DIARRHEA AND ENTERITIS IN PORTO RICO

II. RELATION TO WATER SUPPLIES

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Purpose and Plan of Study.

In a previous paper appearing in this Review (Vol. III, No. 9, p. 345), one of us (Phelps) has shown the extent and certain of the statistical characteristics of diarrhea and enteritis in Porto Rico. The present paper deals with the relation of the disease to domestic water supplies, especially public water supplies, in an endeavor to determine if the disease be wholly or in part water-borne. The study is a purely statistical one.

Three independent lines of investigation have been followed. The distribution of diarrhea and enteritis deaths among the urban and the rural section of the various municipalities, with and without public water supplies. has been studied to determine the relation, if any, between public water supplies and death rates. The seasonal distribution of the disease over the whole Island has also been studied as correlated with temperature and rainfall. Finally, certain facts have been brought out regarding the prevalence of diarrhea and enteritis in San Juan.

Public Water Supplies and Death Rates.

The object of this part of the study was to determine the comparative death rates from diarrhea and enteritis in municipalities with, and those without public water supplies. As death rates are frequently affected by other conditions associated with urban, as distinguished from rural life, it has been necessary to determine this effect separately and make proper allowance for it.

The data employed in this study are the official records of populations, births and deaths maintained in the office of the Commissioner of Health of Porto Rico for the years ending June 1925 and June 1926, and the special report of the United States Census Bureau for 1920 dealing with the composition of the population of Porto Rico. The population of each municipality in the age group under five years has been computed for the period of this study, by assuming that it bears the same numerical relation to the total population of the municipality during the period that obtained in 1920. There has been deducted from each of these population figures the annual number of living births in each municipality. The remainder has been taken as the living population in the age group 1–5 years. Death rates have been computed for the two age groups using the last named value as the divisor in the one case and the number of living births as the divisor in the other. Neither of these divisors has a strictly accurate value. The use of living births as a divisor in computing death rates under one year of age is a common procedure and both procedures will yield comparable results among the municipalities, sufficiently accurate for the purpose of the present computations.

The officially recorded data concerning water supplies has also been taken as a basis except that certain modifications and amendments have been made in the light of personal knowledge. In a few cases, recorded water supplies have been abandoned and in others, supplies have been so recently made available that they have not exerted any influence upon the statistics now being used.

Treatment of the Data.

Each municipality in Porto Rico is composed of a center of population, in which the conditions of living are urban in character, and an outlying district having rural conditions. The statistics refer to the municipality as a unit so that a study of the relation between public water supplies and death rates is somewhat complicated. The population records indicate approximately the subdivision of the populations of each municipality into urban and rural. The proportion of urban population varies quite widely among the municipalities so that it is possible by the method of correlation to determine numerically whether any relation exists between death rates and the per cent of urban population. Inspection of the tabulated death rates of the municipalities, when arranged in the order of increasing proportions of urban populations, shows that there is a well marked relation between deaths from enteritis in both the age groups in question, and the extent of urbanization. Moreover, in comparing this result as between the two classes of municipalities under investigation it appears that the difference between places that are largely rural and those that are more largely urban is more striking in the group having public water supplies than in the other. It has seemed worth while therefore to submit these data to statistical analysis, the result of which will indicate by a formula, the magnitude of this apparent relation and the probability of the relation being a truly significant one.

Such a procedure can not of course prove or disprove the major thesis of this study. It can merely indicate within a stated degree of accuracy how close the relationship is between public water supplies and enteritis death rates in the urban sections. It must retain for further studies of a bacteriological, etiological or clinical nature to determine finally whether the relationship thus established is a truly causal one.

The procedure adopted has been, first, to divide the municipalities into two classes with and without public water supplies, respectively. In each class there has been made a further division into groups according to the percentage of population living under urban conditions.

Each group has then been treated as a single community and the actual proportion of urban dwellers, and the death rate from diarrhea and enteritis in the two age groups under study, have been determined upon its combined population.

In order to avoid the danger, inherent in statistics, of a small number of units, that the particular grouping of units may by chance control the result, we have used two separate systems of groupings and made the computations upon each set. In the method most likely to produce an accurate result the municipalities have been arranged in order, according to the proportion of urban population, starting with those having the smaller values. They have been blocked off into groups of from one to four communities, depending upon their size, keeping the original order, so that each group has a combined population of as nearly 40,000 as is possible under this operation. The arrangement of the groups, and the "per cent urban", and the death rates of each group are shown in Table I for the places with water supply and in Table II for those without. The municipalities making up each group are listed at the foot of each table.

TABLE I

MUNICIPALITIES WITH PUBLIC WATER SUPPLIES IN POPULATION GROUPS

Municipalities	Group	Population in thousands	Per cent Urban	Death Rate	
				0-1 yr.	1-5 yrs.
Barranquitas, Maricao, Lajas, Jayuya	1	46.9	8.5	36.8	4.7
Lares, Peñuelas, Cidra	2	57.8	8.7	26.1	10.8
Utuado, Maunabo	3	45.7	10.5	25.9	11.5
Ciales, Juana Diaz	4	41.0	11.7	13.5	1.9
Patillas, Guayanilla, Naranjito, Ceiba	5	44.9	12.4	41.7	13.6
Yabucoa, Comerío	6	37 3	14.7	32.7	11.9
Aibonito, Gurabo, Aguas Buenas	7	40.3	18.3	18.4	5.0
Arecibo	8	48.7	21.1	51.6	12.1
Cayey, Naguabo	9	43.1	22.0	53.3	21.1
Río Piedras, Humacao	10	48.4	28.7	46.7	18.3
Yauco, Juncos	11	40.8	28.5	46.2	16.2
Caguas	12	40.3	32.4	75.4	30.3
Aguadilla, Guayama	13	45.8	39.8	51.5	20.7
Fajardo	14	15.0	45.3	60.2	30.7
Mayagüez	15	43.1	47.3	69.5	23.9
Ponce	16	75.4	60.2	74.2	20.0

TABLE II

MUNICIPALITIES WITHOUT PUBLIC WATER SUPPLIES, IN POPULATION GROUPS

Municipalities	Group	Population in thousands	Per cent Urban	Death Rate	
				0-1 yr.	1-5 yrs.
Villalba, Hatillo, Rincón	1	38.4	5.5	16.6	7.4
Guaynabo, Loíza, Trujillo Alto	2	37.3	6.4	36.7	12.4
Barros, Morovis, Aguada	3	45 6	8.2	24.3	8.8
Isabela, Adjuntas	4	39.8	9.5	28.6	6.8
Barceloneta, Moca, Toa Alta	5	42 4	11.1	23.7	6.6
Camuy, Hormigueros, San Sebastián	6	44.2	12.4	48.2	8.9
Quebradillas, Cabo Rojo, Dorado, Luquillo	7	46.7	16 6	54.6	10.7
Carolina, Toa Baja, Manatí	8	44.9	26.3	42.2	8.8
Bayamón	9	34.2	59.9	64.5	12.2

Table I shows the definite relation between death rates and the distribution of population between urban and rural. This is a result which would be expected were the disease in question water-borne, and were it more particularly related to public water supplies than to the domestic water supplies of the rural sections. Death rates being computed upon the total population would then naturally be higher in those communities in which a greater proportion of the population is exposed to the polluted water.

Such a conclusion, however, is not justified from the facts thus far developed. They would point equally well to any other conditions of urban life, such as crowding, improper disposal of excreta, public markets and common food supplies, and other factors of like nature. It would likewise be anticipated that if any of the above-named factors, or others, which are common to all municipalities regardless of their sources of water supply, were causative agencies in diarrhea and enteritis, then a similar tabulation of data from the no-water-supply municipalities would show a similar relation of death rates to distribution of populations. This latter group of municipalities has therefore been treated in the same manner, and the resulting data are shown in Table II. In this case also there is a noticeable relation between death rates and distribution of population. While the relation does not appear to be so striking it will be necessary to resort to more exact statistical procedure to determine its full significance; namely, to a determination of the correlation coefficients.

It will be unnecessary to indicate the mathematical work by which the various statistical constants have been obtained. The correlation coefficients, and the derived regression formulas and other constants are shown in Table III.

TABLE III

CORRELATION BETWEEN DEATH RATES FROM DIARRHEA AND ENTERITIS, UNDER ONE YEAR, AND ONE TO FIVE YEARS, RESPECTIVELY, AND PER CENT OF URBAN POPULATION, IN MUNICIPALITIES OF PORTO RICO WITH AND WITHOUT PUBLIC WATER SUPPLIES, 1924–26

Derived Regression Equation and Computed Urban and Rural Death Rates

		With Public Water Supplies	Without Public Water Supplies
Correlation	0–1	.83 ± .05	.65 ± .12
Coefficients	1–5	.73 ± .08	.47 ± .18
Regression	0–1	D = 19 + 1.0 (% U) ± 10.6	D = 27 + .61 (% U) ± 11.5
Equation	1–5	D = 6 + 0.4 (% U) ± 5.6	D = 8 + .06 (% U) ± 1.9
Computed			
Urban Rate	0–1	119 ± 10.6	88 ± 11.5
Rural Rate	......	19 ± 10.6	27 ± 11.5
Urban Rate	1–5	46 ± 5.6	14 ± 1.9
Rural Rate	......	6 ± 5.6	8 ± 1.9

The significance of these various constants is briefly this. The correlation coefficient indicates the degree of apparent association of the two things compared; in this case, death rate and degree of urbanization. If the association were perfect, *i. e.*, death rate increasing exactly as the "per cent urban", the coefficient would be unity. A zero coefficient would mean no apparent association. The coefficients obtained are high and their probable accuracy or reliability is indicated by the standard deviation value attached to each.

The regression equation is the equation in the two variables, the death rate and, the "per cent urban" (% U), which best fits the recorded facts. The equations then give the mathematical relation between the two. Again the attached standard deviations indicate the reliability of the indicated death rates.

Finally, by substituting in the equations a value of 100 for (% U) we obtain the most probable value of the death rate in the wholly urban parts of the municipalities, and by substituting 0 per cent we obtain the corresponding rural death rates. These are the computed rates of the table.

A similar computation has been made as a check upon the work and to determine if some other grouping of municipalities would yield a different result. In this case the municipalities have been arranged in groups according to per cent of urban population, 0–10, 10–20, etc., regardless of the size of the resulting group. As the size of the groups varies widely in this case, each group is weighted in the computation by its relative size. The final results are given in Table IV for comparison with those of Table III.

TABLE IV

CORRELATION BETWEEN DEATH RATES FROM DIARRHEA AND ENTERITIS UNDER ONE YEAR, AND ONE TO FIVE YEARS, RESPECTIVELY, AND PER CENT OF URBAN POPULATION, IN MUNICIPALITIES OF PORTO RICO WITH AND WITHOUT PUBLIC WATER SUPPLIES, 1924–26

Derived Regression Equation and Computed Urban and Rural Death Rates (Second Method)

		With Public Water Supplies	Without Public Water Supplies
Correlation	0–1	.92 ± .04	.90 ± .05
Coefficients	1–5	.79 ± .10	.82 ± .08
Regression	0–1	D=17.5+1.0 (% U) ± 7	D= 23+.7 (% U) ± 4
Equation	1–5	D= 7.0+.34 (% U) ± 4	D=7.5+.06 (% U) ± 0.5
Computed			
Urban Rate	0–1	118 ± 7	93 ± 4
Rural Rate	......	18 ± 7	23 ± 4
Urban Rate	1–5	41 ± 4	13.5 ± 0.5
Rural Rate	......	7 ± 4	7.5 ± 0.5

Significance of the Urban and Rural Rates.

The real interest in the data of Tables III and IV centers in the differences in the death rate as between communities with and without water supplies. These differences with their associated statistical errors are as follows.

TABLE V

EXCESS DEATH RATES FROM DIARRHEA AND ENTERITIS IN MUNICIPALITIES HAVING PUBLIC WATER SUPPLIES

	First Method (Table III)		Second Method (Table IV)	
	0–1	1–5	0–1	1–5
Rural	8±16	2±6	5±8	0.5±4
Urban	31±16	32±6	25±8	27±4

Obviously the rural values are without significance. The high standard deviations indicate that the difference might be reversed in an examination of the data of another year.

The urban rates, under one, are more nearly significant, the difference being twice, or three times its standard deviation. However, this difference might so readily be due to chance or to causes other than those under investigation that it cannot be relied upon. In other words, as far as these figures show, there is no significant difference in death rates in either age group in the rural sections of municipalities with and without public water supplies, and little or none in the urban sections among infants under one. The only truly significant figure is the urban rate one to five year. In this group, the only one in which public water supply could presumably affect the death rate, the rate is about thirty points higher in the municipalities with, than in those without public water supplies. As far as statistical evidence can go this excess of disease is associated with public water supply.

The actual distribution of total population in the two classes of municipalities is as follows (in thousands):

	Without water supplies	With water supplies
Rural	310.2	511.9
Urban	63.3	182.6

Assuming, for the moment, a uniform distribution of children among these population groups and approximately three times as many children in the 1–5 age group as in the 0–1 age group, it appears that about fifty-two per cent of all the diarrhea and enteritis deaths under five years occur in the urban section of the municipalities having water supplies, twenty-two per cent being in the age group 0–1, and twenty-eight per cent in the age group 1–5. Disregarding the possibilities in the younger age group, seventy per cent ± thirteen per cent of the deaths in the 1–5 group are excessive as compared with the similar group without public water supplies, so that about twenty per cent ± four per cent, or probably between sixteen and twenty-four per cent of all the diarrhea and entiritis deaths on the Island, under five, would appear, with reasonable likelihood, to be directly water-borne. What portion of the remainder is likewise directly water-borne from other water than public water supplies, or indirectly water-borne through secondary agencies but traceable to water-borne cases, it is impossible to state. Experience with typhoid fever would indicate that the removal of the known water-borne cases would result in a continuing decrease in rate due to the reduction of foci of infection.

Seasonal Relation.

We have attempted a second line of investigations of the relation between water supplies and incidence of diarrhea and enteritis by studying the correlation between the seasonal incidence of the disease and both temperature and rainfall as related seasonal factors. It is a matter of general experience that intestinal diseases such as typhoid fever, which are at times water-borne and are also often transmitted by other means, may often be studied in this manner to determine the major factor of their causation in any particular case. If largely water-borne, the disease has a seasonal distribution more or less correlated with stream conditions. Heavy rainfall or a spring thaw increases the intensity of pollution from surface wash, but decreases the concentration of municipal sewage in the streams. In periods of high water also the time of transit between sources of pollution and waterworks intakes is reduced with a corresponding reduction in the extent of natural self-purification.

In Porto Rico, with its relatively short rivers, steep slopes, densely populated water-sheds with little or no sanitation and few sewered places, the factor of surface wash is undoubtedly a predominant one in the pollution of streams, and it might be expected, therefore, that a water-borne disease would have periods of maximum incidence following periods of rainfall.

In the case of intestinal infections which are not water-borne a high degree of correlation is frequently noted between incidence rates and temperature. This is variously attributable to the more rapid rate of development of the organism in such articles of food as milk, to the greater prevalence of flies, to out-door vacation and camping life and the more general distribution and exposure of infectious material existing under these conditions, and, according to Arnold (1927), probably in part to a lowered resistance of the human intestine against bacterial invasion.

Thus we find, as was first pointed out by Sedgwick and Winslow (1902) that typhoid fever in cities may show a seasonal distribution curve of either one of two distinct types. The normal type closely parallels the temperature curve, while the curve for those cities with a large amount of water-borne typhoid has a pronounced winter or early spring peak. These facts are frequently utilized to determine the sources of typhoid fever in a community, and an attempt has been made to throw some light upon the source of diarrhea and enteritis in Porto Rico by the same means. Unfortunately, this method of statistical study is not well adapted to the situation in Porto Rico because of the very high degree of correlation existing between the seasonal variations of temperature and rainfall, their mutual correlation coefficient being 0.8 ± 0.1. This means that any actual causal relation that might exist between a disease and either of these physical factors would be sufficient to account for an apparent relation of about the same magnitude between the disease and the other factor, even though the disease itself might be entirely independent of the latter. We have attempted, but unsuccessfully, to distinguish between these two factors by the methods of partial correlation, but the data are too meagre. At best, therefore, it can only be expected to determine the extent of association, if any, between the seasonal incidence of the disease and both temperature and rainfall, and then to analyze the result in the light of other valuable information. As a control on the procedure the typhoid fever statistics have also been subjected to the same test.

Data.

For this purpose there were available the deaths by months, from diarrhea and enteritis under two and over two, and from typhoid fever, all ages, for the periods July, 1918–June 1922, and July 1923–June 1925. As in the previous study, it has seemed best to separate the diarrhea and enteritis deaths under one year, as these would be least likely to be influenced by water supply. This has been done in an approximate manner by deducting from the deaths, all causes, under one year, given also by months, the monthly distributed deaths in early infancy, and by making certain assumptions about the distribution of the remaining causes of death under one year. The reasonable accuracy of the procedure is indicated by the similarity between the remainder, age group one to two years, and the same data for the age group, over two.

The rainfall and temperature data for the same periods were available in the Meteorological Data of the United States Weather Bureau. In every case the mean value for each January, February, etc., during the period has been expressed as a percentage of the mean annual value over the same period. To make temperatures comparable with rainfall and deaths, the annual value has been taken as the sum of the monthly values and the data have been further simplified by recording temperature as excess over 70°. Thus 8.33 per cent is the mean of all the monthly values, whether of deaths, temperatures, or rainfall, and the mean value for any month, as given in Table VI is compared with 8.33 to determine the departures from the mean, used in computing the correlation coefficients.

TABLE VI

DATA FOR THE COMPUTATION OF CORRELATION COEFFICIENTS BETWEEN MONTHLY DEATH RATES FROM TYPHOID FEVER, AND DIARRHEA AND ENTERITIS, AND TEMPERATURE AND RAINFALL

(Monthly Distributions, Expressed as Percentage of Annual Totals, Period July 1911–June 1922, July 1923–June 1925)

Month	Typhoid	Diarrhea and Enteritis			Temperature *	Rainfall
		Under 1	1 to 2	2 plus		
January	7.84	8.48	8.42	8.40	4.57	6.42
February	5.25	7.62	7.34	7.14	4.54	6.94
March	7.39	8.74	5.04	7.88	5.38	5.28
April	7.13	8.45	5.43	6.74	6.88	6.54
May	8.82	9.02	5.31	7.33	9.47	6.96
June	9.08	9.94	8.52	8.82	9.92	8.44
July	7.84	8.67	10.66	9.51	10.91	10.54
August	9.80	8.29	11.28	10.00	11.42	9.34
September	9.34	6.91	8.82	8.26	11.32	12.69
October	10.15	7.66	9.26	8.87	10.59	10.62
November	8.91	7.34	10.52	8.27	8.78	10.86
December	8 46	8.82	9.41	8.96	6.11	5.81

* Excess over 70° taken as unit, and the sum of the monthly values taken as one hundred per cent.

TABLE VII

CORRELATION COEFFICIENTS DERIVED FROM THE DATA OF TABLE VI

Disease and group	Coefficient of Correlation with	
	Temperature	Rain
Typhoid	0.84 ± .06	.69 ± .09
Diarrhea and Enteritis		
Under 1	—0.3 ± .2	—.4 ± .2
1—2	0.80 ± .07	.70 ± .1
Over 2	0.72 ± .09	.64 ± .11

NOTE: A lag of one month is employed; *i. e.*, death rates are compared with the temperature and rainfall of the previous month.

Discussion.

Table VII shows three points of special interest. There is a striking similiarity between the constants of typhoid fever and diarrhea and enteritis over one; there is no seasonal correlation in the deaths from diarrhea and enteritis under one; both typhoid fever and diarrhea and enteritis in the two age groups over one, are closely correlated with temperature and slightly less so with rainfall.

The correlation with temperature and rainfall is most significant, statistically, and points to a clear seasonal, probably meteorological relation. The facts are thus in harmony at least with the view that diarrhea and enteritis in the age groups over one is a water-borne disease. For reasons previously stated the correlation studies in these age groups cannot by themselves produce further evidence for or against this view.

The situation as regards the deaths under one, however, is most suggestive. It might be expected that infants under one would be least affected by the quality of a public water supply and we know from other data, that they are most susceptible to temperature.

The statistics for the United States Registration Area for 1923 give the monthly distribution of deaths under one year from diarrhea and enteritis, expressed as rates per 1,000 births. These facts are shown in Table VIII, which follows.

TABLE VIII

DEATH RATES, UNDER ONE YEAR, PER 1,000 BIRTHS, FROM DIARRHEA AND ENTERITIS, REGISTRATION AREA, UNITED STATES, 1923

(Distribution by Months)

Jan.	7.0	July	13.9
Feb.	6.8	Aug.	21.3
Mar.	6.9	Sept.	22.4
Apr.	7.3	Oct.	17.2
May	7.9	Nov.	8.8
June	11.2	Dec.	7.0

The temperature effect is sufficiently disclosed here, even in the absence of a correlation value, obviously impossible to obtain for this large area. If the seasonal temperature variations in Porto Rico are not of sufficient magnitude to affect the death rates under one, the infants being protected somewhat from the effect of polluted water supplies, it seems probable that temperature is not the controlling factor in the seasonal distribution of deaths in the other age groups.

Finally as regards the similarity between typhoid fever and diarrhea and enteritis over one, as disclosed in the correlation coefficients, it can at least be inferred that the two diseases are probably related to the same primary seasonal factors. Since we know much more about the causation of typhoid fever it may be of interest to direct attention to its seasonal characteristics in Porto Rico as well as in the continental United States.

The temperature variations in the continental United States that have been found to influence markedly the seasonal incidence of typhoid fever are much greater than those which ever occur in Porto Rico. Thus in the city of Baltimore, to take a typical American city which has in the past shown high typhoid fever death rates, and taking the data of Sedgwick and Winslow for the decade 1888–97 when the typhoid fever deaths showed a typical summer peak, the following facts are disclosed. The monthly temperature means ranged from 34 to 76 degrees with a standard deviation of 15.7 degrees. In Porto Rico the corresponding range of monthly means is 73.8 to 79.5 with a standard deviation of 2.56 degrees. The corresponding standard deviation in the monthly percentages of typhoid fever deaths were 4.07 and 1.07. In other words, the variability in death rates was less than four times as great in Baltimore as in Porto Rico with a temperature variability of some six-fold. If we were dealing with a purely temperature phenomenon it might reasonably be expected that an opposite situation would be disclosed. That is, one might expect that small temperature variations would be associated with small variations in death rate and that with increasing temperature the death rates would not only increase but would increase at a still more rapid rate. This is not only true with regard to human physiology but is especially true with regard to those auxiliary factors which are influenced by temperature, namely, the development of the typhoid fever organism in milk and other foods, the breeding of insects and other animal agencies capable of transmitting the organism and the general opportunities for exposure to infection. All these are definitely modified by such temperature changes as occur in the continental United States but could hardly be appreciably affected by such minor changes as occur during the year in Porto Rico.

Furthermore the correlation coefficient for the Baltimore data is $.93 \pm .03$ taking the temperature of the same month and $65 \pm .11$

taking the temperature of the month previous. In other words, the effect of temperature upon typhoid fever deaths is so immediate as to be felt within one month. On the other hand the Porto Rico data show a correlation of 77 ± .08 against the temperature of the present month and .84 ± .06 against the temperature of the previous month. Similar facts are true of diarrhea and enteritis in both age groups over one and hold also for rainfall. It would be expected that rainfall, washing pollution from the water sheds into the streams, would act more slowly and more irregularly (lower correlation coefficient), than would temperature. The greater time lag in the seasonal correlation in Porto Rico and its lower value, when compared with Baltimore, both suggest that the significant correlation is with rainfall rather than temperature.

From these reasons, therefore, and because of the well-known relation between typhoid fever and such polluted water supplies as exist in Porto Rico it may be concluded that the correlation which exists between typhoid fever death rates and both temperature and rainfall variations in Porto Rico is essentially a correlation with rainfall rather than with temperature, and that typhoid fever in Porto Rico is to a large extent water-borne. If this conclusion be accepted then the evidence of the statistical data that have been submitted is that diarrhea and enteritis in all age groups over one is also to a considerable extent water-borne.

The extent of the correlation between death rates from this disease and seasonal factors is much more strikingly indicated by diagram than in the form of correlation coefficients. For this purpose Charts I and II have been prepared showing the seasonal distribution of diarrhea and enteritis in the age groups 1–2 and over 2 respectively, and for purposes of comparison there is likewise shown in each case a curve of death rates computed from the regression equation which results from the multiple correlation coefficients that have been referred to. While the latter in themselves are of little service in distinguishing between the respective effects of temperature and rainfall, the actual, value of the whole equation in expressing the seasonal death rate as a variable associated with temperature and rainfall is indicated by its agreement with the actual death rates.

The regression equation for the age group 1–2 years is—

$$D = 8.3 \text{ per cent} + .53\ dT + .15\ dR \pm 1.2$$

$$D = 8.3 + .22\ dT + .07\ dR \pm 0.3$$

and for the age group over 2 years is—

D is the mean monthly death rate, expressed as per cent of the mean annual rate for the whole period, and dT and dR, the departures of the monthly temperature and rainfall values, as given in Table VI, from the mean of all the monthly values 8.33 per cent.

A lag of one month has been allowed in computing the correlation coefficients and in plotting the data. Thus the death rates for January are compared with the weather conditions of December, etc.

An interesting effect is noted in all three of these charts which is not brought out in the figures. Table VI shows a decided drop in the rainfall during August, while the temperature continues to mount to its highest point in that month. In each case the death rate shows a decline in September, even more pronounced than that indicated in the computed correlation curve. Likewise the general similarity of all three seasonal distributions is more strikingly brought out in the plots.

This particular branch of our investigation, therefore, has developed certain positive facts and leads to some tentative conclusions. The rather striking similarity in the statistical constants of typhoid fever and of diarrhea and enteritis, over one, when each is correlated with temperature and rainfall indicates a similarity in causation. The disease diarrhea and enteritis in the age group under one is indicated by this same procedure to be of somewhat different origin and possibly, therefore, of different type. This latter conclusion was also in evidence in our study of communities with and without public water supplies. Finally we have stated certain reasons which in our opinion tend to exclude temperature *per se* or its related factors of fly breeding, food spoilage, and human susceptibility as causes for the seasonal variation in this group of intestinal diseases, and which consequently lead us to believe that there is a true correlation existing between these death rates and the pollution of rivers which undoubtedly results largely from rainfall and surface wash.

San Juan.

The statistics of San Juan may be utilized in connection with this same study, and seem to furnish some additional evidence. During the period July 1908 to June 1916 this city's death rate from diarrhea and enteritis, under two years, had a mean value of 3.9 per 1,000 of total population and the death rate was increasing at a rate of 0.15 per annum. During the same period similar data for the Island as a whole were, mean death rate 2.4, and rate of increase of the death rate, 0.15 per annum. These facts are shown graphically on Chart IV. The year 1916–17 was apparently a favorable one for the development of diarrhea and enteritis, under two years, and a striking increase of death rate is noted for the Island as a whole and a much more striking one for San Juan.* The relative values are of particular interest here, for the Island as a whole constitutes a sort of base line from which it is possible to measure any changes confined to the city alone.

Up to 1915 the water supply of San Juan had been similar to those of most of the municipalities having water supplies on the Island except, that, owing to the rather densely populated character of the water shed, it was probably somewhat more heavily polluted. In 1915 pressure filters were installed having a rated capacity of 3,000,000 gallons per day. The performance of these filters was apparently unsatisfactory owing to insufficient capacity, for the capacity was doubled in the new installation made during 1917. Since that time the quality of the water supply has not always been entirely satisfactory but it was much improved by the new installation and has been given increasing expert attention and laboratory control since that time. It is of special interest, therefore, to note on the chart a marked decrease in the death rate for San Juan beginning in the year 1917–18 and a continuing drop during the following year when, for the first time throughout the period under discussion, the rate was as low as that for the Island as a whole. Since that time both rates have varied, as it is to be expected, but they have remained of the same general magnitude.

While the improvement noted in the city of San Juan as compared with the Island may be attributed to other measures of sanitation, it is also entirely compatible with the thesis of the water-borne nature of diarrhea and enteritis which has been discussed in this paper, and in the light of other evidence here presented it seems to be somewhat confirmatory of that thesis.

Summary.

1. A study of the distribution of diarrhea and enteritis among the urban and rural sections of the municipalities of Porto Rico with and without public water supplies indicates a distinct excess in death rates in the age group 1–5 years in the urban districts having public water supplies, and a similar excess of unsatisfactory statistical significance in the age group under one year. In the former age group the indicated excess amounts to about twenty per cent of the total deaths, all ages, from this cause, in the Island.

* In the previous paper it was shown that the same fact is true for typhoid fever in Porto Rico.

2. Diarrhea and enteritis under one year of age has very little seasonal variation and its distribution is not associated with temperature or with rainfall.

3. The seasonal distribution of diarrhea and enteritis over one year is distinctly associated with both temperature and rainfall. Several lines of reasoning have been advanced, including comparisons with the typhoid fever statistics, which tend to show that the actual association is with rainfall rather than with temperature. Typhoid fever shows a seasonal distribution quite similar to that of diarrhea and enteritis over one year.

4. The statistics from San Juan for diarrhea and enteritis under 2, show a marked improvement in the death rate following the installation of the enlarged filter plant in 1917, previous to which, it had fluctuated at about sixty-six per cent in excess of the death rate for the Island as a whole and subsequent to which it dropped to about the same general level.

Conclusion.

We are led to conclude from the statistical evidence that diarrhea and enteritis under one year of age, as reported in Porto Rico, is probably of somewhat different origin and possibly, therefore, of somewhat different type from the disease of the same name as reported in the higher age groups; and that in all probability the disease reported in those age groups over one year is to a large extent water-borne.

Such conclusions are necessarily tentative, until further tested by appropriate bacteriological, or other etiological studies, or until confirmed by further studies of improvement following the installation of satisfactory water purification in the cities.

It likewise appears that the typhoid fever death rate in Porto Rico can be materially reduced by improved municipal water works.

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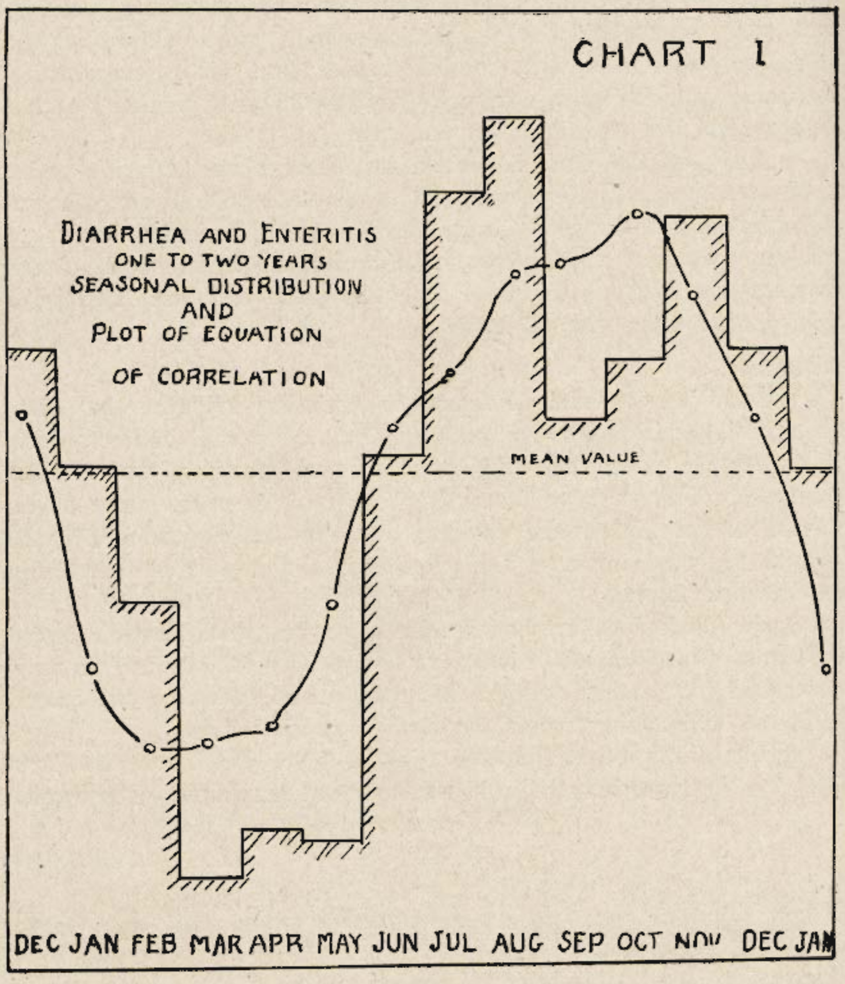
CHART I
DIARRHEA AND ENTERITIS
ONE TO TWO YEARS
SEASONAL DISTRIBUTION
AND
PLOT OF EQUATION
OF CORRELATION
MEAN VALUE
DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN

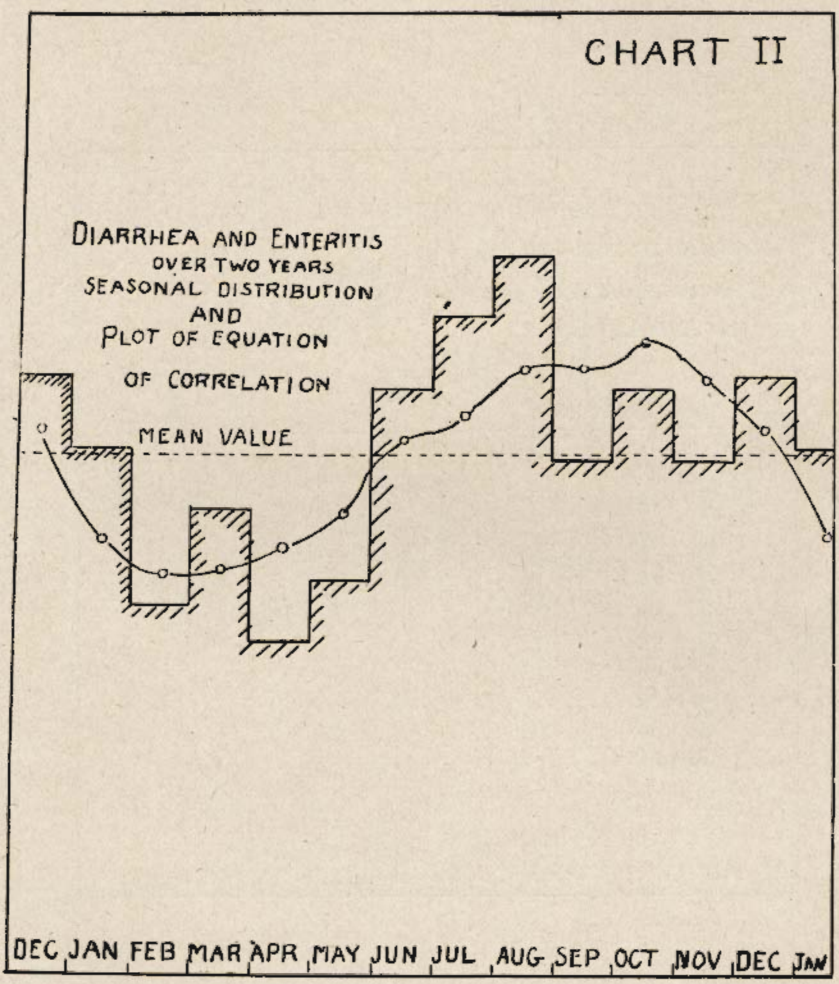
CHART II
DIARRHEA AND ENTERITIS
OVER TWO YEARS
SEASONAL DISTRIBUTION
AND
PLOT OF EQUATION
OF CORRELATION
MEAN VALUE
DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN

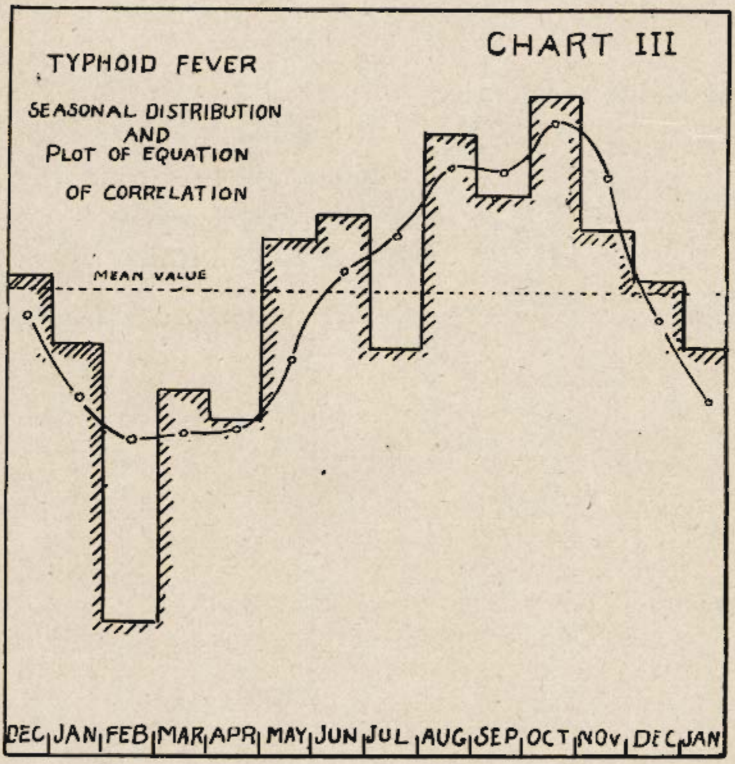
CHART III
TYPHOID FEVER
SEASONAL DISTRIBUTION
AND
PLOT OF EQUATION
OF CORRELATION
MEAN VALUE
DEC JAN FEB MAR APR MAY JUN JUL AUG SEP OCT NOV DEC JAN

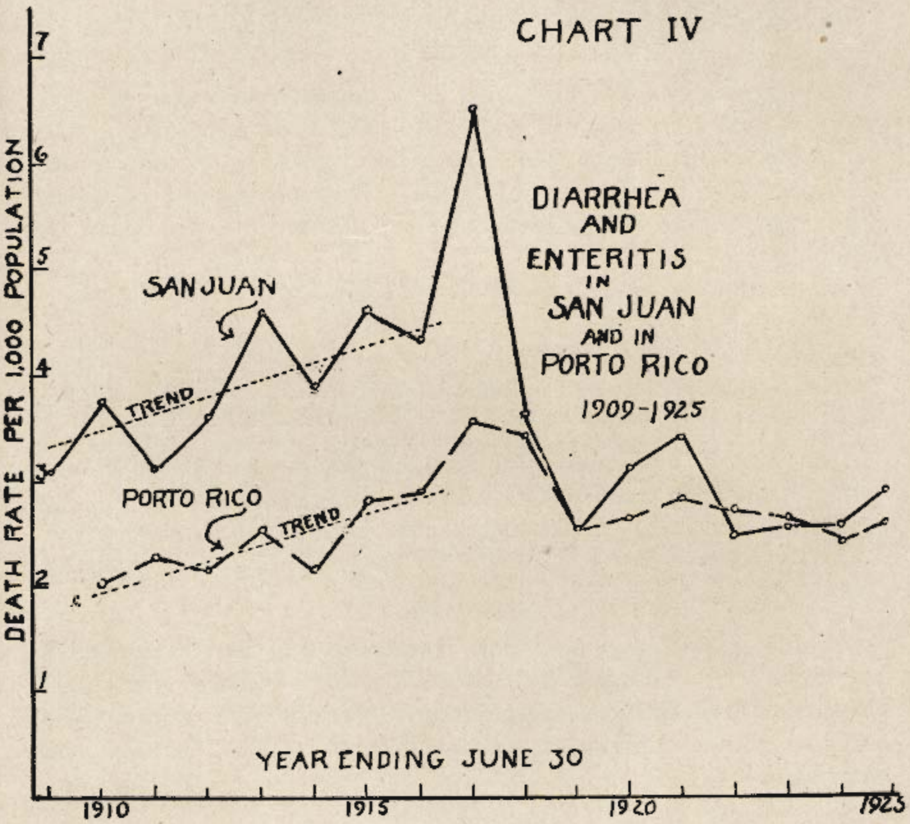
CHART IV
DIARRHEA AND ENTERITIS IN SAN JUAN AND IN PORTO RICO 1909-1925
SAN JUAN
PORTO RICO
TREND
TREND
DEATH RATE PER 1,000 POPULATION
7
6
5
4
3
2
1
YEAR ENDING JUNE 30
1910
1915
1920
1925