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THE GEOGRAPHICAL DISTRIBUTION OF DISEASE

WITH SPECIAL REFERENCE TO CANCER OF THE LUNG AND STOMACH IN WALES

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The geographer in his work relies extensively on maps and in this respect there would seem to be a useful field for joint exploration between geographer, human ecologist, epidemiologist, and medical statistician. The mapping of statistical data is now generally accepted to be the method of attacking many problems in biology, geology, geography, meteorology, climatology, economics, administration, etc., and its obvious importance in the understanding of areal relationships of diseases is such that it is somewhat surprising that more is not being done by the medical profession. The comparison of endemic areas with areas free from the disease may well throw valuable sidelights on causation. Once the active cause and the predisposing associations of a disease are defined, the path is opened to sound preventive measure. If the cause is unknown the difficult early stages of the problem may well be clarified by a map showing the geographical variations of the particular disease. The deeper causes of the distribution can then be studied and it may well be that the distributional patterns displayed are paralleled by those of some other known phenomenon. These, in their turn, may give a clue to causation. This is not to suggest that problems are elucidated merely by mapping broad areal relationships. Rather, it is thought that useful pointers and relationships might well emerge from such an exercise.

The "World Atlas of Epidemic Diseases" (Rodenwaldt, 1954ff.) and the series of maps prepared by May (1950 ff.) for the American Geographical Society are especially valuable for those interested in the environmental conditions of global disease. Learmouth (1954) gives a useful example of how to convey much information in a single map, and has demonstrated the geographical treatment of 20 years' medical statistics for the former British India (Learmouth, 1958). Audy (1958) employs cartographic and graphical techniques to demonstrate the usefulness to the epidemiologist of the synoptic view given by the map. Stocks (1936, 1937, 1939) has frequently adopted cartographic techniques to represent medical statistics, and in 1936 used maps of England and Wales showing standardized mortality of cancer to demonstrate marked contrasts between high incidence in the mountainous areas of Wales and parts of the north of England, and low incidence in the chalk areas of the south-east of England. Subsequent workers were thus able to concentrate their efforts more definitely in the areas of heaviest mortality. Two maps (Figs. 1 and 2) are presented here to illustrate the kind of detailed choropleth (quantity in area) map that can be constructed from mortality data given in the Medical Tables and Text Volumes of the Annual Statistical Reviews of the Registrar General.

Construction of Maps

Malignant disease is selected for study, and the intention is to show the geographical incidence in Wales of mortality from cancer of the lung and bronchus in males, and cancer of the stomach in females during the 7-year period, 1947–53. This period provided a large enough sample of mortality data and it had the advantage that in 1951 a population census took place which enabled accurate calculations. Standardized mortality ratios (S.M.R.) were calculated to obviate fallacious comparisons of crude death rates and to give due allowance for sex-age differences in the population and for degree of urbanization. Deaths from cancer of the lung-bronchus and of the stomach for the period 1947–53 were obtained from the appropriate Statistical Reviews* for the County Boroughs of Wales, and for the urban and rural districts of each Welsh

* These statistics are based on death certificates. Cause of death is not always certain and in the absence of proof by autopsy the complete reliability of these data may be in doubt.

county, including Monmouthshire (Registrar General, 1956). Ratios of deaths from cancer of these organs in England and Wales in the years 1947–53 to the 1951 census populations at six age groups (0–34, 35–44, 45–54, 55–64, 65–74, 75 and over) for each sex were multiplied by the corresponding local census populations and the resulting products aggregated to give "expected" deaths. The actual deaths for 1947–53 were then expressed as percentage ratios of the "expected" totals to give standardized mortality ratios. The standardized mortality ratio is expressed in terms of the standard England and Wales rates taken as 100 in every case. If the S.M.R. of a particular area is 100 it means that this area experienced in the 7 years of study a mortality equal to that for England and Wales as a whole; if the S.M.R. is 200 the rate is twice as great as the national average.

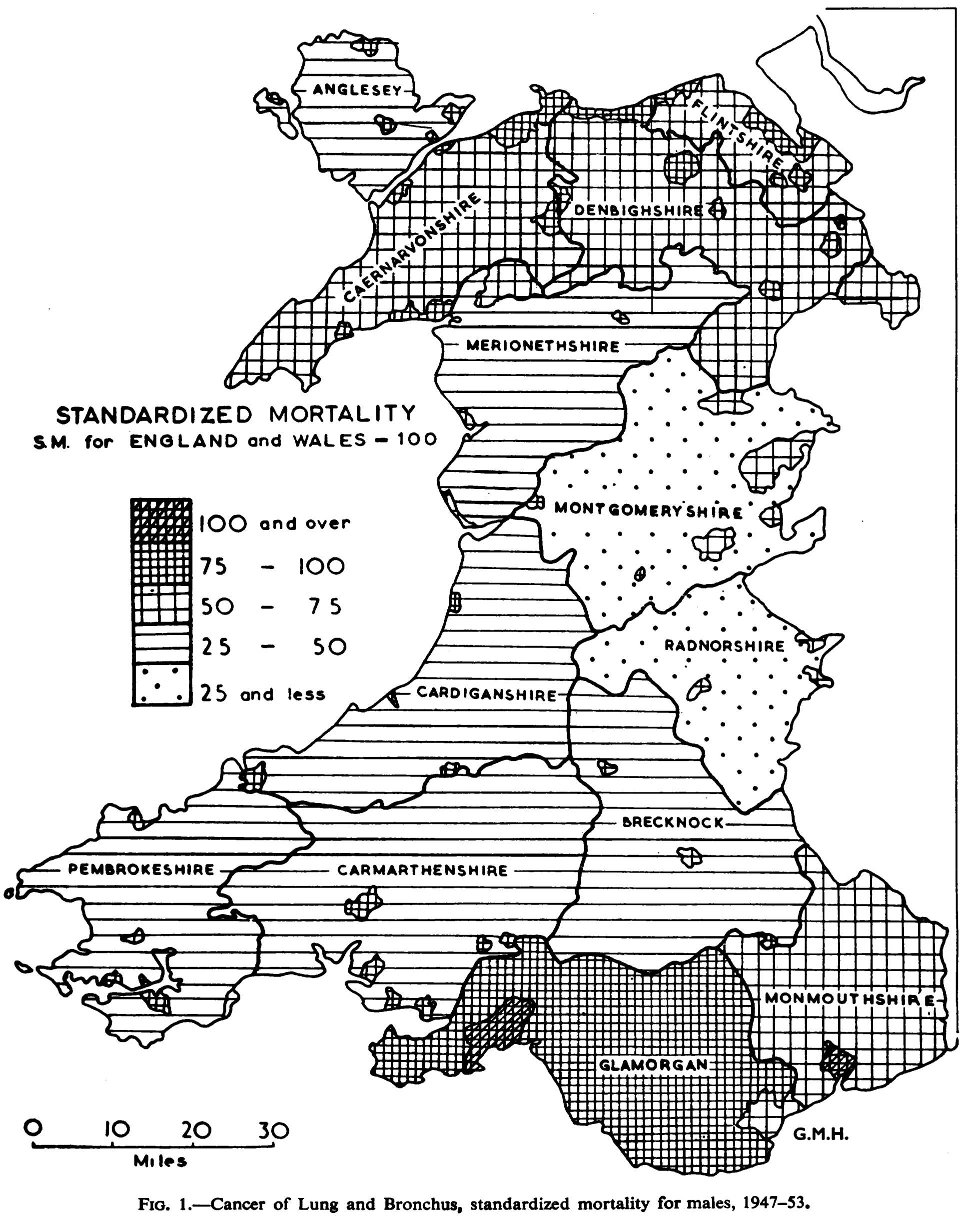

FIG. 1.—Cancer of Lung and Bronchus, standardized mortality for males, 1947–53.

It is necessary to exercise care in choosing interval values for the standardized mortality ratios to be displayed on a map. Ideally a "dispersion diagram" should be prepared to ensure full weight for the major standardized mortality values and for important variations. This has been done for Figs 1 and 2, which, consequently, have different keys.

Computations of S.M.R. have been made on the basis of data available in the Statistical Reviews, and the lines on the map represent county boundaries or the boundaries of county boroughs, urban districts, or rural districts. Where values in adjacent districts correspond there has been grouping, and the administrative boundary has been omitted. It must not be assumed that the mortality rates depicted necessarily prevail over the whole of a particular administrative district whether it be urban, rural, or a county borough. All that can

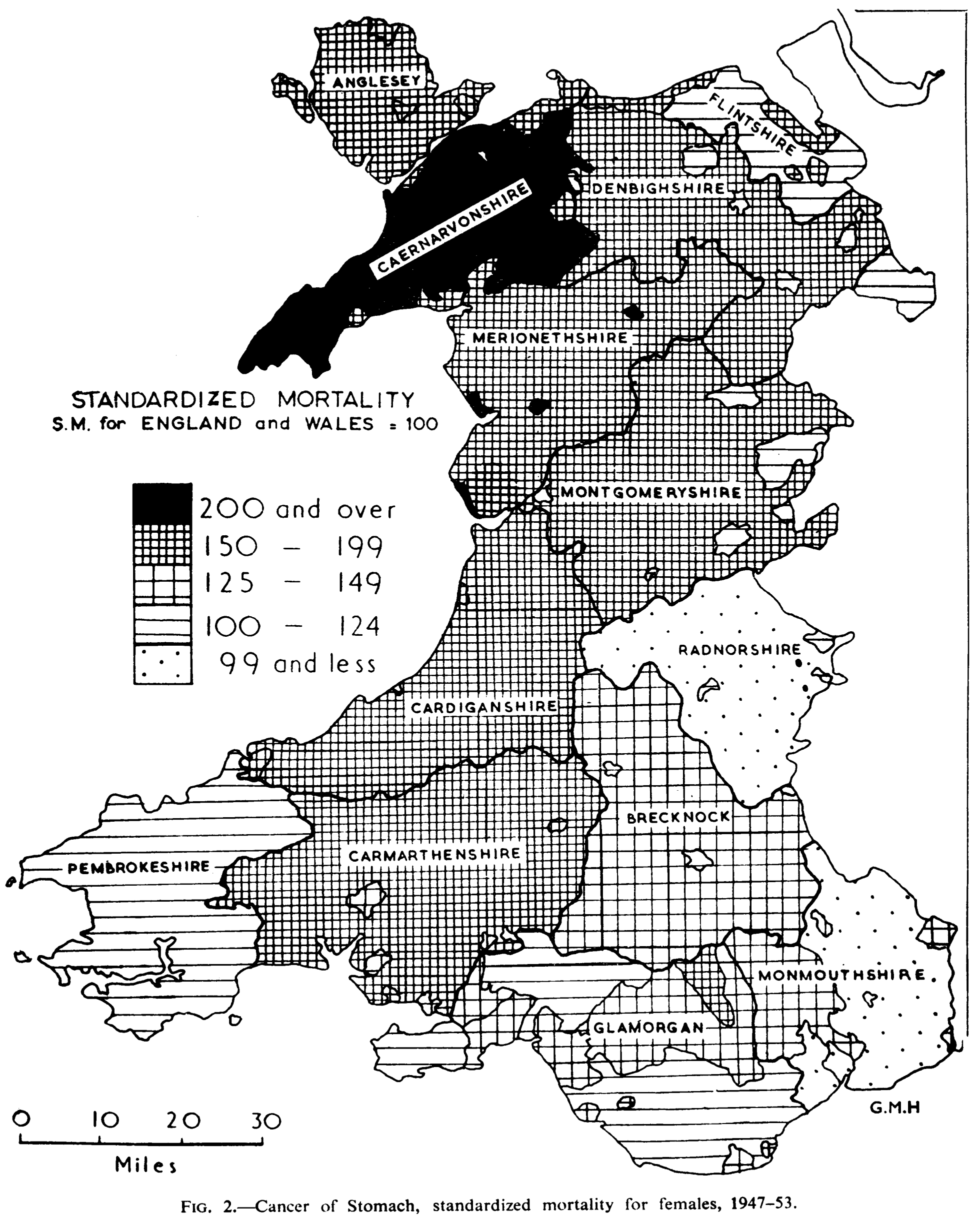

FIG. 2.—Cancer of Stomach, standardized mortality for females, 1947–53.

reasonably be assumed is that the mortality rates so displayed are those which prevail among a large proportion of the populations resident in the counties or parts of the counties mapped. Regions of specific cancer mortality rates must exist in the general areas enclosed by the administrative boundary lines but they are unlikely to be co-extensive with them.

Features of the Distribution of Cancer Mortality revealed by the Maps

Maps of crude aggregates of cancer deaths in Wales would merely reflect the distribution of population which is characterized by an overwhelming dominance of two zones of dense population associated with the industrial areas in North-East Wales and South Wales respectively and a central zone of sparse population associated with the mountainous heartland of the principality (Fig. 3).

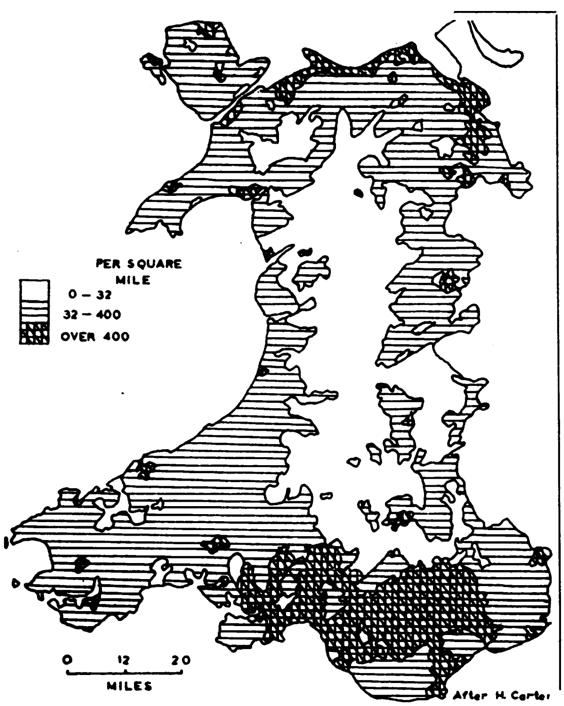

FIG. 3.—Density of population in Wales, 1951 (after H. Carter).

Even so Fig. 1, which is based on S.M.R.s, does bear a resemblance to the distributional pattern revealed in Fig. 3. On the other hand, the pattern shown in Fig. 2 is quite different and reveals a rural distribution.

Welsh rates for cancer of the lung and bronchus for men (Fig. 1) are below the national average for England and Wales, except in Swansea County Borough, where deaths totalled 360 compared with the expected 277 (S.M.R.130), and in Newport County Borough with 193 deaths compared with 170 expected (S.M.R. 105). In every county except Glamorgan, the S.M.R.s for the urban districts are slightly in excess of those for the rural districts. In Glamorgan the S.M.R. for Cardiff County Borough is 58, for Merthyr Tydfil County Borough 81, for Swansea County Borough 130; all other urban Districts 77; rural districts 79.

Cancer of the stomach for females in Wales is such that rural Caernarvonshire and the small urban areas of Merionethshire have ratios more than twice as high as expected (S.M.R.s 243 and 220 respectively). In rural Monmouthshire and Radnorshire there is no excess over the national average. Pembrokeshire, rural Glamorgan, rural Flintshire, and the small urban areas of Montgomershire have indices between 100 and 124; in the remainder of Wales the mortality ratios range from $1\frac{3}{4}$ times to twice the national average.

Discussion

From the contrasting distributional patterns shown in Figs 1 and 2, it seems reasonable to infer that the causal factors differ in each case. The higher ratios for lung and bronchus (Fig. 1) in the more densely populated areas (Fig. 3)—though generally below the England and Wales average—suggest some parallel between the two. This is not to invoke a straightforward causal relationship but rather to reflect that the greater the degree of crowding together of people in industrial communities the greater is the atmospheric pollution resulting from the increased numbers of domestic and industrial chimneys, or from fumes from factories and motor vehicles. In addition there is a greater danger of food contamination from pollution-ridden atmosphere and a greater risk of infections (Boyland, 1958; Stocks, 1959a)—factors which are thought to have an association with cancer of the lung. Not that all the smoke and other pollution generated in an urban industrial area necessarily remains there. In average windy weather about half is blown away. Since the prevailing winds in Wales blow from the west and south-west (see wind roses for Holyhead and St. Ann's Head in Fig. 4, overleaf), the smoke, soot particles, and chemical gases from industrial South and North-East Wales are spread away to the east-north-east, thereby considerably reducing the "country pollution" within Wales itself.

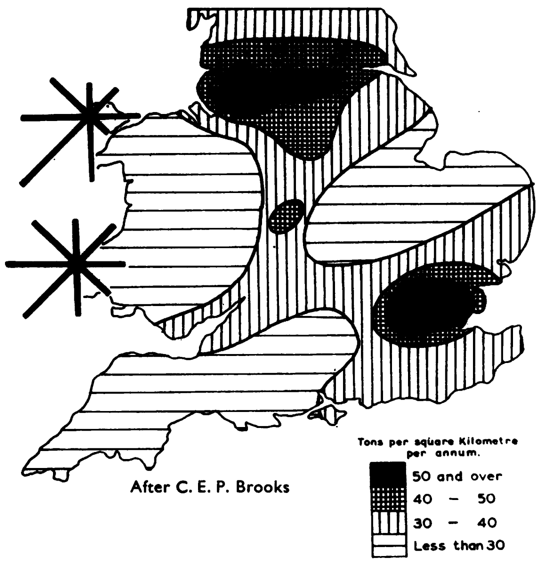

FIG. 4.—Country pollution, based on deposits in pollution gauges (after C. E. P. Brooks).

Fig. 4, adapted from Brooks (1954) reveals that, on the basis of deposits in pollution gauges (values in tons per square kilometre per annum), even the industrial North-East and South Wales are remarkably free from pollution, despite the greater consumption of coal in private houses and factories in these areas compared with the rest of Wales (Fig. 5).

Nevertheless the suggestion that there is "an inverse relationship between hours of sunshine and cancer of the lung" (Roberts and Shaw, 1958) does not appear to be borne out by a comparison of Fig. 1 and Fig. 6.

Stomach cancer (Fig. 2) on the other hand seems to be unrelated to urbanization. On the contrary a rural distribution is illustrated in which some other geographical association, not necessarily social or human, may play a part. Stocks (1959b), Davies and Griffiths (1954) and Legon (1952) have provided evidence for North Wales which suggests a relationship between heavy mortality rates from stomach cancer and soils with high organic content and bad drainage. It is thought that stomach cancer mortality may be "conditioned by micronutrient deficiencies in food plants grown on soils of high organic content". Further, it is suggested that populations whose diets include vegetable foods grown on such soils may be subjected to the action of carcinogens or may be deprived of protective substances". If such a relationship really exists, is not the role of vegetable foods*

* 78–85 per cent. of the vegetables are brought into North Wales, except in the case of potatoes where the consumption of local-grown crops would be high.

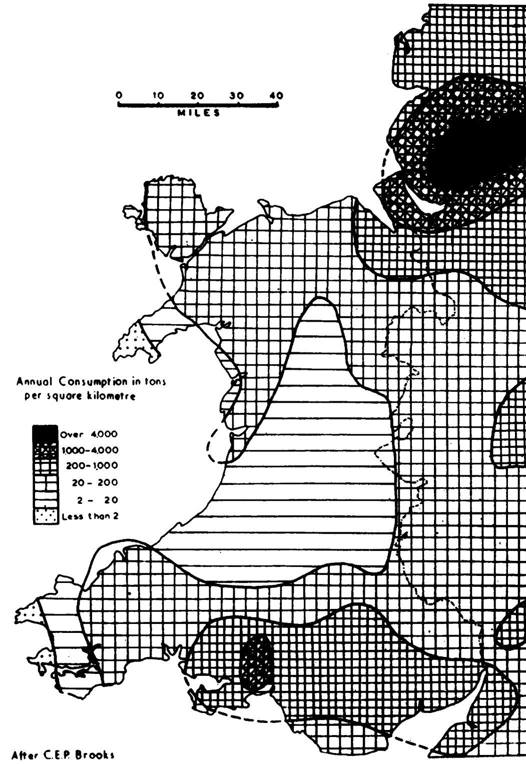

FIG. 5.—Consumption of coal (after C. E. P. Brooks).

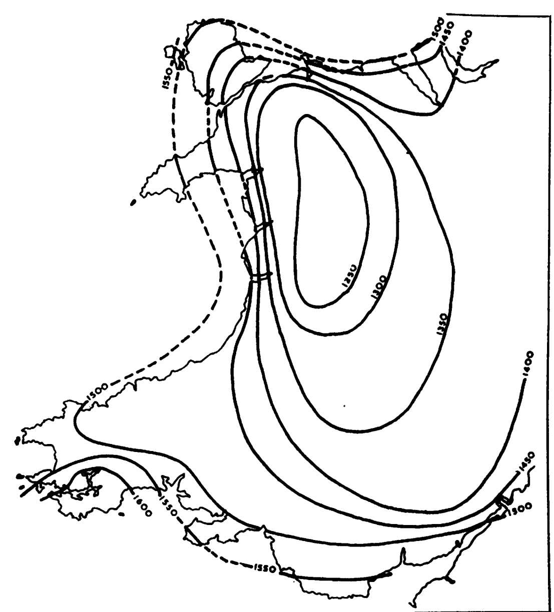

FIG. 6.—Distribution of bright sunshine in Wales, 1921–50 (based on M.O.572).

over-emphasized? It is far more likely that a medium in constant and daily use other than vegetable food is conveying the carcinogens from the ground or soil to the body. Drinking water seems an obvious vehicle since it is affected by the strata and soil over which and through which it flows. In Wales the surface rocks are, on the whole, stable and insoluble, and the underground water supply is comparatively small (North, 1936). Surface water supplies therefore acquire their characteristics either from the atmosphere or from the prevailing soil type. Vast expanses of the water catchment area of upland Wales are covered with hill peats, and it has been estimated that more than half of the soils in Wales suffer from some degree of drainage impedance—presumably more so in the wetter north and west than in the drier south and east (Robinson and Roberts, 1936). Acidity and organic matter is transferred from the peat soils to the water flowing through them, while bad drainage and water logging inevitably leads to water stagnation and pollution. In such cases one is dealing with the circumstances, *viz.* high organic content and the effects of bad drainage, thought by many workers to be related to high incidence of mortality from cancer of the stomach (Stocks, 1959c; Davies and Griffiths, 1954; Legon, 1952; Tromp, 1956).

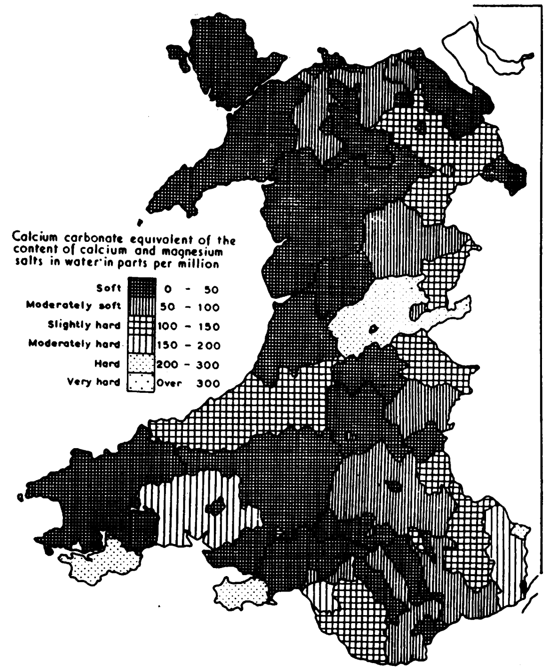

FIG. 7.—Character of water supplied to Welsh consumers, 1958 (from Water Engineer's Handbook).

Fig. 7, based on the "Water Engineer's Handbook" (1958), is included to show that the *treated* water supplied by the majority of the water undertakings in Wales is characterized by an overall deficiency in the sulphates and chlorides of calcium and/or magnesium. The same would seem to apply to farms not in receipt of piped water from public supplies. Of 4,250 farm water supplies examined by bacteriologists of the National Agricultural Advisory Service during the period 1953–58, 72 per cent. were found to be in the soft or moderately soft category and only 7 per cent. hard or excessively hard (Thomas, 1959). In the case of the piped water supplies of the various Welsh undertakings, undesirable characteristics like acidity, organic material, and aquatic organisms (minute crustacea, water fleas, cyclops) will have been removed by sterilization, filtration, chlorination, and general purification. The unpiped water available to much of the rural population receives no such purification.

The proportion of the rural population of Wales that is without piped water is appreciable. The "National Farm Survey of England and Wales" (Ministry of Agriculture and Fisheries, 1946) disclosed that, apart from Glamorgan, Monmouthshire, and Flintshire, over 55 per cent. of the farm holdings in Wales were without a piped water supply. Many of those holdings reporting "piped water supply" received their water, not from public water undertakings, but from local sources like springs, shallow wells, streams, impounded rivers, and lakes, all of which are liable to surface pollution, especially contamination from human and animal sources. The proportion of the rural population receiving untreated water is thus higher than 55 per cent. of the holdings would suggest. In addition, over 20% of the farm holdings in Wales (except Flintshire) experience a seasonal shortage, at which times an already doubtful water supply is made even more questionable.

It is not without significance that, of the 12,863 Welsh farm water supplies examined by N.A.A.S. bacteriologists during the past 9 years (1949–58), only 6,308 supplies (49 per cent.) were classed as acceptable for dairy purposes on field observation and bacteriological examination. Of these 6,308 supplies, 51 per cent. required very little further protective work, 35 per cent. required extensive improvements, and the remaining 14 per cent., although protected as far as was practicable, could only be accepted as suitable provided that the water was boiled or treated with a suitable quantity of hypochlorite (Thomas, 1959). In the course of years the irritant and other effects of drinking water with undesirable constituents may well be appreciable and one wonders if the polluted and untreated waters used by much of the rural population in Wales—where the incidence of stomach cancer is known to be high (Fig. 2)—might not be worthy of detailed examination in relation to stomach cancer?

CONCLUSIONS

It is not intended that the foregoing considerations, illustrated by reference to lung and stomach cancer in Wales, be considered an original contribution to knowledge of cancer causation, but it is hoped to suggest that the mapping of diseases to show areal relationships may help to clarify general situations in the difficult early stages of certain medical problems. The regional confinement of many diseases may well parallel aggregations of population or the secondary effects associated with such aggregations, such as atmospheric pollution, sanitation, etc., or with such factors as marital state, blood groups, diets, climatic factors, soils, or water supplies, most of which can be depicted in map form. In the mapping of these and like phenomena the geographer can claim some expertise, and this, together with his sense of regional variation, should make him a useful collaborator in many medical research projects.

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