Notes on Potable Waters of Mexico

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BY ELLEN H. RICHARDS, MASS. INST. OF TECHNOLOGY, BOSTON, MASS.

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THE water-supply of a country may be considered from three points of view: (1) its abundance and availability for agricultural purposes; (2) its chemical properties in their relation to manufacturing purposes; and (3) its quality and quantity as affecting domestic consumption.

This paper concerns only those characteristics which may affect manufacturing and domestic uses. The so-called sanitary analyses deal not only with the common mineral elements found in water, but with organic matter and with those substances which, by their presence, indicate changes taking place through the agency of living organisms. Since these living organisms are frequently accompanied by others, capable, as we believe, of causing disease, the products of their action are looked upon with suspicion even when, as in the case of nitrates, that action may have taken place at a time long past. Therefore, in the quality of the water-supply lies much of the history of a country, when rightly read, as well as much of its promise for the future.

Thus, the "hardness" or content of calcium and magnesium salts gives a means of distinguishing at once between the waters traversing only igneous or ~~sedimentary~~ other siliceous rocks and those coming from calcareous deposits. The presence of decomposing organic matter and intermediate products betrays a use of the water as the public carrier of refuse, which renders doubtful its fitness for domestic supply.

In certain regions, one of the most valuable historical records is made by the relative amount of chlorine in the different waters. In the absence of rock-deposits carrying salt, the chlorine present in rain and snow, and hence in mountain-streams and springs, appears to be derived from the air-borne, finely divided salt spray resulting from the beating of the ocean waves on the coast. If this be true, then the amount of chlorine found in a given water not contaminated with chlorides

from other sources will vary with the distance from the shore, the character of the shore, and the presence or absence of mountain ranges which intercept and precipitate the moisture.

The lessons taught by the study, in recent years, of the height to which fine dust rises in the atmosphere, and by the seemingly well-substantiated fact that these dust-particles condense around themselves a film of moisture, seem to warrant the attempt to construct, for similarly situated regions of land, lines of equal chlorine ("isochlors"), which indicate the "allowable" chlorine for each locality. For an accurate determination, a series of tests covering a considerable time is needed; but if the volume of water is considerable, a fairly close approximation may be made by a number of single tests. Thus, the isochlors for Jamaica were plotted from the results of 70 samples, collected in one journey covering the length and breadth of the island.* Waters, both superficial and percolating, possess a great solvent and transporting power, so that the residual contents at any place give some indication of the distance and the rock-formations traversed since the fall of the rain or snow, and also give some proofs of the previous use, and of the cleanness or foulness, of the soil through which the waters have filtered.

These isochloric lines give a basis from which to argue that if, in a given case, chlorine is present in excess of the "normal," it must have entered the water by human agency, thus indicating a previous use of the water by man, and hence a possible pollution. Chlorides are especially adapted to this historical tracing of use, because, as a general rule, after they have once entered the water, they are not removed either by rocks or soil, forming therewith insoluble combinations, or by plants, as a means of growth. The first occurs in the case of phosphates; the last, to a certain degree, in the case of nitrates.

The determination of the "normal chlorine" of a country has, therefore, great sanitary value. Advantage was taken of the excursion of the American Institute of Mining Engineers to the Republic and City of Mexico to obtain samples of water, the analysis of which should at least indicate the probable

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amount of this telltale element, and furnish both a basis and an impulse for more extensive investigations.

The inland waters of the United States, when quite unpolluted, show one part (or less) of chlorine per million. Roughly speaking, this point is reached at about 100 miles from the coast, and remains fairly constant for the interior. The mountain-lakes of the Adirondacks show less than half that amount, while bodies of water within 50 miles of the sea contain about 2.5 parts; and those within ten miles of the sea about 10 parts, per million. Every time water is discharged into a stream or underground reservoir, after use by man, it carries an excess of chlorine. Ordinary city-sewage contains from 25 to 60 parts, and house-sewage two or three times as much.

From the table of analyses given herewith, it will be seen that the Cordilleran Plateau of Mexico furnishes water containing approximately the same proportion of chlorine as other inland regions of North America, and that isochlors may be drawn after more determinations have been made. The results at hand will surely be an advantage in the future sanitary surveys, which a government so wide-awake as that of Mexico will be sure to execute.

The sample from Ajusco, on the divide, showing chlorine 0.9 parts per million; that from Cuernavaca, on the Pacific side; and that from Pachuca, on the east,—each showing about 1.0 part and each about 100 miles from the coast,—may be taken as typical. The five others, placed in the first class, approach this limit, and are distributed over the plateau from north to south at distances of about 200 miles from the sea. The anciently famous spring at Thalpan undoubtedly belongs here. Unfortunately, the sample was lost by breakage of the bottle, after the preliminary test.

Classes II*a*, II*b* and III show from two to three times the chlorine of those waters which we may for the present assume as normal.

Class II*a* includes those which show no nitrogen. In Class II*b* is the sample taken from the reservoir at the new dam at San Luis Potosí. This water is placed here because the analysis indicates the probability that, when the collecting ground is washed clean and protected (as it is to be), this water will belong here—if, indeed, the chlorine is not quite normal.

Sanitary Analyses of Mexican Waters.

(Parts in 1,000,000.)

No.	Locality.	Physical.			Residue on Evaporation.			Nitrogen as				Hardness.	Chlorine.	Iron.	Carbon Dioxide.	Sulphates.	Silica.	Calcium Oxide.	Magnesium Oxide.
		Color.	Turbidity.	Sediment.	Total.	Loss on Ignition.	Fixed.	Alb. Am'nia. Total.	Free Am'onia.	Nitrites.	Nitrates.								
	Class I.																		
1...	Ajusco, on the Divide, from hydrant at the station.	0.10	none	decided earthy	98.5	12.5	86.0	0.072	Nov. Dec. .200 .048	Nov. Dec. .001 .010	0.000	16.3	0.89	0.100	.....	v. slight	.....	.....	.....
2...	Hydrant, Pachuca.	0.13	"	sl. floc.	84.5	6.5	78.0	.....	slight	0.000	0.000	21.5	1.05	0.100	faintly acid	v. slight	.....	.....	.....
3...	Fountain, Cuernavaca, Hotel Morellos.	0.00	"	v. sl.	119.0	9.0	110.0	.....	0.060	0.000	0.000	28.6	1.09	0.010	.....	slight	.....	.....	.....
4...	Spring, Santa Barbara, on hill near Montezuma mill.	0.00	"	sl. earthy	364.0	.....	.....	.....	v. sl.	0.000	0.000	215.0	1.17	0.080	faintly alkaline	distinct	.....	.....	.....
5...	Drinking tap, Real del Monte.	0.35	"	sl. floc.	87.0	5.0	82.0	.....	Nov. Dec. .400 .360	Nov. Dec. .000 .0005	0.000	11.1	1.21	0.035	faintly alkaline	....	... ..	.....	.....
6...	Marfil, below Guanajuato, from hydrant at station.	0.10	slight settling out	slight earthy and rusty	209.0	.....	.....	.....	0.060	0.000	0.000	116.5	1.49	0.140	.....	slight	.....	.....	.....
7...	Monterrey, spring at the Diente.	0.07	none	consid. earthy	250.0	.....	.....	.....	0.000	Nov. Dec. .000 .001	0.200	185.8	1.65	0.200	acid	slight	.....	.....	.....
	Class II*a*.																		
8...	Chihuahua, town-supply, tap.	0.00	"	slight earthy	306.0	.....	.....	.....	none	0.000	trace	134	2.96	0.050	faintly acid	distinct	.....	.....	.....
9...	River in Choy Cove.	.....	"	none	828.0	.....	.....	.....	.....	0.000	0.000	471.5	3.34	0.200	.....	272.	36.0	253	.....
	Class II*b*.																		
10...	Dam for new supply, San Luis Potosi, not ready for use.	.....	distinct settling out to nearly clear.	consid. earthy yellow	115.0	22.5	92.5	0.340	1.220	0.003	0.000	22.1	2.48	0.700	.....	.....	.....	.....	6.0

11...	"Drink water," San Luis Potosi.	.....	milky, not settling	sl. earthy	206	22.5	183.5	0.088	0.152	Nov. Dec. .000 .001	0.600	11.1	3.69	0.950	.....	v.slight	.....	.....	.....
	CLASS III.																			
12..	Driven well, Guadalajara, Calle Merced.	0.20	v. f. milky	slight earthy and rusty	210.5	23.0	187.5	.....	Nov. Dec. .200 present	Nov. Dec. .001 .004	5.000	6.3	1.89	5.250	2.64	slight	.....	.....	.....
13...	Hydrant, Guadalajara, Calle San Francisco.	0.20	dist. milky	sl. earthy	237.5	.....	.....	0.060	Nov. Dec. .200 .000	0.000	4.500	14.3	2.74	0.110	0.44	.....	.....	.....	.....
14...	Filter well, Guadalajara, said to be best in Republic.	0.07	none	v. sl.	215.	.....	.....	.....	faint	0.000	6.000	34.5	3.81	0.100	3.52	slight	.....	.....	.....
	CLASS IV.																			
15...	San L. Potosi well, 500 ft.	0.10	"	sl. floc.	205	27	178	0.060	0.232	Nov. Dec. .000 .002	0.000	14.3	6.00	0.040	.....	.....	.....	.....	.....
16...	Guanajuato.	0.15	"	sl. rusty	384	.....	.....	0.072	0.000	0.000	0.000	200.0	7.01	0.160	.....	decided	.....	.....	.....
17...	Hydrant, San Luis Potosi, in Plaza.	0.15	dist. white milky	v. sl.	300	.....	.....	0.048	0.000	0.000	0.600	15.6	13.47	0.100	.....	distinct	.....	.....	.....
18...	Pool at Bridge of the Gods, Cafetal (?) or Cardenas. Tropical vegetation.	.....	none	none	780	.....	.....	.....	0.200	0.001	0.150	414.5	14.30	0.080	.....	.....	.....	.....	.....
19...	Hot springs, tap west side of station, Aguascalientes.	0.00	"	v. sl.	554	.....	.....	0.000	0.000	0.000	0.100	342.8	16.09	0.040	.....	decided	40.0	91.0	.....
20...	Marzio 18. Artesian well on drainage canal.	0.00	"	none	475	.....	.....	.....	Nov. Dec. .060 .000	0.000	0.100	107.5	26.41	0.020	Reaction alkaline	slight	58.5	31.0	27.0
	CLASS V.																			
21...	From vendor, Aguascalientes. Spring in mountains.	0.10	milky, settling clear	dist. earthy	298	.....	.....	.....	Nov. Dec. dist. none	Nov. Dec. .010 .100	4.250	76.4	6.41	0.050	.....	slight	.....	.....	.....
22...	Aguascalientes, tap from river. Smelting-works.	0.30	distinct not clear'ng	decided earthy	405	.....	.....	0.200	0.000	Nov. Dec. .001 .000	0.000	122.6	8.90	0.100	.....	slight	.....	.....	.....
23...	Baroteran, tap at Mine Office.	0.02	milky, settled out	consid. rusty	556	.....	.....	0.120	0.080	Nov. Dec. .005 .0005	1.000	287.4	14.30	0.400	acid	decided	.....	.....	.....
24...	Aguascalientes, tap in Plaza.	0.00	none	v. sl.	457	.....	.....	0.000	Nov. Dec. pres't .000	Nov. Dec. .001 .000	0.350	165.8	17.53	0.020	.....	slight	.....	.....	.....
25...	Spring, Chihuahua, used for drinking.	0.00	"	v. sl. earthy	444	.....	.....	.....	0.000	.000	1.500	221	18.87	0.100	1.76	distinct slight	55.0	115.	.....
26...	Drinking fountain, Zacatecas.	0.10	"	sl. earthy	480	.....	.....	0.108	0.000	Nov. Dec. .000 .040	3.500	314.5	32.77	0.000	alkaline	distinct slight	.....	.....	.....

Sanitary Analyses of Mexican Waters—Continued.

(Parts in 1,000,000.)

No.	Locality.	Physical.			Residue on Evaporation.			Nitrogen as				Hardness.	Chlorine.	Iron.	Carbon Dioxide.	Sulphates.	Silica.	Calcium Oxide.	Magnesium Oxide.
		Color.	Turbidity.	Sediment.	Total.	Loss on Ignition.	Fixed.	Alb. Am'nia. Total.	Free Am'nia.	Nitrites.	Nitrates.								
	Class VI.																		
27...	Pachuca, reservoir below picnic-ground.	0.15	decided settling clear	consid. rusty and floc.	162	.....	.....	.....	Nov. Dec. .400 1.200	Nov. Dec. .008 .060	1.000	58.6	5.45	0.020	faintly acid	.....	.....	.....	.....
28...	Monterrey, well in hotel.	.....	none	v. sl. floc.	458	.....	.....	.....	Nov. Dec. .200 .200	Nov. Dec. .002 .005	4.500	251.2	6.99	0.040	reaction acid	distinct	76.5	127.	.....
29...	Hotel Guadalajara, said to be filtered rain-water.	0.10	"	v. sl.	441	.....	.....	0.080	Nov. Dec. 1.200 .268	Nov. Dec. .020 .200	9.500	65.7	16.54	0.050	0.88	slight	.....	.....	.....
30...	Parral, badly polluted stream, from carafe on table.	0.00	slightly turbid, later clear	sl. earthy	566	.....	.....	0.080	0.000	Nov. Dec. .040 .010	15.000	224	89.77	0.040	faintly acid	distinct	.....	.....	.....
	Class VII.																		
31...	Mineral waters. Holy well, Guadeloupe.	0.20	.....	.....	1820	.....	.....	0.260	1.080	Nov. Dec. .001 .005	0.000	545.0	218.4	25.2	44.0	decided	.....	.....	223.
32...	Mineral water below San Luis Potosi.	1.20	milky	consid. rusty	700	.....	.....	.....	0.460	0.000	0.000	371.5	167.2	0.120	.....	distinct	18.0	189.	.....

Sanitary Analyses of Mexican Waters—Continued.

No.	Unclassified.	Date of Collection. 1902.	Date of Examination. 1902.	Total.	Chlorine.	Nitrogen as Nitrites.	Nitrogen as Nitrates.	Hardness.	Iron.
33	Water from spring at Ubero plantation, Isthmus of Tehuantepec.*	Feb. 27	Mar.	70.5	4.78	.002	1.800	30.6	0.330
34	Water from Junnupa River.*	"	"	103.0	5.46	.000	.000	41.0	0.550

The other sample contains some nitrate, which, however, is not sufficient to render it suspicious; and the ammonia is accompanied by iron—a not uncommon occurrence in deep-seated waters, especially those which have been in contact with the sandstones above the Coal Measures. The presence of chlorine without nitrates may mean one of two things: either (1) that the source of the chlorine is in old rock-formations, still bearing traces of marine deposition; or (2) that the nitrates once present have been completely removed by vegetation, or that, in various transformations underground, they have disappeared, and with them any dangerous accompaniments.

Class III., containing the three samples from Guadalajara, gives evidence of the slow percolation of surface-drainage to the underground sources, since not only is the chlorine increased, but nitrates are present in high amounts.

Class IV., with high chlorine and low nitrogen in any form, should offer interesting lines of study for the geologist.

Class V., with nitrates present, stands intermediate between IV. and VI., which latter class may be said to comprise waters which show undoubted pollution, having all the marks of previous use which are held in other countries to be conclusive on this point.

Class VII. contains two samples of highly-charged mineral water, in which both the chlorine and ammonia may have been derived from geological formations, rather than through contamination from human sources.

Further examination of the well of Guadalupe is needed to determine the geological horizon from which the water is de-

* Collected by Prof. F. L. Bardwell, of the Mass. Institute Technology.

rived. In the case of the other well, the remarkable variation of temperature indicates that it may be a mixed water. Further tests at different seasons are needed.

The only soft waters are from the vicinity of Mexico City, Ajusco, Thalpan, Cuernavaca, and Pachuca, and two at San Luis Potosí.

As to the mineral contents, it is not surprising to find considerable silica and much calcium carbonate in the waters coming in contact with the warm *tepetate* or *caliche*.

The comparatively rare occurrence of magnesium and of sulphates is favorable to the quality of the water for domestic and manufacturing purposes, since it is comparatively easy to remove the calcium carbonate.

The water which escapes from the plateau and passes underground to the sea may be considered to be represented by the sample from the river in Choy Cove, and the artesian well on the drainage-canal near Zumpango.

Mexico may act in time to save her good water-supplies, if she will take to heart the lesson, so dearly bought in the United States, that it is cheaper, as well as wiser, to protect from pollution than to purify afterwards.

Additional Notes.

The tap in the railroad-station at Juarez gave a hardness of 300, and showed high chlorine and sulphates, with considerable carbon dioxide. Ammonia, nitrites and nitrates very low or absent. This and other evidence indicate a deficiency of nitrogen in the arid region.

It was most unfortunate that the bottle containing the sample from the famous spring at Thalpan was broken before the final tests were made. The water is said to come out from under the volcanic sheet forming the last eruptive rock in the valley. The water is barely acid with carbon dioxide; shows normal chlorine with no nitrogen in any form; and a hardness of only 13. per million, thus sustaining the high reputation it has had for so many decades.

Some of the supplies of the City of Mexico are nearly as good as this; others are much harder and less free from contamination.

That water derived from the hard soil is at times polluted,

as is that from gravelly formations, is shown by a sample from Zumpango, which gave a hardness of 63., and ammonia, 1200; nitrites, 30; nitrates, 20; with high chlorine and some sulphates.

As was to be expected, few samples gave any considerable amount of the salts of potassium and sodium. In a few cases determinations were made, and the results will be found in the table.

In consequence of the small amounts of nitrates usually present, there was, at the season in which these observations were made, very little of that growth of green plant-life which is so characteristic of many of the northern water-courses.

The objectionable blue-green alga *Anabæna* was observed only once, at the Borda garden, Cuernavaca, where the air was heavy with its unmistakable odor.

A microscopical examination, made some two months after the samples were collected, showed a very wide distribution of diatoms, both of common and of unusual forms.

Varieties of *tabellaria*, *fragilaria*, *navicula* and *synedra* were common. Very few green *algæ* developed. Now and then a form of *palmella* was observed.

In several samples the diatoms had a sheath or envelope of oxide of manganese, after the manner of iron oxide about *crenothrix*.

In conclusion, it may be stated that this examination, imperfect as it is, was made possible by the use of a portable case of apparatus* and reagents, carefully standardized just before leaving the laboratory at Boston. By this means certain tests were made on the spot, both to determine what samples it was worth while to bring north, and to make the transportation of a smaller sample compatible with good work. Moreover, a comparison of the results reached on the spot with those of a month later permits an opinion to be formed as to the changeable character of the organic matter.

My thanks are due to Miss I. F. Hyams for aid in making the preliminary tests during the journey, and to many members of the Institute party for aid in collecting the samples.

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* Figured and described in the *Technology Quarterly*, vol. xiv., page 295.