Notes on well waters with special reference to Sugarcane Irrigation.

The ryot generally realises the importance of water for his crops. But little attention is usually paid to the matter whether the water he uses to irrigate his fields is suitable for the crop he grows. No doubt in extreme cases, he finds from experience that his irrigation water is unsuited for any particular crop and then tries another. Sometimes when the water is extremely saline, the fields irrigated with the same get in time so impregnated with saline matter as to render the field unfit for any crop. Under favourable conditions, as when there is good rainfall or when fresh water is available to wash away the accumulated salts, such lands improve in course of time. In cases, however, where such facilities do not exist, the land is rendered permanently unfit for cultivation, for example, some fields of Thekka theruvu near Madura. The present article deals with the irrigation waters with reference to salts injurious to plant growth and the tolerance which certain crops are known to show towards the saline constituents.

Sources of irrigation. The sources of irrigation are rivers, springs, ordinary wells, artesian wells, tanks and reservoirs. Of these, river and spring waters are generally good containing little of saline matter, as a reference to the result of analysis appended will show. Tank and reservoir waters are also generally good. In climates like our own, the natural sources of water indicated above (rivers and springs) are not sufficient—on account of scarcity of rainfall and large amount of evaporation. Hence the necessity for supplementing the rainfall by well irrigation. Therefore the success or otherwise of a ryot's cultivation mainly depends upon the quality of water at his command.

Methods of analysis. It has been found from observation that the salts that are harmful for plant life are sodium carbonate and the chlorides and sulphates of sodium and magnesium. The methods adopted by chemists for determining the different constituents of waters and the methods of combining these constituents show great variance and are more or less conventional.

Professor Hilgard of the University of California, in his bulletin on waters and water supply, gives his results as follows :—

Total solid residues after evaporation.

Soluble part after evaporation.

Insoluble part after evaporation.

Organic matter.

Silica, ferric oxide and alumina.

From the above it will be seen that calcium and magnesium carbonates which, after evaporation, become insoluble on account of the dissolved carbon dioxide escaping, are separated out, and only that part which is soluble in water after evaporation is considered harmful for plant life. In col. 10 of the Table of Analysis appended are shown the soluble portions injurious to plant life in the waters analysed in the Laboratory of the Government Agricultural Chemist, Madras.

Another method adopted for determining alkalinity as sodium carbonate and permanent hardness as calcium sulphate, consists (Arizona Bulletin No. 404) in adding dilute standard sodium carbonate solution to a portion of the water, evaporating to dryness, again taking up with water and titrating with sulphuric acid. If the sulphuric acid required is less than the equivalent of sodium carbonate employed, some of the latter is shown to have been changed through reaction with the permanent hardness of water.

Thus:—$CaSO_4 + Na_2CO_3 = CaCO_3 + Na_2SO_4$

But if more than the equivalent amount of sulphuric acid is required, the sample is shown to have originally contained an excess of alkalinity, presumably sodium carbonate. With phenolphthalein, this alkalinity signifies for the most part calcium and magnesium carbonates in these dilute saltish waters ; with mythyl orange, it indicates in addition the presence of bicarbonates. The order of the combination of sulphuric acid with the bases is given as sodium, potassium, calcium and magnesium.

In the Wyoming Agricultural Experimental Station, (Bulletin No. 24) the bases are combined in the order, Li, K, Na, Mg and Ca and acids as Cl, SO_3 and CO_2; and the easily soluble salts

NaCl, Na_2SO_4, Na_2CO_3, K_2SO_4, KCl, $MgCl_2$ and $MgSO_4$ constitute the alkali which is harmful for plant growth.

In the Bulletin on Salt lands in the Nira Valley by Harold Mann, (Bombay Bulletin) it is stated that "potash is not usually estimated. Material alkaline to potassium hydrogen sulphate using phenolphthalein as indicator is counted as sodium carbonate. All other CO_2 is combined with calcium, the excess with magnesium and again the excess with sodium as (bicarbonate)". Sulphuric acid and chlorine are combined with the base in the same order as stated in the Wyoming Agricultural Station Bulletin above referred to.

From the above it is seen that the estimation of ingredients and their conventional combination are varied and complicated. The method adopted for water analyses here, is the same as the determination of soluble salts in the water-extract of alkaline lands and is as follows :— It consists in determining CO_2 using mythyl orange as indicator and combining the same as carbonate with calcium, magnesium and sodium in order and then sulphuric acid and lastly chlorine with the above bases in the same order. In this method, though sodium may exist as bicarbonate, to avoid complication and because sodium bicarbonate is also injurious to plant life, though in a less degree, the whole quantity is entered as sodium carbonate. The total solids are obtained by evaporation on the water bath and then dried in the steam oven and sometimes in an air oven kept below 110°C, but without any ignition. The entries are all given per 100,000 parts, though in some books "grains in a gallon" (that is, per 70,000 grains) is the usual entry. If required, parts per. 100,000 may be converted into grains in a gallon by multiplying the same by 7 and dividing by 10.

Amounts of salts in waters harmful to crops. The liability of crops to injury owing to the unsuitability of irrigation water is determined by the following factors:

(1) The nature of the soil.

(2) The amount and nature of the saline constituents present.

(3) The nature of the crop.

In a stiff soil which does not allow of good drainage and where the downward movement of the roots is restricted, a comparatively small amount of alkali is harmful, while, in a sandy soil, a comparatively large amount of alkali may not be harmful.

The chief alkaline constituents of water which affect its suitability for irrigation purposes are the following:—sodium carbonate and chlorides and sulphates of sodium and magnesium. Under natural soil conditions, sodium carbonate is the most harmful of all the alkaline salts. Porfessor Hilgard says that the effects of carbonate of soda are seen in the yellowing of the leaves of a tree caused by its corrosive action on the root crown, whereby the proper flow of sap and food supply to the leaves is prevented. It further spoils the mechanical texture of a soil. It dissolves the humus of a soil and black patches of this are seen here and there. An accumulation of this salt on any land causes "black alkali". Sodium chloride is the next harmful of the salts. Sodium sulphate is harmful only when present in very large quantities. This causes what is known as "white alkali" in soils. In water cultures, magnesium salts (especially magnesium chloride) have been shown to be as harmful as sodium carbonate.

In the annexed table are given the analyses of certain well waters situated in or about the Central Agricultural Station, Coimbatore. From this it will be seen that, out of the total amount of alkali shown in Col. 10, (sum of Na_2CO_3, $MgSO_4$, Na_2SO_4, $MgCl_2$ and $NaCl$) sodium carbonate which is the most harmful forms, however, only a small percentage ; the alkalinity of the waters being due chiefly to the large amount (75%) of sodium chloride present.

With regard to the actual amount of alkaline matter present in a water which decides its suitability or unsuitability for irrigation purposes, it is not always possible to go by any definite rule as other factors have also to be taken into consideration. A few examples of cases where the effect of irrigation with saline water have been observed are quoted below.

In the Arizona Bulletin No. 33, it is stated that, with the agricultural conditions found in Arizona including calcareous soils, invariably salty irrigation waters, good drainage and great evaporation, generally loams after 8 to 12 year's irrigation from salt river, through shallow furrows and shallow irrigation, have been observed to accumulate amounts of alkali salts near the surface of the soil, injurious to the more susceptible crop, plants and trees. The salts of the salt river above referred to vary from 71 to 157 per 100,000 parts during different periods of the year. The main character of the salt is sodium sulphate.

Professor Hilgard, in the Californian Bulletins, says that waters in New Mexico containing 113 to 152 parts of common salt and sulphates of sodium, potassium and magnesium in 100,000 parts of water have embarassed the agriculture of the district, and, in some cases, have caused the abandonment of farms.

Again in river side country, 137 to 171 parts per 100,000 consisting of $\frac{3}{5}$th sodium chloride, $\frac{1}{5}$th sodium sulphate and $\frac{1}{5}$th sodium carbonate have, in 3 years, caused the death of orange trees.

In the Wyoming Agricultural Experimental Station Bulletin, No. 24 of 1895, a water containing about 52 parts of total solids and 27. 4 of alkali is spoken of as 'not a good water.'

The following observations of Professor Hilgard on the analyses of certain well waters will be of interest :—

1. Spring water at the foot of the hills of the coast range in western Tular country. The water is clear, odourless, but with a flat brackish taste. It has a strong alkaline reaction. Total residue on evaporation 356·8.

Remarks :—This water, by far, is too strongly mineral to be safely used by either man or beast, being a saline purgative of considerable strength and unfit for any but careful medicinal use. The soluble part chiefly contains glauber and common salts, (sodium sulphate and chloride).

2. An artesian well. Total residue on evaporation 244·

Remarks:—This water is altogether too strongly impregnate with mineral salts for domestic use and could be used fo irrigation, only under exceptional conditions.

3. Artesian water used for irrigation. Total solids left afte evaporation 136·3.

Remarks :— The amount of mineral water contained is abou 4 times as great as is usually considered compatible with the us of water for irrigation, unless special precautions are observed The main ingredient is common salt which is not very injurious unless accumulated in very large quantities. This accumulation can be prevented by proper drainage from time to time.

Professor Hilgard concludes that 80 to 100 grains of salt pe gallon which is roughly equivalent to 120 to 152 parts in 100,000 parts is dangerous.

Storer says that any water which contains more than $\frac{1}{1000}$th the part of salt (equivalent to 100 parts in 100,000 of water) cannot be recommended for irrigation.

Broadly speaking, we may say that 40 grains per gallon or 60 parts in 100,000 of water is a fair quantity of salt allowable in an irrigation water for crops like betel which stand long on the land and which require large amount of irrigation waters. For crops which require, however, occasional irrigation such as maize, wheat, etc., as much as 100 parts per 100,000 may be allowed.

Tolerance of salt by differeut crops. Different crops stand different amounts of salinity. With regard to crops like cholam which require occasional watering and which can stand fairly large amounts of salts, deep tillage, good drainage, soil mulch and other methods which prevent accumulation of salts on the surface should be adopted when salty waters are used. Tobacco is said to be one of those which can stand large amount of alkaline salts but the burning quality of tobacco is affected by the use of waters which contain chlorides. The highest amount of tolerance of salts in 4 feet of soil as stated by Professor Hilgard is noted below.

	Highest amount of tolerance of salt in 4 feet of soil.
Sorghum	81360 lbs.
Radish	62840 ,,
Sunflower	59840 ,,
Sugar beet	54480 ,,
Potatoes	38340 ,,
Barley	25520 ,,
Wheat	17280 ,,
Ragi	12000 ,,
Pennisetum Tybhoideum	9000 ,,
Legumes	3000 to 4000 lbs.

Leguminous crops do not seem to show the same amount of tolerance towards saline ingredients as cereals.

In the above bulletin it is stated that citron is affected by a small quantity of salt in water and that other fruit trees *e. g.* figs, cannot be grown with water which gives luxuriant crops of sorghum and wheat.

Turning now to the table of analyses appended, it will be seen that Nanjappa Aiyer's well (Lab. No. 40), contains more than 400 parts of alkaline salts. It was recently observed that even cholam crop which was growing under it was pale and unhealthy. Garden lands very rarely possess facilities for flooding the land with channel, river or tank waters. Except in very few favourable localities like the West Coast, rainfall also is not so abundant as to wash out all accumulated salts. The natural drainage of such garden lands is not always very good. Moreover on account of evaporation, salts accumulate in the surface soil, wherefrom the young seedlings get their nourishment. Hence, where flooding and washing of salts are not possible if once salts accumulate on the surface, it is very difficult to reclaim such lands. Thus Lab. No. 40 well contains more than 400 parts of alkaline salts. Taking one acre-inch of water as 100 tons or 22,400 lbs we find that for an acre-inch of water, the amount of salt added to the land would be 896 lbs.. Therefore to saturate a soil with the highest amount of alkali that a crop like cholam can stand, we have to use 81360 ÷ 826 or roughly 90 acre-inches of water. Assuming that cholam requires only 15 inches of water, it is seen that in six years the land becomes so saturated with salt that it is unfit to grow anything else. Natural drainage and rainfall, no doubt, wash out some of the accumulated salt. These may prolong the life of a field to grow any crop by a few years more. It is therefore dangerous to irrigate lands with water which contain 400 parts of alkali. Under careful cultivation, water containing about 150 parts of salts per 100,000 may be used for raising crops like cholam and wheat. Cocoanuts are said to stand a larger amount of salt. The tolerance of salts of chillies, tobacco etc. are not known. They also seem to stand fairly large amount of salt. The subject of the tolerance of Indian crops to alkaline salts does not appear however, to have been studied in any detail.

Sugarcane and its tolerance of salt. In the Bulletin on the salt lands of Nira valley, it is stated sugarcane, when well manured and watered, is a crop very resistant to be damaged by salt and, as a rule when it will not grow, the land can be used for little else. But the effects of salt in water has a very injurious effect on the quality of the cane as also on its outturn, as has been found from experiments conducted in Hawaii by the Sugar Planters' Association.

REPORT OF HAWAII SUGAR PLANTERS' ASSOCIATION (1913).

IRRIGATION WITH SALT WATER.

Water used for irrigation containing.	Salts added per acre during crop growth.	Canes per acre.	Sucrose %	Chlorine. %
50 grains salts per gallon	14,159 lbs.	135,675	18·1	0·052
100 " " "	28,318 "	92,754	18·3	0·0778
150 " " "	42,477 "	102,744	17·0	00·778
200 " " "	56,636 "	79,860	16·35	0·1010

It may be noted that availability of sugar is greatly influenced by the amount of chlorine (salt) in juice.

Plot No.	Salt per gallon of irrigation water.	Lime added.	Sucrose %	Glucose %	Chlorine per gallon of juice grains	Sugar per acre.
1.	None	No lime	18·90	·43	9·8	25,648lb.
2.	200 grains	coral (powdered)	14·40	·53	93·1	5,448
3.	200 grains	Gypsum	14·50	·56	84·94	5,461
4.	200 grains	No lime	13·80	·50	105·24	3,715

From the above it is seen that salt in water influences the quality of juice to a great extent. The effect of lime, in some form or other, gave slightly better results than the plots where there was no application of lime. It is also stated that occasional heavy irrigations given to a moderately porous soil receiving brackish irrigation is most effective.

Results of analyses of samples of River, tank and well waters analysed at the Laboratory of the Government Agricultural Chemist.

Laby. No.	Particulars.	Calcium carbonate ($Ca CO_3$).	Magnesium carbonate ($Mg CO_3$).	Sodium carbonate (Na_2CO_3).	Calcium sulphate ($Ca SO_4$)	Magnesium sulphate ($Mg SO_4$)	Sodium sulphate (Na_2SO_4.)	Magnesium chloride ($Mg Cl_2$)	Sodium chloride (NaCl).	Total solids by evaporation.	Total alkalin, salts (sum of 5, 78 ,·9 and 10).	Remarks.
1	2	3	4	5	6	7	8	9	10	11	12	13
		In 100,000 parts of water.—										
192-09	Hagari farm well water.	29·5			77·7	139·5	427·4		561·1	13100	1157·5	Unfit for irrigation and drinking purposes.
214-09	Godavery river water at low tide	5·80	3·53			·36	2·62		24·57	1235·2	1205·7	The above analyses show that river waters are all good. Besides the above a large number of high and low tide waters of Yenamaduru drain have been analysed. These analyses vary at different times and at different seasons. When the drain waters get mixed with a large amount of sea water they become unfit for irrigation.
215	,, high tide	4·29	1·86			·31	·	·22	5·5	12·23	6·0	
612	,, low tide	5·18	1·53				·2		4·98	11·9	5·2	
217	,, high tide	4·02	2 08			·165	·11		3·51	9·8	3·8	
225	,, low tide	4·91	·08			·39		2·38	5·87	16·85	10·64	
226	,, high tide	4·50	·26			·01		2·35	·99	16·50	4·34	
242	Cauvery river water									16·0		
282	,,									17·75		
585	,,									20·0		
293	Krishna river water.									16·5		

278	Tank water, Nuzvid	7·14	2·41			1·41	11·73		40·95	69·0	54·09	This water is passable for irrigation.
234	Surappa Naicken's well,—Mannargudy.	17·86	10·23			9·69	117·15		39·22	214·5	166·06	Provided there is good drainage, these waters could be used for crops like cholam and ragi.
298	Venkatappa's well, Porto Novo.	14·82	8·16			15·9	11·66		108·27	168·6	135·86	

Errata :-

On page 24, opposite to Hagari Farm well water, for 13100 in column 11, read 1235·2.
" " 1157·5 " 12, " 1128·0.
On page 24, opposite to Godavery river water, 214|09, for 1235·2 in column 11, read 36·88.
" " " for 1205·7 " 12, " 27·55.

Results of analyses of well waters of Cane Breeding station, Settipalayam and also some of the wells of the Central Farm, Coimbatore and wells of Singanallur and Samakulam Agraharam.

(In 100,000 parts of water)

Laby Nos.	Particulars.	$Ca CO_3$	$Mg CO_3$	$Na_2 CO_3$	$Ca SO_4$	$Mg SO_4$	$Na_2 SO_4$	$Mg Cl_2$	Na Cl	Total solids by evaporation	Total injurious or alkaline salts cols. 3,5,6,7 & 8
		1	2	3	4	5	6	7	8	9	10
	Settipalayam—										
1	„ No. 1 well water	21·42	9 07	10·39	„	„	10·37	„	32·58	91·00	53·34
2	„ No. 3 „	26·80	29·55			11·85	48·16	„	188·98	342·00	248·99
8	„ No. 2 „	26·80	23·70			9·30	21·66	„	151·90	252·00	182·86
9	„ No. 4 „	21·42	21·95	16·38	„	„	49·35	„	133·38	260·00	199·11
10	„ No. 5 „	23·20	31·79	2·09	„	„	82·89	„	235·16	388·00	320·14
11	„ No. 6 „	14·30	25·35	12·19	„	„	54·85	„	154·44	274·00	221·48
	Central Farm—										
12	Bellary mhote well	22·32	28·29		„	5·01	38·57	„	91·29	212·00	134·87
13	„ Bot. garden well	30·36	18·79			32·97	„	„	127·42	239·00	165.24
14	„ 4 mhote well	17·86	19·68	17·	„	„	43·27	4·85	88·93	204·00	149·91
15	„ Soda well water	13·21	4·87	„	„	·60	0·39	„	0·36	30·00	10·35
30	Channel water Settipalayam	11·61	12·87	1·13			1·20	„	13·44	44·00	15·77
	Singanallur										
22	„ Krishnan Naicken's well	24·10	14·62			13·14	„	„	52·65	126·00	65·79
23	„ Palni Naicken's 5 mhote well.	17·86	17·41	7·85	„	„	7·31	„	33·93	93.00	49·09
24	„ Palni Naicken's 3 mhote well.	20·54	19·70			2·16	4·76	„	36·27	95·00	48·19
25	„ Kasturi Naicken's well	26·78	12·38			12·87	„	5·72	49·40	128·00	67·99

26	,, Ranganath Naidu's well.	26·78	1·15			15·45	,,	10·90	35·90	107·00	62·25
27	,, Sundara Naicken's well.	22·32	19 89			1·86	4·51	,,	34·93	93·00	41·30
28	,, Rangaswami Naicken's well	34·82	1·49			24·36	17·29	,,	96 52	190·00	138·17
29	,, Guruswami Naicken's well	20·55	12·46			3·58	6.49	,,	33·93	89·00	44·00
35	*Samakulam Agraharam*										
36	,, Appu Iyer's well No. i	16·07	12·12	6·35	,,	,,	2·73	,,	8·19	54·50	17·27
37	,, ,, No. ii	14·30	9·85	8·43	,,	,,	1·24	,,	4·68	46·00	14·35
38	,, Muthu Iyer's well	14·30	13·25	4·15			3·05	,,	5·85	49·00	13·05
39	,, Kuppu Iyer's well	29·46	10·12			15·21	1·65	,,	72·54	155·00	89·40
40	,, Venkata Ponnya's well	17·86	9·85	3·62			3·66	,,	8·19	52 00	15·47
	,, Nanjappa Iyer's well	49·00	,,	,,	25·65	92·97	176·48	,,	141·57	530 00	436·67

Remarks about Settipalayam wells. Except No. 1 well, all others contain large amounts of alkaline salts. Crops that stand alkaline salts well and which require occasional irrigation, like cholam and tobacco are being grown.

Central Farm wells. The quality and out-turn of sugar-cane grown under the four mhote well in the Central Farm were not satisfactory. Good crops of cholam and ragi are grown under under these wells.

Soda well water and Settipalayam channel water. The waters are quite good, the latter being the source of irrigation for the adjoining paddy fields.

Singanallur wells. The drainage of the soils is good. Many of the lands under these wells are irrigated by well, as well as, tank water, and hence any accumulation of salts due to well water irrigation will be washed out by the purer tank water. Betel leaf gardens are grown under wells Lab. Nos. 23 and 27. The quality of water differs in different parts of the year. Sugar-cane is grown under all the wells.

Samakulam Agraharam wells. The water of well Lab. No. 38 is said by ryots to be not so good for sugar-cane cultivation Wells Nos. 35, 36, 37 and 39 are all very good. Good crops of sugar-cane are grown. The ryots claim that the jaggery produced is sweeter and superior to that of Singanallur jaggery. Well No. 40 is the worst. Water of that well shoud not be used for any crop. Cholam and cotton which were growing were pale and poor.

SUMMARY.

1. Irrigation well waters generally contain in solution salts harmful, in a greater or less degree, to plant life.

2. The more common harmful salts are the chlorides and sulphates of sodium and magnesium and the carbonate of sodium.

3. Sodium carbonate is the most harmful, sodium chloride comes next in its bad effects on plant life and the least harmful are the sulphates.

4. Usually, water containing 50 parts of total solids in 100,000 parts, can be utilized for irrigating any crop and may be classed as good water.

5 More than 150 parts of total solids in 100,000 parts of water is considered bad for crops like betel which stand long on the land and which require large amounts of irrigation water. Some crops like cholam can stand much larger amounts of these salts. Different crops can tolerate different amounts of salts.

6. Sugar-cane can come up well with waters containing large amounts of salts in a well manured and well drained soil, but the quality of juice will be inferior and the quantity of sugar obtained will be very much less.

K. KRISHNAMURTI RAO.

NOTES

Presiding at the 32nd Annual Meeting of the Society of Chemical Industry, held at Liverpool in July 1913, Professor Marston Bogert of the United States delivered an interesting address on "the Chemical Industries and the Universities." Defining education as "the process of fitting the individual to take his place and do his best in the life of his age and nation," he said that the properly trained chemical graduate is, in the vast majority of cases, a far more valuable man to a chemical concern than the employee who knows only mechanical details and has not had the benefit of any real scientific education. At first the latter may appear to greater advantage because of his familiarities with the processes involved, but he will be very speedily outstripped by the University man, given at all a similar initial endowment. One is likely to be a rule-of-thumb man whose actions are wholly determined by experience and who is completely lost when anything new or unexpected happens. The other is the more resourceful and will seek the underlying cause of the difficulty and independently work out a remedy. Each has his place in the industrial life, but the scientifically trained man will rise to higher levels of usefulness. Manual skill is quite essential for a University man."