possible to detect *Vibrio cholerae* in main sewer lines after its casual and transient introduction by an unidentified carrier.**

**Transmission occurred in the acclimatisation centre, probably through the drinking of water contaminated after it had been drawn from the tap. Faecal contamination of the environment was demonstrated, and *V. cholerae* was isolated from the floor, onto which it had been disseminated from the perianal region by means of profuse perspiration.**

**Perpetuation of cholera was probably aided by a faecally contaminated air-humidifying water reservoir, the water of which experimentally allows survival and multiplication of *V. cholerae* for a week and longer.**

**Prophylactic treatment of selected high-risk groups of people was administered in the form of doxycycline, which appeared to result in rapid termination of the epidemic.**

**Mass vaccination of all mine personnel (20 000) was carried out to reduce the incidence of clinical cholera and the bacterial load.**


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The presence in Malawi, Mozambique and Angola of cholera as an endemic disease during 1973 was followed by the introduction of a cholera surveillance programme designed especially, but not exclusively, for the South African mining industry. The need for this arose from the fact that the abovementioned countries formed a major source of foreign migrant labour, which therefore constituted a potential route for the introduction of cholera into South Africa.

## MATERIALS AND METHODS

### Surveillance Methods

Cholera surveillance may be based on various combinations of many well-tried and proven methods.[1] These vary from one country to another and their selection is determined by a variety of considerations, such as the prevailing sanitary facilities, size of population at risk, staff, laboratory facilities, cost, etc. The scheme adopted for South African needs incorporated the following components:

**Monitoring of sewage:** Since virtually all large mines are provided with water-borne sewerage, Moore's method of detecting *Salmonella paratyphi* in sewage by means of gauze pads[2] was modified for cholera isolation by the use of double-strength alkaline peptone water as the transport medium for the pad and its contents. Pads are inserted in the sewers once every week and removed 24 - 72 hours later.

**Rectal swab examination** of people who had used a sewer line which yielded a cholera-positive pad. Rectal swabs were forwarded to the laboratory in alkaline peptone water or in Carey-Blair medium,[3] depending on the period of delay in transport anticipated by the sender.

**Isolation and rectal swab examination** for cholera of all people who developed a diarrhoeal illness within a few weeks of arrival from declared cholera-affected countries.

**Examination of seafood** imported from cholera-affected countries.

## Laboratory Methods

All specimens, irrespective of their nature, were enriched at least once in alkaline peptone water before planting on the selective TCBS agar.[3] Rectal swabs which arrived in the laboratory in alkaline peptone water were plated directly on TCBS agar, and underwent a second enrichment procedure in alkaline peptone water.

Bacteria resembling *Vibrio cholerae* on TCBS agar were immediately subjected to slide agglutination with polyvalent and monospecific cholera sera when they were of individual human origin, in order to avoid delay in diagnosis.

Sewer pad cultures, on the other hand, underwent a screening procedure. This was necessitated by the large number of sewage specimens processed daily and the presence in most of these of non-cholera vibrios (NCVs), also known as NAG (non-agglutinable) *V. cholerae* which are distinguishable from choleragenic *V. cholerae* only on the basis of their failure to agglutinate with the O-group 1 antiserum.

The screening procedure was based on the demonstration of indole production and a positive oxidase reaction of suspicious sucrose fermenters subcultured from TCBS agar. Such cultures were boiled[4] and submitted to slide agglutination with cholera antisera and, if necessary, fully investigated.

Details of the ramifications of cholera laboratory diagnosis are to be published in a later article. It is sufficient now to say that all *V. cholerae* isolates were subjected to full routine biochemical examination, including decarboxylase and dihydrolase activity, were serologically confirmed after the suspected culture was boiled for 2½ hours at 94°C, and were initially biotyped by means of the polymyxin sensitivity method, which was later supplemented by sensitivity testing against Mukerjee group IV cholera phage. The eltor biotype is resistant to this phage.

Doxycycline sensitivity of the *V. cholerae* isolates was tested by means of the disc method. Discs containing 30 μg doxycycline were placed on Mueller-Hinton agar planted with a lawn of the organisms under test.

# THE COURSE OF THE OUTBREAK

## Clinical Aspects

The mines concerned in this epidemic are served by a large, modern and well-staffed hospital which, on the finding of the first cholera-positive sewer pad and cholera carriers, was made ready in anticipation of a possible outbreak of the disease. Cholera beds[3] were constructed by replacing the springs of normal hospital beds by wooden boards in which a hole was cut. A corresponding hole was made in the plastic-covered mattress and a graduated plastic bucket placed on the floor underneath the hole. These beds were found to be invaluable for the proper nursing care of patients with profuse rice-water stools, in that soiling was minimised, and for the easy assessment of the intravenous therapy required after initial rehydration had been achieved.

Only 5 of the 31 cholera patients presented with severe diarrhoea and dehydration. They were apyrexial, vomiting occurred in only 1, and abdominal cramps in 2 of these 5 cases. Intravenous replacement therapy was administered to these patients in the form of Plasmalyte-B and dextrose in saline.

It should be stressed, however, that oral replacement therapy alone is effective in all but the most serious cases,[3,5] and should be considered wherever facilities for intravenous therapy or sufficient numbers of qualified personnel are not available. The solution recommended for oral therapy contains glucose (110 m-mol/litre), NaCl (72 m-mol/litre), $NaHCO_3$ (48 m-mol/litre) and KCl (25 m-mol/litre). Vomiting should not be a criterion for withholding oral therapy in favour of intravenous therapy.

Chemotherapy was administered to all patients, and carriers in the form of a short-acting tetracycline, 500 mg every 6 hours for 5 days. On completion of treatment and after 3 consecutive negative daily rectal swabs, the patients and carriers were discharged from hospital. In only 1 case did the rectal swab remain positive after treatment, and a second course of tetracycline was required. Thirty-three of the 63 cholera patients and carriers had received cholera vaccine between 12 days and 7 months before leaving their home countries. This emphasises the well-known fact that the present vaccine is of limited value and does not prevent the carrier state nor the geographical spread of the disease. The value of vaccine to the individual, in that it probably reduces the severity of the illness, is illustrated by our 5 severe cholera cases, none of whom had been vaccinated prior to infection.

## Epidemiology and Control

The cholera surveillance programme for the mining industry was commenced in November 1973. The major problem encountered in the early stages was the delay of up to 2 weeks in the transport of most specimens. If permitted to continue, this would have totally defeated the aim of surveillance, i.e. early detection. This problem was therefore rapidly tackled and virtually all specimens, even from remote parts, have since arrived at the central or peripheral laboratories on the day of despatch or on the day thereafter. During the next 4½ months none of the specimens examined was found to be cholera-positive.

Moore's technique was tried in Hong Kong in 1961/62 in the Resettlement Estates, which were served by waterborne sewerage. The results were consistently negative and since the nightsoil sampling proved to be an effective indicator of the presence of cholera, the sewer pads were discontinued.[6] Moore's technique has recently been recommended elsewhere for the detection of *V. cholerae* in sewage.[7]

During March 1974, two coal mines in the eastern Transvaal and one gold mine (Mines A, B and C) yielded cholera-positive sewer pads. The isolates were all of the eltor biotype and Inaba serotype. These findings were followed up by rectal swabbing of recent arrivals from cholera-affected countries on the 3 mines concerned, but no cholera carriers were detected, and on each mine the subsequent sewer pad had reverted to negative.

On 25 March the first cholera-positive sewer pad was obtained from mine D, a western Transvaal gold mine. In this instance, the rectal swab survey of new arrivals yielded 2 healthy cholera carriers.

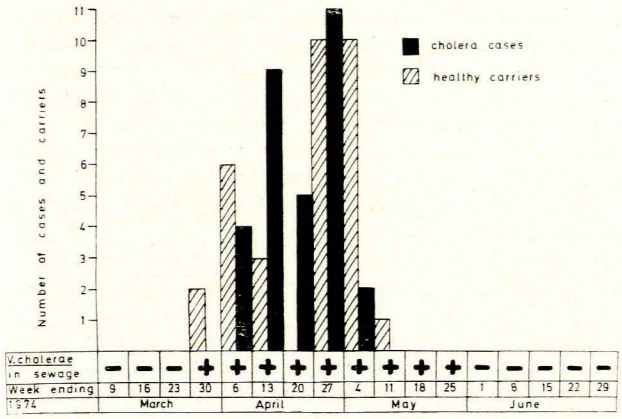


**Fig. 1. Course of the cholera epidemic on a South African gold mine.**

Fig. 1 shows the subsequent events on this mine, where the introduction of cholera by a few healthy carriers was followed by spread to workers who had been on the mine for long periods, and a local cholera epidemic developed. It is important to note that the use of the modified Moore technique resulted in the detection of the presence of cholera on this mine a full 10 days before the occurrence of the first symptomatic cholera patient on 4 April, by which time 8 healthy carriers had already been identified and treated in isolation. At the end of the third week after the first positive sewer pad was obtained, only 3 of the by then 24 cholera-positive people were veteran workers who must have contracted cholera on the mine, but it was at that stage not clear how, or precisely where, infection had occurred. During the week that followed, a further 4 veterans became ill and a pattern began to emerge.

Since 1965 new recruits to the South African gold mines (some of which have the deepest shafts in the world) have undergone an 8-day period of acclimatisation by means of the climatic room technique,[8] the purpose of which is the prevention of heat stroke, which is an occupational hazard at great depths where temperatures and humidity are high. Acclimatisation is carried out during the initial induction period of the new mine labourer concurrently with aptitude testing, job training and lectures on various subjects such as language training, accident prevention, etc. The acclimatisation process involves carefully controlled and graduated exercise under conditions of high environmental temperature and humidity. These conditions are simulated on most mines in the acclimatisation chamber of the training centre.[9] Acclimatisation is rapidly achieved by most people but is equally rapidly lost when exposure to underground heat conditions is interrupted for 8 days or more. For this reason, veteran workers who have been off work because of, for example, hospitalisation or holidays, must undergo a course of reacclimatisation. With the occurrence of the 4 additional veteran miners with cholera mentioned above, it emerged that all 7 cholera-positive veterans had, shortly before the onset of their illness, undergone reacclimatisation, and an association between acclimatisation and exposure to cholera came to be suspected. The trainees are dressed only in loose trunks or loin cloths and perspire profusely during their acclimatisation sessions. Three litres of water are consumed by each person during a 4-hour acclimatisation session, and the mugs used for drinking as well as the water dispenser were kept on the floor. Faecal contamination of the water dispenser was demonstrated. It was postulated that *V. cholerae* might be disseminated from the perianal region of healthy carriers and carried by means of perspiration to the floor. This postulate was confirmed by the demonstration of gross faecal contamination and the isolation of *V. cholerae* from sweat collected from the floor.

When the implications of these findings were recognised, immediate steps were taken to eliminate the possibility of contamination of the water by healthy cholera carriers in the centre. Mugs were removed after use and were washed and disinfected, returned to the trainees and refilled from a closed water dispenser which was not subject to contamination. In addition, all occupants of the centre, including staff members, were screened for *V. cholerae*, and such healthy carriers as were identified were moved into isolation and treated.

During the fourth week, the sewage examination had been extended on this particular mine and a number of individual tributaries to the main sewer lines were examined on a daily basis. One of these tributaries served the acclimatisation centre exclusively.

Contrary to expectations, the strict supervision of the drinking water and its administration in the acclimatisation centre as well as the removal of all demonstrable cholera carriers, not only failed to achieve a significant decline in the epidemic, but the sewer pads, including the pad monitoring the acclimatisation centre, remained positive. Pending the elucidation of epidemiological factors predisposing to the development and persistence of a possible local focus, it was decided to introduce prophylactic antibiotic treatment to selected groups of people such as all staff members and new recruits at the acclimatisation centre and close contacts of cases. Mass vaccination of all mine workers (20 000) was carried out at the same time with a view to reducing the numbers of symptomatic cholera patients and therefore the number of bacteria excreted and released into the environment. The vaccine used was a formalin-killed, phenol-preserved SAIMR preparation containing $8 \times 10^9$ cells/ml in an equal mixture of *V. cholerae* classical biotype Inaba serotype 35A3, and *V. cholerae* classical biotype Ogawa serotype 41.

Because of the difficulties in ensuring that conventional oral tetracycline would be taken 4 times daily by healthy mine labourers, it was decided to use the long-acting doxycycline which needs to be taken only once daily and its administration could therefore be properly supervised. Doxycycline was administered in a single 200-mg dose on the first day and 100 mg daily during the next 4 days.

Doxycycline has not yet been described for the treatment or prophylaxis of cholera, but a scrutiny of the

general literature[10,11] showed other potential advantages besides the easier control of administration, namely its concentration in bile and faeces and, compared with the short-acting tetracyclines, its minimal excretion via the kidneys. The latter is of obvious importance in the treatment of the dehydrated patient and in the prophylactic treatment of labourers in training or working environments where heat stroke is a potential danger. The doxycycline regimen was introduced on 2 May, after which only 2 more cholera-positive people were identified on the mine, the last on 8 May.

Investigation into the standard of environmental sanitation revealed that:

1. Domestic water is a filtered and chlorinated product which is piped throughout the mine and to other consumers.

2. Sewage disposal is a water-borne system.

3. Food handling and preparation is organised on a communal basis and the standard of hygiene of the premises and food-processing was found to be very high. Food-handlers are checked as a routine to exclude typhoid and, since the onset of the cholera epidemic, cholera carriers.

4. In spite of a sanitary food and water supply, the collection on the consumer level was such that faecal contamination could occur, e.g. food was left uncovered and was seen to attract flies. Where necessary, a stricter control was exercised over the observance of hygienic procedures and facilities.

Sewer pads remained positive, and on 16 May, two sewer lines were experimentally treated with chloride of lime, and these became negative. However, other untreated sewer lines spontaneously became negative during the next 5 days.

The disease spread, or was introduced, during this period to the adjoining gold mine E (positive sewer pad, 5 symptomatic patients), gold mine F (positive sewer pad, no cases or carriers) and gold mine G (positive sewer pad, 1 symptomatic patient).

The size of the communities concerned made enforced isolation impractical but, when the situation was explained to the labourers, a voluntary restriction of interhostel movement for social and recreational purposes was readily obtained.

In addition to these control measures, all new labour recruits to mines D and E had rectal swabs taken on arrival, and were isolated in a separate section of a hostel, given a course of doxycycline and were integrated into the community only after a negative post-treatment rectal swab. None of the pretreatment swabs yielded positive results. This is further support for our belief that the great majority of the cholera-positive new recruits acquired their infection on the mine during the training period.

The cholera epidemic on mine D resulted in 31 symptomatic patients and 32 known healthy carriers. There were no deaths. The causative organism in all cases was *V. cholerae*, biotype eltor, serotype Inaba, which was sensitive to tetracyclines including doxycycline.

A thorough investigation was undertaken on gold mine D towards the end of May, and it was found that a water reservoir which served to supply the water sprays which humidify the air entering the acclimatisation centre, was faecally contaminated. Current laboratory experiments, the full results of which will be published at a later date, indicate that this reservoir water allows the survival and multiplication of *V. cholerae*, and it is postulated that this reservoir may have served as a local focus of *V. cholerae* which bridged the gap between the removal of the last carrier and the arrival of the next susceptible individual. The reservoir was emptied and refilled with clean water on a fortnightly basis, and the good survival of *V. cholerae* in the reservoir and the overflow sump from the chamber floor in which the water has a high pH and high salt content, may also have been responsible for the persistence of *V. cholerae* in the sewer pads for 2 weeks after the last cholera-positive person was identified. Subsequently the use of stored water for humidifying purposes has been abandoned in favour of fresh water.

An investigation on mine E where, contrary to mine D, none of the cholera patients were associated with acclimatisation, revealed that the humidifying system is *not* served by a water reservoir but employs freshly flowing water. No stagnation and no contamination could therefore occur. All 5 patients were, however, employed underground at low levels where a tropical microclimate prevailed. Here too, the water consumption was therefore high. Although the drinking water supplied to these levels in the shaft concerned was chlorinated and shown to have satisfactory bacteriological standards, the way in which it was seen to be collected by a worker (who filled a bottle by means of a hose nozzle trailing in a waste-water ditch) introduced the potential danger of cholera contamination, since the waste water was shown to be faecally contaminated. Profuse sweating and physical exertion, as shown during this epidemic, may in fact play an important role in cholera epidemiology, and be a factor in the observed prevalence of the disease in the tropics and during hot seasons. It is suggested that, especially in unsophisticated communities, perspiration may serve as the vehicle by which *V. cholerae* is transmitted from the faecally contaminated perianal region of the healthy carrier to the environment. While it is generally accepted that *V. cholerae* has a limited survival in water, especially heavily contaminated water, the exception occurs in water which has a high salt content.[7] This condition for survival is supplied by the presence of sweat.

The presence of *V. cholerae* in sewage underlines the importance of ensuring that sewage disposal plants are in optimal operating condition. Overloaded plants may result in too rapid a turnover and the consequent presence of *V. cholerae* in final effluent.

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