NATURAL WATERS OF THE QUEENSLAND COASTAL BELT.

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SUMMARY.

1. A number of natural waters have been examined, some by complete analysis and others by partial analysis; the methods are given in detail, with notes on cloudy waters.

2. The data are presented in terms of various ionic ratios, and in comparison with the two great divisions of natural water—the ocean and the great rivers of the world.

3. Compared with those of the great rivers, the waters of the Queensland coastal area exhibit a low ratio of calcium to magnesium, of divalent to monovalent bases (cations), and of bicarbonate to chloride. All these anomalies reflect oceanic influence.

4. The application of the data to boiler feed supply is discussed briefly. It is concluded that silica is not unduly high for tropical conditions.

Introduction.

The sugar-cane-growing tract in Queensland is a relatively narrow strip following the coastline and at no point extending more than about 50 miles from the sea. Although the average annual rainfall within this tract varies from less than 40 inches to over 200 inches, it might be expected that the natural waters of the region would have something in common in respect of the kinds of dissolved substances as distinct from their concentration. Particularly is this the case in view of the established fact (Anderson, 1941; Teakle, 1937) that "cyclic salt" caught up from ocean spray may be carried many miles inland and dominate the mineral content of the rivers and ground waters. Since the relative amounts of various ions in a water supply may often be of greater importance than the total amount of those ions, this paper aims at characterizing the waters of the Queensland coastal belt on the basis of ionic ratios, comparing them with the natural waters of other countries, and making what deductions are possible regarding their use.

The available data consist of a large number of partial analyses, and a smaller number of complete analyses in which all the ions commonly present were estimated or in which one ion was found by difference.

Methods.

(a) *Partial Analysis:*

Chlorides.—Titrate 50 ml. (10 ml. for brackish waters) with $N/_{35}$ silver nitrate, using a few drops of 10 per cent. potassium chromate as indicator.

$$1 \text{ ml. } N/_{35} \text{ AgNO}_3 = 0.00165 \text{ g. NaCl};$$

Per cent. $\times$ 700 = grains per gallon (gr.p.g.).

Chlorides are here reported as grains of equivalent NaCl per gallon. This is justified by the absence of wide divergences in the $^{Na}/_{Cl}$ ratio of the waters analysed.

Total Alkalinity.—Titrate 100 ml. water, in an Erlenmeyer flask, with $^N/_{20}$ HCl, using as an indicator four drops of a 0·1 per cent. alcoholic solution of methyl red. (Acid waters are titrated with $^N/_{20}$ NaOH).

$$1 \text{ ml. } ^N/_{20} \text{ HCl} = 0.0025 \text{ g. } CaCO_3.$$

In conformity with convention alkalinity is expressed as grains of $CaCO_3$ per gallon.

Total Hardness.—Take the titrated sample used for determining total alkalinity, heat to boiling point, and add 50 ml. of a $^N/_{20}$ alkali solution which contains equivalent parts of NaOH and Na_2CO_3. Bring the solution to the boil, cool, and transfer to a 200 ml. graduated flask. Make to the 200 ml. mark, and filter through an open paper. Titrate 100 ml. filtrate with $^N/_{20}$ HCl, after adding two more drops of indicator.

Treat 100 ml. distilled water in the same way for a blank determination.

In cases where the back-titration requires less than 10 ml. of $^N/_{20}$ HCl, the estimation should be repeated, using 50 ml. water for both test and blank. This is to ensure that there is sufficient hydroxyl ion present to precipitate all the magnesium.

Hardness is calculated from the amount of alkali consumed and is reported as grains of $CaCO_3$ per gallon.

Free Alkali.—When Total Alkalinity exceeds Total Hardness the excess is due to Free Alkali, which is also expressed as $CaCO_3$.

(*b*) *Complete Analysis.*

Chlorides.—Determine as for partial analysis, but report as milliequivalents of Cl per litre.

Carbonate and Bicarbonate.—Test 100 ml. water for presence of carbonate with a few drops of 1 per cent. alcoholic solution of phenolphthalein and if necessary titrate with $^N/_{20}$ HCl till colourless. Proceed with the methyl red titration as in partial analysis under "Total Alkalinity." Report as milliequivalents of HCO_3 (or CO_3) per litre.

Sodium.—

Reagent: 30 g. uranyl acetate $(2H_2O)$;
           90 g. zinc acetate $(3H_2O)$;
           27 ml. 30 per cent. acetic acid ;
           243 ml. distilled water.

Weigh the salts into a flask, add the acetic acid, then the water, and warm till dissolved. Filter before use.

Evaporate 25 ml. water (less if Cl exceeds 5 m.e. per litre) to dryness in a porcelain basin. Ignite gradually till the floor of the furnace is dull red,

and then for a further ten minutes to char organic matter. Cool, extract the
contents several times with distilled water, using gentle heating, and filter using
an acid-washed paper and a porcelain receiving dish. (A coloured extract
indicates that the igniting must be repeated). Evaporate filtrate to dryness,
add 1 ml. of distilled water and 10 ml. reagent; cover well to prevent evapora-
tion, and let stand for four hours. Filter through a glass filter (grade 1G3),
sucking the precipitate dry before washing several times with 95 per cent.
alcohol saturated with the triple sodium salt. Wash twice with ether and stand
in a warm place till ether has evaporated. Cool and weigh.

$$\text{Wt. of precipitate} \times 0.65 = \text{m.e. Na.}$$

Silica, Sesquioxides, etc.—Evaporate 500 ml. water to dryness, flood the
residue with conc. HNO_3, and evaporate dry. Repeat this twice with 20 per
cent. HCl, and bake on a hot plate for one hour. Take up in 20 per cent. HCl
and warm water, so that only flocculent silica (but no granular salts) remains
undissolved. Filter through an open paper. Wash the filter well, dry, and
gently ignite in a platinum dish, increasing the heat until a clear ash is obtained.
Cool and weigh. Report as p.p.m. SiO_2. Make the filtrate to a known volume
for determination of sesquioxides.

(Silica may also be determined with sufficient accuracy by a colorimetric
method (Queensland Department of Agriculture and Stock, Bureau of Sugar
Experiment Stations, 1939, p. 146)).

Treat one-half of the filtrate with a few ml. of bromine-water and boil
off the fumes. Add more bromine-water, and then add ammonia until fuming
in the mouth of the beaker ceases. Add 5 g. NH_4Cl and completely neutralize
with ammonia. Bring to boil and filter through an open paper. Wash precipi-
tate well with 2 per cent. ammonium nitrate solution made just alkaline with
ammonia. Ignite and weigh the precipitate as for SiO_2 determination.

Calcium.—Boil the filtrate from sesquioxide determination till, on adding
HCl and methyl red, the indicator still retains its red colour. Add 10 ml.
saturated ammonium oxalate solution and gradually bring to a yellow colour
with ammonia. Stand overnight, filter, and wash precipitate repeatedly till the
washings have ceased to reduce acidified permanganate. Then dissolve the
precipitate in dilute H_2SO_4, add 20 ml. conc. H_2SO_4, and titrate with $^N/_{20}$
$KMnO_4$.

$$\text{Titration} \times 0.05 = \text{m.e. Ca.}$$

Magnesium.—Concentrate the calcium filtrate to 100 ml., add 10 ml. $^N/_2$
sodium dihydrogen phosphate and, stirring vigorously, add ammonia to an
excess of 20 ml. 5N solution. Stand overnight. Filter through asbestos in a
Gooch crucible, wash with 2 per cent. ammonia, dry in an oven, ignite strongly
for 20 minutes, cool and weigh.

$$\text{Wt. of precipitate} \times 17.96 = \text{m.e. Mg.}$$

Sulphate.—Boil the other half of the filtrate from the silica determination and add 5 ml. $N/_2$ BaCl$_2$ drop by drop. Stand overnight. Filter through the finest paper, wash, and ignite as for SiO$_2$.

$$\text{Wt. of precipitate} \times 8.57 = \text{m.e. SO}_4.$$

Potassium.—Take 500 ml. water and determine potassium by the platinic chloride method (Queensland Department of Agriculture and Stock, Bureau of Sugar Experiment Stations, 1939, p. 154).

Discussion of Methods.

Analysis of Coloured and Cloudy Samples.—Soil colloids readily absorb methyl red indicator, and soluble organic matter masks its colour. Experiments, as shown in Table 1, were carried out on clear samples of known analysis to determine the effects of various clarifying treatments. The agents used were B.D.H. acid-washed kieselguhr, Merck's X-ray grade barium sulphate, and Merck's bone char, each at the rate of 1g.-2½ g. per 100 ml. water. The samples were either centrifuged or filtered through a Whatman's No. 4, a Whatman's No. 50, or a "Postlip" No. 633 filter paper. The results of the experiments indicated that—

(1) Centrifuging with either barium sulphate or kieselguhr resulted in a colloidal condition;

(2) Filtration alone was more effective with an open paper (No. 4) than with a close one (No. 50);

(3) 1 per cent. kieselguhr treatment and filtration through No. 4 paper gave sparkling solutions. The disturbance due to filtration was usually enough to lower the bicarbonate content; and kieselguhr, besides having the most desirable qualities in producing bright solutions, had little other effect on the composition of the water.

Table 1.

EFFECT OF CLARIFYING AGENTS ON ANALYSIS OF WATERS.

Water.	Treatment.	Chlorides (as NaCl).	Total Alkalinity.	Total Hardness.	Free Alkali.
		gr. p.g.	gr. p.g.	gr. p.g.	gr. p.g.
Mossman Mill—					
Well Water	Filtration only				
	(Whatman's No. 50)	3·3	..	1·1	1·0
	1 % kieselguhr	3·3	..	0·9	1·55
A. J. Jacobsen, Graham's	None (cloudy water)	..	0·1	—0·2	..
Creek	1 % kieselguhr	..	0·4	0·4	..
Mixed Burdekin Waters	None	..	..	10·2	..
	Filtration only				
	("Postlip" paper)	..	..	9·9	..
B. Tapiolas, Ayr	None	..	..	4·5	..
	Filtration only				
	("Postlip" paper)	..	..	4·4	..
Synthetic Irrigation	None	..	..	5·2	..
Water	Filtration only				
	("Postlip" paper)	..	..	5·1	..

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Table 1—continued.

EFFECT OF CLARIFYING AGENTS ON ANALYSIS OF WATERS.

Water.	Treatment.	Chlorides (as NaCl).	Total Alkalinity.	Total Hardness.	Free Alkali.
		gr. pg.	gr. pg.	gr. pg.	gr. pg.
Mixed Burdekin Waters	None	..	10·2	9·45	0·75
	1% kieselguhr + 1% bone char ..	..	9·7	8·4	1·3
B. Tapiolas, Ayr ..	None	12·0	4·5	17·7	..
	1% kieselguhr + 1% bone char ..	12·35	4·5	17·0	..
Synthetic Irrigation Water	None	10·6	5·2	5·25	..
	1% kieselguhr + 1% bone char ..	10·9	5·2	5·4	..
Brisbane Water Supply (12–9–39)	None	9·7	7·4	12·1	..
	1% kieselguhr + 2½ % bone char ..	9·7	7·0	10·7	..
Brisbane Water Supply (6–12–30)	None	..	8·6	13·5	..
	1% bone char ..	..	8·0	13·3	..
Brisbane Water Supply (13–4–31)	None	..	5·0	7·4	..
	1% bone char ..	..	4·2	6·7	..
Brisbane Water Supply	None	..	7·7	..	..
	Filtration only ..	..	7·6	..	..
	1% kieselguhr ..	..	7·5	..	..
J. Toft, Avoca	1% kieselguhr ..	4·0	7·9	7·4	0·5
	1% kieselguhr + BaSO₄	3·6	7·3	6·3	1·0
J. H. Muir, Seaforth (1)	None	29·9	15·9	7·2	8·7
	Filtration only ..	29·9	15·8	..	..
	1% kieselguhr ..	29·9	15·8	6·65	9·15
J. H. Muir, Seaforth (2)	None	50·0	13·9	11·9	2·0
	Filtration only ..	50·2	13·7	11·4	2·3
	1% kieselguhr ..	51·2	13·7	11·0	2·7
Distilled Water	None	0·3	0·2	0·4	..
	Kieselguhr	1·6	1·6	2·6	..

The preferred method of treatment for a cloudy water which will not clear by standing or by direct filtration is, therefore, to add 1 per cent. of kieselguhr and filter through an open paper. The flocculent precipitate formed in the hardness estimation automatically leaves the solution clear for subsequent titration.

For more accurate work, and when colour is not easily removed, chlorides are estimated by the electrometric method (Best, 1929); and bicarbonates by a titration curve, using the glass electrode.

Value of Partial Analysis.—It may be noted that Total Hardness determined by partial analysis gives a good estimate of Ca + Mg as found by complete analysis. This is shown in Table 2. In the case of the sample Composite V it was found that the precipitate in the partial analysis contained silica

equivalent to 1·1 grains per gallon, suggesting that the slightly higher values for Total Hardness usually given by partial analysis may be due to co-precipitated silica.

Table 2.
SHOWING ACCURACY ATTAINED IN PARTIAL ANALYSIS.

Water.	Total Hardness.	
	By Partial Analysis.	From Ca + Mg Equivalent.
	gr. p.g. CaCO$_3$.	gr. p.g. CaCO$_3$.
Lab. 576, Fairymead Plantation—No. 1 Dam	2·1	1·6
Lab. A. 2176, North Eton Mill—Loco. Supply	7·0	6·9
Composite V. Mixed Burdekin Waters	7·3	6·2
Lab. A. 1437, Sarina Distillery—Boiler Feed	10·7	9·3
Irrigation Water	11·1	8·9
Composite XVII., Mixed Burdekin Waters..	12·7	12·8
Lab. 851, Qunaba Plantation—Irrigation Supply	55·0	49·7

The partial analysis may also be used to obtain an approximate value of the important $\dfrac{Ca + Mg}{Na + K}$ ratio. Total Hardness is substituted for Ca + Mg, and the Chloride content is used as an indication of the alkalis present. The justification for the latter assumption lies in the fairly constant approach of the ratio $^{Na}/_{Cl}$ to unity, as shown in Table 5, and the negligible amount of K in natural waters. Before the $\dfrac{Ca + Mg}{Na + K}$ ratio can be calculated the Total Hardness and the Chloride content must be converted to chemically equivalent values. The conversion gives the equations:—

$$\frac{Ca + Mg}{Na + K} = \frac{Total\ Hardness}{50} \times \frac{58·5}{Chloride} = \frac{Total\ Hardness}{Chloride} \times 1·2.$$

The writer has shown (Cassidy, 1944) that the value of the $\dfrac{Ca + Mg}{Na + K}$ ratio determines the quality of an irrigation water and the effect it will have on the replaceable bases of a soil. Since the divalent bases produce desirable physical properties in a soil, whilst the monovalent bases have the reverse effect, the importance of the ratio from the agricultural aspect is apparent.

Discussion of Data.

Composition of Waters.—Table 3 presents data on waters from various parts of coastal Queensland, representing either sugar mill boiler-feed supplies or farmers' irrigation water. The concentrations of the various ions are given as milliequivalents per litre, and in Table 4 they are expressed as a percentage of the total ion content. This means that only the relative proportions of the ions present need be considered and that the actual concentration of salts in the water may be disregarded. The relative values for some

southern Australian rivers and water-supplies are also given, as well as those for sea water and for the mean of the great rivers of the world (Clarke, 1924).

Table 3.
ILLUSTRATING THE COMPOSITION OF SOME QUEENSLAND COASTAL WATERS.

Lab. No.	Water.	HCO_3	Cl	SO_4	Ca	Mg	Na	K
		(Milliequivalents per litre).						
A.2020	Meringa Experiment Station ..	0·27	0·29	0·03	0·08	0·18	0·24	0·04
	Racecourse Mill—							
561	Supply Tank	1·17	0·52	0·09	0·9		0·88	
562	Pump Delivery	1·17	0·44	0·09	1·0		0·70	
A.1037	Farleigh Mill—Foulden Supply	1·05	0·50	0·14	0·60	0·35	0·73	0·03
A.1437	Sarina Distillery—Boiler Feed ..	2·42	1·75	0·16	1·52	1·13	1·25	..
A.2176	North Eton Mill—Loco. Supply ..	1·08	2·34	0·36	1·12	0·87	1·73	0·07
A.2203	Ollett Bros., Habana—Well ..	5·40	3·36	0·10	4·24	1·65	2·79	..
A.2187	W. E. Kelly, Hebron	1·18	1·71	0·86	1·38	1·52	0·85	..
	Qunaba Plantation—							
851	Irrigation Supply	4·12	21·51	3·66	3·99	10·18	12·62	0·27
	Fairymead Plantation—							
576	No. 1 Dam	0·93	2·11	0·14	0·20	0·25	2·7	..
635	Old Irrigation Plant, No. 1 ..	4·12	5·72	..	3·92		..	..
636	Old Irrigation Plant, No. 2 ..	3·62	5·47	..	4·09		..	..
	Fairymead Mill—Boiler Supply—							
A.1103	No. 1	0·72	2·09	..	0·27	0·49	..	..
A.1104	No. 12	20·82	5·58	0·80	0·50	1·42	5·28	..
A.1115	No. 2	0·90	2·58	0·63	0·20	0·53	3·38	..
A.1146	No. 2 (Repeat)	0·72	2·70	0·58	0·07	0·35	3·58	..
..	Brisbane Water Supply	1·48	1·67	0·27	1·17	0·62	1·71	..
..	Hawaiian Irrigation Waters (Aver.)	0·98	1·13	0·25	0·55	0·67	1·04	0·10

The sharp contrast between the composition of sea water and that of the great rivers is evident. Whilst sea water is dominated by sodium and chloride ions, the great rivers are dominated by calcium and bicarbonate. The waters of the Queensland sugar-cane-growing areas are intermediate in composition. This is well illustrated in Table 5, where ratios of one ion to another are given. These ratios emphasise the radical differences in composition between sea water and the great river waters. Anderson (1940) has stressed the equivalence ratio of $^{Na}/_{Cl} = 0.85$ as the characteristic of sea water, but Table 5 shows three other ratios demonstrating better the unique character of sea water among natural waters. This is doubtless due to the removal of calcium carbonate from the incoming river waters by sea organisms. The average $^{HCO_3}/_{Cl}$ ratio of 7 for river waters is thus reduced in sea water to a negligible value. The last column of the table shows that all the Australian waters listed have a $^{HCO_3}/_{Cl}$ ratio much lower than that of the average for world river waters. The low content of calcium *in relation to magnesium,* and of the divalent

bases in relation to the monovalent, is shown in the centre columns of the table. A large number of waters have been examined only by the partial method of analysis but they show a general conformity to the type revealed by the

Table 4.

COMPARING WATERS OF THE QUEENSLAND COAST WITH VARIOUS OTHER NATURAL WATERS.

Water.	HCO_3	Cl	SO_4	Ca	Mg	Na	K
			(Per Cent. of Total Milliequivalents.)				
Rivers Waters (World)	36·6	5·0	7·9	31·9	8·7	7·8	1·7
Sea Water	0·2	45·2	4·6	1·7	8·9	38·5	0·8
Queensland Sugarcane-growing Areas—							
Meringa Experiment Station	23·9	25·8	2·7	7·0	15·9	21·2	3·5
Racecourse Mill—Supply Tank	32·9	14·6	2·5	25·3		24·7	
Farleigh Mill—Foulden Supply	30·9	14·7	4·1	17·6	10·3	21·5	0·9
Plane Creek Distillery, Sarina—							
August, 1934	23·8	23·7	2·4	19·8	9·6	20·6	..
April, 1936	29·4	21·3	1·9	18·5	13·7	15·2	..
W. E. Kelly, Hebron	15·7	22·8	11·5	18·4	20·3	11·3	..
North Eton Mill—Loco. Supply	14·3	30·9	4·8	14·8	11·5	22·8	0·9
Ollett Bros., Habana—Well	30·7	19·2	0·6	24·2	9·4	15·9	..
Qunaba Plantation—Irrigation Supply	7·3	38·2	6·5	7·1	18·0	22·4	0·5
Fairymead Plantation—No. 1 Dam	14·7	33·3	2·2	3·2	4·0	42·6	..
Fairymead Mill—Boiler Supply—							
No. 12	5·7	38·6	5·6	3·5	9·9	36·7	..
No. 2	11·0	31·4	7·7	2·4	6·4	41·1	..
No. 2 (Repeat)	9·0	33·7	7·3	0·9	4·4	44·7	..
Other Queensland Waters—							
Copperfield River	34·7	15·3	0·0	16·5	18·2	15·3	..
Don River, Bowen	19·6	14·2	17·3	17·3	17·3	14·2	..
Dee River, Mount Morgan	14·5	23·3	12·2	12·2	19·2	18·6	..
Dawson River	23·5	24·3	2·2	25·7	16·3	8·0	..
Mary River (May, 1915)	23·7	26·3	0·0	11·8	19·1	19·1	..
Mary River (July, 1935)	10·6	35·4	4·0	6·9	22·3	20·8	..
Lockyer Creek	23·6	26·1	0·3	8·5	15·6	25·9	..
Tenthill Creek, Gatton	30·2	18·4	1·4	16·7	19·7	13·6	..
Brisbane River, Lowood (November, 1940)	15·4	32·5	2·1	10·9	17·1	22·0	..
Stanley River Dam	14·5	32·0	3·5	18·1	15·4	16·5	..
Brisbane Water Supply	21·4	24·1	3·9	16·9	9·0	24·7	..
Other Australian Waters—							
Sydney Water Supply	11·2	32·3	5·9	6·6	11·9	32·1	
Murray River, Merbein, Victoria	23·7	19·8	6·5	15·2	15·4	19·4	
Yarra River, Warrandyte, Victoria	15·4	30·2	2·4	9·1	13·2	25·7	3·2
Emu River, Burnie, Tasmania	15·6	29·1	4·6	16·6	5·6	23·3	5·3
Adelaide Water Supply	15·1	29·3	4·2	10·0	13·8	24·9	2·7
Canning River, West Australia	4·5	40·8	4·4	5·2	14·9	29·9	
Hawaiian Irrigation Waters (Average)	20·8	23·9	5·3	11·7	14·2	22·0	2·1

Table 5.

CHARACTERIZING THE TYPE OF WATER BY THE RATIOS OF ITS IONS.

Water.	Na/Cl	Ca/Mg	$\dfrac{Ca + Mg}{Na + K}$	$\dfrac{HCO_3}{Cl}$
River Waters (World)	1·6	3·7	4·3	7·3
Sea Water	0·85	0·2	0·27	0·005
Queensland Sugarcane-growing Areas—				
Meringa Experiment Station	0·8	0·4	0·9	0·9
Racecourse Mill—				
Supply Tank	1·6	..	1·0	2·2
Pump Delivery	1·6	..	1·4	2·7
Farleigh Mill—Foulden Supply	1·5	1·7	1·2	2·1
Plane Creek Distillery, Sarina—				
August, 1934	0·9	2·1	1·9	1·0
April, 1936	0·7	1·3	1·7	1·4
North Eton Mill—Loco. Supply	0·7	1·3	1·1	0·5
Ollett Bros., Habana—Well	0·8	2·6	2·0	1·6
W. E. Kelly, Hebron	0·5	0·9	3·4	0·7
Qunaba Plantation—Irrigation Supply ..	0·6	0·4	1·1	0·2
Fairymead Plantation—				
No. 1 Dam	1·3	..	0·2	0·4
Old Irrigation Plant No. 1	..	..	..	0·7
Old Irrigation Plant No. 2	..	..	..	0·7
Fairymead Mill—Boiler Supply—				
No. 1	1·0	0·6	..	0·3
No. 12	0·9	0·4	0·4	0·1
No. 2	1·3	0·4	0·2	0·3
No. 2 (Repeat)	1·3	0·2	0·1	0·3
Other Queensland Waters—				
Copperfield River	1·0	0·9	2·3	2·3
Don River, Bowen	1·0	1·0	2·4	1·4
Dee River, Mount Morgan	0·8	0·6	0·7	0·8
Dawson River	0·3	1·6	5·3	1·0
Mary River (May, 1915)	0·8	0·6	1·6	0·9
Mary River (July, 1935)	0·6	0·3	1·4	0·3
Lockyer Creek	1·1	0·5	0·9	0·9
Tenthill Creek, Gatton	0·7	0·8	0·3	1·6
Brisbane River, Lowood (November, 1940) ..	0·7	0·6	1·3	0·5
Stanley River Dam	1·1	1·2	2·0	0·4
Brisbane Water Supply	1·0	1·9	1·0	0·9
Other Australian Waters—				
Sydney Water Supply	1·0	0·6..	0·6	0·3
Murray River, Merbein, Victoria	1·0	1·0	1·6	1·2
Yarra River, Warrandyte, Victoria	0·8	0·7	0·8	0·5
Emu River, Burnie, Tasmania	0·8	3·0	0·8	0·5
Adelaide Water Supply	0·8	0·7	0·9	0·5
Canning River, West Australia	0·7	0·4	0·7	0·1
Hawaiian Irrigation Waters (Average)	0·9	0·8	1·1	0·9

complete analyses. For example, the ionic ratio of bicarbonate to chloride is usually less than unity. These facts are of considerable agricultural significance in their bearing on the use of water for irrigation; this aspect is discussed elsewhere (Cassidy, 1944).

Boiler-supply Water.—It is well known that the total amount of dissolved solids is of primary importance in water for steam-raising purposes, but that the sodium salts are of much less moment than are calcium and magnesium salts and silica. The Java Proefstation based its treatment of boiler waters on these facts by proportioning the dosage of tannin to the total hardness and to the silica present (see Queensland Department of Agriculture, Bureau of Sugar Experiment Stations, 1939, p. 144). It has been suggested that a boiler water will not deposit scale of any consequence if $SiO_2 + 2.95$ Ca $+ 1.66$ Mg is less than 300 p.p.m. In this formula Ca (in parts per million) has been calculated to a mixture of carbonate and sulphate, and magnesium to the oxide. This criterion was applied by the author to 63 cases cited by Paul (1923) and others, with the results shown in Table 6.

Table 6.

USEFULNESS OF FORMULA FOR PREDICTING SCALE-FORMATION IN BOILERS.

Designation.	Total Number.	Number Correctly Placed.	Average Coefficient. p.p.m.
Badly scaling waters ..	39	31	503
Non-scaling waters ..	24	22	173

Because sugar factories use relatively low-pressure boilers and a high percentage of condenser water, water-treatment plants are installed at very few Queensland sugar mills. The criterion given should therefore prove useful in testing the suitability of new supplies. The experience of Smith (1941) with boiler-water at an alcohol distillery is at variance with the rule given, but the high evaporation rate and the non-recovery of condensate in an alcohol distillery are probably responsible for the heavy scaling reported.

The presence of silica is important because it produces the hardest scale. Paul (loc. cit.) quotes cases of waters containing as much as 120 p.p.m. SiO_2, and tropical waters are commonly high in silica because of the effects of the particular soil weathering conditions. However, as shown in Table 7, the amount of silica present in Queensland coastal area waters is not high, although Kelly (1939) cites the unusual case of Kalamia mill water, in which the silica is present, not in the usual colloidal and uncombined state, but as sodium silicate and in fairly large amounts.

Liability to corrosion is not so readily predicted from chemical analysis; dissolved oxygen and the presence of much magnesium, accompanied by little bicarbonate ion, are factors favouring corrosion. Here again sugar factory practice averts most of the trouble and the maintenance of a sufficiently high pH in the boilers completes the control.

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Table 7.

SILICA CONTENT AND SCALE-FORMING FACTOR FOR VARIOUS WATERS.

Water.	SiO_2 (p.p.m.)	Ca (p.p.m.)	Mg (p.p.m.)	Coefficient (p.p.m.)
Mossman Mill	27	..	..	41*
Meringa Experiment Station	4	2	2	13
Racecourse Mill—Loco. Supply	28	..	..	593*
Racecourse Mill—Mount Ossa	16	..	..	120*
Farleigh Mill—Foulden Supply	29	12	4	71
Sarina Distillery—Boiler Feed	18	30	14	129
North Eton Mill—Loco. Supply	3	22	10	85
Kalamia Mill Supply	73	1·6	trace	78
B. Tapiolas, Ayr	24 / 55	..	..	270*
J. H. Muir, Seaforth	35 / 40	..	..	170*
J. Breen, Ayr—Lagoon	5	..	..	36*
Finn Bros., Home Hill	25	..	..	533*
G. Rogers, Peri	31	..	..	145*
Richards Plantation Creek	40	..	..	147*
Dick's Bank Lagoon	35	..	..	49*
Qunaba Plantation—Irrigation Supply	47	80	124	489
Fairymead Mill—				
No. 1 Pump	..	5	6	>25
No. 12 Pump	..	10	17	>58
No. 2 Pump	58	4	6	80
Brisbane Water Supply	24	23	8	105

* Derived from the Total Hardness + Silica.

Exceptional Waters.—In the preceding discussion attention has been confined for the most part to the normal waters of the region. There are, however, many instances of waters which fall outside the normal range because of some factor such as free acid, excess salt, or much free alkali. Examples are given in Table 8 of waters which would require special consideration. Only partial analyses are available, so Brisbane Water Supply is quoted in the same form for comparison.

Quite apart from these abnormal waters, there are waters in which the salt content is affected by heavy falls of rain following a dry period. Such waters usually return to normal as conditions become more regular, and the evidence on hand shows that ordinary fluctuations of this kind do not affect the major conclusion of this paper regarding the type of water, as demonstrated by the various ionic ratios shown in Table 5.

Need for Uniformity of Expression.—The fact that three systems of units—viz., grains per gallon, milliequivalents per litre, and parts per million—have had to be used in this paper draws attention to the need for uniformity of expression of analytical results, with chemically equivalent units as the only logical basis.

Table 8.

EXAMPLES OF EXCEPTIONAL WATERS.

Water.	Chlorides. (gr. p.g. NaCl)	Total Hardness. (gr. p.g.)	Free Alkali. (gr. p.g.)	Acidity. (gr. p.g.)
R. C. Quod, Proserpine	22	11	8	..
W. J. Nelson, Giru..	44	40	31	..
W. Moratt, Ayr	59	7	25	..
J. O. Jensen, Narpi, Mackay	25	31	10	..
Mullet Creek—Currajong ..	107	61	..	..
Mullet Creek—Well	446	42	..	3·5
Gin Gin—Creek	120	45	..	..
S. A. Wood, Bauple	9	2	12	..
Mount Bauple Mill	16	2	..	(pH 4·3)
Childers—Apple Tree Creek	170	51	..	..
Cordalba—Gregory River	170	42	..	..
H. H. Plath, Doolbi	306	66	..	(pH 4·0)
H. Cox, Horton	37	4	37	..
M. B. Fisher, Kolan R.—Creek ..	324	66	..	(pH 3·0)
M. B. Fisher, Kolan R.—Well	62	7	..	(pH 3·6)
Fairymead ..	19	3	31	..
H. J. Jacobsen, Graham's Creek, Maryborough	38	5	14	..
Brisbane Water Supply	6·8	6·3	..	..

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