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# A method for macroscopic assessment of countries' receptivity to cholera

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In memoriam Oscar Felsenfeld

## Summary

It was shown possible to assess macroscopically countries' receptivity to cholera through the use of two commonly available socio-economic indicators. The indicators used were per capita GNP and population density per km$^2$ of inhabitable area. These are related respectively to two major determinants of cholera receptivity: standard of living and population congestion. The global assessment of cholera receptivity indicated the seriousness of cholera as a public health problem in Africa and Asia. It also showed that cholera epidemics are a potential danger to a majority of the population of Latin America.

*Key words:* cholera; epidemiology; statistics; socio-economic indices.

## Introduction

The correlation between poor socio-economic conditions and cholera epidemics has been noted repeatedly (Felsenfeld, 1966; Nájera, 1976; Pollitzer, 1959). However, the assessment of a country's degree of cholera receptivity and the likely outcome of a cholera outbreak there has not yet been attempted. Such an assessment would be useful for estimating the existing and future global situation of cholera and for planning any international cooperation for control of the disease. This paper presents one such attempt based on the use of a few socio-economic indicators that are commonly available for international comparison.

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## Materials and methods

*Basic approach.* Sanitation, nutrition, education, and availability of health services are some of the socio-economic conditions that are often considered as being determinants of cholera receptivity (Nájera, 1976). Unfortunately, there are few practical indicators of these conditions, and there are even fewer indicators available for meaningful international comparison. The above socio-economic conditions are, however, all closely, related to the so-called "standard of living", for which per capita GNP is widely used as an indicator. Hence per capita GNP is the logical choice as a primary indicator for the assessment of cholera receptivity.

Another factor of importance in the spread of cholera, but which is not directly related to standard of living, is the degree of human contact. This can be seen from the higher risks involved in congested living (Pollitzer, 1959). Population density is probably the only available indicator of this. For the ratio to be meaningful it must be calculated with the inhabitable area as the denominator instead of the total territorial area, which may include such uninhabitable regions as lakes, deserts, and mountains. This modified ratio may be termed "living density" in order to distinguish it from the more usual population density.

Although the positive relationship between the availability of health services and the health status of a population has long been taken for granted, some serious doubts have recently been cast on its significance (McKeown, 1976). The controversy is not easy to resolve because the availability of health services is closely correlated with the standard of living. In our preliminary analysis, using available health manpower and per capital GNP as the respective indicators, such a close correlation was observed that it was felt that there would be only a marginal gain in using the availability of health services in the assessment of cholera receptivity. This indicator was therefore omitted from the later analyses. However, it is an important factor to consider when assessing a country's potential capacility for implementing cholera control measures.

*Statistical data used.* Since the International Health Regulations require all Member countries of the World Health Organization to notify cholera cases, the data from the WHO Weekly Epidemiological Record was used. The years 1970–1973 were chosen since this was the time of the latest cholera pandemic, when cholera spread to the African continent; and it was during this period that countries at large were most concerned with their cholera epidemics and interested in reporting them.

Many countries reported no cholera statistics, in some cases because they experienced no cholera cases, in others because they produce no such statistics. To distinguish between the two, the reporting was reviewed as from 1961: if a country reported cholera during any year since 1961 it was assumed to produce cholera statistics, and lack of reporting in subsequent years was interpreted as zero cases of cholera; if, however, a country never reported any cases since 1961, the assumption was made that cholera statistics were not available from that country.

The population and GNP of a country change over time, and so does the per capita GNP. For our assessment, however, the per capita GNP statistics were wanted as an indicator of the standard of living over the 4-year period of 1970–1973, and the GNP figure of a mid-period year could serve the purpose. Hence, the 1971 figures shown in the 1973 World Bank Atlas were used.

No statistics on inhabitable land are found in the literature. The closest figures available are the statistics on land areas under different use, given in the FAO Production Yearbook, 1972. Inhabitable area was therefore postulated to be equivalent to the area under permanent crops (if any) plus 10% of permanent meadows (if any), the statistics being derived from the Production Yearbook. In order to calculate the "living density" the population figures of 1971 from the 1972 United Nations Yearbook were used.

All the statistical data used for the assessment are summarized in Table 1. Some countries are not shown in the Table either because statistics are unavailable or because the country had a population of less than one million as at 1971.

*Analysis.* One objective of the analysis was to test whether the selection of the standard of living and the living density as two determinants of cholera receptivity is justifiable with respect to

Table 1. Reported cholera cases and socio-economic indicators of countries

| (1) Region and country | (2) Number of reported cholera cases | | | | (3) Per capita GNP (1971, US$) | (4) Population per km² inhabitable area (1971) |
|---|---|---|---|---|---|---|
| | 1970 | 1971 | 1972 | 1973 | | |
| *Africa* | | | | | | |
| Algeria | * | 12 | 27 | 39 | 360 | 217 |
| Angola | * | 1 | 268 | 253 | 370 | 653 |
| Burundi | * | * | * | * | 60 | 301 |
| Cameroon | * | 2,377 | 362 | 195 | 200 | 80 |
| Central African Rep. | * | * | * | * | 150 | 28 |
| Chad | * | 8,236 | 5 | – | 80 | 54 |
| Congo | * | * | * | * | 270 | 152 |
| Egypt | * | * | * | * | 220 | 1,197 |
| Ethiopia | 850 | – | – | – | 80 | 191 |
| Ghana | 3,815 | 11,885 | 619 | 623 | 250 | 312 |
| Guinea | 2,000 | – | – | – | 90 | 267 |
| Ivory Coast | 828 | 668 | – | – | 330 | 50 |
| Kenya | * | 257 | 51 | – | 160 | 700 |
| Liberia | 121 | 606 | 947 | 1,154 | 210 | 41 |
| Libyan Arab Rep. | 28 | – | – | – | 1,450 | 80 |
| Malagasy Republic | * | (1) | – | – | 140 | 236 |
| Malawi | * | * | * | 302 | 90 | 153 |
| Mali | 2,655 | 4,822 | 2 | 219 | 70 | 44 |
| Mauritania | * | 1,135 | 148 | 150 | 170 | 29 |
| Morocco | * | 56 | 7 | – | 260 | 193 |
| Mozambique | * | * | * | 744 | 280 | 113 |
| Niger | 16 | 9,268 | 51 | 168 | 100 | 28 |
| Nigeria | 15 | 22,139 | 3,300 | 828 | 140 | 259 |
| Ruwanda | * | * | * | * | 60 | 683 |
| Senegal | * | 265 | 385 | 2,219 | 250 | 72 |
| Sierra Leone | 293 | 210 | – | – | 200 | 71 |
| Somalia | 43 | 295 | – | – | 70 | 95 |
| South Africa | * | * | * | * | 810 | 183 |
| Sudan | * | * | * | * | 120 | 227 |
| Tanzania | * | * | * | * | 110 | 84 |
| Togo | 74 | 335 | 16 | – | 150 | 96 |
| Uganda | * | 757 | – | – | 130 | 206 |
| Upper Volta | 25 | 1,736 | 1 | 1,118 | 70 | 102 |
| Zaire | * | * | * | * | 90 | 312 |
| Zambia | * | * | * | * | 380 | 89 |
| *Asia* | | | | | | |
| Afganistan | * | * | * | * | 80 | 219 |
| Bangladesh | 9,626 | 1,527 | 304 | 580 | 70 | 1,505 |
| Burma | 808 | 292 | 61 | 248 | 80 | 150 |
| Hong Kong | – | – | – | – | 900 | 31,115 |
| India | 13,755 | 16,577 | 20,453 | 35,768 | 110 | 334 |
| Indonesia | 6,140 | 21,580 | 43,833 | 24,408 | 80 | 694 |
| Iran | * | * | * | * | 450 | 178 |

Table 1 (continued)

| (1) Region and country | (2) Number of reported cholera cases | | | | (3) Per capita GNP (1971, US$) | (4) Population per km² inhabitable area (1971) |
|---|---|---|---|---|---|---|
| | 1970 | 1971 | 1972 | 1973 | | |
| *Asia* (continued) | | | | | | |
| Iraq | * | * | * | * | 370 | 97 |
| Israel | 180 | – | 7 | – | 2,190 | 723 |
| Japan | (2) | – | – | – | 2,130 | 1,922 |
| Jordan | 3 | – | – | – | 260 | 183 |
| Khumer Republic | * | * | * | * | 130 | 308 |
| Korea, Rep. of | 206 | – | – | – | 290 | 1,999 |
| Laos | – | – | – | 127 | 120 | 319 |
| Lebanon | 54 | – | – | – | 660 | 909 |
| Malaysia | 66 | 53 | 860 | 381 | 400 | 96 |
| Nepal | 293 | 4 | 1 | 7 | 90 | 570 |
| Pakistan | 2 | 1,022 | – | – | 130 | 606 |
| Philippines | 856 | 2,814 | 5,601 | 2,055 | 240 | 340 |
| Saudi Arabia | 266 | – | 301 | – | 540 | 985 |
| Sri Lanka | * | * | * | * | 100 | 645 |
| Singapore | – | – | 114 | 1 | 1,200 | 21,100 |
| Syrian Arab Rep. | 49 | – | 505 | – | 290 | 109 |
| Thailand | – | – | – | 848 | 210 | 310 |
| Viet Nam, Rep. of | 122 | 32 | 184 | 1 367 | 230 | 614 |
| Yemen Arab Rep. | * | 27 | 156 | 215 | 90 | 492 |
| Yemen, People's Dem. Rep. of | * | 40 | 454 | – | 120 | 585 |
| *America* | | | | | | |
| Argentina | * | * | * | * | 1,230 | 90 |
| Bolivia | * | * | * | * | 190 | 164 |
| Brazil | * | * | * | * | 460 | 321 |
| Canada | * | * | * | * | 4,140 | 49 |
| Chile | * | * | * | * | 760 | 194 |
| Columbia | * | * | * | * | 370 | 431 |
| Costa Rica | * | * | * | * | 590 | 184 |
| Dominican Rep. | * | * | * | * | 430 | 430 |
| Ecuador | * | * | * | * | 310 | 165 |
| El Salvador | * | * | * | * | 320 | 577 |
| Guatemala | * | * | * | * | 390 | 360 |
| Haiti | * | * | * | * | 120 | 1,343 |
| Honduras | * | * | * | * | 300 | 290 |
| Jamaica | * | * | * | * | 720 | 787 |
| Mexico | * | * | * | * | 700 | 213 |
| Nicaragua | * | * | * | * | 450 | 207 |
| Panama | * | * | * | * | 820 | 290 |
| Paraguay | * | * | * | * | 280 | 236 |
| Peru | * | * | * | * | 480 | 470 |
| Puerto Rico | * | * | * | * | 1,830 | 1,168 |
| USA | – | – | – | – | 5,160 | 108 |

Table 1 (continued)

| (1) Region and country | (2) Number of reported cholera cases | | | | (3) Per capita GNP (1971, US$) | (4) Population per km² inhabitable area (1971) |
|---|---|---|---|---|---|---|
| | 1970 | 1971 | 1972 | 1973 | | |
| *America* (continued) | | | | | | |
| Uruguay | * | * | * | * | 750 | 149 |
| Venezuela | * | * | * | * | 1,060 | 183 |
| *Europe* | | | | | | |
| Austria | * | * | * | * | 2,200 | 444 |
| Belgium | * | * | * | * | 2,960 | 1,147 |
| Denmark | * | * | * | * | 3,430 | 186 |
| Finland | * | * | * | * | 2,550 | 172 |
| France | 1 | (3) | – | (4) | 3,360 | 268 |
| Germany, Fed. Rep. | – | (1) | (2) | (4) | 3,210 | 634 |
| Greece | * | * | * | * | 1,250 | 246 |
| Ireland | * | * | * | * | 1,510 | 260 |
| Italy | – | – | – | 265 | 1,860 | 436 |
| Netherlands | * | * | * | * | 2,620 | 1,556 |
| Norway | * | * | * | * | 3,130 | 484 |
| Portugal | – | 49 | – | – | 730 | 242 |
| Spain | – | 22 | – | – | 1,100 | 165 |
| Sweden | – | (2) | – | 10) | 4,240 | 266 |
| Switzerland | * | * | * | * | 3,640 | 1,638 |
| Turkey | 384 | – | – | – | 340 | 132 |
| United Kingdom | (1) | (3) | (2) | (6) | 2,430 | 769 |
| *Oceania* | | | | | | |
| Australia | – | – | (40) | – | 2,870 | 29 |
| New Zealand | – | – | (3) | – | 2,470 | 342 |

the 1970–1973 cholera epidemics. Cholera receptivity is an indication of the potential of cholera as a public health problem; and the following classification was used: a country where any outbreak of cholera entails a high risk of immediate epidemic and subsequent endemicity is classified as vulnerable; a country where an outbreak is likely to cause an epidemic though the endemicity may be contained is classified as susceptible; a country where an outbreak is possible but can be contained within localities is classified as receptive; and a country where an outbreak is unlikely is classified as resistant. The basic proposition for the analysis was: the lower the standard of living and the higher the living density, the more receptive a country is to cholera, and vice-versa. This relationship is illustrated by a schematic model in Fig. 1.

The establishment of a functional relationship between cholera receptivity and the two determinant factors – as implied by the dividing lines in the schematic model – is, however, difficult in practice. The reason for this is two-fold. First, the per capita GNP and the population per km² of inhabitable land are merely approximate indicators of the standard of living and the living density, respectively. Furthermore, their statistics have inherent limitations for accurate quantitative comparison because of the variances in measurement standards between countries. Second, the number of cholera cases reported may not accurately reflect the cholera situation, as the reporting depends greatly on the country's capacity for surveillance and laboratory diagnosis.

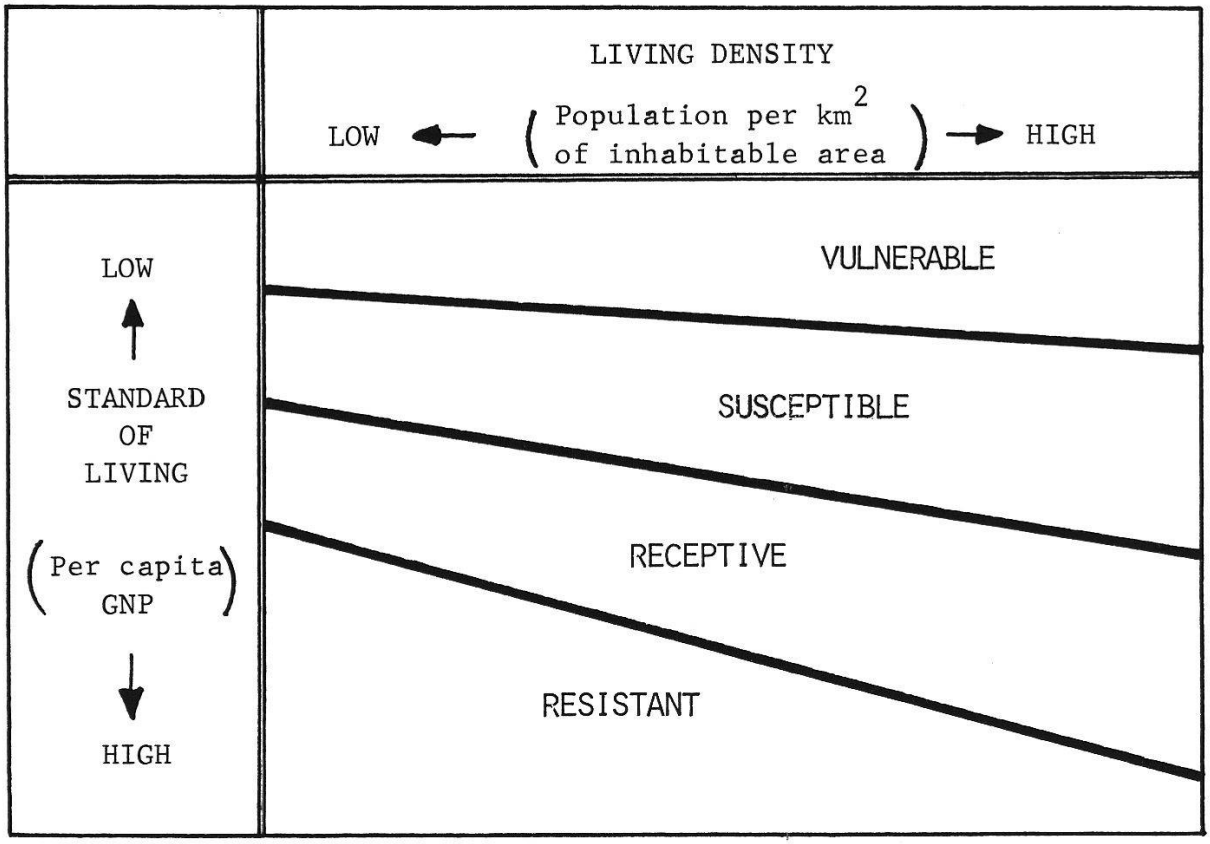


Fig. 1. Schematic model of cholera receptivity.

In order to circumvent the first limitation, appropriate ranges were chosen for both indicators, and a region of specific cholera receptivity was approximated by a combination of the meshes defined by these ranges. These ranges and regions are illustrated in Fig. 2.

To overcome the second limitation, significance was placed on whether cholera cases were reported or not during the period 1970–1973. Each country was assigned a score, ranging from 0 to 4, according to the number of years in which it reported one or more cases of cholera. Its receptivity was then expressed by the ratio between this score and the number of years in which it had a chance of experiencing a cholera outbreak (i.e. = 4 if the country reported any cholera incidence before the period 1970–1974, and = 1975 – "the year when cholera incidence was first reported" if it did so during the period). For all the countries in each mesh the score and the number of chances were totaled. The results are shown in Fig. 3, where the lefthand and righthand number in each mesh indicate the total score and the total number of chances, respectively, for all countries in that mesh.

The cholera receptivity of the group of countries in each receptivity category was estimated by the ratio of the sum of the scores and the sum of the chances of all the countries belonging to the corresponding category. The validity test for the receptivity classification is consequently the significance test of the difference in the ratios between the groups in different receptivity categories.

## Results

For expedience, the subscripts v, s, c, and r are used to represent the four categories, i.e. vulnerable, susceptible, receptive, and resistant. The total score (M), total chances (N), and the receptivity ratio (P = M/N) of each category, derived from Fig. 3, are as follows:

| PER CAPITA GNP (1971, US$) | POPULATION PER $km^2$ OF INHABITABLE AREA (1971) | | | | |
|---|---|---|---|---|---|
| | 0-100 | 100-300 | 300-900 | 900-2700 | 2700+ |
| 0-250 | V | V | V | V | V |
| 250-500 | S | S | V | V | V |
| 500-1000 | C | S | S | S | S |
| 1000-1750 | C | C | C | S | S |
| 1750-3000 | R | R | C | C | C |
| 3000+ | R | R | R | R | C |

Fig. 2. Relationships between cholera receptivity and levels of socio-economic indicators. V = Vulnerable, S = Susceptible, C = Receptive, R = Resistant.

| | | | |
|---|---|---|---|
| Vulnerable: | $M_v = 92$ | $N_v = 123$ | $P_v = 92/123$ |
| Susceptible: | $M_s = 22$ | $N_s = 47$ | $P_s = 22/47$ |
| Receptive: | $M_c = 6$ | $N_c = 32$ | $P_c = 6/32$ |
| Resistant: | $M_r = 1$ | $N_r = 20$ | $P_r = 1/20$ |

The significance test of the difference was based on the test statistic, Z, which is supposed to have the normal distribution under the null hypothesis. For example, the difference between $P_v$ and $P_s$ is tested by:

$$Z_{vs} = (P_v - P_s) \Big/ \sqrt{\frac{M_v + M_s}{N_v + N_s}\left(1 - \frac{M_v + M_s}{N_v + N_s}\right)\left(\frac{1}{N_v} + \frac{1}{N_s}\right)}$$

and its comparison with the normal distribution.

The results of the significance test are as follows:

$Z_{vs} = 3.473 > 2.326$ (99% significance level)
$Z_{sc} = 2.559 > 2.326$ (99% significance level)
$Z_{cr} = 1.413 > 1.292$ (90% significance level)

| PER CAPITA GNP (1971, US$) | POPULATION PER $km^2$ OF INHABITABLE AREA (1971) | | | | |
|---|---|---|---|---|---|
| | 0-100 | 100-300 | 300-900 | 900-2700 | 2700+ |
| 0-250 | 26 : 32 | 23 : 35 | 35 : 45 | 4 : 4 | - : - |
| 250-500 | 6 : 8 | 10 : 19 | 3 : 3 | 1 : 4 | - : - |
| 500-1000 | - : - | 1 : 4 | - : - | 3 : 8 | 0 : 4 |
| 1000-1750 | 1 : 4 | 1 : 4 | 1 : 4 | - : - | 2 : 4 |
| 1750-3000 | 0 : 4 | - : - | 3 : 16 | 0 : 4 | - : - |
| 3000+ | - : - | 1 : 12 | 0 : 4 | - : - | - : - |

Fig. 3. Observed propensity to cholera receptivity for countries in various socio-economic situations (No. of reported outbreaks) : (No. of chances).

## Discussion

The above results clearly support the proposed scheme for the assessment of cholera receptivity. If the incompleteness of the WHO cholera statistics is taken into consideration, the high significance level obtained for the difference in receptivity between the vulnerable, susceptible, and receptive groups is noteworthy. It probably implies that the grouping of countries into four regions by the per capita GNP and living density levels may have been rather rough, or that with more reliable data more refined classifications of countries and cholera receptivity would be possible, using the same two determinant indicators.

If, as the above analysis suggests, this macroscopic assessment of countries' cholera receptivity is meaningful, it may reasonably be expected that the same assessment sheme would also be meaningful for the receptivity of regions and districts within a country. Two constraints are likely to be met in such an assessment, however. One is the difficulty of finding equivalent statistics of per capita GNP for localities; the other is the likelihood that localities may have some

Table 2. Distribution of population according to receptivity categories

| Region | Total population (million) | Percentage distribution | | | |
|---|---|---|---|---|---|
| | | vulnerable | susceptible | receptive | resistant |
| Africa ..... | 340 | 78.5 | 20.9 | 0.9 | 0.0 |
| Asia ..... | 1,201 | 84.7 | 6.3 | 9.0 | 0.0 |
| Latin America ... | 276 | 56.8 | 29.8 | 13.4 | 0.0 |
| Europe ..... | 373 | 0.0 | 21.4 | 40.9 | 37.7 |

environmental and behavioral characteristics – such as sources of drinking water and breastfeeding habits – which may strongly bias their cholera receptivity.

One question left unanswered by the analysis is important to a more refined assessment of receptivity. The analysis has supported the basic proposition, namely, the lower the living standard and the higher the living density, the more receptive a country is to cholera, and vice-versa. This proposition, however, makes no mention of a possible interaction between the two factors. The unanswered question is concerned with this interaction, and it can be phrased as follows: "Would the effect of living density on cholera receptivity be more significant at a lower level, than at a higher level, of standard of living?" Given the limitations on the quality and quantity of available data, no definitive answer may be found from their analysis. If, however, the authors are permitted to speculate, they would answer the above question in the affirmative.

An interesting question for which the present method of assessment can help find the answer is, "How many people are living under high-risk conditions?" Table 2 shows a partial answer to this question with respect to three regions, namely, Africa, Asia, and Latin America (the European region is shown for purposes of comparison). This is only a partial answer because only the countries listed in Table 1 are considered. The first column of Table 2 shows the estimated total populations of the regions; the second column shows the distributions of these populations among the various conditions of cholera receptivity. The distribution is calculated by allotting the total population of a country to the receptivity category to which the country as a whole belongs.

Table 2 suggests that nearly all the people on the African continent live in vulnerable or susceptible conditions or under threat of cholera epidemics. However, it is Asia – or, more precisely, the Middle East and South-East Asia – where over 1000 million people live under vulnerable conditions. The situation in Latin America is somewhat but not much better than in these two regions. In contrast, to nearly 80% of the population in Western Europe cholera is not a serious threat.

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