THE INFLUENCE OF OCEAN SPINDRIFT AND BLOWN SPRAY ON THE CHLORINE CONTENT OF INLAND GROUND WATERS[1].

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(With 3 Maps.)

Introduction.

In works on Public Health and Water Analysis, it is a common observation that the amount of chlorine in inland surface waters near the seaboard is considerably higher than what obtains in samples from more inland parts.

While this is true, there seems to have been little attention given to a minute study of the ocean's influence on those inland waters and of the several factors which more or less modify such action.

The first endeavour to show that the sea made any change on the chlorine figure of inland waters was made by the State of Massachusetts.

It was found that the waters if unpolluted varied in their chlorine figures relatively to their distances from the sea, and as the state has a very uniform composition, the tabulation of the waters into groups of equal chlorine content by means of isochlor lines is of great service in estimating the purity or otherwise of any given sample, since if a water from a given area has over the normal chlorine, suspicion is aroused.

While the utility of plotting an area into "isochlors" has been appreciated in Massachusetts, very little in the direction of application to Public Health Chemistry has been attempted in this country.

Indeed, according to Thresh (*Water Supplies*, 1896, page 162), it is stated that the estimation of chlorine is of little value in insular countries since isochlors cannot be mapped out. Again, Somerville

[1] Dissertation for the M.D. degree in the University of Glasgow, June 1913.

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(*Sanitary Science*, 1906, page 19) says "In districts remote from the sea and centres of population and land cultivation, such maps may be more or less reliable, but in this country they would be useless." The only endeavour so far made in Great Britain is that by Don and Chisholm. In their book (*Modern Methods of Water Purification*, 1st Edition, page 278) a map of Ayrshire is given showing the variation in the chlorine content of waters depending on their distances from the seaboard.

This map has been kindly lent me by the authors, and is here reproduced (Map 1). Apart from this, the present position seems to be that it is granted the ocean has an influence on waters in close proximity to it, but that so far as more remote waters are concerned such influence is of no moment or beyond measurement. Now, if the sea has an influence on waters near the shore, it is equally certain that such an influence cannot stop short at some fixed point, but must extend inland, depending on wind prevalence, contour of land, and other factors, and be accordingly measurable by analysis.

Area under Review.

For the purpose of this study that part of Scotland lying south of the river Forth was taken.

This gives a tract of land of sufficient size to show large variations in the analysis of its water samples. It is rich in geographical and geological variety, and is, moreover, an area showing appreciable differences in its meteorological conditions of rainfall, wind prevalence, etc.

Data for Thesis.

Through the courtesy of the Medical Officers of Health and Sanitary Inspectors, the water analysis figures for the various counties were utilised.

Methods.

These records were all carefully examined, and all suspicious and impure waters rejected. In this way a series of chlorine figures was obtained for each county. By referring to maps, the figures for small areas or certain places were then added together and the arithmetical mean computed. This value was taken as the normal for the place in question.

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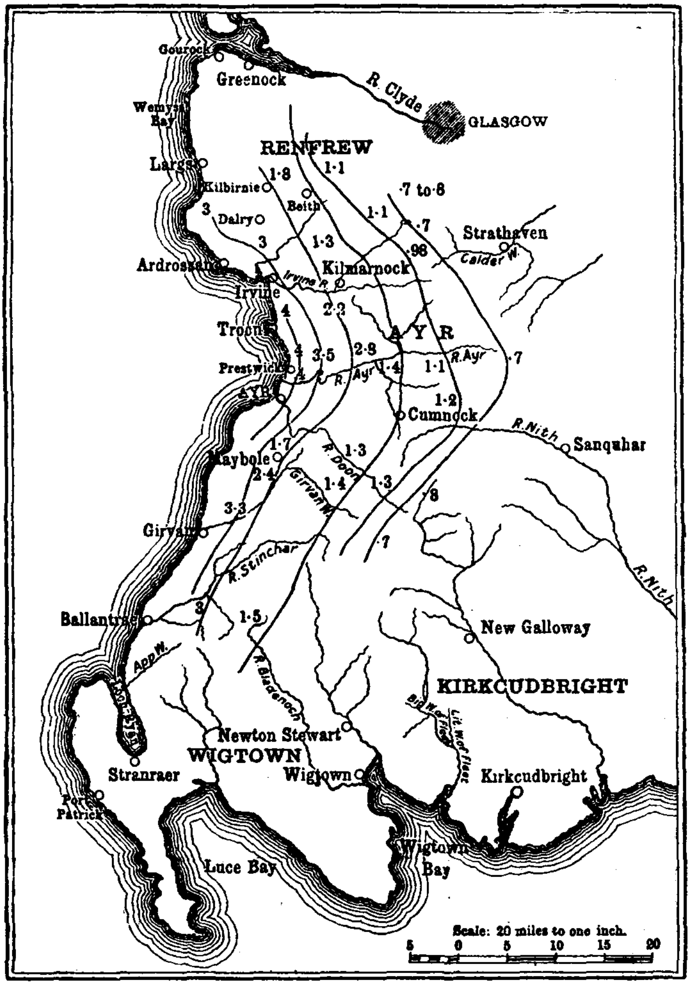

Map 1. Lines of equal chlorine content (isochlor lines) in ground water supplies.

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It was found that when the series was long—that is when several values were available—the average approximated very closely to the lowest figure. Accordingly, when only two analyses were given, and the chlorine figures varied considerably, the lesser figure was taken. By reference to an area near at hand this figure was invariably found to be the truer.

With such a variable constituent of water as chlorine, liable to be increased by the slightest contamination, it was found essential, in order to minimise error, to divide waters respective of their chlorine into groups as follows:—under 1 part per 100,000, 1—1·4 inclusive, 1·5—1·9, 2—2·4, 2·5—2·9, 3 and over.

The waters, depending on the groups into which they fell, were thereafter plotted on to maps.

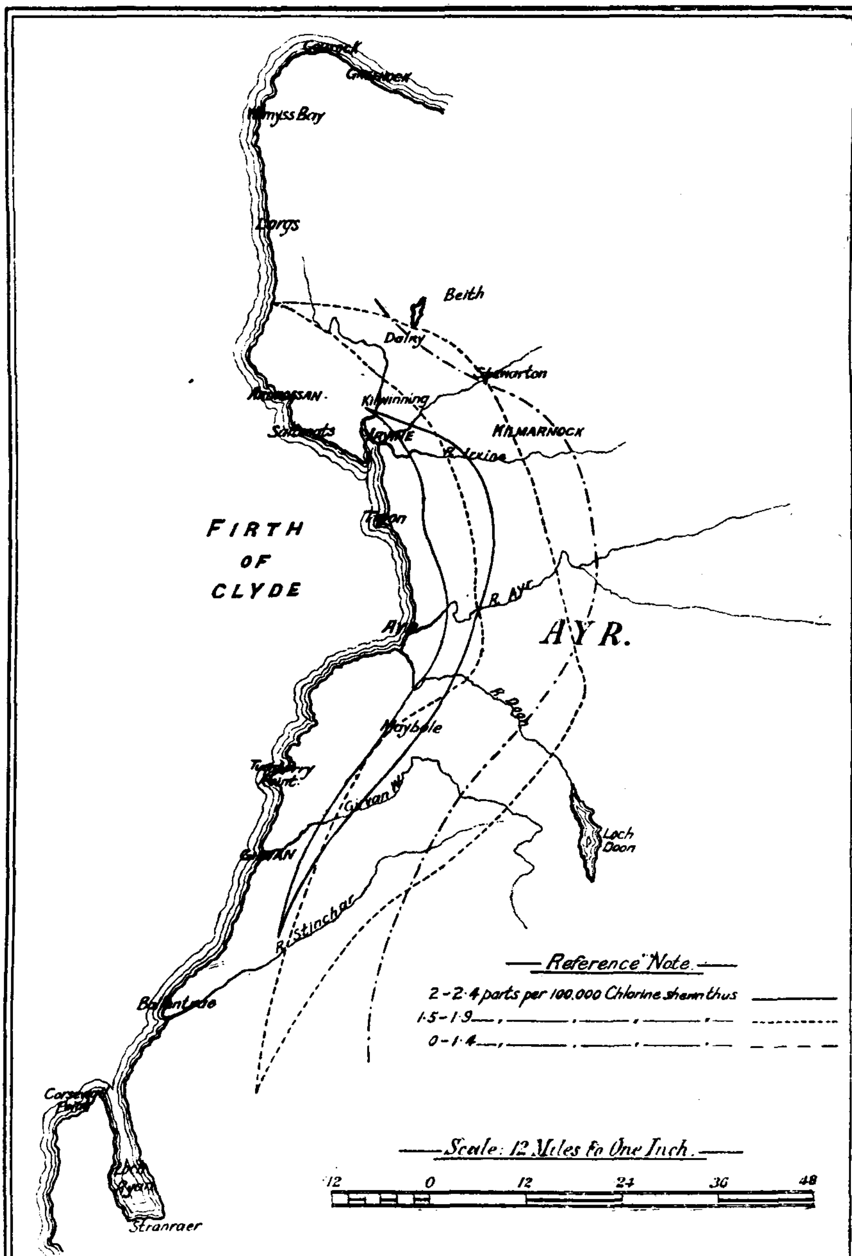
Since ·1 per 100,000 chlorine was sufficient to alter any water from one group to another, great care had to be taken in drawing the isochlor lines or lines joining places of equal chlorine content. A map of Ayrshire (Map 2) shows how areas of certain chlorine values overlap and invade each other.

Accordingly in drawing an individual line of separation between two such areas the average had to be taken graphically.

In drawing isochlor lines there are two methods which may be termed the forward extension method and the backward extension method. In the former method points of equal value nearest the shore are joined together, in the latter points of equal value furthest from the shore.

Isochlor Lines.

In the construction of the maps the forward extension method was adopted, as it was found to show in a more convincing manner minute variations in the chlorine content. On the map (Map 3) it will be observed that the land area under consideration is divided by lines into smaller areas. These lines, drawn through places of equal chlorine content, delimit the forward extension of the given chlorine value. From the shore line to the first line inland represents that area in which the chlorine in ground waters reaches 3 and over 3 parts per 100,000. Similarly between the first and second lines the chlorine figure is 2·5—2·9 parts per 100,000.



Map 2. Overlapping of chlorine values.

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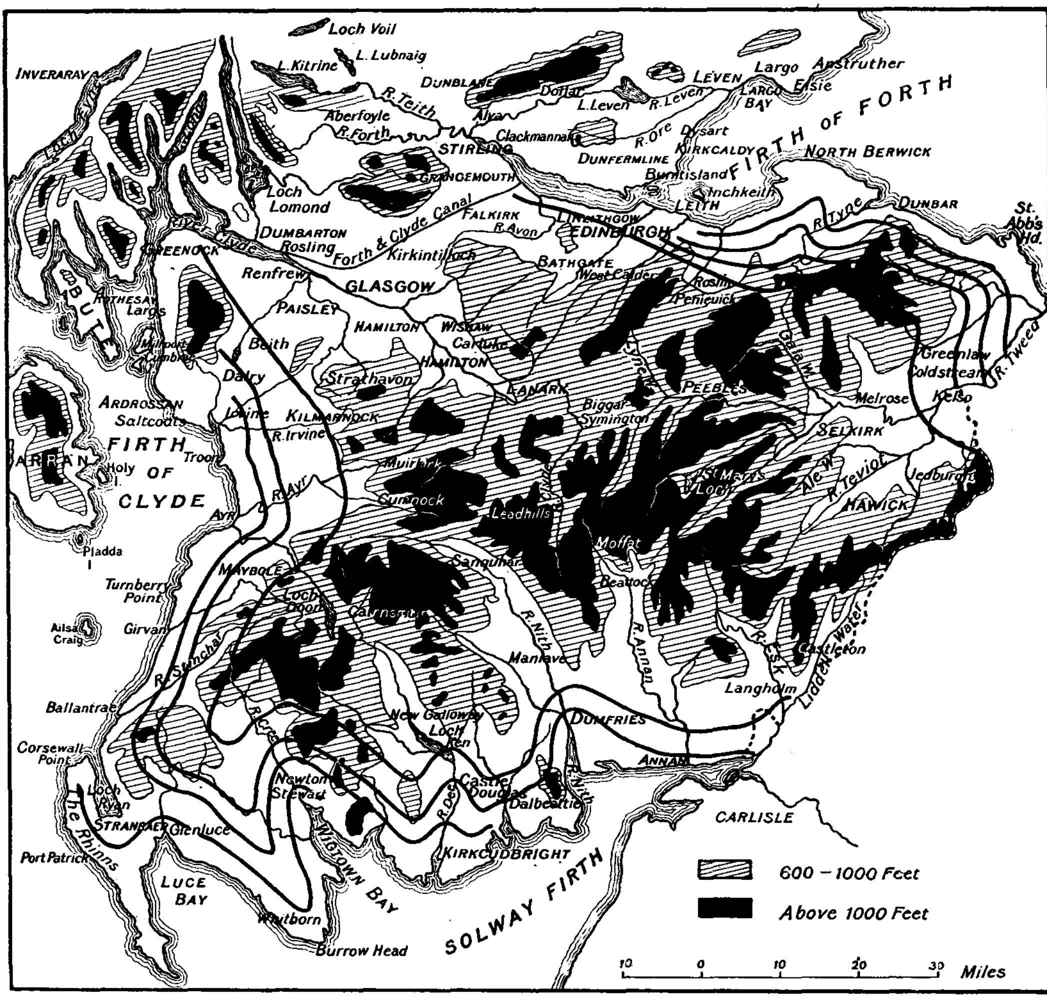

Map 3. Areas of equal chlorine content.

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The Ocean's Influence.

It will thus be seen that the chlorine content of ground waters is a diminishing one from the seaboard inland, and for this there can only be one explanation, namely, that the sea by some means or other exercises an action over inland waters.

It is commonly found that water collections on shingly land near the coast have high chlorine values due to the percolation of sea water.

This, however, can only influence surface waters within a very short distance from the shore.

Spindrift and Blown Spray.

The most potent influence the ocean has on the chlorine in inland waters is through its spindrift and blown spray. During high winds from seaward spray is carried inland in great quantity, and gets deposited over land surfaces as such.

Effect of Distance from Seaboard.

From the shore inland there is an increasing diminution in its amount due to gravitation, and consequently the amount of chlorine deposited diminishes in the same ratio as the spray does. For this reason the chlorine figure is high near the seaboard, and increasingly less as more inland parts are reached.

Effect of Land Contour.

In addition to blown spray as a factor exercising its action on the chlorine content of inland waters, minute saline particles derived from ocean spindrift are constantly producing their effect. Sodium chloride is one of the commonest constituents of the atmosphere. In greater quantity near the seaboard, being derived from ocean spindrift and blown spray, it is responsible in great part for fog and cloud production (Moore, *Meteorology, Practical and Applied*, 1910, page 197). Being particulate these particles follow the laws which govern all particulate matter, and are consequently more abundant in the lower strata of the air. In this way there is a gradual deposition of such particles from the shore inland, with a proportionate diminution in the chlorine value of inland ground waters. The next point to be observed is that there is a deflection of the isochlor lines inland where there are valleys, or where the land is continuously low from the shore.

Effect of Wind.

In order to demonstrate this feature an orographical map has been incorporated in Map 3, showing altitudes from sea level to 650 feet, 650 feet to 1000 and over 1000 feet. By comparing this map with that showing isochlor lines it is seen to what extent the sea's influence depends on the elevation of the land surface and the presence or absence of impediment to the inward progress of ocean saline matter. Where chlorine-containing clouds are concerned, the relative elevation of the land surface is a most important factor, since on this depends in great part the precipitation of rain and the consequent liberation of the chlorine. If the land is low no precipitation occurs till high land is reached, when owing to the adiabatic cooling of the cloud, condensation takes place and there is rain. In this way the chlorine figure of waters where such conditions prevail is much higher than what obtains in the waters of the surrounding country. Since it has been shown that the sea's influence on the chlorine content of inland ground waters is exerted through the agency of ocean spindrift and blown spray, it might be expected there would be some relationship between the results of such influence and the direction of the prevailing ocean winds. For the area under consideration, however, no perceptible relationship exists. In the analysis of the ultimate results of the ocean's influence on the chlorine content of inland ground waters the factors of land elevation and wind prevalence are inseparably connected, as the former in great part assists or nullifies any action the latter may have.

Effect of the Geological Character of the Water Bearing Strata.

On comparing the isochlor map with a geological map of the same tract of country it will be noted that the individual isochlor lines show no marked divergence from their accustomed regularity on emergence from one area of certain geological formation into that of another. In works on Public Health Chemistry it is generally stated that the figure of waters varies with the geological formation of the source. As an example, the Rivers Pollution Commission of 1868 gave a table showing the analysis of upland surface waters collected from various sources of different geological character. This Table (Thresh, *Water Supplies*, 1896, page 40), with slight alterations, is as follows:—

Rivers Pollution Commission, 1868.

Chlorine in Upland Surface Waters in parts per 100,000.

Geological formation	Highest	Lowest
Igneous Rocks	2·1	·31
Metamorphic, Cambrian, Silurian, and Devonian	3·3	·14
Calcareous Silurian and Calcareous Devonian	1·6	·85
Yoredale and Millstone Grits and Non-Calcareous Portion of Coal Measures	1·6	·64
Calcareous Portion of Coal Measures	4·9	·85
Mountain Limestone...	1·6	·9

It is quite erroneous to set limits to the amount of chlorine in waters from any geological formation, except where beds of salt occur. The chlorine figure is entirely dependent on the factors which have been heretofore discussed, being high when the sample has been derived from near the seaboard and low when from more inland parts.

Chlorine Figure as an Index to the Degree of Purity of Water.

Now that it has been shown that within slight margins of error the chlorine of uncontaminated ground waters of given areas approximates a normal, it would appear that the estimation of chlorine would form a rapid method of gauging for preliminary purposes the purity or otherwise of any water sample. Once the normal has been established any water showing an excess of chlorine could be classed as suspicious or impure till a fuller analysis confirmed or rejected the decision. For this purpose it would be necessary to have each district mapped out into areas of equal chlorine content by means of isochlor lines. In this way the normal could be rapidly found and the chlorine value of the sample of water under consideration compared with it.

As a result of these observations the following conclusions have been arrived at:—

Conclusions.

1. That the ocean has an influence on the chlorine content of Inland Ground Waters, an influence which is not limited to waters near the seaboard only.

2. That this influence is exerted through the ocean spindrift and blown spray deposited on the land by all forms of precipitation.

3. That this influence manifested by the chlorine in such waters varies with the distance from the seaboard, diminishing as it extends inland.

4. That this influence is modified by the configuration of the land surface being greater where the land is continuously low from the shore.

5. That to some extent this influence depends on the direction of the prevailing winds from seaward.

6. That (except where beds of salt occur) chlorine in inland ground waters is not due to the geological character of the water-bearing strata, but is derived from the sea.

7. That the chlorine figure may be utilised as a preliminary means of gauging the purity or otherwise of water samples from a district where the normal chlorine content has been established.

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