XC.—*Some Excessively Saline Indian Well Waters.*

By JOHN WALTER LEATHER.

I HAD recently occasion to examine some well waters from the Muttra District of the United Provinces, which in addition to being unusually saline, are interesting from another, the agricultural, point of view.

The Muttra District lies in the Indo-Gangetic Alluvium, and to the south-west side of the River Jumna. The soil is somewhat coarser and more open than much of this great belt of alluvium, but it is free from stones.

The analyses are set out in the accompanying two tables (pp. 890, 891). The local name of each sort is given, but it is apparently of very little value as an indication of the nature and amount of the dissolved salts.

Regarding the manner in which the acids and bases are combined, all the nitric acid has been calculated as calcium nitrate. The nitrates of drainage waters usually consist, for the most part, of the calcium salt, and, moreover, in the case of the present samples, there was insufficient potash to combine with the nitric acid in all the samples, whereas lime was in excess in all of them.

Carbonic acid, and, after it, sulphuric acid, have been combined with lime, then with magnesia, and the remainder, if any, with soda. Any excess of these bases has been combined with chlorine. All potash has been calculated as chloride, and any excess of chlorine as sodium chloride.

About one-half of the total salts is, in most cases, sodium chloride. The amount of nitrate varies enormously, not only as between waters which are classed differently by the cultivator, but even in waters which are named identically by him. It seems hardly possible that nitrates can have been formed in the presence of so much other salt, but if not, then they must have been formed either at a different period or in a different place.

The amount of carbonates (measured alkalimetrically, using methyl-orange as indicator) is comparatively small, and varies only immaterially, although in three of the samples the amount of carbonic acid was more than sufficient to combine with all the lime and magnesia, thus proving the presence of potassium or sodium carbonate.

In addition to the very large amounts of sulphates which most of these waters contained, there were three in which the nitric, carbonic, and sulphuric acids were insufficient to satisfy all the lime, and the remainder was assumed to be calcium chloride. The presence of this salt in natural waters is quite exceptional, although probably not more so than is the general excessive amount of total salt.

These waters have also an interest agriculturally. As some of them are used for irrigation, they supply an index of the strength of saline solutions in which plants can live.

Throughout the Punjab and the United Provinces are vast areas of land which suffer from an accumulation of sodium salts in the surface soil. Usually, either the carbonate or sulphate predominates, and the chloride is nearly always subordinate. They are similar to the "alkali" lands of some parts of the United States.

One of the questions which the chemist has endeavoured to solve is: How much of these sodium salts may be present in a soil without causing serious harm to crops, and how much renders the land sterile?

Hilgard found that barley grew well in soil containing an average of 0·159 per cent. of sodium salts in the soil down to 4 feet, whilst the same crop failed in the presence of 0·203 per cent. *Eleusine coracana*, a small millet, he found to succeed well in soils containing as much as 0·075 per cent. of salts; and *Pennisetum typhoideum*, another millet, on soil containing 0·056 per cent. Most of the *Leguminosæ* suffer more readily. Alfafa or lucerne grows with difficulty in the presence of 0·025 per cent., but *Melilotus indica* and *M. alba* succeeded in presence of 0·12 per cent. up to 0·18 per cent. (*California Bull.*, No. 128, U.S. Dept. of Agriculture).

In India, I have found cereals growing well in the presence of 0·099 per cent. of sodium carbonate, and 0·018 of sodium chloride in the Cawnpore District. In the Aligarh District, wheat grew well in one case in the presence of 0·044 per cent. of carbonate *plus* 0·021 of chloride, and in another in the presence of 0·137 per cent. of carbonate *plus* 0·062 of chloride. The crop failed, however, in the presence of 0·193 per cent. of carbonate *plus* 0·01 of chloride in one plot, and of 0·251 per cent. of carbonate *plus* 0·008 of chloride in another (*Agric. Ledger*, 1897, No. 13).

These Indian records agree very closely with those of Hilgard. There is sometimes an apparent contradiction. For instance, if wheat fails to grow at all in the presence of 0·193 per cent. of sodium carbonate *plus* 0·01 of sodium chloride, it would hardly be expected to grow perfectly in the presence of 0·137 per cent. of carbonate *plus* 0·062 of chloride, which was actually the case at Aligarh. The difference is only a small one, and at the most it might be assumed that the crop would do a little better in the one case than in the other. One of the instances quoted by Hilgard is equally curious. It is probable that the explanation lies in the respective amounts of rain-water which the several soils would allow to enter at the surface. The word "drain" cannot here be properly used, because the presence of these salts is a proof that the drainage conditions are extremely imperfect. But one soil will allow more water to descend into the surface soil than another. This would produce more dilute solutions of the salts in the one case than in the other, and it would explain why considerable differences in the growth of crops may occur in soils which contain much about the same proportion of salts. It is, indeed, a question of concentration of solutions that must be considered rather than weight of these salts per 100 parts of soil or per acre.

Incidentally, the saline waters which form the subject of this communication provide some further evidence on the subject.

Although so saline, some of them are used for irrigation. The soil of the Muttra District is an open, naturally well-drained alluvium, and includes no "alkali" lands. There is no material amount of concentration of the salts in the surface soil, and the plant roots are thus exposed to solutions of approximately the same strength as the irrigation water. These well waters are not considered so good as "sweet"* water, and among those examined only the "Mitha bunga" (124 parts and 294 parts of salt) is considered fit for application to the land before sowing. Several others, however, are applied to *growing* crops. "Khari" (1023 parts and 388 parts), "Khari bunga" (448 parts and 682 parts), "Marmora" (319 parts and 313 parts), and "Marmora telia" (276 parts and 408 parts of salts) are actually considered better than "sweet"

* In India the people very commonly apply this term to well-waters as a distinction from those which are saline.

TABLE I.—*Showing the Amounts of Bases and Acids in Well Waters* (*parts per* 100,000)

	Field No. 444. Village Mohamadpur.	Field No. 419. Village Jatipura.	Field No. 1547. Village Anaur.	Field No. 1449. Village Anaur.	Field No. 426. Village Ganthauli.	Field No. 1898. Village Sakitra.	Field No. 94. Village Kanwar.	Field No. 175. Village Kanwar.	Field No. 1834. Village Kosi.	Field No. 1734. Village Kosi.	Field No. 2040. Village Kujera.	Field No. 960. Village Pali.	Field No. 2783. Village Ganthauli.	Field No. 1694. Village Anaur.	Field No. 2754. Village Ganthauli.	Field No. 701. Village Gardhan Gaurwa.	Field No. 2702. Village Niligaon.	Field No. 969. Village Jatipura.	Field No. 569. Village Jatipura.	Field No. 1765. Village Anaur.	Field No. 2752. Village Parai.	Field No. 2648. Village Parai.
	Mitha telia.		Marmora telia.		Mitha bunga.		Marmora.		Irlia.		Khari telia.		Khari bunga.		Khari.		Khari jarel.		Kurua.		Kurua telia.	
	A. 67.	B. 68.	A. 69.	B. 70.	A. 61.	B. 62.	A. 75.	B. 76.	A. 73.	B. 74.	A. 55.	B. 56.	A. 65.	B. 66.	A. 63.	B. 64.	A. 57.	B. 58.	A. 71.	B. 72.	A. 59.	B. 60.
Lime, CaO	5·6	21·30	6·72	11·21	11·38	17·76	14·01	14·01	48·76	53·80	59·97	61·98	28·58	116·60	80·14	43·15	124·00	153·20	183·80	154·10	135·30	121·40
Magnesia, MgO	11·59	23·17	13·40	16·29	16·65	30·96	28·24	26·07	41·64	51·78	39·47	88·53	43·81	40·56	41·28	42 00	63·44	116·10	114·10	166·50	135·80	201·40
Potash, K_2O.....	0·39	—	0·77	0·19	3·30	1·55	1·94	—	—	—	21·34	14·55	12·03	0·97	5·43	0·58	14·74	3·68	6·01	2·91	184·80	201·40
Soda, Na_2O	85·36	64·62	120·57	178·86	27·23	93·15	108·03	108·35	154·90	135·30	131·40	213·90	131·10	160 00	372·54	98·94	187·80	286·50	195·30	345·00	441·60	393·90
Carbonic acid, CO_2...	27·99	11·80	30·35	37·60	20·73	24·62	23·27	23·43	15·68	15·68	16·00	12·56	20·40	11·73	17·87	21·75	22·25	17·87	12·31	13·66	16·10	16·86
Sulphuric acid, SO_3 .	16·14	47·39	31·93	60·43	16·48	41·96	71·07	51·50	112·60	115·70	95·90	173·40	72·79	57·34	178·90	67·29	228·00	231·80	104·40	150·10	435·90	454·30
Nitric acid, N_2O_5 ...	—	0·97	1·16	0·77	12·30	4·49	3·26	17·82	1·92	1·92	43·55	0·76	5·61	73·10	6·19	0·38	0·95	4·56	115·00	1·35	160·90	160·70
Chlorine, Cl	66·22	84·28	92·88	133·30	21·50	104·50	90·30	92·88	186·60	185·80	172·90	316·90	172·00	287·20	414·50	147·90	257·10	493·60	475·60	731·90	539·20	578·30

TABLE II.—*Showing the Amounts of Salts in Well Waters* (*parts per* 100,000).

	Village Mohamadpur.	Village Jatipura.	Village Anaur.	Village Anaur.	Village Ganthauli.	Village Sakitra.	Village Kanwar.	Village Kanwar.	Village Kosi.	Village Kosi.	Village Kujera.	Village Pali.	Village Ganthauli.	Village Anaur.	Village Ganthauli.	Village Gardham Gaurwa.	Village Nilegaon.	Village Jatipura.	Village Jatipura.	Village Anaur.	Village Paral.	Village Paral.
Local name given to water.	Mitha telia.		Marmora telia.		Mitha bunga.		Marmora.		Telia.		Khari telia.		Khari bunga.		Khari.		Khari Jarel.		Kurua.		Kurua telia.	
No.	A. 67.	B. 68.	A. 69.	B. 70.	A. 61.	B. 62.	A. 75.	B. 76.	A. 73.	B. 74.	A. 55.	B. 56.	A. 65.	B. 66.	A. 63.	B. 64.	A. 57.	B. 58.	A. 71.	B. 72.	A. 59.	B. 60.
Calcium nitrate	—	1·47	1·76	1·17	18·68	6·82	4·95	27·06	2·91	2·91	66·13	1·15	8·52	111·00	9·40	0·58	1·44	6·92	174·61	2·04	244·33	244·03
Calcium carbonate ...	10·00	26·82	10·93	19·31	8·93	27·56	22·00	8·52	35·64	35·64	36·60	28·55	46·37	25·30	40·62	49·44	50·58	40·62	27·98	31·05	36·60	38·32
Magnesium carbonate ...	24·34	—	28·14	34·21	32·07	23·84	25·94	37·57	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Sodium carbonate ...	26·11	—	26·02	26·93	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Calcium sulphate ...	—	14·04	—	—	—	—	—	—	67·54	79·78	41·02	110·74	—	97·48	131·58	37·06	231·15	311·05	177·48	255·17	76·18	40·34
Magnesium sulphate ...	—	58·70	—	—	4·14	58·83	47·67	24·54	109·30	103·15	107·65	162·39	109·19	—	123·84	68·23	138·04	73·24	—	—	407·40	604·20
Sodium sulphate ...	28·65	—	56·68	107·26	24·35	4·86	69·74	62·37	—	—	—	—	—	—	33·62	—	—	—	—	—	212·10	49·29
Calcium chloride	—	—	—	—	—	—	—	—	—	—	—	—	—	48·32	—	—	—	—	70·21	61·30	—	—
Magnesium chloride	—	8·55	—	—	—	—	—	—	12·38	41·32	8·52	81·62	17·60	96·31	—	45·76	41·40	217·82	270·83	395·53	—	—
Potassium chloride	0·61	—	1·23	0·31	5·22	2·46	3·07	—	—	—	33·81	23·05	19·04	1·54	8·60	0·92	23·35	5·84	9·53	4·60	292·80	319·00
Sodium chloride	108·64	128·35	152·10	219·42	31·33	170·28	146·40	153·06	292·30	255·23	247·93	403·60	247·39	302·60	676·31	186·68	354·35	540·70	368·60	650·90	659·00	702·80
	198·35	237·93	276·86	408·61	124·72	294·65	319·77	313·12	520·07	518·03	541·66	811·10	448·11	682·55	1023·97	388 67	840·81	1196·19	1099·24	1400·59	1928·41	1997·98

water for growing cereals. Such a qualification would lead one to anticipate the presence of some considerable proportion of nitrates in these waters. In some parts of India, very saline well waters are applied to land on account of the nitrates which they contain. This practice I found in Gujerat (*Agric. Ledger*, 1895, No. 14). When, however, the amount of total salts is high, the water is there mixed with that from less saline wells. For instance, in one case the water contained about 1400 parts of salts per 100,000, of which about 310 parts were sodium nitrate. This water was mixed with about four volumes of other less saline water before application to the land. But whilst one of the well waters named (No. 66) contained a high proportion, and another (No. 76) a moderate proportion of nitrates, the others contain so little that this cannot be considered as an explanation.

The remainder of the waters cannot be used for irrigation in the absence of a good rainfall. Used alone in dry weather, they are practically fatal to crops. Here, as in the case of analyses of alkali lands, a distinct line cannot be drawn between waters which are fatal to crops and those which are not fatal. But there is general evidence that the most that crops such as cereals will bear is a solution containing some 400 to 500 parts of salts per 100,000; in other words, solutions up to 0·5 per cent. Even if the salts which may be considered harmless, namely, calcium nitrate, carbonate, and sulphate, magnesium carbonate, and potassium chloride be deducted, there still remain in some of the waters which are regularly used for irrigation some 400 to 500 parts of harmful salts. More generally, it may be assumed that many crops, especially the *Leguminosæ*, would suffer in solutions of 0·3 per cent. of total salts.

In order to compare such figures with those showing the proportions of salts per 100 parts of soil, it may be assumed that the proportion of water in soils varies, shortly after irrigation, from 30 per cent., decreasing to 10 per cent. or 15 per cent. according to the nature of the soil and climatic conditions. A soil containing 0·1 per cent. of salts and 30 per cent. of water may be considered as holding a solution of 0·33 per cent. of salts (330 parts per 100,000), and if the proportion of water fell to 15 per cent., then the solution would become one containing 0·66 per cent. of salts.

Judging by the evidence of the agricultural effects of the well waters, such a proportion is as much as cereal crops could be expected to bear, and the conclusion would be drawn that a soil containing so high a proportion as 0·1 per cent. of total salts could only be expected to bear good crops if the water supply be regular throughout the season. Generally, this figure agrees with the experience of Hilgard and with that obtained at Aligarh in India.

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