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THE ISOCHLORS OF NOVA SCOTIA—By HUBERT BRADFORD VICKERY, M. Sc., Halifax, N. S.

INTRODUCTION.

The object of this research is to determine the normal chlorine content of spring and brook waters of Nova Scotia. By normal chlorine content is meant the amount of chlorine, chiefly as sodium chloride, found in unpolluted waters that may be considered to have been taken up by the water from the soil of the surrounding area. This chlorine content is estimated along certain lines crossing the region, and points having the same content are connected by lines on a map of the region. These latter lines are therefore Isochlor Lines, or shortly Isochlors, (just as we have isobars, isotherms, etc.).

SOURCES OF CHLORINE.

There are probably three main sources from which this chlorine is derived—chlorine mineral deposits, the sea and sewage. According to the "Report of the Salt Deposits of Canada and the Salt Industry", prepared by Heber Cole, B. Sc. (No. 325 of the publications of the Departments of Mines of Canada), there are nine separate salt spring regions in the Province of Nova Scotia. Of these four are in Cape

Breton, notably that at Whycocomagh. In the peninsula the largest springs are at Antigonish, but there is a small spring at Walton, Hants County, with a percentage of a trifle over unity. At Salt Springs, Pictou County, there is a spring yielding 5.9 per cent. of salt, and at Cheverie, Hants County, deep borings through gypsum gave strong brines. Also there is a brine spring at Springhill. These isolated points, however, probably have very little effect upon the normal chlorine lines as herein determined, though an observation of Mr. Cole's states that salt is very often found associated with gypsum, and this may contribute in some measure to the rather wide areas between the normals along the Annapolis Valley as compared with those along the Atlantic Coast.

With the introduction of chlorine by means of sewage we have nothing to do in this paper, because the estimations were made on water taken from sources as far as possible from any probable animal polution. The influence of the sea on the amount of chlorine normally found is quite striking, as the results of the estimations show. The observations show that at the sea coast the chlorine content is high, while as we travel inland there is a gradual decrease in the amount of chlorine normally found, this decrease being more rapid travelling inland from the Atlantic Coast than it is travelling inland from the Bay of Fundy shores.

Use of Isochlor Determinations. The judgment passed by the chemical analyst upon waters which are to be used for drinking purposes is based partly upon the amount of chlorine found in it, hence the object of determining isochlors is to give the analyst information as to the amount of chlorine normally found in water of known purity taken from the locality from which the sample under examination was obtained. Any excess over this amount would probably be due to influences other than that of minerals or of the ocean; that is to say, due to pollution. The correctness of his judgment, therefore, would depend upon an accurate knowledge of this amount. For example: a potable water showing a chlorine content of 16 parts per million, coming from a region where the normal chlorine content was three parts per million, would be subject to suspicion; while coming from a region where the normal chlorine content was 12, it would probably be perfectly wholesome, as far as the analyst could judge from this determination alone.

Method of Procedure in Analysis. The estimation of chlorine in drinking water depends upon the titration of the chlorine with standardized silver nitrate solution, using potassium chromate as an indicator; the theory being that the chloride ion will be removed from the solution by the silver ion before the chromate ion is attacked. When all the chloride ion has been removed, the reddish color of the insoluble silver chromate appears, this forming a most delicate end point.

The silver nitrate solution is so made that one cubic centimeter contains sufficient silver to combine with one milligram of chlorine. Silver nitrate is carefully dried at 100 degrees in the oven, and an amount slightly exceeding 4.7937 grams is weighed out; this is dissolved in water, and the solution is made up to one liter in a flask which has previously been standardized and its error corrected. This solution was carefully mixed. In order to standardize this solution, potassium chloride was re-crystalized from a sample of known purity (Merck's guaranteed). The fine crystals thus obtained were carefully dried to a constant weight in the oven, and exactly 2.1065 grams were weighed out, dissolved in distilled water and made up to one liter in the standardized flask. This solution thus contained one milligram of chlorine per cubic centimeter. The silver solution was standardized by titrating from two to three cubic centimeters of potassium chloride solution, using potassium chromate as an indicator, and determining the end point by comparing the color of the solution under examination with one clouded by a previous precipitation of approximately the same amount of silver chloride as would be obtained in the titration. This artifice was used throughout the experimental work. It was found that a definite amount of silver nitrate solution was necessary in order that pure distilled water, colored with potassium chromate should give the distinct color which served as an end point. This amount was determined by numerous experiments to be 0.09 cubic centimeters, and this amount was subtracted from the amount of silver nitrate solution necessary to give the end point reaction during the standardization experiments. In the standardization made a year later, this number was found to be .04 cc. By this means the ratio between the silver nitrate solution and potassium chloride solution was obtained, and the necessary dilution of the silver nitrate calculated. Thus the volume of the solution containing the excess amount of silver nitrate could be determined and removed, and the solution again made up.

Standardization Data.

The average of four accurate determinations of the ratio between the chlorine and silver solution gave:—

Chlorine : Silver : : .9565 : 1

Hence, the amount silver contained : proper amount : : 1 : .9565

1 mg. chlorine is equivalent to $\frac{107.93}{35.45} = 3.045$ mg. silver

$$X : .003045 : : 1 : .9565$$

$$\therefore X = .003183$$

which is the actual amount of silver in 1 cc. solution. But, 1000cc. should contain 3.045 mg. silver;

$\therefore \frac{1000 \times 3.045}{3.183} = 957.0$ cc. solution contain the proper amount of silver. Hence it is necessary to remove 43 cc. from the solution and dilute to the mark with water. The ratio between the chlorine and the silver solutions was then found as follows:—

Chlorine	*Silver*
4.21	5.06
6.21	7.16
2.00	2.10 — .09 = 2.01
6.21	7.24
8.21	9.33
2.00	2.09 — .09 = 2.00

∴ 2.00 cc. chlorine solution = 2.00 cc. silver solution.

After a year of use the solution was again standardized, with the following results:—

Chlorine	*Silver*
4.79	5.28
6.86	7.42
2.07	2.14 — .04 = 2.10
Ratio 1.014	
.82	.93
2.85	2.96
2.03	2.03 = .04 = 1.99
Ratio = .9804	
2.84	2.99
5.04	5.18
2.20	2.19 = .04 = 2.15
Ratio = .9772	
Average Ratio = .9906	

It is observed from the above that one cubic centimeter of the silver nitrate solution will precipitate one milligram of chlorine; hence the number of cubic centimeters of silver nitrate solution used in titrating 100 cc. sample of water multiplied by ten will give the number of parts of chlorine per million parts of water in the sample.

The indicator solution was prepared by weighing two grams of chemically pure potassium chromate dissolved in 100 cubic centimeters of water and adding silver nitrate until a permanent red precipitate is formed—the filtrate would thus be chloride free. One or two cubic centimeters of this indicator solution were used, depending upon the color of the water under examination.

The experimental method used in determining the chlorine content of a sample of water was to measure 100 cc. of water into a procelain casserole and color it with one cubic centimeter of the indicator solution. This was then titrated until a faint difference in color was observed between the sample and another one similarly prepared, which was placed beside it. By this means a very sharp endpoint was easily attained. The 100 cc. graduate was used in measuring the samples, as it was found impracticable to carry a 100 cc. pipette. In some cases difficulty was experienced in getting a sharp endpoint, owing to the water being discolored by peat, but by the use of the clouded control only in two or three instances was the error greater than .03 cc. of solution, that is, .3 parts per million.

The work of obtaining the samples of water necessitated covering large stretches of country; the work was of necessity done slowly, at different seasons of the year, and under different conditions of drought and freshet, making strict comparisons between the results obtained difficult. With a few exceptions the samples were collected by the writer, with the observance of every precaution, and all the analytical work was carried out by him. No use could be made of data derived from Governmental Reports, since water analyzed in public laboratories would probably be taken from doubtful or suspected sources. The work was done either in the laboratory of Bloomfield High School, or in a small laboratory fitted up for the purpose at the writer's home, but in all cases the utmost precautions were observed as regards lighting and to guard against any chlorine introduced by improperly cleansed apparatus. The same silver nitrate solution which was prepared in the laboratory at Dalhousie University was used throughout the work, and was kept carefully protected from light and pollution.

No data was accepted without being carefully checked by two, and in most cases three, separate determinations of each sample. Wherever possible a number of samples were collected from a small area, and the lowest of these taken as the normal for that vicinity. The burette used in the titration was one containing 10 cc. of the solution, ringed around, and read by means of a lens. Great care was exercised in keeping this burette in perfect condition during the analytical work. The use of a graduate in measuring out the samples for analysis was necessitated, as above mentioned, by the inconvenience of carrying about a 100 cc. pipette, and it is believed that the error in reading this is well below the experimental error in reading the burette. In draining this graduate into the porcelain casserole a definite time interval was always allowed to elapse, and as far as possible all observations were made under identical conditions, so far as light was concerned, so that the experimental results at least would be strictly comparable.

The determination of the exact endpoint in white porcelain dishes was found to be somewhat easier than in the ordinarily used 100 cc. Nessler Jars. When dealing with water discoloured with peat, use was at times made of a drop or two of the chloride solution, to make sure that the endpoint had been attained, although, as mentioned above, in every case the standard of comparison was an identically prepared sample, and in cases where the chlorine content was high, and the cloud of precipitated chlorine rendered comparison difficult, the control was itself clouded by titrating it nearly to the endpoint, and using this as a standard of comparison.

For the purpose of collecting samples, a number of new ten and sixteen ounce bottles were provided and fitted with new corks. These bottles were invariably rinsed three times with the water being collected before being finally filled, and these bottles were used for no other purpose save collecting water samples.

Wherever possible samples were taken from small brooks, usually at a distance of some forty to fifty yards from the road, and from a portion of the brook where the water was running freely. The greatest care was observed to avoid, as far as possible, portions of the brook used by animals, and when a brook ran through a meadow, it was followed up to the woodlands, where running water was obtained.

It was noticed that a large lake, which has no obvious source of pollution, shows a chlorine content as low, or lower, than small brooks running into it. In other words, a large lake gives a normal chlorine for that vicinity. For example, the northern arm of Lake George, in Yarmouth County, has a chlorine content of 10.0 parts per million, while a small brook discharging into the lake gave a chlorine content of 10.2 parts per million. Milton Ponds in Yarmouth County, in June, 1914, gave 13.0 parts per million, while several brooks running into the ponds ranged from 15 to 20 parts per million. In explanation it might be said that Milton Ponds are surrounded by farms. Grand Lake, in Halifax County, showed 4.1 parts per million, and as it was found impossible to obtain a sample from a brook discharging into Grand Lake, it was thought reasonable to assume that 4.1 was the normal for that vicinity.

This observation was later confirmed by noticing that the United States Geological Survey in the examination of waters in New England, frequently made use of determinations of chlorine in reservoirs, lakes serving as town and city water supply, ponds, etc. (See U. S. Geological Survey, "The Normal Distribution of Chlorine", by Daniel W. Jackson, Water Supply and Irrigation Paper, No. 144.)

A number of determinations of well water, even under the most ideal conditions, showed that little confidence could be placed in results obtained from them.

Ideal conditions for normal chlorine content were considered to be a clear running brook, having its course through woodland; where there was no probability of pollution by cattle or sheep, and as far as possible from farms or dwellings. A few samples taken from brooks running through cleared land or pastures, with farms on all sides, were clearly polluted.

LOCALITIES INVESTIGATED.

A series of observations were made along lines running from the sea coast as far inland as possible. In this way six distinct series of samples were collected:—

One. A series from Halifax, Rockingham, Bedford, and Grand Lake to Truro.

Two. A series from Margaretville to Middleton, and thence along the line of the Halifax and South Western to New Germany and Bridgewater.

Three. A series from Yarmouth inland some thirty miles to Kemptville.

Four. A few observations in Musquodoboit Harbour and the Musquodoboits.

Five. A series taken from Pictou to Sherbrooke from samples collected by Dr. Mackay.

Six. A few samples in the extreme eastern end of the Province, Antigonish, Port Mulgrave, etc.

It will be noticed that these lines are at right angles to the seaboard. The second and fifth series stretch across the Province.

Series One. Several samples in the vicinity of Halifax, Melville Cove, Fairview, Rockingham and Bedford ran from 6.5 to 4.8; Grand Lake 4.1, Truro 4.9, showed a decrease to a minimum and then an increase. An observation of 4.4 at Middle Musquodoboit closely corresponded to these.

Series Two. At Margaretville a small brook running over the cliff into the Bay of Fundy showed 33; another a mile back over the mountain, 8.5. A small brook on the top of the mountain, under ideal conditions, gave 10.1, while a brook at Spa Springs showed 9.8. These observations, although showing an increase on the line over the mountain, are checked by an observation from a small spring by the roadside of 10.4, and the Spa Springs brook itself, 11.5. Middleton tap water, derived from a lake on the South Mountain, somewhere near Nictaux, showed 6.6, Alpena 6.7, Lake Pleasant at Springfield, 4.6 (sample taken from lake), New Germany 3.8 (the lowest of the three observations, the others being 4.3 and 4.4), Northfield 4.3, WestNorthfield 5.0, Bridgewater 5.4. A brook six miles below Bridgewater running into the salt estuary of the LaHave 7.5, completes the series. This series shows a distinct decrease to a minimum at New Germany and a clearly defined increase from New Germany to the mouth of the LaHave.

Series Three. A number of observations in the vicinity of Yarmouth, ranging from 65 in a sample taken from at well in a narrow sand spit between the Bay of Fundy and Yarmouth Harbor to 21.5 in a well near Yarmouth Harbour, under ideal conditions, and numerous observations of 16 and 17 taken at various points within a few miles of the town, show very clearly the influence of the salt water and salt water estuaries in that vicinity. Two series of observations were made; one covering a small section of country from the northern part, Lake George to Lake Annis (three or four miles) another over a twenty mile stretch from Deerfield to Kemptville. Lake Annis showed 10.0 and Deerfield 10.2, and as these two points are equi-distant from salt water, a clearly defined line (the ten normal) can here be drawn. Carleton showed 8.4, and a brook a little further up 8.2. A brook just below Kemptville 7.0, and a large stream above Kemptville, 28 miles from Yarmouth, 5.1.

This series shows a continuous decrease, running from the coast line inland, and it is noticed that the observation of 5.1 near Kemptville, is about the same distance from the salt water as the observation 5.0 at West Northfield (Series 2).

With reference to the high chlorine content of wells and brooks near Yarmouth, the prevailing winds are to some extent responsible, for during heavy, south westerly gales, windows in the lower parts of the town of Yarmouth are sometimes covered with an encrustation of salt carried evidently in spray from the breakers on the rocky coast, fully two miles away.

Series Four. This consists of only three or four observations, one of a sample taken from a well at Musquodoboit Harbor, which showed 4.6, and a few observations in the vicinity of Middle Musquodoboit; the lowest being 4.4 from a brook running about two miles above the river.

Series Five. At the mouth of Pictou Harbor a brook gave 10.4, two or three brooks south of New Glasgow 4.6 and 4.1; brooks at Kerrogare and eastward 5.1, 5.3 and 5.4. Melrose Lake 5.1 and Sherbrooke Lake 7.0, again showing the decrease and increase.

Series Six. A brook supplying the reservoir at Antigonish gave 6.8, defining an important corner of the seven normal. A brook at Port Mulgrave gave 8.2, locating the ten normal practically on the Strait of Canso shore. A brook near Philip's Harbor gave over 15, a value recalling those obtained near Yarmouth at the other end of the Province.

The Ten Normal.

The location of the ten normal line in Yarmouth County is clearly defined by the observations at Lake Annis and Deerfield. By drawing a line roughly parallel to the coast line of the Bay of Fundy, it is found to pass well inside of Annapolis Basin, up through the Annapolis Valley—its location being defined at Spa Springs and passing somewhere north of Canning. Around the southern shore this normal may be drawn in the same way, following the coast line, passing north of Shelburne, crossing the LaHave River at a point about five miles from its mouth and appearing at Halifax, probably near Herring Cove, and from there east quite close to the Atlantic Coast. Still further east it lies well outside Sherbrooke, cuts across the head of Chedabucto Bay, is located at Port Mulgrave, passes north of Antigonish and through Pictou Harbor.

The Seven Normal.

Starting from a point south west of Kemptville in Yarmouth County, the seven normal line runs parallel to the ten normal, about seven miles from it, and gradually increasing this distance to about ten miles, according to the observation at Alpena, and running about three miles north of Kentville and along the south shore of Minas Basin. Running south from Yarmouth County the seven normal apparently is only four or five miles from the ten normal, and passes through Bridgewater, appearing at Halifax a little south of Melville Cove, thence easterly, but still south of Musquodoboit Harbor. It passes through Sherbrooke and follows the trend of the ten normal, passing just north of Antigonish and through Pictou.

The Five Normal.

Starting at a point above Kemptville, about four miles from the seven normal, running northerly, crossing the Halifax and South Western Railway at Dalhousie, at which point it is about eleven miles from the seven normal. It runs a few miles south of Windsor, and thence nearly to the head of Cobequid Bay, its distance from the seven normal gradually increasing. Around the Southern shore it apparently runs from six to seven miles from the seven normal, crossing the same railway at West Northfield, cutting across Bedford Basin between Rockingham and Bedford, and appearing somewhere south of Musquodoboit Harbor, at which point it is only about two miles from the seven normal. It turns north through Guysboro County and is well located by several observations in eastern Pictou County, passes north of New Glasgow and joins the branch passing just north of Truro.

The Four Normal.

Conforming to the normals already drawn in the Western part of the Province, the four normal apparently forms a closed curve, crossing the Halifax and South Western Railway just south of Springfield, and again south of New Germany; crossing a part of the Province in which many large lakes, such as Lake Rossignol, are situated. Another limb of the curve probably passes through Grand Lake. and also somewhere about ten miles east of Truro, and curves back just south of Ferrona, uniting with the line passing north of Middle Musquodoboit as the normal at Musquodoboit was 4.4. This indicates that the larger portion of Halifax County lies between the four and five normal and only in a narrow strip of country might chlorine contents of less than four be expected.

Isochlor Work in Other Places.

Isochlor maps of the New England States and of New York have been prepared and are given in the U. S. Geological Survey paper, already cited. Those of Massachusetts and Connecticut are given in "Examination of Water", by Dr. W. P. Mason. A comparison of these maps with that given herewith shows that high normal chlorine does not occur as close to the sea coast in those States as is the case in Nova Scotia. The Cape Cod Peninsula, as might be expected, shows rather high observations, ranging from ten to twenty-five parts per million, and these values are comparable to those found in the vicinity of Yarmouth, Nova Scotia, which is also more or less surrounded with salt water. These maps, which are based upon an enormous number of observations throughout the States, are necessarily much more complete than that of Nova Scotia.

It will be noticed that no observations from the extreme eastern part of the Province have been included. This is owing to the difficulties and expense involved of personally obtaining samples in Cape Breton. No samples were collected in northern Colchester and Cumberland County for the same reason.

One other line along which the research was prosecuted deserves notice. In the paper of the U. S. Geological Survey already cited, tables are included giving monthly observations of numerous sources. An attempt to verify the result noted there was made in a very small way. Monthly observations were taken from two brooks with the object of discovering any great seasonal variation. Only one of the two, as will be noted from the appended table, is very satisfactory; this shows a fair degree of constancy over the time that the observations extended, that is to say, the seasonal variation is very slight.

In conclusion, I have to thank the kind offices of many friends who made it possible for me to collect samples in what would have been, without their help, inaccessible places, and also for information regarding the location and sources of streams. In particular, I have to thank Dr. Mackay of Dalhousie University for not only proposing the work, but for collecting samples which made it possible to draw the isochlors over the eastern part of the Province.

A table giving the observations which were of the greatest value in determining the position of the isochlors is appended, together with a map upon which the position of these observations is indicated as closely as possible.

Sample No.	LOCATION	Chlorine Content	No. Analysis in Notebook
1.	Purcell's Cove	9.5	92
2.	Brook Dutch Village	5.1	48
3.	Brook Dutch Village	5.8	3
4.	Giezer Hill	5.5	49
5.	Melville Cove	6.5	51
6.	Rockingham	5.4	50
7.	Moir's Mill, Bedford	4.8	52
8.	Sackville River, Bedford	4.3	53
9.	Grand Lake	4.1	57
10.	Brook Lake Thomas	4.8	63
11.	Truro Park	4.9	58
12.	Musquodoboit Harbor	4.6	54
13.	Middle Musquodoboit	4.4	56
14.	Coldbrook	6.4	91
15.	Two miles north Coldbrook	6.4	90
16.	One mile south Wolfville	6.8	89
17.	Margaretsville Cliff	33.7	46
18.	One mile south Margaretville	8.3	45
19.	Three miles south Margaretville	10.1	44
20.	Spa Springs	9.8	41
21.	Middleton tap water	6.6	47
22.	Alpena	6.7	1
13.	Springfield (Annapolis)	4.6	2
24.	New Germany	3.8	5
25.	Wentzell's Lake (♦rook)	4.3	10
26.	Northfield	5.0	9
27.	Three miles north Bridgewater	5.5	7
28.	One mile north Bridgewater	5.4	6
29.	One mile south Bridgewater	7.1	11
30.	Six miles south Bridgewater	7.5	12
31.	Brooklyn, Yarmouth County	15.9	16
32.	West Brooklyn, Yarmouth Co	17.3	39
33.	Lakeside Park, Yarmouth	16.3	17
34.	Well near No. 33	16.7	19
35.	Well, Overton, Yarmouth	21.5	21
36.	Well Yarmouth Bar	65.0	22

37.	Lake Annis Brook	10.2	24
38.	Lake Jessie Brook	10.2	23
39.	Lake George, East shore	11.7	25
40.	Brook discharging near No. 39	11.5	26
41.	Lake Annis	10.0	27
42.	Ohio	17.4	28
43.	North Ohio	13.2	29
44.	Deerfield, brook	9.7	30
45.	One mile south of Carleton	8.4	32
46.	Two miles north of Carleton	8.2	33
47.	Four miles north of Carleton	7.0	37
48.	Kemptville River	5.1	35
49.	Mountain Rill, Pictou County	4.6	60
50.	Forbes Lake	4.1	61
51.	Simms Anderson Brook, Pictou Harbor	10.4	62
52.	Four miles north of Sunnybrae	5.2	75
53.	Kerrogare	5.1	76
54.	Eden Lake	5.3	77
55.	Neil Grimms Brook	5.4	78
56.	Sherbrooke Lake	7.0	79
57.	Melrose Lake	5.1	80
58.	Salmon River Lake, Halifax County	5.8	81
59.	Giant Lake	6.0	84
60.	Hurlbert Brook, Lochaber	5.4	85
61.	Brook at Reservoir, Antigonish	6.8	86
62.	Port Mulgrave	8.2	87

Sample 9 collected by Miss Nora Piers.
Sample 11 collected by Mr. E. Chesley Allen.
Samples 49-61 collected by Dr. E. Mackay.
Sample 62 collected by Miss Grace M. Huestis.

MONTHLY OBSERVATIONS.

Month 1917	Fenerty's Brook	Melville Cove Brook
March	7.5	11.3
April	6.7	8.7
May	7.0	9.2
June	7.2	8.7
July	7.7	9.2
August	7.9	8.4
September	8.0	8.7
October	...	9.2
November	7.9	9.4
Average	7.5	9.2