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Chemical analyses of surface waters of Missouri

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CHEMICAL ANALYSES OF SURFACE WATERS
OF MISSOURI.

BY

HERBERT W. MUNDT.

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
CHEMICAL ENGINEER

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Approved by ______________________

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CHEMICAL ANALYSES OF SURFACE WATERS OF MISSOURI.

INTRODUCTION

This investigation was made by the Missouri Bureau of Geology and Mines. The results of the analyses of surface waters of Missouri are published elsewhere.

The object of the investigation was to obtain information as to the chemical character of the river and spring waters of the state, such information being valuable and interesting to the industries and geologist as well as to the consumer of such waters.

The work for this investigation was started in June 1925 and was continued intensively during the entire summer, a few additional samples being analyzed during the spring and summer of 1926.

The samples were collected by members of the Water Resources Branch of the United States Geological Survey, and the field staff of the Bureau of Geology and Mines. The turbidity determinations were made by the State Board of Health.

The entire state was covered in an attempt to secure at least one sample from each section. Fewer analyses are reported for the area north of the Missouri River than the area south of the Missouri River for several reasons, one of which is that there are fewer springs. Of the 92 springs sampled, only two are located north of the Missouri River. Practically all of the springs sampled are located in the area underlain by Mississippian and Cambro-Ordovician rocks. Furthermore, there are fewer large rivers north of the Missouri River. In several cases, samples of the same river or spring were taken but at different times.

Of the 237 analyses reported, 114 are of river waters, 92 are of spring waters and 34 are summaries. Seven analyses are by W. D. Turner, 26 are by Herbert W. Mundt, and 173 are by W. D. Turner and Herbert W. Mundt.

SAMPLING.

The samples were collected in one-gallon glass bottles which were rinsed with the water to be sampled before the sample was taken. Samples of streams were taken as nearly as possible in the center, by holding the mouth of the bottle against the flow, about four inches below the surface. Samples of the springs were secured at the mouth of the spring whenever possible. The samples were packed four to a case, and shipped to the laboratory as soon as possible after being collected.

On reaching the laboratory, the samples were filtered to remove suspended matter, but a portion for the determination of suspended matter was first removed, if the quantity was large. To insure uniformity, the sample was shaken vigorously before each succeeding part was removed. About two liters were filtered and portions were taken as follows, the constituents written together all being determined on one portion:

Constituent determined.		Amount taken.
Silica, calcium, and magnesium	-	500 cc
(Sodium and Potassium) as sodium	-	250 cc
Carbonates, bicarbonates, and sulphates	-	200 cc
Chlorides	-	200 cc
Nitrates	-	100 cc
Iron	-	50 cc
Total solids	-	100 cc

If the constituent to be determined was present in large amounts, the portion taken for the determination was smaller than given in the above table. For the determination of suspended matter, 100 cc was taken if the waters were excessively turbid or muddy. From waters which contained but small amounts of suspended matter, 1000 cc was taken for the determination of suspended matter, the filtered portion being used for the other determinations.

DISSOLVED MINERAL CONSTITUENTS.

Silica:

Silica is assumed to be present in colloidal state. Summaries by drainage basins show about 5 to 15 parts per million.

Iron:

Iron occurs in all the waters but rarely in quantities greater than two parts per million.

Calcium and Magnesium:

Calcium and Magnesium are dissolved in all the waters in appreciable quantities, the amount varying with locality of the state from which the sample was taken. They are responsible for the general high hardness of the waters analyzed.

Sodium and Potassium as Sodium:

Sodium and potassium are dissolved in nearly all of the waters analyzed, the amounts usually being smaller in samples of spring water and larger in the samples of river water but varying with the locality of the state from which the sample was taken. Large amounts promote foaming and priming in boiler waters.

Chlorides:

Chlorides are usually low, occurring in increased amounts in more thickly populated districts. Spring waters in general do not contain much chloride and some of the river waters have but small amounts. Except in waters from the larger rivers, the content is too small to have any effect on industrial processes.

Nitrates:

Nitrates occur in negligible quantities in practically all of the waters.

METHODS.

Turbidity:

Turbidity where reported was determined in the State Board of Health Laboratory.

Total Suspended Matter:

For waters that contained suspended matter in large amount, (principally Missouri River, Mississippi River and rivers in the northern part of the state) 100 c.c. of unfiltered water were evaporated to dryness in a tared dish and the amount of suspended matter plus total dissolved solids, determined on a filtered sample, was deducted leaving the amount of suspended matter. This method was necessary because of exceedingly slow filtration when the usual method was used, i.e. filtration through an asbestos padded Gooch crucible. For waters having but a small amount of suspended matter, the usual method, filtration of 1000 c.c. of water through an asbestos padded Gooch crucible, was used.

Volatile and Non-volatile Suspended Matter:

After obtaining the weight of total suspended matter, the crucible was ignited, cooled, and re-weighed and amounts of volatile and non-volatile suspended matter derived from the weights so obtained.

Coefficient of Fineness:

Coefficient of fineness is the ratio of the suspended matter to the turbidity and is a measure of the size of the particles in suspension. As the coefficient becomes greater so will the removal of suspended matter be accomplished with greater facility.

Silica:

Silica was obtained by evaporation with hydrochloric acid, dehydration and filtration; ignition, cooling and weighing before and after adding sulphuric acid and hydrofluoric acid was required to determine true silica.

Iron:

Iron was determined by the colorimetric sulphocyanide method, the comparison being made in a Duboscq colorimeter. Nitric[1] acid was used in place of hydrochloric acid since the color produced by the addition of sulphocyanide is deeper and does not fade so rapidly. Also the necessity of using potassium permanganate to oxidize the ferrous to ferric iron is obviated.

Alumina:

Alumina is not reported because of the generally minute quantity present. In such small quantity its condition and effect would be negligible in most industrial processes.

Calcium:

After removing silica and combined oxides, calcium

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[1] Leighton, Marshall O., Field assay of water--U.S. Geol. Survey Water Supply and Irrigation Paper No.151--pp.46-47 1905.

was determined by precipitation with ammonium oxalate which was added in excess to the faintly ammonaical boiling solution containing calcium and magnesium. After filtering and thoroughly washing, the calcium oxalate was dissolved in dilute sulphuric acid, heated and titrated with a standard solution of potassium permanganate.

Magnesium:

Magnesium was precipitated in the cold filtrate from the calcium by the addition of a solution of microcosmic salt. Concentrated ammonia was added equal to one-tenth[2] the volume of the solution. Filtration, washing, ignition, cooling and weighing of the precipitate was carried out after the solution had stood over night or at least twelve hours.

Sodium and Potassium as Sodium:

In as much as the quantity of water was sufficient to warrant it, a separate portion was taken for this determination instead of using the filtrate from the sulphate determination. Magnesium was removed with barium hydroxide and after filtration and concentration, calcium and barium and other impurities were removed by repeated treatments with ammonia, ammonia oxalate, and ammonium carbonate. Ammonium salts were expelled by evaporating to dryness and heating after each treatment. The treatments were repeated until no apparent impurities remained. The small volume of solution containing the sodium and potassium together with a few drops of

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[2] Large amounts of ammonium hydroxide added here are disadvantageous --Bulletin U.S.Geol. Survey 176--P.65--1900.

concentrated hydrochloric acid, was evaporated to dryness, heated to about 600°C., cooled and weighed as sodium and potassium chlorides. Because of the small quantity of potassium in most of the waters, it was thought unnecessary to separate sodium and potassium. They are therefore calculated and reported together as sodium. The error involved in thus reporting is negligible.[1]

Carbonate and Bicarbonate:

Carbonate was determined by adding phenolphtalein to the sample. If a pink color was produced, titration with standard acid to a colorless end point was required. After recording the amount of acid required for carbonate, or if no color was produced with phenolphtalein, three drops of methyl orange was added and the titration continued to the usual end point. From the size of the sample, the normality of the acid and relation between alkalinity by phenolphtalein and by methyl orange, the amount of carbonate and bicarbonate were calculated.

Sulphate:

Sulphate was determined on the portion used for carbonate and bicarbonate. After the addition of a few c.c. of hydrochloric acid, the sample was heated to boiling and the sulphate was precipitated as barium sulphate by the slow addition of barium chloride. The precipitate was filtered, washed , ignited, cooled and weighed.

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[1] Dole, R.B. Analyses of Waters East of the One Hundredth Meridian, Water Supply Paper No. 236, p. 33--1909.

Chloride:

Chloride was determined by adding 1 c.c. of 5% potassium chromate solution and titrating with standard silver nitrate to the customary end point.

Nitrate:

For the determination of nitrate, the water was evaporated to dryness with two c.c. of a 10% solution of sodium carbonate. After adding two c.c. of phenosulphonic acid and making alkaline with ammonium hydroxide, the yellow color developed was compared with similarly developed shades of known nitrate content. The comparison was made in a Duboscq colorimeter.

Blanks:

Blank determinations were made on all the regular methods. The amounts found were deducted, where required, from the regular determinations.

Hardness:

Total hardness has been calculated as calcium carbonate from determined calcium and magnesium, assuming magnesium to be present as calcium. This is, in general, a more reliable figure than the soap hardness result which was found to be at variance with the calculated hardness in at least one third of the analyses made.

Alkalinity has been calculated as calcium carbonate from the carbonate and bicarbonate computed as carbonate,and represents temporary hardness only in those cases where sodium and potassium carbonates occur in small amounts or not at all, since residual alkalinity after boiling was not determined.

Sum of Constituents:

The sum of constituents has been reported instead of the customary total dissolved solids. As the total dissolved solids were dried at 120°C., it is probable that all of the occluded water and the water of crystallization was not driven off. Further, if there were much organic matter, part at least would be carbonized and some of it would be completely destroyed if a higher temperature (180°C.) had been used. It would seem, therefore, that the sum of the constituents would more accurately represent the amount of mineral matter dissolved in the water if the quantity of organic matter were small. The bicarbonate, of course, has been calculated to carbonate and is included as such in the sum of the constituents but the negligible amount of combined oxides was not included.

Residue after Ignition:

Residue after ignition represents the amount of material remaining after the total dissolved solids were ignited at 650° to 700°C.

EXPRESSION OF RESULTS.

The results are expressed in parts per million of the radicles determined. For the convenience of those who may desire the results in other forms, it may be stated that for practical purposes, multiplying parts per million by 0.058 gives the equivalent in grains per U. S. gallon and multiplying by 0.070 gives the equivalent in grains per imperial gallon.

The springs and rivers are tabulated separately and are further classified according to drainage basins. The location from which samples of the rivers or springs were taken appears on one page with such information as is relevant and the analysis appears on the page directly opposite. Each location is given a number which corresponds to the analysis on the opposite page having a like number. The drainage basin and sources are arranged alphabetically. Summaries of individual drainage basins are reported.

ACCURACY.

Established methods were used in making the analyses and the manipulative technique was accompanied by the necessary care. The analyses have been carefully checked for indications of errors. Stabler's[1] method for computing per cent of error was applied to all analyses and together with Dole's[2] table of criteria for accepting analytical data, formed the standards to which all the analyses conform.

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[1] Stabler, Herman, Some Stream Waters of the Western United States, U.S. Geol. Survey, Water Supply Paper No. 274 p. 167 -- 1911.

[2] Dole, R. B. Analyses of Waters East of the One Hundredth Meridian, Water Supply Paper No. 236 p. 38 --1908.

Tables of Analyses
of River and Spring Waters.

NOTE:

Pages 14 to 28 inclusive - Analyses of the waters outlined in index. These analyses are being published as Chapter Five of Volume XX, Water Resources of Missouri. They will probably be returned by the printer about July 1st, 1927, and placed on the pages above mentioned.

INDUSTRIAL APPLICATIONS.

General Uses of Water:

Water is consumed in large quantities for domestic use, laundering, steam making, and various industrial processes. The requirements are not alike in all cases. Generally, as the amount of dissolved mineral matter in a water decreases, its acceptability for all uses increases. For domestic use and the preparation of food products, potable water is required. For laundering, steam making, and many other industrial processes soft water is required.

Potability:

A water to be potable should be free from disease germs and organic or inorganic matter in suspension, possess no color or disagreeable odor, and should not contain excessive amounts of dissolved mineral matter. The following requirements for potable water are taken from Reprint No. 1029, U.S.Public Health Service, pp. 24-25.

PHYSICAL CHARACTERISTICS.

1. Turbidity should not exceed 10 (silica scale), and in general it should not be more than 5.

2. Color should not exceed 20 (standard cobalt scale), and preferably should be less than 10.

3. There should be no odor or hydrogen sulphide, chlorine, or any other substance, and the water should be free from odors caused by the presence of

microscopic organisms.

CHEMICAL SUBSTANCES WHICH MAY BE PRESENT IN NATURAL WATERS.

1. Lead (Pb) shall not exceed 0.1 p.p.m., and copper (Cu) shall not exceed 0.2 p.p.m.
2. Zinc (Zn) shall not exceed 5.0 p.p.m.
3. Sulphate (SO_4) should not exceed 250 p.p.m.
4. Magnesium (Mg) should not exceed 100 p.p.m.
5. Total solids should not exceed 1,000 p.p.m.
6. Chlorides (Cl) should not exceed 250 p.p.m.
7. Iron (Fe) should not exceed 0.3 p.p.m.

Most of the spring and some of the river waters analyzed would be potable without treatment. Coagulation, filtration, sterilization, and softening could be used separately or in combination where required to produce water suitable for most purposes.

Hardness:

Hardness is undoubtedly the most important property of a water with reference to its industrial use. This is especially true with reference to laundering and steam making. Hardness is indicated by the increased amount of soap necessary to produce a lather, by the scum which accumulates before a lather is produced, due to the formation of insoluble calcium and magnesium compounds, and by the formation of scale in boilers or any other vessel in which the water has been heated.

Hardness is usually expressed as parts per million of calcium carbonate. For example, if a water had a hardness of 100 parts per million of calcium carbonate, it could be stated in a different way that 100 pounds of calcium carbonate were dissolved in 1,000,000 pounds of water, or on the basis of liquid measure that 100 pounds of calcium carbonate were dissolved in approximately 120,000 U. S. gallons of the water. With this particular water about 612 pounds of pure anhydrous or about 1000 pounds of laundry soap would be used without producing a lather in the 120,000 gallons of water as this amount of soap would be required to react with and effect the removal of the calcium. In laundering, it would thus seem necessary to remove the hardness by more economical methods.

Hardness in the waters analyzed is due to calcium and magnesium. They may be in solution as bicarbonates, sulphates, nitrates or chlorides. Other elements could cause hardness but the quantity in the waters analysed was not sufficient to contribute much, if anything to the hardness.

There are two kinds of hardness, temporary and permanent. Temporary or carbonate hardness is indicated when the reacting value of carbonate and bicarbonate is equal to or greater than the reacting value of calcium and magnesium. Such hardness may be almost completely destroyed by boiling or heating as the bicarbonate is decomposed and the calcium and magnesium are thrown out to the extent of their solubility in the water. Alkalinity reported in terms of calcium carbonate would be a measure of this hardness if there were no sodium and potassium carbonates in the water. If the sodium and potassium carbonates were present, residual alkalinity would have to be determined and deducted from the total alkalinity and the difference would be equal to the true temporary hardness. Residual alkalinity determinations were not made on the waters analyzed as the quantity of sodium and potassium was usually small. Permanent or non-carbonate hardness due to sulphates, nitrates or chlorides of the alkaline earths is indicated when the reacting value of the carbonate and bicarbonate is less than the reacting value of the calcium and magnesium. In such waters, the hardness cannot be completely destroyed by heating or boiling and recourse must be had to chemical means for completely removing the calcium and magnesium.

Softening of Hard Water:

The hardness of water may be destroyed by several different methods. For temporary or carbonate hardness, heating is usually sufficient to render the water soft enough for most purposes. A water treated under ideal conditions may still have in solution 5.2 parts per million of calcium and 3.8 parts per million of magnesium. This would represent hardness of about 27.7 parts per million and it would be safe to say from a practical standpoint that a water could not be softened to less than 30 to 40 parts per million of hardness calculated as calcium carbonate.

Lime and soda ash are the chemicals usually used to soften water, principally because of their cheapness. Lime is added as limewater equivalent to the free acids, free carbon dioxide, bicarbonates, iron, aluminum, and the magnesium. Sodium carbonate in solution is added equivalent to the calcium present as sulphate and chloride, or introduced by addition of limewater. Naturally if the softening is conducted at an elevated temperature with agitation, there will be greater efficiency and the reaction will take place more rapidly. Barium carbonate could be used in some cases in place of sodium carbonate but the poisonous effect of even small amounts of barium in the water would not balance its usefulness in the removal of sulphates. Its increased cost over sodium carbonate would also have to be considered.

Among the other substances sometimes used to soften water are sodium silicate, hydroxide and phosphate, barium oxide and hydroxide, aluminum and iron sulphate, boiler compounds, which are principally strong solutions of soda ash, and the zeolites[1] or exchange silicate softeners in which use is made of the property of some silicates of exchanging sodium for calcium and magnesiaum. When the silicate begins to lose its exchange capacity, it may be regenerated by passing through it a solution of common salt, which now exchanges sodium for the calcium and magnesium in the silicate. "Permutit" (an artificial silicate whose formula is approximately $2\ SiO_2\ Al_2O_3\ Na_2O + 6\ H_2O$) is an example of such silicate. The advantages and efficiency

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[1] Gans, R., On Zeolites and Similar Compounds. Abstracted in Jour. Soc. Chem. Ind. Vol. XXVI pp. 1091 and 1251 -- 1907.

of this type of softener are apparent.

Analyses of water from the City well at Rolla before and after being passed through a "Permutit" water softener are given below. Results are in parts per million.

	Before[1]	After[2]
SiO_2	8.0	10.2
Fe	0.34	0.2
Ca	49.6	0.4
Mg	28.5	0.4
(NaK)Na	7.7	135.3
CO_3	8.4	24.6
HCO_3	261.0	272.8
SO_4	19.9	25.1
Cl	3.2	5.0
NO_3	0.0	trace
Alkalinity as $CaCO_3$	228.0	264.8
Total hardness as $CaCO_3$ (Calculated)	240.8	2.6
Sum of constituents	253.8	335.1
Total suspended matter	0.1	8.4
Error in per cent	+0.8	-0.08

Foaming, Priming and Corrosion:

Foaming, or the formation of bubbles upon or above the surface of the water which is being used in a boiler is usually attributed to suspended or organic matter and excessive amounts of sodium and potassium. In this connection, it would seem that the injudicious use of the boiler compounds sometimes used to treat the water within the boiler, would increase the tendency of the water to foam and their beneficial effect, usually that of producing soft scale could easily be offset by the introduction of foaming. Small pieces of scale, which have become detached

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[1] This sample was taken from water tap at 1111 State Street and was analyzed July 30, 1925.

[2] This sample was taken directly from the soft water tap of the softener and was analyzed Feb. 28, 1927.

from the deposit in the boiler, may also promote foaming. As there is no practical way to remove the sodium or potassium from the water, frequent blowing off or change of feed water supply would seem to be the only remedies. Foaming, due to suspended matter in the feed water, can easily be remedied by coagulation or filtration before the water enters the boiler. According to Stabler[1] waters may be classed according to their tendency to foam in a locomotive boiler as follows:

Non-foaming - Can be used one week without foaming.
Semi-foaming - One complete change of water necessary, to avoid foaming oftener than every two days.
Foaming - - - - Foams in less than two days, if changing water or blowing off is not resorted to.

Priming occurs, if foaming proceeds to the extent that water is carried from the boiler with the steam in the form of a spray. It is therefore intimately related to foaming.

Foaming and priming due to sodium and potassium would probably not occur in most of the waters analyzed. Some of the river waters contain large amounts of suspended matter and moderate amounts of sodium and potassium. After removal of suspended matter, however, little difficulty should be experienced because of foaming.

Corrosion and pitting of a boiler may be caused by free acids which may be present in the original water, or which may be developed after the water has been heated. Substances which undergo hydrolysis, as the salts of sodium, potassium, and magnesium cause corrosion. Organic acids

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[1] Stabler, Herman, Some Stream Waters of the Western United States, Water Supply Paper No. 274 p. 174 -- 1911.

formed by the decomposition of organic matter contribute to the difficulty. Carbon dioxide either free or evolved by the decomposition of calcium and magnesium bicarbonates upon heating the water also is important. In other words, corrosion will occur if the hydrogen in any of the acids which might be formed as suggested above, is replaced by the metal of the boiler.

Corrosion may be prevented by allowing a thin film[1] of scale to form in the boiler. This will protect the boiler, partly because of the coating of scale formed and partly because of the alkalinity introduced. Free acidity or acidity which may develop when the water is heated may be counteracted by increasing the alkalinity of the water. The high alkalinity of most of the waters analyzed indicates that corrosion would not be probable.

<u>Scale</u>:

Scale deposited within the boiler is due to settling out of suspended matter, to precipitation of sparingly soluble compounds, or to concentration of the water. Such scale may be hard or soft, depending on the insoluble compounds which are precipitated. Calcium and magnesium are the predominant constituents of both hard and soft scale. As sulphates, they would produce a hard, and as carbonates a soft scale. Sodium and potassium have no effect on scale formation as their salts are soluble. Silica, iron, and aluminum all contribute to the formation of scale but the quantities are unimportant as compared with

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[1] Kent, Wm., Eng. News Vol. 52, p. 198 --1904.

calcium and magnesium which predominate as scale forming constituents in the waters analyzed. For formation of soft scale, which can be removed with greater facility and is more desirable than hard scale, sodium carbonate seems to be efficacious[1]. Boiler compounds (essentially solutions of sodium carbonate), or tannin, starch, molasses, and other organic substances which produce soft scale are apt to be injurious because of the possibility that by their decomposition, corrosive organic acids will be formed and the metal of the boiler will be attacked.

The most reliable practice is to soften the water before it enters the boiler and in this connection preheating or the soda-lime method is suggested because of economy. Sulphates could be removed with barium carbonate but the expense would probably be prohibitive.

Other Industrial Considerations:

In the paper making industry pure water is essential for the manufacture of a uniform high-grade product. Alkaline waters which contain much iron, suspended matter or calcium and magnesium bicarbonates interfere with the pulping, sizing and bleaching of the paper. Acids and vegetable coloring matter also have a deleterious effect. In dyeing and bleaching, suspended matter, iron, calcium, magnesium, and bicarbonate seriously interfere with the production of colors and the efficiency of bleaching. In

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[1] **Peter, Robert, Well water-Geological Survey Kentucky Vol. 5 new series 1880 pp. 188-190. Cited by Chase Palmer U.S. Geol.Survey Water Supply Paper No. 233, p. 190.**

tanning, bicarbonate interferes with the removal of hair from the hide and decreases the absorption of tannin because of precipitation of calcium carbonate in the tissue. Iron produces black spots which are undesirable except on black leather. Organic matter causes leather rot and chlorides interfere in the swelling process. Softening applied to the waters analyzed will effect the removal of the harmful constituents and permit their use in any of the above mentioned processes.

SUMMARY

Analyses of 114 river waters and 92 spring waters and 34 summaries by drainage basins are given, together with the methods used for determining the various constituents. The industrial application of the analyses and suggestions for treatment of water for different purposes are described.

Bibliography:

Deming, Horace G., General Chemistry, John Wiley & Sons, 1923.

Journal Soc. Chem. Ind., vol. 26, pp 1091 and 1251 - 1907.

Kent, William, Corrosion produced by rain water in steam boilers. Engineering News, Vol. 52, No. 9, p.198 -- 1904.

Rogers, Allen, Manual of Industrial Chemistry, Vol. 1 and 2, 4th ed., D. Van Nostrand Co., 1925.

Standard Methods of Chemical Analysis, Wilfred W. Scott, D. Van Nostrand Co., 1917.

Standard Methods of Water Analysis, American Public Health Association 1912.

Publications of United States Geological Survey, as follows:

Capps, S. R. & Dole, R. B., Underground Waters of North Central Indiana. Water Supply Paper No. 254, 1910.

Collins, W. D., Quality of the Surface Waters of Illinois, Water Supply Paper No. 239, 1910.

Collins, W. D.,Field Examination of Water, Circular No. 15298, March, 1922.

Dole, R. B., Analyses of Waters East of the One Hundredth Meridian, Water Supply Paper No. 236, 1909.

Johnson, G. A., Purification of Public Water Supplies, Water Supply Paper No. 315, 1913.

Leighton, Marshall O., Field Assay of Water, Water Supply Paper No. 151, 1905.

Matson and Palmer, Water Resources of the Blue Grass Region of Kentucky, Water Supply Paper No. 233, 1909.

Stabler, Herman, Some Stream Waters of the Western United States, Water Supply Paper No. 274, 1911.

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DRAINAGE MAP OF MISSOURI

DRAINAGE AREAS COMPILED BY
H. C. BECKMAN, DISTRICT ENGINEER

COMPILED IN COOPERATION WITH THE
UNITED STATES GEOLOGICAL SURVEY

LEGEND

●	Stream flow measuring station.
■	River stage station of U. S. Weather Bureau.
▲	Present rainfall station of U. S. Weather Bureau.
━━	Boundary of primary drainage basin.
- - - -	Boundary of secondary drainage basin.
580	Red figures below name give total area of drainage basin.
264 →	Red figures with arrow give drainage area of stream above that point.

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Note
Boundaries of drainage areas as shown are approximate. Areas were measured on more detailed maps.