Epidemiology of Endemic Cholera

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THE MAIN epidemiological features of endemic cholera have been long known, with some of the original observations dating back nearly a century. The available information has been reviewed extensively by Pollitzer (*1*), and unless otherwise stated, all references are taken from this monograph.

By the end of the 19th century, the areas of endemicity had been clearly defined, the nature of the countryside in which it was found was described, the relationship of the disease to the weather, especially the monsoon, had been noted, and the inability of *Vibrio cholerae* to survive for long periods in water containing large numbers of competing organisms and the potentialities of the village tanks, or ponds of surface water, in spreading infection had been observed. The fact that the cholera vibrio could withstand a very high pH had been discovered and indeed utilized in isolating the organism in pure culture.

However, efforts to provide an explanation for these features have so far been unsuccessful. In this paper we have reexamined and confirmed some of these epidemiological features and offer a theory and supporting data to explain them.

The theory is that the tanks of water are, in fact, the main means of spread of the infection; the seasonal fluctuations of the disease and possibly the limitations of the endemic area are the results of fluctuations in the pH of the tank water. Examination of a number of tanks over a period of a year has shown that in sunny weather the pH commonly rises from about 7.0–7.5 in the morning to as high as 10.0 and occasionally to 10.5 in the afternoon. But when it rains this rise is prevented, and the pH may fall below 7.0. These fluctuations are the result of the activity of the algae in the water which liberate either carbon dioxide or oxygen according to the intensity of the light available. This range of pH's would give an advantage to the vibrio in the water over other intestinal organisms and permit them to survive, and, through natural selection, may have been responsible for producing the alkaline-resisting capacities of the organism.

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Epidemiology of Cholera

Cholera has been known as a distinct entity since 1817. In severe epidemic classic form it appeared in Calcutta in 1817 and spread rapidly around the world in a great pandemic that was repeated no less than five times in the 19th century. The epidemiology of the epidemic type of infection was clearly worked out, with the spread being along the trade and pilgrim routes through the agencies of bad hygiene, polluted water, flies, and overcrowding. The most significant feature of these 19th century pandemics was that they died away, leaving no permanent foci outside Asia. In the 20th century these Asian foci rapidly dwindled down to one or two sharply localized areas. Today, the disease does not exist in Russia or China (personal communication from Prof. B. H. Pastukhov, of the 1958 Soviet Medical Mission to East Pakistan) or in Japan, the Philippines, Indonesia, or Ceylon (*1*), except when introduced from outside. In Thailand, cholera appears for about 3 years at a time, but then is not seen for 5 or 7 years. It is not known whether the infection is endemic there or is repeatedly reintroduced. The only place where it has been found with regularity all the year round, year after year, decade after decade, has been the Indian subcontinent.

At the beginning of the 20th century, cholera seems to have been endemic in Burma, Bengal, and on the east coast of India near the sea and associated with rivers. However, in the course of 50 years, the geographic distribution of the endemic infection has progressively dwindled so that today, although the epidemic type is still likely to appear in most parts, only Bengal remains a permanent focus. Further research may show that cryptic or undiagnosed cholera is present in all seasons and years in places like Burma, Nepal, and Thailand; but until this has been demonstrated, Bengal must be regarded as the primary source of all epidemics. Therefore, should the infection be eliminated from Bengal, it would almost certainly disappear from the world.

The Endemic Area

Bengal is mainly the land formed by the Ganges-Brahmaputra Delta. In the 1947 partition it was divided between India and Pakistan, and the eastern half is now East Pakistan. Ecologically, the two sides differ significantly; West Bengal has an enormous urban population centered on Calcutta, while East Pakistan is one of the most rural countries in the world. There are only two large towns in East Pakistan, Dacca with about 600,000 population and Chittagong with 300,000 and these have reached these proportions only since partition. So far as the cholera vibrio is concerned, Bengal must be regarded as one unit, for considerable numbers of people, presumably carrying with them the causal organisms of the disease, still move across the border.

Calcutta was founded by the British in the 18th century, and one is tempted to suggest that there is an association between this newly created concentration of people and the appearance of the disease in epidemic form in 1817. It is a great sprawling slum with most unhygienic conditions. The overcrowding is gross, and every night large numbers of people sleep on the streets and in the railway stations. Poverty is everywhere, and beggars are numerous. Half of the water supply is simply untreated crude river water. The river itself is highly polluted, and the cholera vibrio has been found in it at most times of the year.

East Pakistan is different. Here, about 45 million people, more than 95 percent of the population, live in small communities, each with its own farming area. Some have only a few individuals of one family, while others may hold up to several hundred persons. Where the land is most suitable for farming, the communities are smaller and only a hundred yards or so apart; where flooding is frequent, they are farther apart and larger. Since each group of houses is hidden by trees and surrounded by apparently empty fields of rice and jute, at first sight the countryside seems almost uninhabited; in reality it is one of the most heavily populated areas of the world, with nearly 1,000 persons per square mile.

The land is flat and only a few feet above sea level. Dacca Airport, about 100 miles from the sea, is 24 feet above sea level, and much of the coastal area is actually below the high-tide level, being protected by a system of dikes. The heavy rainfall of the monsoon and the huge masses of water pouring down the Ganges and Brahmaputra Rivers cause extensive flooding, and in most years about one-third of the land disappears under water. In real flood years, such as 1954, the larger portion of the delta area is submerged.

The inhabitants have become adapted to life under these conditions during many centuries. To cope with the floods, each hamlet or village has been built on a mound. The holes in the ground made by digging soil for these mounds are the tanks, and each village is usually surrounded by a number of them. In dry weather these tanks are the source of the water for the community, and a center of social life. Everyone visits them daily to wash clothes, for ablutions, to swim, to collect water for drinking and cooking, to fish, or to wash a cow or a buffalo. Sometimes there is a latrine perched on one end, and commonly when it rains the surface water from the houses flows into the tanks.

The houses are usually clean, with polished

Woman drawing water at a tank as her family waits on the bank

beaten mud and dung floors and little refuse lying around. Flies are not a major problem except around cattle sheds, and in the monsoon they are almost absent. Each family stores the year's supply of rice in large pots. After the monsoon starts in July, the mounds with their dwellings stick above the water like little islands. Nearly all roads disappear, and the villagers travel by their boats, which during the dry weather have been lying submerged in the tanks. At any time the rivers are the main highways of the Eastern Province, but during the monsoon almost everything goes by water. Water transport by sail or oar is slow, and 10 miles can be a hard day's journey. North of Dacca, the land rises slightly and is more heavily wooded, so that these conditions are found largely only along the rivers.

Patterns of Occurrence

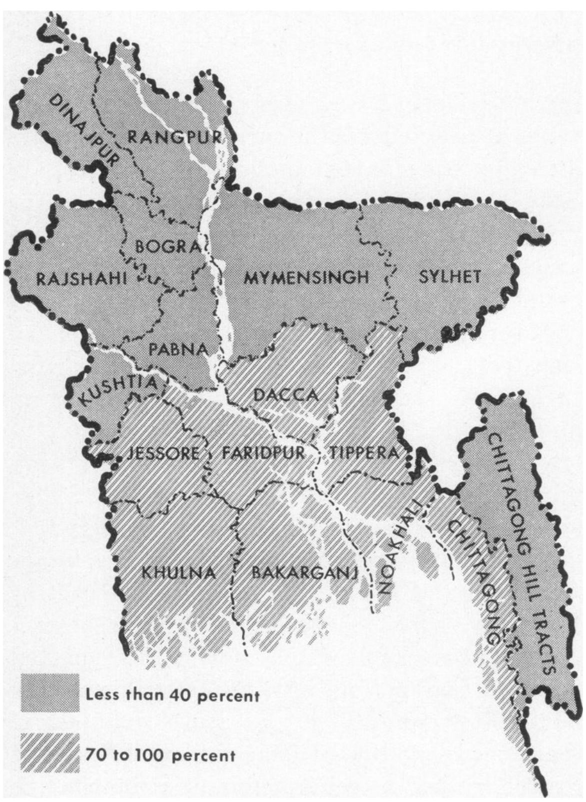
In Bengal cholera occurs all the year round in both the rural areas and Calcutta. Calcutta has long been the industrial and commercial heart of Bengal, and every day tens of thousands of people from the rural areas pour into it, although since partition those from East Pakistan have been diverted to Dacca. Since the infection is, without doubt, endemic in the rural areas, almost every day the vibrio must be reintroduced into Calcutta and Dacca.

Many years ago a number of workers delineated the extent of the rural endemic area in Bengal. It consisted of the coastal region and extended inland to include Rajshahi District. North of that, cases of cholera were numerous, but only in the dry season. This situation is much the same today. In figure 1, based on the weekly reports of the Province's Directorate of Health Services, the districts of East Pakistan are marked according to the proportion of weeks in which cholera was reported over a 4-year period. About 150 miles inland, parallel to the coast, but now south of Rajshahi, there is a clear line of demarcation. North of this endemic borderline cholera is reported in the dry season only, 40 percent of the total weeks or less. South of it, the disease occurs 70–100 percent of the weeks, or all year round when allowance is made for the deficiencies of the reporting system.

On a map of the Province marked with 250-foot contours, the endemic and nonendemic areas seem to be identical except for some slightly higher ground north of Dacca and the range of hills to the east. However, in this flat land even a few feet make a big difference, and in general, except for the land along the river bottoms, the terrain rises gently to the north of the endemic borderline; south of it the land is universally flat and barely above sea level. This affects drainage, for as described by Macnamara, the water in the endemic area is almost stationary in the dry season.

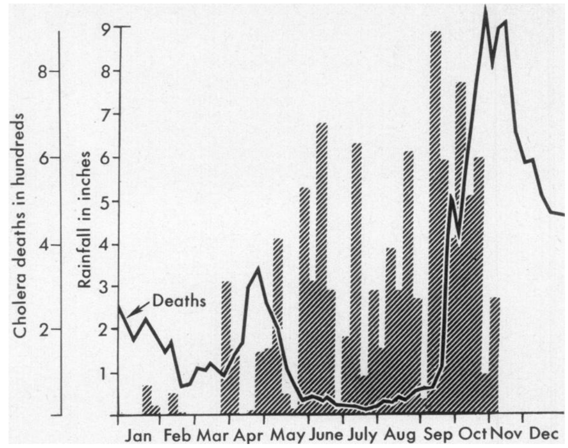
The spread of cholera in the rural area differs from that in the city, for there is little overcrowding in the small hamlets except during the monsoons. There is also a relatively large

Figure 1. Percent of 208 weeks when cases of cholera were notified, by district,[1] East Pakistan, 1956–59



[1] No districts reported cases for 40–70 percent of the total weeks.

Figure 2. Rainfall in Dacca and deaths from cholera in East Pakistan, by week, 1959



Note: The lag in case reporting of deaths may be as much as 2 weeks.

degree of isolation between the tiny communities since the women are in purdah and seldom leave the home, and most travel is on foot or by the slow-moving boat. Except for the tanks and the methods of excreta disposal, the hygiene of the communities is of a fairly high standard.

It was Koch who first suggested that the tanks might be the most important means of spread, and many other workers have agreed with him. When the whole population washes in the water used for drinking and cooking, there must be a communal sharing of intestinal organisms. Most communities have isolated and screened latrines, but sometimes these are perched on the edge of the tanks, so that the water is further polluted. Toward the end of the dry season in April and May the water has sunk to a low level and become stagnant and unpleasant. Beyond doubt the tank is the greatest means of spreading the cholera vibrio during the greater part of the year. However, it is not the only means. The factors of personal contact, flies, and infected food still play a part, if only a minor one, especially in the larger villages, the overcrowded and insanitary "old" towns of Dacca and Chittagong, and in the crowded trains and other public transport systems.

That the tanks are closely implicated in the spread of infection is indicated by the epidemiology of the infection in the endemic areas. There are two kinds of occurrences. In the

Figure 3. Deaths from cholera in East Pakistan, by month, 1954–59 average

Photographic background shows latrines perched on the edge of a tank.

first, only one or two persons, usually small children, become ill in a village; in the second, 20 or 30 persons acquire cholera within 1 or 2 days and then only a few more, indicating an explosive common-source infection. The former type of outbreak is probably expressive of the immunity status of the village, in which only the small children are still susceptible, while the latter can be explained best on the basis of some vehicle of spread common to everyone, such as the tank water.

Traditionally, the cholera seasons ends with the onset of the monsoon (fig. 2). The abatement of local epidemics whenever a heavy, unseasonable rainfall occurred in the dry season of 1958 has been described elsewhere (*2*).

The influence of temperature has been less well recognized. When deaths from cholera in East Pakistan are averaged over a 5-year period, a smaller cholera cycle during the winter months can be recognized in addition to the major cycle during the dry months (fig. 3). As the days grow shorter and colder, cholera diminishes, although there is some lag from the fall peak in November and December. Rainfall, sunshine, and temperature data are given in table 1. The peak periods for cholera are in the hot months of the year when there is no rain.

Two exceptional years in the past decade were 1953 and 1954. In 1953 the monsoon finished earlier than usual, the cholera season started sooner, and the incidence was higher than normal. In 1954, flooding was extensive, largely due to unusually heavy flows down the Brahmaputra. Most of the delta was under water, some of it for as long as 3 months. During that time cholera was at a particularly low level for East Pakistan.

Experimental Theory

There have been many attempts to explain the epidemiology of cholera by changes in the physical conditions of water, but so far none have been successful. There is no difficulty in finding the vibrio in the rivers around Calcutta or in places such as the tanks where religious washings take place, but the difficulty is in accounting for the relationship between the rainfall and temperature and the appearances of outbreaks, as well as the confinement of the endemic disease in so small an area.

The one feature that sets the vibrio apart from all other intestinal pathogens is its capability of thriving in media that are highly alkaline. The upper limits of resistance to pH do not seem to have been clearly defined, but the organism can multiply at a pH of 9.2 and probably survive for long periods at a much higher pH. Generally in biology, characteristics so marked as these are not due to chance, but are the results of intense natural selection pressures in the environment. It seemed to us that the water in the tanks might have alkalinities of a magnitude that would provide the necessary selection pressures and that the seasonal and geographic relationships of the disease could be accounted for by variations in the pH. Other workers have studied this matter, but they emphasized chiefly the river water and not the tanks, and no allowance was made for the biological activity of the algae in the water at different times of the day.

The tanks in Bengal contain so much algae that normally the water is a deep green color when it is not muddied. The concentration of algae and the rate of photosynthesis at any given time are the result of a highly complex interplay of many factors, but the major ones are the amount of organic and inorganic matter in the water and the amount of light available. Related to the photosynthesis, but not proportional to it (*3*), is the respiration of water plants. Since the rate of photosynthesis is normally faster than the rate of respiration, in daylight these plants absorb carbon dioxide from and liberate oxygen into the water. At night the reverse process takes place. Also, photosynthesis is inhibited by too much sunlight (*3*). Beyond the optimum, the rate of activity falls rapidly, so that in bright light the maximum respiration of the algae will take place not at the surface of the water but deeper down, and in shallow surface water this factor might be of importance.

Table 1. Length of day, sunshine, rainfall, and mean temperature, by month, Khulna, East Pakistan, 1959

Month	Day length (hours)	Sunshine (hours)	Temperature [1] (degrees Fahrenheit)	Total rainfall (inches)
January	11. 00	9. 57	68	0. 4
February	11. 25	9. 34	74	1. 0
March	12. 00	8. 00	81	1. 3
April	12. 40	7. 55	86	3. 9
May	13. 10	7. 10	87	7. 4
June	13. 30	4. 43	85	12. 0
July	13. 25	4. 52	84	14. 4
August	12. 55	4. 01	84	13. 2
September	12. 20	4. 88	85	8. 4
October	11. 40	5. 70	82	5. 4
November	11. 05	8. 82	76	1. 0
December	10. 50	9. 03	70	. 1

[1] Highest recorded, 107° F., lowest recorded, 39° F.

SOURCE: Report on the Khulna Multipurpose Project, East Pakistan Water and Power Development Authority, 1959.

Since the endemic areas are closely linked to lands very little above sea level, and the vibrio is known to have a salt requirement, a brief exploratory study was made to see if the endemicity could be linked to the salinity of the water.

It is well known that the cholera vibrio does not live long in river water such as that of the Ganges and Nile or in sewage, and the usual explanation is that in such places it cannot cope with the competition of other organisms. In Bengal, if it could be shown that tank water has a high pH, the situation would be reversed, for intestinal organisms such as *Salmonella typhi* would soon die off (table 2), and the cholera vibrio would survive. Should testing of surface waters in other parts of the world reveal different pH levels, an explanation would be provided for the limitation of the endemic area to small parts of Asia.

However, when heavy rain muddies and dilutes the tank water and the sky is overcast with thick clouds, the pH might not rise, and the cholera vibrio would then lose its advantage in survival. If such a situation could be shown to exist, then a reasonable explanation could be given for the well-known phenomenon of the disappearance of cholera during the monsoon.

Cholera diminishes regularly almost every year in the winter months when little or no rain falls (fig. 3). This dwindling of cases could possibly be caused by variations in the pH due to a drop in temperature, shorter days, and fewer hours of sunlight per unit of water surface area.

Collection of Samples

Therefore, it was decided in 1959 to test six tanks in the Motijheel area of Dacca for 1 year to see how the pH of their waters varied during changing climatic conditions and to attempt to correlate these changes with the general incidence of cholera.

The tanks were typical of those throughout the Province, except that people did not drink so much from them, since piped water was available. The people used all the tanks for washing clothes, ablutions, swimming, and fishing. Professional dhobies washed clothes in tanks 1 and 2; bullocks and buffaloes were often cleaned in tank 2; 3 had a latrine on one edge; and tanks 3, 4, 5, and 6 were close to houses whose drainage had access to the tanks. Tanks 1 and 2 were open to the sun from sunrise to sunset, while the others had a varying number of one- or two-storied houses or shacks and an occasional tree close to them. The tanks ranged in size from 50 by 100 yards to 100 by 200 yards and in depth from 4 to 18 feet.

Samples of water were usually collected from the six tanks every Monday. The water was taken from the same spot every time and from about 6 inches under the surface. Most of the time, specimens were taken three times in the day, at 5:30 to 5:45 a.m., at 11:30 to 11:45 a.m., and at 3:30 to 3:45 p.m. In a series of more intensive investigations two of the tanks with the largest ranges of pH were sampled six times in the day at 2-hour intervals beginning at 5:30 a.m. During the summer, it was daylight at 5:30, but dark during the winter.

The 5:30 a.m. specimens were kept in the dark until the laboratory opened at 8:00 a.m.; the others were all tested within half an hour of collection. Attempts were made to test water outside Dacca, especially in the nonendemic areas. After sensitive paper proved unreliable in determining the pH, a portable pH meter was used to test water on a trip to the southern end of the endemic area.

Analytical Procedures

The analytical determinations were made in the Dacca laboratory of the Ralph M. Parsons Co., of Los Angeles, Calif., which, under an ICA contract, collects data needed for its design of water supply and sewage disposal systems for Dacca and Chittagong. This laboratory is equivalent in scope and equipment to public health laboratories in the United States. After completion of the contract, the laboratory will become the nucleus of the water and sewage section of the new public health laboratory for East Pakistan. The initial specimens were tested by Dr. Gordon E. Mau, and the later ones by Jack R. Snead, both of the Parsons firm.

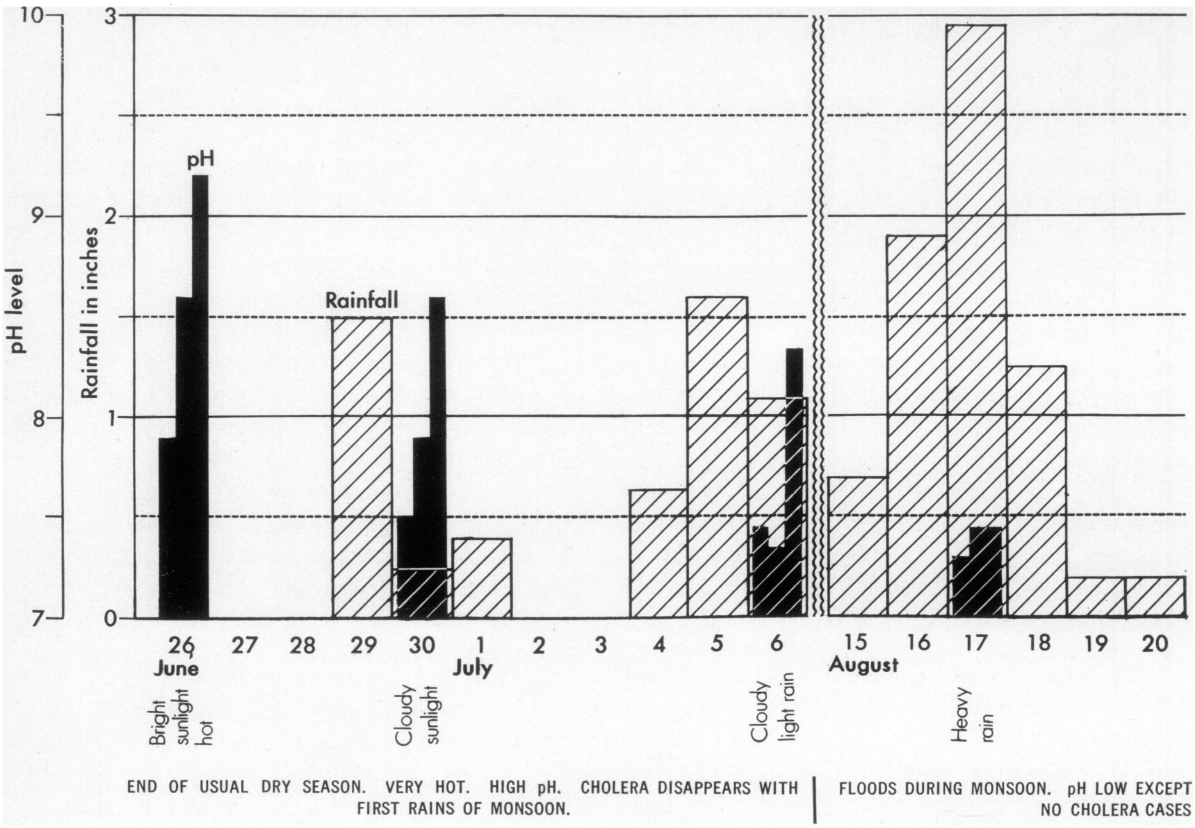
The procedures followed in this laboratory are those of the 10th edition of "Standard Methods for the Examination of Water, Sewage, and Industrial Waste." Precision and accuracy of analytical results are maintained by having each chemist periodically run a quantitative analysis of an unknown synthetic sample. Any errors reported are called to the attention

Table 2. Relationship of pH to the death rate of *Salmonella (Eberthella) typhi* at 20° C

pH	3. 8	5. 0	5. 4	6. 4	7. 1	7. 6	8. 7	9. 5
Half-life (hours)	0. 28	23. 0	27. 0	21. 0	6. 8	2. 7	1. 4	1. 0

Source: Reference 4.

Figure 4. Average of the pH levels



of the analyst, and after the cause of the errors has been determined, the previously submitted data are either corrected or discarded. From these continuous checks, it is believed that the reported data are accurate to ±5 percent of the reported values.

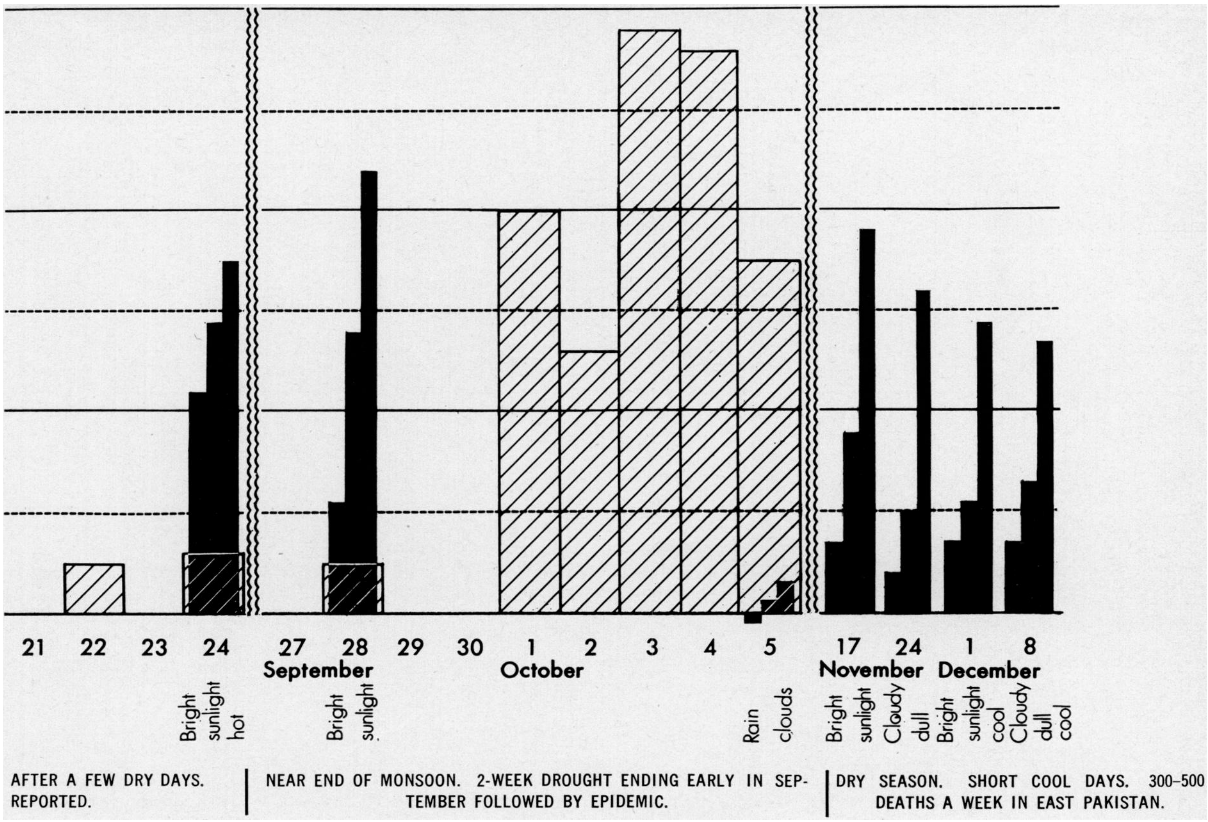
Findings

The year 1959 was atypical so far as the weather was concerned. Normally, there is some light rain in January and severe wind storms with occasional rain in April, but in 1959 heavy showers occurred frequently between January and June. During the monsoon which was expected to start in June, there were often intervals of many days when no rain fell or only a little during the night. The apparent result of the unusual rains was that the anticipated epidemic peak of April and May did not materialize on the usual scale, while perhaps as a result of the light monsoon, the cholera started earlier and more heavily in September with deaths reaching nearly 1,000 per week. The data are given in figure 2, which shows deaths for the whole Province but the rainfall only for Dacca. The abnormal rainfall also made more difficult the obtaining of clear-cut results with regard to the pH and its relation to sunlight and rainfall.

Samples of the relationship between the pH, the rainfall, sunlight, and time of day at four different periods of the year are given in figures 4 and 5. At sunrise, the pH is usually quite low, being either a little above or below 7.0, but on clear days with bright sunlight it is often above 9.0 by noon, and it can reach as high as 10.5 by late afternoon. A similar daily summer rise in the pH of a springfed pool with abundant *Chara fragilis* was observed in 1928 in the United States (*5*).

However, when the heavy rain, normal for the monsoon, falls either on the day of sampling or for some days before it, the pH does not rise much above 7.0 and on occasion may fall below it.

of six tanks, Dacca, East Pakistan, 1959



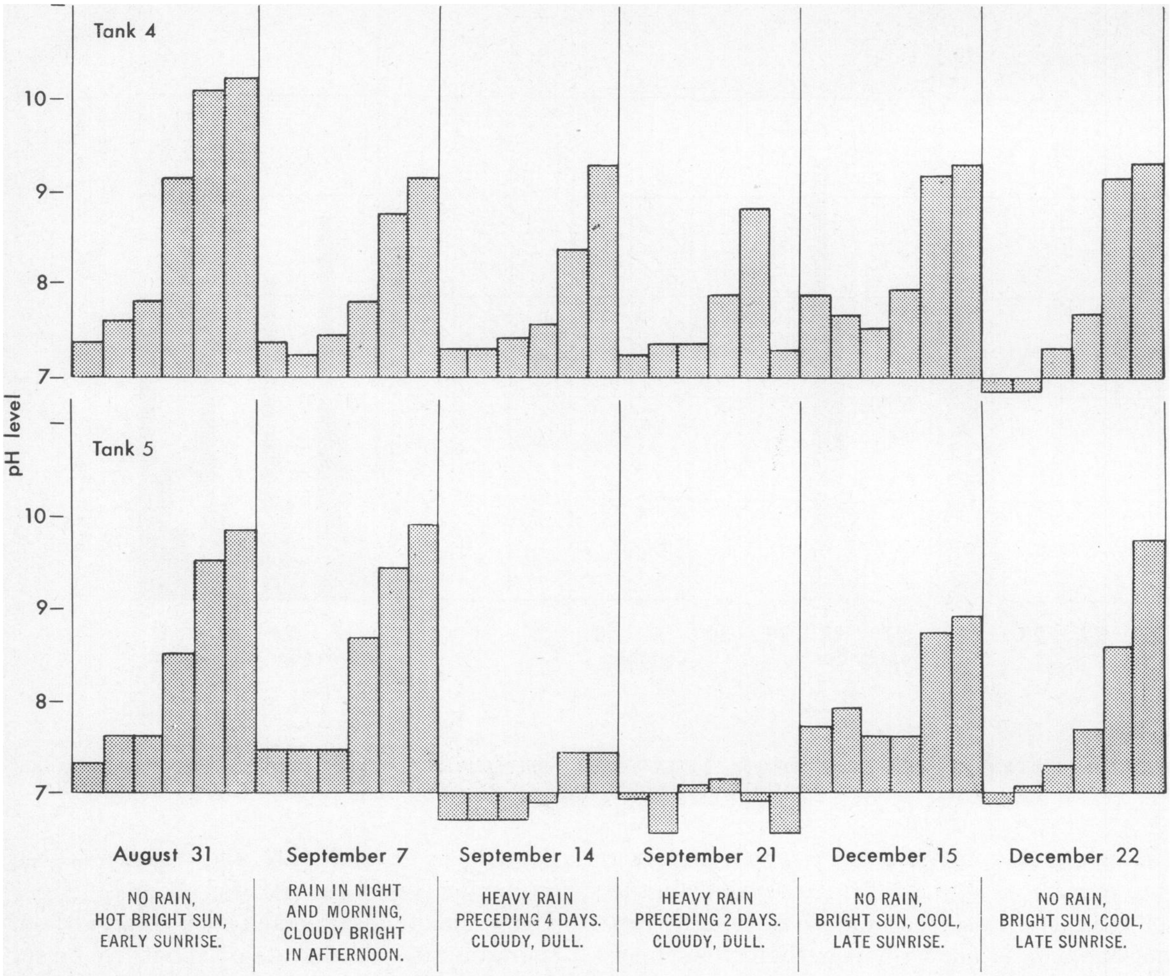
In winter, the pH still can rise to high levels but not quite so high as during dry spells in the hot weather. Also the number of hours when this happens is much shorter than in summer when there is no rain. During a long, hot, rainless summer day the pH is above 9.0 for at least 6 hours, but it is at that height for only 4 hours in winter (fig. 5).

Toward the end of the monsoon in 1959, a sharp epidemic of cholera occurred in Dacca District and in the city itself. It was reported to have started the week ending September 25, but when the time lag in case reporting, which can be as much as 2 weeks, and the incubation period of the disease are taken into account, the date when the population first became generally infected is advanced 2 or 3 weeks to about the beginning of September. This can be related to two comparatively dry, hot, and sunny weeks beginning on August 19, when the pH of the tank water was regularly at a high level for many hours a day. The sunny period was followed by heavy rains, including 5 inches on September 12, and when the water was tested on September 14, the pH was about 7.0 (fig. 5). The epidemic disappeared soon after, although sporadic cases at the rate of about five or six a day continued to be admitted to the hospital in Dacca.

Observations of tanks in other parts of the endemic area were not so complete as those in Dacca, but, in general, the findings were much the same. All tanks had abundant algae except one near the town of Khulna which did not show a rise in pH. In Khulna District many tanks were surrounded by trees and shaded for most of the day, and they showed little rise in pH above 8.0.

Estimates of chloride content of water showed no differences among the surface water near the sea at Barisal and Khulna, the study area at Dacca, and Rajshahi. In general the ranges were low, between 15 and 30 mg. per liter; tank 3 which had a latrine perched on one side consistently had a content of 50–60 mg. per liter. Other data on the chemistry of the tank water

Figure 5. Studies of the pH in tanks 4 and 5,[1] Dacca, East Pakistan, 1959



[1] Specimens collected at 2-hour intervals starting at 5:30 a.m.

in Dacca are given in table 3. The water is very lightly buffered so that relatively large shifts in the pH can be easily attained. The chloride levels are low, which could be of significance in view of the requirements of the vibrio in culture.

The turbidity is high compared with that of river water. In December when the testing was done there is little flow in the rivers, consequently little mud, and the turbidity is about 30. The difference in turbidity is due almost entirely to the fact that tank water is full of algae and river water is comparatively free of it, which would explain why earlier observers, who tested only river water, failed to find significant pH changes. During the monsoon the river turbidity due to mud is more than 300. There is no evidence of gross pollution with sewage.

Because the rate of photosynthesis depends on the intensity of sunlight, the rate varies according to the season of the year and the degree of cloudiness. However, experience shows that local factors such as the muddiness of the water, the amount of shade provided by trees and buildings, and the cover provided by water plants on the surface have considerable influence on a particular tank. For example, in most tanks the pH dropped rapidly within half an hour after sunset, but the presence of a two-story house on the west side of a tank would be the equivalent of a half-hour advance in the

Table 3. Chemical analyses in milligrams per liter of tank water in Dacca, East Pakistan

Components analyzed	Tank number and date of sample					
	1 Dec. 28, 1959	2 Dec. 28, 1959	3 Jan. 5, 1960	4 Jan. 5, 1960	5 Jan. 11, 1960	6 Jan. 11, 1960
pH	7.40	7.40	7.25	7.20	7.12	8.05
Total dissolved solids	256	264	366	217	151	148
Turbidity	140	140	50	85	130	37
Total hardness as $CaCO_3$	64	42	47	62	50	30
Total alkalinity as $CaCO_3$	78	116	56	86	56	72
Ca^{++}	16.0	9.6	9.6	15.2	14.4	8.0
Mg^{++}	4.7	1.9	3.0	4.2	2.4	1.6
Na^{+}	22.4	39.7	15.8	20.4	---------	28.0
K^{+}	16.6	4.8	9.3	11.4	9.8	6.4
Fe^{+++}	0.68	1.28	0.6	1.0	0.18	0.30
Mn^{+++}	0.00	0.00	0.00	0.00	0.00	0.00
NH_4^{+}	0.17	0.03	0.008	0.08	0.05	0.23
CO_3^{-}	0.00	0.00	0.00	0.00	0.00	0.00
HCO_3^{-}	47.6	70.8	34.2	52.5	34.2	43.9
$SO_4^{=}$	1.8	0.8	11.0	13.0	11.4	11.6
Cl^{-}	33.0	17.2	26.1	34.0	22.7	22.3
NO_3^{-}	0.16	0.05	0.42	0.22	0.44	0.44
NO_2^{-}	0.11	0.01	0.01	0.13	0.02	0.03
$PO_4^{\equiv}$	0.05	0.04	0.02	0.06	0.34	0.12
F^{-}	0.10	0.05	0.10	Tr.	0.15	0.10
$SiO_3^{=}$	27.2	19.2	7.6	12.1	18.9	13.6
BO_2^{-}	6.73	10.3	---------	---------	13.1	4.8

sunset and a shortening by that time period of the pH peak.

In the summer, the days are longer and the period of high pH is also longer. The sun is overhead so that each unit of water surface receives more light than in winter when the sun's rays hit the water at an angle. However, in a normal year the summer also largely coincides with the monsoon when rain reduces the number of sunny hours each day and muddies and dilutes the water in the tanks.

Discussion

Cholera is a disease in retreat. After being spread over nearly all the world in the 19th century, it is now largely pinned down to a small and diminishing portion of southeast Asia. Even here, the trend in the incidence is decidedly downward, as indicated in the yearly figures for East Pakistan (*2*), and the shrinking of the area where the disease is found all year round. A few decades ago the endemic area included the Rajshahi District; now the area's northern boundary is about 50 miles south. However, cholera is still a serious potential threat to mankind. Deaths at a rate approaching 1,000 a week are reported at certain seasons in East Pakistan, and developments such as fast jet plane travel or the chance of a war in the region might tip the balance once again in favor of the vibrio and result in major epidemics elsewhere. Therefore, it is of importance to know the factors which influence the infection in its original and perhaps only permanent home.

Most studies, even the most recent (*6*, *7*), consider Calcutta to be the main focus of cholera. We suggest that in Bengal the endemic infection is primarily rural, and that the Calcutta urban region is of secondary importance. Many other cities in the world with large populations and overcrowding like Calcutta have experienced cholera epidemics, but in these always the infection has died out. London in the mid-19th century days of John Snow closely resembled Calcutta with its masses of people, insanitary slums, and cholera-infected river, but the vibrio failed to establish a permanent foothold. Calcutta has what the other cities do not have, a surrounding countryside in which cholera always exists.

Of course, the ecology of any infection is a highly complex affair. Variations in three main

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factors, the host, the pathogen, and the environment, all must be taken into account. However, there must be something special to account for the persistence of cholera in Bengal when the infection dies out so easily elsewhere. The dominant factor cannot be merely bad hygiene or polluted river water, or the infection would have persisted in many other parts of the world. The investigations reported here were limited to the endemic area of Bengal, so that it is not possible to deduce from the data that the pH of the tank water alone is responsible for the localized endemicity. To test this possibility, similar studies would have to be undertaken in areas in which cholera has never been endemic. The data do allow concluding that the pH is a factor to be taken into account. They also permit theorizing that the pH is responsible for making the tanks the main means of spread of the vibrio and provide an explanation for the connection between the incidence of the disease and the changing climatic conditions.

One can even speculate that the infection evolved in Bengal because of this factor. It is well known that vibrios morphologically similar to the cholera vibrio abound in the water of this region, and it is easy to imagine that the population became parasitized with them through drinking this water. Indeed, a main difficulty in diagnosing sporadic cases of cholera here is that a certain percentage of the population are carriers of vibrios that look like the cholera vibrio but are said to be nonpathogenic. As the population of Bengal increased, especially after the founding of Calcutta, increased passage of these could produce a strain of vibrio pathogenic to man.

If further work should confirm that cholera is endemic in Bengal because of polluted tank water, then the answer to the problem of eradication of the infection lies in the provision of pure water for the villagers. The Government of East Pakistan, with the assistance of the United States through the International Cooperation Administration, is engaged in a program with a goal of 1 tubewell for every 400 people. About 120,000 wells are required. By the end of June 1960, 13,000 new wells were sunk and 12,000 choked-up wells rehabilitated, bringing the total of functioning wells in the Province to about 65,000. A similar program with the same target, which was set by the Bhore Commission before the partition of India, is underway in the rural areas of West Bengal.

Because of the population distribution, even the achievement of this first target will not bring clean water to every villager. If cholera is to be eradicated, a special effort must be made, particularly in the endemic areas of Bengal on both sides of the border, to provide enough tubewells to reach everyone. International agencies that are interested in wiping out this disease should actively support these efforts of the local governments.

Summary

A theory is presented to explain the long recognized connection between the incidence of cholera and changing weather conditions in Bengal. The theory is that in hot, dry weather algae in the village water tanks raise the pH of the water so high that the cholera vibrio is favored over other organisms.

The potentialities of these ponds of surface water which serve as the village water supply in spreading infection and the ability of the cholera vibrio to withstand a high pH have been noted.

Results of weekly tests of the pH of six tanks for a 1-year period and observations of the relationship of the pH to weather and to incidence indicate that the pH is a factor to be taken into account. It is suggested that the tanks are the chief means for spread of the vibrio and that the endemic infection is primarily rural rather than urban.

Cholera is endemic in Bengal, the major remaining focus of infection, because of polluted drinking water. The eradication of cholera from Bengal, and therefore from the world, depends largely on the success of the Pakistani and Indian Governments in replacing the village tanks with a source of safe water.

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Community Dental Health

Approximately 300 dentists in private practice in Hartford, Conn., were offered an orientation course in the broad concepts of public health and preventive dentistry through a series of lectures and discussions during 1959.

Six basic goals were the main objective of the sponsoring organizations, the Hartford Health Department, Hartford Dental Society, and the Greater Hartford Community Council. These goals were:

1. To acquaint dentists, engaged part time in community dental programs, with the meaning, significance, and goals of public health.
2. To develop the thinking of these clinicians along public health lines and thus aid and interest them in improving their respective programs.
3. To encourage higher standards of clinical dentistry, both in public institutions and in private practice.
4. To create an atmosphere which will encourage community responsibility and community participation in dental public health programs by other private dentists.
5. To promote the concept of preventive dentistry.
6. To aid in bridging the gap between private dental practice and community health programs.

Nine lectures were given by nationally recognized specialists between January and November at 2- to 4-week intervals, with the summer months unscheduled. The 10th meeting was a field trip to the Murry and Leonie Guggenheim Dental Clinic in New York City.

The planning group believed that Hartford dentists, untrained in public health yet giving their time and professional services in order to improve the health of the total community, would benefit from the program, which was made possible by a grant from the Hartford Foundation for Public Giving.

Meetings were held in an informal lounge area of the Hartford Medical Society building. An average lecture, with a social intermission at the halfway mark, lasted from 2 to 3 hours.

The speakers and their subject matter for this series are listed below:

Dimensions of Public Health: Edward G. McGavran, M.D., D.Sc., M.P.H., University of North Carolina.

Planning for Local Community Dental Programs: Carl L. Sebelius, D.D.S., M.P.H., Tennessee Department of Public Health.

Interceptive Orthodontics—Tooth Guidance: John F. Mortell, D.D.S., M.S., University of Michigan.

Methods, Materials, and Motivation in Dental Health Education: Perry Sandell, B.A., M.A., American Dental Association.

Meeting the Dental Needs of the Physically Handicapped and Mentally Retarded: Robert L. Fisher, D.D.S., Long Island College Hospital, and Albert Green, D.D.S., Columbia University.

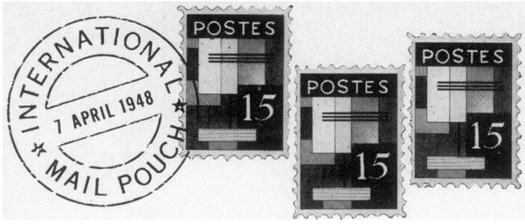
Prevention and Control of Dental and Other Oral Diseases: Robert G. Kesel, D.D.S., M.S., University of Illinois.

More Effective Public Speaking, or Did They Understand What You Said? David C. Philips, M.A., Ph.D., University of Connecticut.

Oral Lesions in Infancy and Childhood: Joseph L. Bernier, M.S., D.D.S., Armed Forces Institute of Pathology.

X-ray Radiation and Its Significance: Leonard F. Menczer, D.D.S., M.P.H., Hartford Health Department.

Additional information, if desired, will be supplied upon request to Dr. Leonard F. Menczer, Hartford Health Department, Hartford, Conn.



Farm Education Improves Public Diet

"For the past 20 years, The Rockefeller Foundation has been working with the Ministry of Agriculture and Animal Husbandry of Mexico. At a cost of something less than $2 million per year, American agronomists have been supplied to Mexico, and young Mexicans have been trained in the agricultural sciences. In this period, the food production of the country has mounted 80 percent. The gains have been achieved by improved yields of Mexico's own staple crops, the development of new varieties of wheat and potatoes, and the establishment of something like our own county-agent system for farmer education. Not a single tractor or fertilizer plant is in the expense account; the money has been spent for the intangibles of information, education, and expert consultation. The 4 percent per annum gain safely exceeds the 3 percent increase in population and has brought an improvement in the people's diet that is already showing up in the vital statistics."

—From "The Revolution in Man's Labor," a speech delivered by Gerard Piel, April 9, 1959, at St. John's College, Annapolis, Md.

Health Education in Ghana

The health inspectors were chosen to spearhead education for health among the people of Ghana. Inservice courses for selected inspectors were held in each region. The Cocoa Marketing Board provided the funds for the health education project in the Northern Region.

Approximately 50 local health committees in the Eastern, Western, and Volta Regions have been formed as a result of the inspectors' work. The following excerpts from reports indicate the reactions and achievements in the villages.

The Suhum Health Education Committee organized a 1-day school on hygiene for palm wine sellers, chop barkeepers, bread sellers, and wine and beer barkeepers. The committee has also put up with voluntary labor two urinals for patrons of some nearby palm wine bars. Members of the committee gave talks in schools and churches and at village gatherings.

The Diase Health Education Committee has a bilharzia education program in progress. People make less use of river water. Weeds on the outskirts of town have been cleared by the committee through communal labor.

The Bogoso School Health Committee conducted a group discussion on the health of the school child. A large number of parents were present. "Keep Bogo Clean" was the theme for a health week with parents, teachers, and children participating in cleaning homes and the town.

Sakai, Tumu District, is a village of about 600. Its people have a reputation for their stubbornness, but they pledged full support to the health committee.

Pregnant women and children under 5 years were registered. Weekly child welfare clinics were started and have been heavily patronized. Bathing of children has become competitive.

The people weeded and swept the entire village and built 12 pit latrines. "The spirit of cooperation and self-help had strongly seized the hearts of every member of the village. . . ."

In Bongo, Bolgatanga District, we were able to form a women's health committee. The women meet every Monday to discuss matters of interest and have asked for more demonstrations about bathing the baby and the preparation of orange squash. The committee members divided themselves into groups, and they visit pregnant women and the sick to advise them to go to the hospital.

Before our arrival in Sekoiega, Yendi District, there was not a single latrine. For this reason, we tackled the construction of pit latrines the second week. The people built seven pit latrines, which are fairly distributed over the village.

Most of the mothers have begun to give the babies boiled water and fruit juices. Most of them do not add eggs to kako, a type of porridge. The general reason given is lack of means.

The people feel the dire need for a dam; they have pledged to contribute manual labor to any scheme to materialize the construction of a dam.

—Jean M. Pinder, *health education adviser, U.S. Operations Mission, Ghana.*