1927

A study of the iodine content of representative Missouri waters

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A STUDY OF THE IODINE CONTENT OF REPRESENTATIVE MISSOURI WATERS

BY

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A

THESIS

submitted to the faculty of the

SCHOOL OF MINES AND METALLURGY OF THE UNIVERSITY OF MISSOURI

in partial fulfillment of the work required for the

Degree of

MASTER OF SCIENCE IN CHEMICAL ENGINEERING

Rolla, Missouri

1927

Approved by W. T. Schrenk.
Associate Professor of Chemistry

Thesis: A study of the oidine content of representative Missouri waters. Hunze 1927.

FOREWORD

The author wishes to express his utmost appreciation to Dr. W. T. Schrenk for the suggestion of this research and for the valuable advice and many suggestions offered during the course of the investigation.

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A STUDY OF THE IODINE CONTENT OF REPRESENTATIVE MISSOURI WATERS

INTRODUCTION

Investigations have shown that the iodine content of natural waters bears a direct relationship to the goiter incidence of a given region. A number of the states have analysed their water for this constituent in the development of this hypothesis.

A search of the literature revealed the fact that with the exception of two instances the iodine content of Missouri waters had not been determined. Since in certain regions of Missouri there is quite a prevalence of goiter, it was deemed important to determine the iodine content of Missouri waters. It was believed that such information would be a valuable contribution to the study of the goiter situation of Missouri and the possibility of affording data for the adoption of some plan whereby simple goiter could be prevented and the number of existing cases reduced. The present investigation was carried out preliminary to a goiter survey to be conducted in this state.

The literature contains many references to the work being done on this subject. The following is a brief resumé of the most important references pertaining to the iodine content of natural waters, the relation of iodine to simple goiter and the developments in the use of iodine compounds in the prophylactic treatment of this malady.

A survey was made by J. F. McClendon[1] on a number of representative river waters of the country for their iodine content and a map of the United States prepared showing that the country could be divided into more or less definite regions as regards iodine distribution. From an observation of the map, it is readily seen that Missouri lies adjacent to the low iodine belt.

The same author[2], in his research work on natural waters and foods, has shown that an inverse ratio exists between the goiter in a given district and the iodine content of natural waters and foods. This simply means that a low iodine region indicates a high goitrous region. He also demonstrated that the regions in which waters are low in iodine produce cereals and vegetables of low iodine value due to the very small amount of iodine in the soil. A goiter survey made by McClendon and Williams[3] on men drafted in the World War proved that men coming from low iodine regions showed

1. Am. Public Health J., 14, 750, (1924)
2. J. Am. Med. Assn., 82, 1668, (1924)
3. J. Am. Med. Assn., 80, 600-601, (1923)

the greatest percentage of goiter.

W. N. Swingle[4] in his research work on the thyroid gland concluded that iodine was the active principle of the thyroid. The gland serves as a storage base and distributing center for the iodine in the body. When the body receives iodine in some form, either from food or drink, the thyroid gland remains in a normal condition, administering properly its bodily functions. However, when the food and drink of a certain region do not contain the proper amount of iodine, abnormalities develop. The thyroid, not finding sufficient iodine in the blood stream to meet current demands, adjusts itself to the new condition by increasing in size. This abnormal growth is termed goiter.

The fact that iodine does play a very important part in the cause, treatment and prevention of simple goiter has been known some seventy or eighty years. The use of iodine as a prophylactic in the prevention of simple goiter was advocated by Chatin[5], a French biochemist, as early as 1852. Numerous experiments on both man and animal have been conducted since that time and the experimenters in practically every case have concluded that iodine in some form is

4. Endocrinology, 2, 283, (1918)
5. Journal Am. W. W. Assn., 12, 76, (1924)

either the direct cause or the specific. The idea of using iodine as a prophylactic procedure, however, did not gain much favor with the public for a number of years. It was not until Marine and Kimball[6] carried out their work in the public schools of Akron, Ohio, that the prophylactic procedure was adopted. This was the first application of the principle of goiter prevention as a public-health measure, beginning in 1916 and continuing until 1920. The conclusions drawn by them conform very closely to the conclusions drawn by previous investigators. They make the following statement, "After consideration of all the various substances, agents, and theories that have been put forward as having a role in the etiology or cause of goiter, we at present must fall back upon the view that goiter is a compensatory reaction arising from a relative or absolute deficiency in iodine". Marine[7] makes a further statement that goiter is one of the easiest known diseases to prevent. From 100-200 milligrams of iodine administered twice a year over periods of two or three weeks is sufficient to prevent goiter since the maximum storage of the thyroid is not over thirty milligrams.

Switzerland, having the highest goiter incidence

6. Am. J. Public Health 8, 81 (1923)
7. Public Health J. (Mich.), 11, 23, (1923)

in the world, soon adopted the plan used by Marine and Kimball. However, instead of using sodium iodide tablets, as did Marine and Kimball, they employed a tasteless organic iodide. The results obtained here were remarkable and show conclusively the importance of iodine in thyroid activity. Before adopting the prophylaxis treatment, a survey revealed the fact that eighty-seven percent of all the school children of St. Gallen, Switzerland had goiter. Three years after the plan had been adopted, a second survey showed that the percentage of goiter had been cut to thirteen percent - almost one-ninth of what it was before the treatment was started. Further proof[8] of the importance of iodine in thyroid activity is shown by the fact that the Japanese, whose diet is essentially the rich iodine sea foods, have thyroids one-half to two-thirds the size of the individuals in certain parts of Europe or America and consequently they have a very low goiter incidence.

Surveys similar to the present investigation have been conducted in Michigan[9], Massachusetts[10], New Jersey[11], Pennsylvania[12], and Utah and the information

8. Jap. Medical World, 2, 45, (1922)
9. J. Am. Med. Assn., 82, 1328, (1924)
10. Eng. News Record, 95, 470, (1925)
11. Public Health News, (N.J.), 10, 164, (1925)

obtained, with the exception of Pennsylvania, had been used in conjunction with a goiter survey to determine the prevalence and non-prevalence of goiter in low-iodine and high-iodine regions. The results obtained in practically every case have confirmed the inverse ratio as set forth by McClendon and different methods are being adopted to prevent and reduce the present goiter incidence.

METHODS OF IODINE ADMINISTRATION

Many methods of administering iodine are in existence but they all embody the same principle, namely, supplying iodine in some form or other to the body. The methods of treatment may be classified under the following heads:

1. Iodine administered as medicine, such as iodized chocolate candy, tablets, kelp, etc.
2. Iodizing essential foods, i.e., sodium chloride, bread, etc.
3. Iodizing water supplies.

All of the above methods are in use today and all are criticized pro and con. The first two methods depend chiefly upon the individual and since individuals between the ages of ten and twenty are most susceptible

12. J. Am. Water Works Assn., 16, 227, Aug. (1926)

to the malady[13], those which are most in need would not receive the treatment. However, in cities where iodine in tablet form is being administered to school children, considerable benefits result.

Since the appearance of iodized salt on the market, many authorities have recommended its use. This type of iodine administration is particularly serviceable to the small community.

Iodization of city water supplies to furnish the deficiency of iodine has been practised for several years and is finding much favor in cities where such treatment is used. The chief objection raised to this method is that much of the iodized water is not consumed as drinking water by the individual. Nevertheless, this method carries its merits in that it reaches every individual. The method of iodizing twice a year seems to have been adopted by all the cities treating water supplies for the prevention of goiter altho the method of administering varies considerably. In some cases the iodine is placed in bags and dissolved in the reservoir. In other cases the iodide in solution is added to the main water line. The results achieved are virtually the same, however, in that the iodine content is built up to a concentration of

13. Ann. Clin. Med., 3, 487, (1925)

75 parts per billion for a considerable length of time. The cost of such iodization has been estimated variously ranging from one and one-half cents to five cents per individual per year. Rochester, New York[14], was the first city to practise the iodization of the city water supply and reports very satisfactory results. The method as used by them consists of supplying 0.664 pounds of sodium iodide per million gallons of water per day for three weeks biannually. The estimated cost of such treatment is three cents per capita per year and they believe it to be the cheapest as well as the most effective means of administration. Some of the other cities following the same practise as at Rochester are Minneapolis, Minnesota; Anaconda, Montana; Sault Ste. Marie, Michigan; and Cincinnati, Ohio.

Some of the cities supplying the iodine deficiency by the use of sodium iodide or iodized tablets are Akron, Ohio; Kent and Revenna Counties, Ohio; Anaconda, Montana; Chicago, Illinois; Detroit, Michigan.

Many figures have been given for the amount of iodine necessary to prevent goitre. McClendon[15] states that .01 milligrams of iodine per day is a sufficient prophylactic for goitre. On this basis he

14. J. Am. Water Works Assn., 12, 69, (1924)
15. J. Am. Water Works Assn., 12, 73, (1924)

figures that 0.1 pounds of sodium iodide per million gallons of water is a satisfactory treatment for water if continued thruout the year. If this is not put in the water continuously, a proportionately increased quantity must be put in at intervals, the intervals being determined by experiment.

In the cities where iodization of water supplies is practised, sodium iodide is added to bring the iodine concentration up to nine to ten parts per billion when calculated to a daily basis.

Other authorities recommend greater amounts of iodine consumption per year to prevent goiter. Doctor Marine[16] recommends that from 200 to 400 milligrams be consumed per year. The minimum recommended by him is more than 500 times as large as that recommended by McClendon.

Doctor R. M. Olin[17] recommends that 300 milligrams be given per year which is over 800 times as much as that recommended by McClendon.

Assuming that an individual consumes two liters of water per day, a normal sodium iodide content of water on this basis would be five parts per billion. On the basis of one liter consumption per individual per

16. J. Pub. Health (Mich.) 11, 23 (1923)
17. J. Am. Med. Assn., 82, 1328, (1924)

day this would be ten parts per billion. If ten parts per billion is assumed to be the iodine content which a normal natural water should carry in order to obtain a low goiter belt, it affords a basis of comparing the analyses of natural waters.

Besides the foregoing methods of iodine administration, many methods of individual treatment have been pointed out such as, adding small amounts of solid sodium iodide, solutions of sodium iodide and iodine tincture to water prior to use. These methods are all good provided the individual uses the iodine within reasonable limits. Many cases have been cited whereby iodine poisoning resulted from overdosing from such treatment.

It, therefore, follows that if iodine is to be used as a preventative for simple goiter it should be administered under the direction of authorities who can control the dosage to such an extent that each individual will receive the maximum benefit and that no ill effects will result to those persons already suffering from exophthalmic or advanced stages of goiter.

METHOD AND MATERIALS

There are available numerous methods for the determination of iodine. Baughman and Skinner[18] recom-

18. Ind. & Eng. Chem., 11, 563, (1919)

mend the permanganate method whereby iodine in alkaline solution is oxidized to iodate by means of potassium permanganate according to the following reaction,

$$KI + K_2Mn_2O_8 + H_2O \text{ ------- } KIO_3 + 2KOH + 2MnO_2$$

The solution then being acidified with hydrochloric acid, potassium iodide added, and the liberated iodine titrated with potassium thiosulphate. Brubaker, Blarcom, and Walker[19] oxidized the iodine to iodate by boiling with a solution of sodium hypochlorite acidified with phosphoric acid, boiling off excess chlorine, adding potassium iodide and titrating the liberated iodine with sodium thiosulphate. The method used by McClendon[20] consisted of reducing any iodate to iodide by means of arsenious acid, oxidizing the iodide to iodine with potassium nitrite, extracting the liberated iodine with carbon disulphide and analysing colorimetrically.

In selecting a method for iodine determination it was desirous to use a method whereby a rapid determination could be made with a minimum of apparatus and minute amounts could be determined accurately and still not be too accurate as to be inconsistent with the results required.

The method as finally selected for use was

19. J. Am. Chem. Soc., 48, 1503, (1926)
20. J. Biol., Chem., 60, 289, (1924)

that of M. J. Dubief[21] as modified and used by E. F. Eldridge[22], with slight further modifications to suit the conditions at hand.

The various samples analysed during the course of investigation varied in quantity from 38 to 50 liters, the majority, however, falling within the range of 45 to 48 liters.

A chloride determination was first made on the raw water. This consisted of titrating one hundred cubic centimeter samples with one-fiftieth normal silver nitrate, using potassium chromate as an indicator. The entire sample was then measured into an enamel-lined, steam jacketed evaporator. About six grams of sodium carbonate were added and the sample evaporated to a small volume - from four to five hours being required for the actual evaporation. The sample was then transferred quantitatively into a large evaporating dish and evaporated to a moist saline mass.

If the chloride content is greater than 60-70 parts per million, a considerable quantity of 95% alcohol is added to the evaporated solution and the mixture filtered. The residue is boiled three times with 95% al-

21. Ann. Falsificat, 16, 80, (1923)

22. Am. J. Public Health, 14, 750, (1924)

cohol, filtered, and the filtrates combined. Two or three drops of strong potassium hydroxide solution are added and the alcohol removed by evaporation. The residue is dissolved in a little water and the above process repeated if necessary until the bulk of the chlorides are removed. If the chloride content is below seventy parts per million, the extraction with alcohol is omitted. All the samples under investigation were below 70 parts per million so the above modification was unnecessary.

The moist saline mass was extracted with a small amount of distilled water, filtered, and again evaporated to a volume of approximately 100 cubic centimeters and finally filtered into a 250 cubic centimeter glass stoppered bottle. If not sufficiently alkaline, 4-5 cubic centimeters of a saturated sodium bicarbonate solution was added. A solution of potassium permanganate (25 grams per liter) was added, drop by drop, until the permanganate color persisted. About 5 cubic centimeters of the permanganate was added in excess and the bottle placed in an ice bath and cooled below ten degrees Centigrade. After being allowed to stand for a period of from 30-40 minutes, 3 cubic centimeters of carbon disulphide were added followed by 5 cubic centimeters of concentrated sulphuric acid.

The sulphuric acid was cautiously added, drop by drop, with constant agitation and cooling. The bottle was then shaken to insure the iodine thus freed being taken up by the carbon disulphide. The above reaction may be represented by the following equation,

$$10KI + K_2Mn_2O_8 + 8H_2SO_4 ---- 5I_2 + 6K_2SO_4 + 2MnSo_4 + 8H_2O$$

After the addition of the permanganate is complete the excess permanganate is destroyed by a careful addition of hydrogen peroxide. A large excess of this reagent was avoided. When the solution had been thoroughly shaken the carbon disulphide was drawn off from the solution by means of a separatory funnel. The extraction with carbon disulphide was repeated until no further color developed and the extracts combined, transferred to a Du Boscq colorimeter and compared to a standard containing a known amount of iodine. Previously analysed potassium iodide was used in making up the standard solution. The standard solution was treated in identically the same way as was the sample being analysed. The standards were made up so as to contain approximately the same amount of iodine as the unknown.

The preceeding method gave results accurate to one part of iodine in a billion parts of water, meaning that iodine as low as .05 milligrams in 1-2 cubic centimeters of carbon disulphide could easily be duplicated. This degree of accuracy was within the limits of the results required since iodine in amounts below one part in a billion parts of water would be so small as to have no bearing on the goitre situation.

All the reagents and solutions used in the analyses were analysed by this method for iodine. A negative result was obtained in each case. The residue resulting in the evaporation was tested in a large number of cases and no iodine found.

In a large number of cases, the solutions and standards, after being extracted with carbon disulphide were further treated with arsenious acid and potassium nitrite to see if any undecomposed iodides still remained. Any traces of iodine extracted by this treatment were added to the original extractions before the solutions were compared. In all cases the recovery by this treatment was small, being considerably less than one part per billion and practically the same relative amounts were recovered from both sample and standard.

Preliminary to the investigation, two series of standards "A" and "B" were made up containing known amounts of iodine. Series "A" was treated with potassium permanganate and sulfuric acid and series "B" with potassium nitrite and sulfuric acid. The carbon disulfide extracts were then compared colorimetrically. The calculated results agreed within one-tenth part per billion of iodine.

In order to determine further the degree of accuracy of the method used in the subsequent analyses, fifty liter samples of water were treated according to the permanganate method and the extracts compared colorimetrically. The extracts were then titrated with a very dilute solution of standard sodium thiosulfate. The calculated results from the titrations were greater than those derived from the colorimetric comparison but in no case did the results differ by more than five-tenths parts per billion.

During the present investigation the chlorine content of most of the waters was determined volumetrically by the Mohr method. Attempts to correlate the iodine and chlorine content of the waters analysed showed that apparently no definite ratio existed. Though chlorine and iodine are usually found together, we must conclude that a high chlorine content does not mean a high iodine content. This conclusion confirms the one drawn by Wm. de Kleine[23] in a similar investigation carried out in Saginaw, Michigan. Here some

23. Pub. Health J. (Mich.) (New Series), 13,146,(1925)

one-hundred-and-seventy wells were investigated and iodine and chlorine determinations made. It was found there that the chlorine content varied from 9-3350 parts per million and the iodine varied from 6-342 parts per billion. The chlorine content of the various waters examined in this state will be found in tables three and four.

The samples under investigation were obtained from all sections of the state through the hearty co-operation of the Missouri State Board of Health. Many types of water were represented in the analyses - namely, rivers, deep wells, reservoirs, shallow wells, ground waters, treated and untreated waters were investigated.

TABLE I

Gravimetric Analysis of KI

	KI taken grams	AgI found grams	percent KI calculated	Percent error
1.	.30026	.42446	99.95	-0.05
2.	.30006	.42470	100.08	+0.08
3.	.30006	.42507	100.16	+0.16

Average Purity 100.07%

The KI was analysed gravimetrically by precipitating AgI with Ag NO_3 in HNO_3 solution, filtering thru a Gooch crucible and weighing the precipitated AgI. The high purity value was probably due to the presence of a small amount of NaI. However, the use of this reagent did not introduce an appreciable error due to the very small amounts of iodine used in the comparisons.

TABLE II

City	Source	Depth	Geological Strata
New Madrid	Well	110'	From Quaternary sands and gravels, or possibly from unconsolidated Tertiary sands.
Joplin	Surface Shoal Creek		
Springfield	Wells & Springs	1404'	Roubidoux sand 565'-600'. Gunter sand 958'-993'. Sandy limestone from 993'-1320'. Cherty limestone from 1320'-1404'. Mixed water.
Neosho	Springs		Boone formation, cherty limestone of Mississippian Age.
Anderson	Well	1000'	No record, but from location and depth bulk of water probably comes from the Roubidoux.
Webb City	Wells	Deep	#6 Water level 255' from surface. 10" casing set at 409'. Some water at 450' in Jefferson City formation. White sand 945'-955'. Roubidoux sand. Probably a mixed water.
Carthage	Wells	Deep	#6 Roubidoux sand 890'-915'. Lamotte sand 1610 1815-205'. After passing thru Roubidoux, test was made and later after drilling, Lamotte pumping test showed more water. Mixed water.

TABLE II

Treatment	Iodine Content P.P.B.	Sodium Iodide P.P.B.	Percent of Normal
None	0.0	0.0	0.0
Chlorinated-alum Settled & filtered	?		
Chlorinated alum Settled and filtered	?		
None	?		
None	?		
None	Less than one		
None	?		

TABLE II

City	Source	Depth	Geological Strata
Yancy Mills	Spring		
Excelsior Springs	Wells		No record, 90' would probably be in Pleasonton formation, consisting of shales and sandstones.
Sedalia	Reservoir		
Sikeston	Wells	410'	From tertiary formations which underlie southeast Missouri lowlands and consist of sands, clays, and gravels.
Jefferson City	Mo. River		
Crane	Well	890'	Water encountered at 160' in the lower Burlington formation 285', 585', and 695' in the Jefferson City formation, and the bulk was obtained from the sands in the Roubidoux formation from 790'-875'.
Hannibal	Miss. River		
St. James	Well	700'	Roubidoux sand 135', 195' furnished some water. Bulk comes from crevice in Dolomite at about 700' probably in Gasconade or Eminence formation.

TABLE II

Treatment	Iodine Content P.P.B.	Sodium Iodide P.P.B.	Percent of Normal
None	Less than one		
Aerator-iron removal. Filter-lime.	0.42	0.5	5.0
Coagulation, filtration, chlorination, iron, lime, alum, chlorine.	0.66	0.78	7.8
None	0.67	0.79	7.9
Coagulation, filtration, chlorination, iron, lime, chlorine.	0.67	0.79	7.9
None	0.93	1.1	11.0
Coagulation, filtration, chlorination, alum, lime, iron, chlorine.	0.96	1.13	11.3
None	1.0	1.18	11.8

TABLE II

City	Source	Depth	Geological Strata
Palmyra	Spring North River		
Kennett	Well	80'-86'	Water comes from 45' of sand, from 41'-6" to 86'-6". Probably tertiary sands.
Chilicothe	Surface Grand River		
Independence	Mo. River from Kansas City		
Farmington	Wells (2)	520' & 720' Casing 290' & 409'	
Thayer	Wells		No record
Meramec Springs	Spring		No record
Eldon	Wells	Deep	No record. Another well at this place hit sandstone, probably the Roubidoux at 380'-420'. The Gunter would be found at this place at about 725-50'.
Willow Springs	Wells (2)	272'-350' Casing 272'	
Kirksville	Surface - Chariton River		

TABLE II

Treatment	Iodine Content P.P.B.	Sodium Iodide P.P.B.	Percent of Normal
Coagulation, filtration, chlorination, alum, chlorine.	1.0	1.18	11.8
None	1.14	1.35	13.5
Alum-Lime-chlorine, settled and filtered.	1.2	1.42	14.2
Coagulation, chlorination, lime,alum,chlorine.	1.31	1.55	15.5
None	1.34	1.58	15.8
None	1.37	1.63	16.3
None	1.4	1.65	16.5
None	1.46	1.72	17.2
None	1.68	1.98	19.8
Alum-Lime-Chlorine settled and filtered.	1.79	2.11	21.1

TABLE II

City	Source	Depth	Geological Strata
Unionville	Surface - Impounding Reservoir		
Mo. School of Mines	Well	600'	Roubidoux Sandstone from 224'-314'. Dolomite to bottom.
Bonne Terre	Lead Mines		
Lebanon	Wells	985'	Roubidoux sand 429'-459'. Gasconade or older limestone 459'-980'. Quartzite 980'-985'. Opening 2' --620'-622'. Opening 3' --761'-764'.
Trenton	Surface Thompson River		
Flat River	Lead Mines		
Odessa	Surface Impounding Reservoir		
Rolla	Well	930'	Sandstone probably the Roubidoux from 210'-300'. Dolomite from 300'-930'. Mixed water.
Kirkwood	Wells (2) Meramec River		
Moberly	Surface, Impounding Reservoir		
Maryville	Surface, One Hundred & Two River		

TABLE II

Treatment	Iodine Content P.P.B.	Sodium Iodide P.P.B.	Percent of Normal
Alum-chlorine settling & Filtration	1.99	2.35	23.5
None	2.2	2.59	25.9
Chlorination	2.42	2.86	28.6
None	3.17	3.74	37.4
Lime-alum-chlorine settled & filtered	3.26	3.85	38.5
Chlorination	3.44	4.06	40.6
Alum-lime-chlorine settled & filtered	4.55	5.37	53.7
None	4.6	5.43	54.3
Coagulation, filtration, chlorination, lime, chlorine.	5.32	6.28	62.8
Lime, alum, chlorine, settled & filtered.	7.4	8.74	87.4
Lime, alum, calcium, hypochlorite. Settled & filtered	14.77	17.44	174.4

TABLE II

City	Source	Depth	Geological Strata
Maryville (Before Treatment)	Surface One Hundred & Two River		
Maryville (After Treatment)	Surface One Hundred & Two River		

TABLE II

Treatment	Iodine Content P.P.B.	Sodium Iodide P.P.B.	Percent of Normal
	1.86	2.2	22.0
Lime, alum, calcium, hypochlorite. settled & Filtered.	1.61	1.90	19.0

Table (2) shows the source, depth, and geological strata of wells, types of treatment, iodine content, sodium iodide content, and the percent of normal sodium iodide contained in the various waters analysed. The percent of normal is calculated from the assumption that a normal water contains the equivalent of ten parts per billion of sodium iodide.

It is seen from the table that all the waters of Missouri thus far analysed are below normal, varying from 0-7.4 parts per billion. The one exception shown in the table is the first sample from Maryville which gave an iodine content of 14.77 parts per billion. Since this was the only exceptional case showing such an extremely high result, two more samples were obtained for analysis and the results found as tabulated in the table. The high result was probably due to contamination of some sort preliminary to the analysis.

On the first page of table (2) it is observed that the iodine content of the waters from Joplin, Springfield, Neosho, Anderson, and Carthage is questionable. During the analyses of these waters a brownish color was imparted to the carbon disulphide extract which could not be removed. The color was so distinct that it masked the color due to the iodine and the determinations were ruined. It was at first thought that the color was due to the presence of bromides but upon treatment with potassium sulphocyanate the color remained unaffected.

Since all of the waters analysed were found low in iodine, it indicates that the soils thru which the water is percolating must be low in this constituent, as any increased iodine content over that contained in surface waters must come from the soil thru which it flows. This increase of iodine content must depend upon the iodine content of the soils thru which it is flowing, the length of contact or rapidity of water flow.

TABLE III

Iodine and Chlorine content of various waters analysed

City	Source Surface Waters	Iodine Content P.P.B.	Chlorine Content P.P.M.
Maryville	102 River	14.77 1.86 1.61	5.5
Moberly	Reservoir	7.4	3.33
Kirkwood	Meramec River (2) Wells	5.32	28.74
Odessa	Reservoir	4.55	2.12
Trenton	Thompson River	3.26	2.55
Unionville	Reservoir	1.99	9.0
Kirksville	Chariton River	1.79	6.8
Independence	Missouri River (from Kansas City)	1.31	19.15
Chilicothe	Grand River	1.2	4.42
Palmyra	Spring North River	1.0	26.63
Hannibal	Mississippi River	0.96	5.6
Jefferson City	Missouri River	0.67	10.46
Sedalia	Reservoir	0.66	2.27
Joplin	Shoal Creek	?	
	Springs		
Meramec Springs		1.4	0.88
Yancy Mills		Less than one	
Neosho		?	

TABLE III

City	Source Wells and Ground Waters	Iodine Content P.P.B.	Chlorine Content P.P.M.
Rolla		4.6	
Flat River	Lead Mines	3.44	21.02
Lebanon		3.17	3.19
Bonne Terre	Lead Mines	2.42	19.25
Missouri School of Mines		2.2	
Willow Springs	(2) Wells	1.68	3.26
Eldon		1.46	0.71
Thayer		1.37	20.56
Farmington	(2) Wells	1.34	2.4
Kennett		1.14	33.61
St. James		1.0	10.0
Crane		0.93	3.16
Sikeston		0.67	8.68
Excelsior Springs		0.42	4.18
Webb City		Less than one	
Anderson		?	
Carthage		?	
Springfield		?	
New Madrid		0.0	5.0

Table (3) shows the city, source, iodine content in parts per billion, and chlorine content in parts per million of all the waters analysed. Both treated and untreated waters are included in the table.

TABLE IV

Iodine and Chlorine content of Untreated Waters

City	Source	Iodine Content P.P.B.	Chlorine Content P.P.M.
	Spring		
Meramec Springs		1.4	0.88
	Wells		
Lebanon		3.17	3.19
Willow Springs		1.68	3.26
Eldon		1.46	0.71
Thayer		1.37	20.56
Farmington		1.34	2.4
Kennett		1.14	33.61
St. James		1.0	10.0
Crane		0.93	3.16
Sikeston		0.67	8.68
New Madrid		0.0	5.0

Table (4) shows the iodine content and chlorine content of natural untreated waters. It is interesting to note from the table that there is no definite ratio or relation between the iodine and chlorine content of a natural untreated water.

Thayer being in the extreme south and Kennett being in the extreme southeastern part of the state both show a relatively high chlorine content. New Madrid being only a short distance from Kennett has a much lower chlorine content, whereas, the water from Sikeston, a few miles north of New Madrid, contained almost twice as much chlorine as did that from New Madrid. This, as well as the fact that the iodine content for New Madrid, would tend to indicate that the soil in that vicinity has been leached to a greater extent than has that of Sikeston or Kennett. New Madrid being located near the Mississippi River, it is quite plausible for such a conclusion to be drawn.

It is also noted that Crane and Willow Springs being on an almost horizontal line in the southern part of the state show practically the same chlorine content.

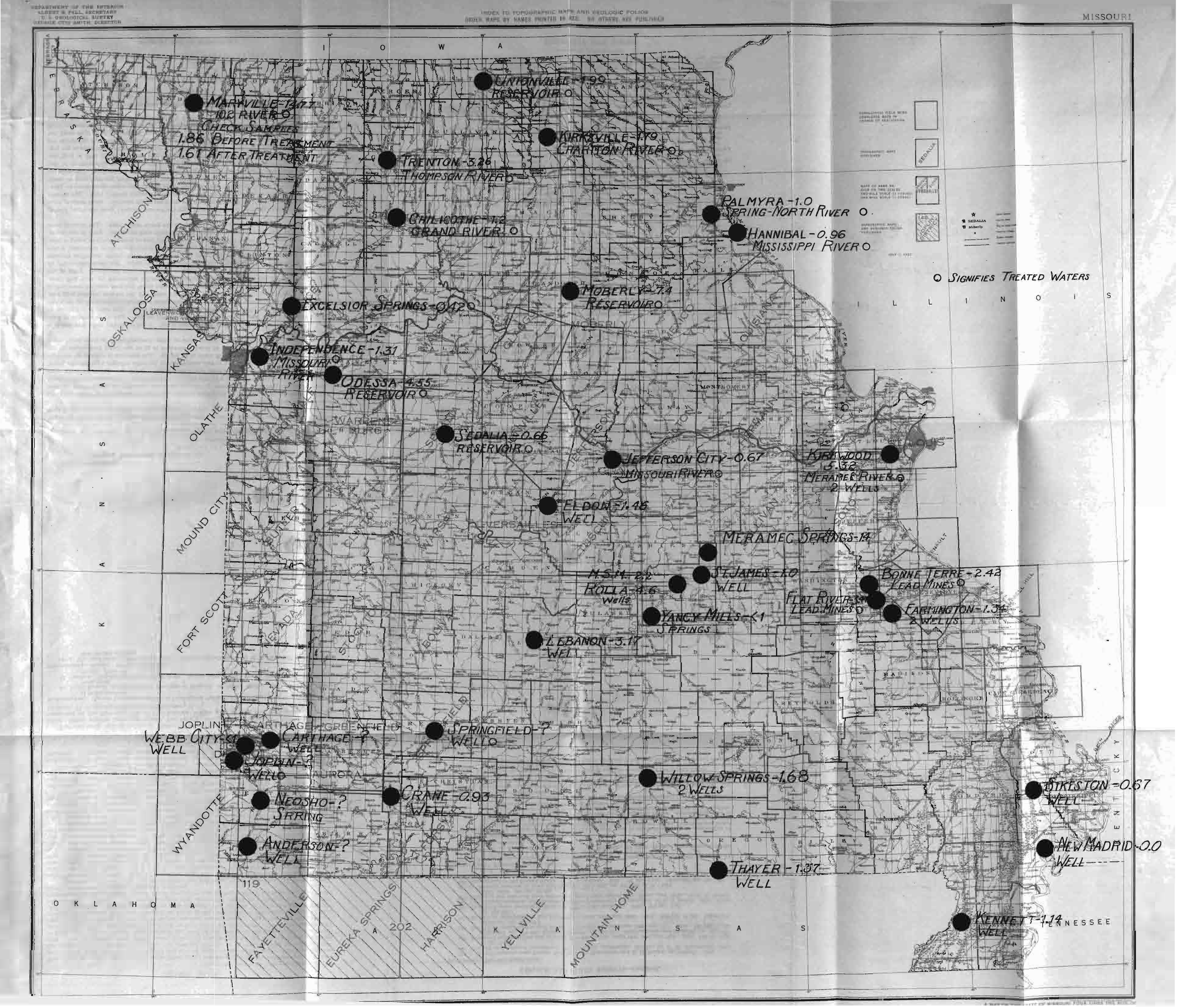
TABLE V

Analysis of Iodized Table Salts

Trade name of salt	Wgt. Sample grams	Percent Iodine found	Percent NaI or KI calculated
Colonial Iodized salt	2.00	.0118	.0139 NaI
	2.00	.0118	.0139 NaI
Mortons Iodized salt	2.00	.0114	.015 KI
	2.00	.0128	.0168 KI

Table (5) shows the analyses of two iodized salts on the market. The determinations were made according to the method of Gröger* with some modifications. The solution of the salts were first treated with alcohol to precipitate the chlorides. After complete precipitation the iodine, as sodium iodide or potassium iodide, was converted to iodate by means of potassium permanganate. The excess permanganate was destroyed with alcohol, the solution filtered, potassium iodide and hydrochloric acid added and the liberated iodine titrated with sodium thiosulphate.

* Ind. & Eng. Chem. 11, 564 (1919)



MISSOURI
I O W A
MARYVILLE-1.77
102 RIVER O
CHECK SAMPLES
1.86 BEFORE TREATMENT
1.61 AFTER TREATMENT
UNIONVILLE-1.99
RESERVOIR O
KIRKSVILLE-1.70
CHARITON RIVER O
TRENTON-3.26
THOMPSON RIVER O
CHILICOTHE-1.2
GRAND RIVER O
PALMYRA-1.0
SPRING-NORTH RIVER O
HANNIBAL-0.96
MISSISSIPPI RIVER O
O SIGNIFIES TREATED WATERS
MOBERLY-7.4
RESERVOIR O
EXCELSIOR SPRINGS-0.42 O
INDEPENDENCE-1.31
MISSOURI RIVER O
ODESSA-4.55
RESERVOIR O
SEDALIA-0.66
RESERVOIR O
JEFFERSON CITY-0.67
MISSOURI RIVER O
KIRKWOOD
5.32
MERAMEC RIVER O
2 WELLS
ELDON-1.46
WELL
MERAMEC SPRINGS-14
M.S.M.-2.2
ROLLA-4.6
Wells
ST. JAMES-1.0
WELL
BONNE TERRE-2.42
LEAD MINES O
FLAT RIVER-3.4
LEAD MINES O
FARMINGTON-1.34
2 WELLS
YANCY MILLS-<1
SPRINGS
LEBANON-3.17
WELL
SPRINGFIELD-?
WELL O
WEBB CITY-<1
WELL
CARTHAGE-?
WELL
JOPLIN-?
WELL O
NEOSHO-?
SPRING
CRANE-0.93
WELL
WILLOW SPRINGS-1.68
2 WELLS
SIKESTON-0.67
WELL
NEW MADRID-0.0
WELL
ANDERSON-?
WELL
THAYER-1.37
WELL
KENNETT-1.14
WELL
ATCHISON
OSKALOOSA
KANSAS CITY
OLATHE
MOUND CITY
FORT SCOTT
WYANDOTTE
JOPLIN
CARTHAGE
GREENFIELD
AURORA
119
FAYETTEVILLE
EUREKA SPRINGS
202
HARRISON
YELLVILLE
MOUNTAIN HOME
O K L A H O M A
K A N S A S
A R K A N S A S
I L L I N O I S
N E B R A S K A
K E N T U C K Y
TENNESSEE

SPECIAL MAPS AND SHEETS.

[Measurements are approximate.]

Aurora, Mo. This map shows parts of the Carthage and Greenfield quadrangles, especially the mining region adjacent to Aurora, on a larger scale. Limiting parallels, 93° 36′ 35″ and 94° 15′ 40″. Limiting meridians, 86° 50′ and 37° 07′ 30″. Size, 20 by 39½ inches. Scale, 1:62,500, or about 1 mile to 1 inch. Contour interval, 10 feet. Price, 30 cents; if included in wholesale orders, 18 cents.

Joplin district, Mo.-Kans.-Okla. This map shows parts of the Carthage and Joplin quadrangles, especially the mining region adjacent to Joplin, on a larger scale. Limiting parallels, 37° and 37° 15′. Limiting meridians, 94° 15′ and 94° 45′. Size, 22 by 31 inches. Scale, 1:62,500, or about 1 mile to 1 inch. Contour interval, 10 feet. Price, 20 cents; if included in wholesale orders, 12 cents. Counted as two atlas sheets in the text of this circular because it is twice the size of a standard topographic map.

Leavenworth and vicinity, Kans.-Mo. This map shows the Leavenworth quadrangle and part of the Oskaloosa quadrangle. Limiting parallels, 39° 13′ and 39° 30′. Limiting meridians, 94° 45′ and 95° 09′. Size, 23 by 24 inches. Scale, 1:62,500, or about 1 mile to 1 inch. Contour interval, 20 feet. Price, 20 cents; if included in wholesale orders, 12 cents.

Missouri (State). This map is in black and white and does not show contours. Size, 44½ by 50 inches. Scale, 1:500,000, or about 8 miles to 1 inch. Price, 25 cents; if included in wholesale orders, 15 cents. Also published on a scale of 1:1,000,000, or about 16 miles to 1 inch; price, 5 cents; if included in wholesale orders, 3 cents.

Platte County, Mo. This map is in three colors. Size, 29 by 32 inches. Scale, 1:62,500, or about 1 mile to 1 inch. Contour interval, 20 feet. Price, 20 cents; if included in wholesale orders, 12 cents.

St. Louis, Mo.-Ill. This map embraces an area of one-eighth of a square degree, equivalent in this latitude to 467 square miles. Limiting parallels, 38° 30′ and 38° 45′. Limiting meridians, 90° and 90° 30′. Size, 20 by 33 inches. Scale, 1:62,500, or about 1 mile to 1 inch. Contour interval, 20 feet. Price, 20 cents; if included in wholesale orders, 12 cents. Counted as two atlas sheets in the text of this circular because it is twice the size of a standard topographic map.

North America. This map does not show contours. Size, 29 by 38 inches. Scale, 1:10,000,000, or about 158 miles to 1 inch. Price, 40 cents; if included in wholesale orders, 24 cents.

Sheet of conventional signs. Shows symbols and abbreviations adopted by the U. S. Geographic Board and recommended for use on Government maps. Size, 20 by 33 inches. Price, 20 cents; if included in wholesale orders, 12 cents.

Sheet of lettering and conventional signs. Shows lettering and symbols used on the topographic maps of the U. S. Geological Survey. Size, 16½ by 20 inches. Price, 10 cents; if included in wholesale orders, 6 cents.

Maps of the United States.

A wall map, 55 by 85 inches, in two sheets, on a scale of 37 miles to 1 inch, without contours, showing coal fields. Price, $1; if included in wholesale orders, 60 cents.

A wall map, 49 by 76 inches, in two sheets, on a scale of 40 miles to 1 inch, either with or without contours. Price, 60 cents; if included in wholesale orders, 36 cents.

A wall map, same size and scale as next above, without contours, showing producing coal districts. 1922. Price, 75 cents; if included in wholesale orders, 45 cents.

A wall map, 40 by 62 inches, on a scale of 50 miles to 1 inch, on which is indicated by depth of brown and blue colors the relative heights of the land and the depth of the sea. The position of the principal cities and the boundaries of the States are shown. Price, 75 cents; in lots of 10 or more, 50 cents.

A map, 18 by 28 inches, on a scale of 110 miles to 1 inch, either with or without contours. Price, 15 cents; if included in wholesale orders, 9 cents.

A relief or hypsometric map, same size, scale, and price as next above; elevations indicated by colors.

A base map, 11 by 16 inches, on a scale of 190 miles to 1 inch. Price, 5 cents; if included in wholesale orders, 3 cents.

A base map, 8½ by 12 inches, on a scale of 260 miles to 1 inch. Price, 1 cent; if included in wholesale orders, five for 3 cents.

LOCAL AGENTS FOR TOPOGRAPHIC MAPS.

Purchasers may save delay incident to ordering through the mails by buying of the following agents, who carry in stock maps of areas in their vicinity and sell them at prices slightly in advance of rates mentioned in this circular:

MISSOURI.

COLUMBIA:
The Missouri Store Co.

JOPLIN:
McGehee & Co., 118 West Fourth Street
T. W. Osterloh, 312 Main Street.

KANSAS CITY:
F. E. Gallup Map Co., 919 Baltimore Avenue.

ST. LOUIS:
Arcade Book Shop, Eighth and Olive streets.
C. Weller, 19 South Broadway.

WARRENSBURG:
W. H. Beazell.

OKLAHOMA.

OKLAHOMA CITY:
Adams Engineering & Blue Printing Co., 306 North Robinson Street.

DEPARTMENT OF THE INTERIOR

UNITED STATES GEOLOGICAL SURVEY

TOPOGRAPHIC MAPS OF MISSOURI

MADE AND FOR SALE BY THE UNITED STATES GEOLOGICAL SURVEY.

The United States Geological Survey is making a topographic survey and atlas of the United States. The unit of survey is a quadrangle measuring 15′, 30′, or 1° each way, an area covering one-sixteenth, one-fourth, or one "square degree." The unit of publication is an atlas sheet 16½ by 20 inches, and each sheet is a topographic map of one of the above areas. As the sheets are uniform in size, the larger the area covered the smaller the scale of the map. The scale of the full-degree map is 1:250,000, that of the 30′ map is 1:125,000, and that of the 15′ map is 1:62,500. Each map is designated by the name of some well-known place or feature appearing on it, and the names of published maps of adjoining quadrangles are printed on its margins. The maps are engraved on copper and printed from stone, in three colors. The cultural features, such as roads, railroads, cities, and towns, as well as the lettering, are in black; the water features are in blue; and the features of relief—hills, mountains, etc.—are shown by brown contour lines. The contour interval differs according to the scale of the map and the relief of the country. Some maps of areas that are economically important do not conform with the general scheme; these are called special maps.

The progress of this work in Missouri is shown on the index map within. The surveys from 1907 to 1916 and from 1920 to 1922 were made in cooperation with the State. Each of the rectangles outlined in red on the index map shows the location and area of a quadrangle of which a topographic survey has been made. The name of the resulting topographic map, if published, is also shown, and its scale is indicated by the size of the rectangle; thus the larger rectangles indicate the smaller-scale maps and the smaller rectangles the larger-scale maps. For areas represented by small rectangles within larger ones maps on different scales have been published. Each of the maps represented by the smaller rectangles shows a quadrangle measuring 15′ each way (one-sixteenth of a "square degree"), or from 227 to 236 square miles, the area differing according to the latitude. The scale is 1:62,500, or about 1 mile to 1 inch, and the contour interval is 20 feet. Each of the sheets represented by the larger rectangles shows a quadrangle measuring 30′ each way (one-fourth of a "square degree"), or from 912 to 962 square miles. The scale is 1:125,000, or about 2 miles to 1 inch, and the contour interval is usually 50 feet. The whole number of published topographic maps of quadrangles in Missouri is 78. A list of special maps and sheets is given on page 4.

The price of the standard maps of either large or small quadrangles is 10 cents each, but a discount of 40 per cent is allowed on an order amounting to $5 at the retail price—that is, the wholesale rate for standard topographic maps is $3 for 50. The discount is allowed on an order for maps alone, either of one kind or in any assortment, or for maps together with geologic folios, except the folios reduced in price because of damage by fire. (See p. 2.) Prices for maps other than the standard are given on page 4 of this circular. No discount will be allowed on an order amounting to less than $3. Prepayment is required and may be made by money order, payable to the Director of the United States Geological Survey (not postage stamps), or in cash—the exact amount—at sender's risk.

If maps ordered are not in stock the right is reserved to substitute other sheets rather than return very small sums of money by mail, unless directions to the contrary are given in the order. *Name of county should be included in post-office address.*

The Survey can not supply mounted maps.

All correspondence should be addressed to—

THE DIRECTOR,
UNITED STATES GEOLOGICAL SURVEY,
WASHINGTON, D. C.

July, 1922.

3—6,000

The map shows the location, type, treated and untreated waters and the iodine content in parts per billion of all the waters analysed. The southern and southeastern sections of the state show the lowest iodine values. This would indicate that the highest goiter incident would prevail in these sections.

Some of the surface waters contained considerable more iodine than did some of the deep wells.

The data on the map emphasizes the fact that considerable variation in the iodine content of waters may occur in a given area or in waters located relatively short distances from one another.

Table of Averages for Waters Analysed

1. Average for 29 results	2.04
2. Average of wells (15)	1.72
3. Average of rivers (10)	1.9
4. Average of reservoirs (4)	3.65
5. Average of rivers plus reservoirs (14).	2.4
6. Average of northern half	2.2
7. Average of southern half	1.8

SUMMARY

1. All the waters analysed show a low iodine content when compared to 10 parts per billion of sodium iodide as normal.

2. In certain parts of Missouri a high incidence of goiter must exist if an inverse relation between the iodine content of water and goiter exists.

3. Cistern or rain water is entirely deficient in iodine and in its use provision should be made for an increased consumption of iodine.

4. Waters from shallow wells and springs are usually deficient in iodine. Iodization of these waters may be practised without danger.

5. There is no definite ratio or relation between the iodine and chlorine content of a natural untreated water.

6. Waters from the northern portions of Missouri are slightly higher in iodine content than those from the southern portions.

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