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Water Supply for Industry  
at Lista.

By

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## 1. INTRODUCTION.

The following report describes an investigation of the lakes Kraagenesvatn, Hanangervatn, Neseimvatn and Brastadvatn as possible sources of industrial water for Elektrokemisk A/S, (Oslo). The samples were taken and observations in the field made on the 25th and 26th July, 1962. The purpose of the investigation was to determine the quality of the water in these lakes, particularly with regard to use of the water as a coolant. In judging the usefulness of a water for cooling purposes the possibilities for corrosion and biological growth in the cooling systems are of particular interest.

## 2. RESULTS OF THE INVESTIGATION.

The results of the limnological investigation and of the physico-chemical analyses carried out on water samples from the various lakes are shown in table 1 and figure 1. In figure 2 is given a survey sketch of the localisation of the sampling stations, which were chosen to lie in the deepest areas of the lakes. These lakes lie in a bedrock area which consists of acidic and difficultly erodable rock types. The loose surface covering is sand and gravel. There is a good deal of cultivated land in the watersheds. The lakes shores are to a large extent overgrown with higher plants.

### 2.1. Kraagenesvatn, station 1.

This lake is contemplated as the intake reservoir for the projected factory. The depth was approximately 14,5 m at the sampling station.

The temperature curve in figure 1 shows that the thermocline is not very distinct and lies deep. This is a result of the fact that the lake is situated in an exposed position in a flat area with a mild climate and much wind, so that in summer the water at the surface become heated, and with the help of the wind is mixed with the deeper layers. The change in temperature with depth begins at 8 m. At this depth the oxygen content of the water suddenly decreases and at 14 m there is practically no

oxygen present. This condition is due to the decomposition of organic material by micro-organisms in the lake. Oxygen is used in this decomposition process and the transfer of oxygen from the surface layers is too small to counterbalance the consumption in the summer.

The pH of the water is slightly acidic and decreases with depth, probably because acidic compounds are produced by the decomposition processes in the lower layers.

The hardness of the water is relatively low, and the chloride content is due to the fact that the lake is near the sea. The electrical conductivity increases with depth as a result of mineralisation and decomposition processes in the deeper layers.

The colour, turbidity and permanganate value for the water are relatively low at the surface but increase with depth owing to the biological decomposition processes. Apart from in the deepest layer, there is relatively little iron and manganese in the water.

## 2.2. Hanangervatn, station 2.

This lake is connected to Kraagenesvatn by a narrow sound. The depth at the sampling station was circa 10 m. The temperature curve shows little difference between the surface and lower layers of the lake. Hanangervatn is greater in surface area than Kraagenesvatn and is more affected by wind and waves, so that mixing of the layers is more extensive than in Kraagenesvatn. As a result the conditions of oxygenation in the lake are good at all depths.

The pH of the water is a little higher than in Kraagenesvatn, while the conductivity is consistently a little lower. The hardness is insignificantly lower than in Kraagenesvatn. Colour, turbidity and permanganate value are all lower than in Kraagenesvatn and the iron- and manganese contents are low.

The water in Hanangervatn is from a chemical point of view better throughout in quality than in Kraagenesvatn.

### 2.3. Neseimvatn, station 3.

The depth measured at the sampling station was circa 12 m. This lake resembles Hanangervatn with regard to temperature measurements and oxygen content. The pH of the water varies between 7,0 and 7,1 from the surface to the bottom. The electrolytic conductivity and hardness are higher than in Kraagenesvatn and Hanangervatn.

The colour of the water is higher than in Hanangervatn and of about the same order as in Kraagenesvatn. The same applies to the permanganate value, whilst the turbidity is low. The content of manganese is small but the iron concentration is a little higher than that regarded as desirable for a good-quality drinking water.

### 2.4. Præstvatn, station 4.

The depth measured at the sampling station was circa 12 m. No real thermocline is evident from the temperature data but the water below 10 m is a little colder than that above 10 m. At 10 m a decrease in oxygen due to decomposition processes becomes apparent. The water in the deepest layer does not become mixed with that in the shallower layer so that aeration cannot proceed to the same extent as in Hanangervatn and Neseimvatn. With regard to temperature and oxygen, it might be said that Præstvatn occupies a position between Kraagenesvatn on the one hand and Hanangervatn and Neseimvatn on the other.

The pH of the water of Præstvatn is a little on the acid side, and it decreases with depth owing to the production of acidic compounds by decomposition processes. The electrolytic conductivity and hardness are lower than those of Kraagenesvatn, Hanangervatn and Neseimvatn. The conductivity increases with depth because of mineralisation due to the decomposition processes. Colour, turbidity and permanganate value are all low but increase in the deeper layers. The content of iron and manganese is low apart from in the deepest layers.

### 2.5. Brastadvatn, station 5.

The depth measured at the sampling station was circa 10 m. The conditions of temperature and oxygenation here are similar to those measured in Hanangervatn and Neseimvatn.

The pH varies from 6,9 - 7,2 and the electrolytic conductivity from 11,3 - 11,4 .  $10^{-5}$  ohm<sup>-1</sup>. cm<sup>-1</sup>. The conductivity and hardness are thus higher than in any of the other four lakes. The turbidity is also a little higher than in the other lakes. Colour, permanganate value and iron content are very high, probably owing to large quantities of humus which enter the water from marshy land. From a chemical standpoint the water of Brastadvatn is of poor quality.

### 2.6. Corrosiveness of the different lake waters.

To obtain some idea of the corrosiveness of the lake waters towards objects made of cement, a "marble test" was carried out on samples from Kraagenesvatn, Hanangervatn, Neseimvatn, and Præstvatn. The samples were taken from a depth of 2 m in each case. The ability of the water to dissolve calcium carbonate over a contact period of 3 days was determined. The result of the marble test is really a measure of the content of calcium-carbonate corroding carbon dioxide. Carbon dioxide dissolved in the water transforms the insoluble calcium carbonate to soluble calcium bicarbonate. The results of the marble test are presented in table 2. All values are given as mg calcium carbonate/l. The figures in the table show that the water from each of the lakes contains a certain amount of carbon dioxide. The content of carbon dioxide is highest in Præstvatn, where the water is of low alkalinity, hardness and pH. The increase in alkalinity and hardness in Kraagenesvatn, Hanangervatn and Neseimvatn is of the same order.

### 2.7. Water samples from streams, stations 6, 7 and 8.

Stations 6, 7 and 8 in table 1 represent samples from streams. Station 6 is in the stream from Brastadvatn below the waste water outfall from a dairy. Station 7 is in the stream from Præstvatn, while station 8 is in the stream below the confluence

of the streams from Brastadvatn and Præstvatn. The figures in table 1 and observations in situ show that the water in the stream at station 6 and station 8 is affected by the waste water from the dairy.

### 3. SUMMARY AND CONCLUSIONS.

We have carried out, for Elektrokemisk A/S., Oslo, a limnological and physicochemical investigation of the lakes Kraagenesvatn, Hanangervatn, Neseimvatn, Præstvatn and Brastadvatn, at Lista. The results are presented in table 1 - 2 and figure 1. Figure 2 is a survey sketch showing the positions of the sampling stations.

The temperature values for Kraagenesvatn show a poorly developed and deep lying thermocline. Below 8 m the oxygen content of the water decreases owing to decomposition of organic materials. In spite of the small temperature difference between the upper and lower layers, the lake is relatively well stabilised. The temperature of the water is high enough to permit rapid decomposition in the lower layers. The hardness is relatively low as are the colour, turbidity, permanganate value, and iron and manganese contents, apart from in the decomposition zone.

There is no marked thermocline in Hanangervatn, and the temperature is about the same from the surface to the bottom. Under these conditions the wind causes practically complete mixing of the water masses at all depths and as a consequence of this good aeration the oxygen content is about the same throughout the lake. The water in Hanangervatn is a little more basic (pH 7,0 - 7,1) than that in Kraagenesvatn, and the electrolytic conductivity is a little lower than in Kraagenesvatn. The water in Hanangervatn is chemically, particularly with respect to colour and organic matter, of better quality throughout than that in Kraagenesvatn.

The temperature and oxygen values for Neseimvatn correspond to those of Hanangervatn. The pH is the same as in Hanangervatn, but the conductivity and hardness are higher than in Kraagenesvatn and Hanangervatn. The colour and permanganate value for Nes-

eimvatn are in the main similar to those in the oxygen-rich part of Kraagenesvatn. From a chemical point of view the quality of the water in Neseimvatn is slightly better than that of Kraagenesvatn but not quite as good as that of Hanangervatn.

The temperature and oxygen values for Præstvatn show that the deep layers contain rather colder water where decomposition is occurring. The low oxygen values near the bottom have the same cause as in Kraagenesvatn. Præstvatn has a lower pH, electrolytic conductivity and hardness than Kraagenesvatn, Hanangervatn and Neseimvatn. Apart from in the decomposition zone, the colour and permanganate value are of the same order as in Hanangervatn. Therefore, with regard to the content of organic matter, as expressed by colour and permanganate value, the water in the upper layers of Præstvatn is of the same quality, chemically speaking, as that of Hanangervatn.

The value for temperature and oxygen content in Brastadvatn correspond to those for Hanangervatn and Neseimvatn. The pH varies from 6,9 - 7,2. The electrolytic conductivity is higher than in Kraagenesvatn, Hanangervatn, Neseimvatn and Præstvatn, and the hardness is therefore also higher. The colour, permanganate value and iron content are all very high, probably owing to the presence of humus. The chemical quality of the water in Brastadvatn is poor.

Taking all the observations into consideration, it is possible to classify roughly the upper layers of the waters of the 5 lakes in order of decreasing chemical quality as follows:

- No. 1 - Hanangervatn.
- " 2 - Præstvatn.
- " 3 - Neseimvatn.
- " 4 - Kraagenesvatn.
- " 5 - Brastadvatn.

All of the lakes are somewhat eutrophied (i.e. rich in nutrients), a condition which amongst other things is indicated by the values for oxygen and the vegetation in the littoral zones.

The marble test shows that the water in Kraagenesvatn, Hananger-



vatn, Neseimvatn and Præstvatn contains a certain amount of calciumcarbonate-corroding carbon dioxide, the amount being highest in the case of Præstvatn.

An intake in Kraagenesvatn should not be placed below a depth of 8 m because of the possibility of drawing off water of none oxygen content. In all probability the water from Kraagenesvatn, besides being slightly corrosive towards objects of cement, will also corrode certain metals. The possibility of addition of inhibitors must be appraised on the basis of the nature of the cooling system and the quality of the water.

Biological growth in the cooling system, with consequent slowing down of flow rate, is another possibility that must be considered. Development of such growth can be controlled by chlorination of the cooling water.

Table 1.  
Elektrokemisk A/S.

Analyses	Kraagensv. station 1										Hanangerv. station 2					
	0	1	2	4	8	10	11	12	14	16	0	1	2	4	8	10
Depth in m	6,8	6,9	6,9	6,9	6,9	6,6	6,4	6,5	6,4	7,1	7,0	7,0	7,1	7,1	7,1	7,1
pH	9,05	9,15	9,00	9,15	9,15	9,25	9,60	9,50	9,60	9,25	8,75	8,48	8,75	8,75	8,75	8,75
El. conductivity, % 20 °C. 10 <sup>5</sup> , ohm <sup>-1</sup> . cm <sup>-1</sup>	12	20	14	16	18	24	37	53	146	9	9	9	12	11	9	9
Colour, mg Pt/l	0,4	0,6	0,5	0,6	0,6	0,8	1,3	1,5	7,9	0,6	0,6	0,4	0,6	0,6	0,6	0,6
Turbidity, mg SiO <sub>2</sub> /l	3,0	2,8	2,9	3,2	2,7	2,7	2,9	3,1	4,4	1,9	1,3	1,9	2,0	2,0	2,1	2,1
Permanganate value, mg O/l	2,0	-	-	2,0	-	-	-	-	3,0	1,8	-	-	-	-	-	1,8
Alkalinity <sup>1)</sup> , ml N/10 HCl/l	8	-	-	9	-	-	-	-	5	8	-	-	-	-	-	8
Sulphate, mg SO <sub>4</sub> /l	17	-	-	17	-	-	-	-	16	17	-	-	-	-	-	17
Chloride	-	-	0,03	-	-	-	-	-	-	-	-	0,04	-	-	-	-
Phosphate, total, mg PO <sub>4</sub> /l	10,7	-	-	10,7	-	-	-	-	11,7	10,2	-	-	-	-	-	10,3
Hardness <sup>2)</sup> , mg CaO/l	4,2	-	-	4,5	-	-	-	-	5,5	4,0	-	-	-	-	-	7,4
Magnesium, mg MgO/l	<0,05	-	-	0,06	-	-	-	0,38	1,4	0,06	-	-	<0,05	-	-	<0,05
Iron, mg Fe/l	<0,05	-	-	<0,05	-	-	-	0,23	0,45	<0,05	-	-	<0,05	-	-	<0,05
Manganese, mg Mn/l	-	8,8	-	8,6	8,7	5,0	1,7	0,7	0,04	-	9,5	-	9,4	9,8	9,4	9,4
Oxygen, mg O <sub>2</sub> /l																

1) Conversion to p.p.m. CaCO<sub>3</sub> by multiplication with 5.

2) Conversion to p.p.m. CaCO<sub>3</sub> by multiplication with 1,79.

Table 1 (cont.)  
Elektrokemisk A/S.

Analyses	Neseimv. station 3					Præstv. station 4								
	0	1	2	4	8	11,5	0	1	2	4	8	10	11	11,5
pH	7,0	7,0	7,1	7,0	7,0	7,1	6,8	6,7	6,7	6,8	6,6	6,6	6,3	6,3
El. conductivity, % 20°C. 10 <sup>5</sup> , ohm <sup>-1</sup> . cm	10,1	9,97	9,73	9,97	9,97	10,1	7,88	7,88	7,88	7,80	7,80	7,88	8,05	8,05
Colour, mg Pt/l	16	20	20	20	18	20	7	9	9	5	7	7	14	28
Turbidity, mg SiO <sub>2</sub> /l	0,6	0,6	0,5	0,6	0,7	0,7	0,5	0,6	0,5	0,5	0,5	0,6	0,6	0,8
Permanganate value, mg O/l	2,4	2,3	2,4	2,4	2,4	2,3	1,6	1,5	1,5	1,6	1,8	1,9	1,5	3,1
Alkalinity <sup>1)</sup> , ml N/10 HCl/l	2,1	-	-	2,1	-	2,1	1,2	-	-	1,1	-	-	-	1,4
Sulphate, mg SO <sub>4</sub> /l	10	-	-	10	-	10	7	-	-	7	-	-	-	7
Chloride, mg Cl/l	19	-	-	19	-	19	16	-	-	16	-	-	-	16
Phosphate, total, mg PO <sub>4</sub> /l	-	-	0,05	-	-	-	-	-	0,03	-	-	-	-	-
Hardness <sup>2)</sup> , mg CaO/l	12,2	-	-	13,7	-	12,4	8,5	-	-	8,0	-	-	-	10,5
Magnesium, mg MgO/l	5,7	-	-	7,1	-	6,5	6,1	-	-	5,7	-	-	-	7,6
Iron, mg Fe/l	0,16	-	-	0,13	-	0,15	0,07	-	-	0,06	-	-	-	0,50
Manganese, mg Mn/l	<0,05	-	-	<0,05	-	<0,05	<0,05	-	-	<0,05	-	-	-	0,56
Oxygen, mg O <sub>2</sub> /l	-	9,7	-	9,7	9,3	9,3	-	9,0	-	9,0	8,6	8,5	3,1	1,4

1) Conversion to p.p.m. CaCO<sub>3</sub> by multiplication with 5.

2) Conversion to p.p.m. CaCO<sub>3</sub> by multiplication with 1,79.

Table 1 (cont.)  
Elektrokemisk A/S.

Analyses	Brastadv. station 5								Samples from streams <sup>3)</sup>			Notes:
	0	1	2	4	8	9,5	St.6	St.7	St.8			
Depth in m	7,2	7,2	6,9	7,2	7,1	7,1	9,5	St.6	St.7	St.8		
pH	7,2	7,2	6,9	7,2	7,1	7,1	7,1	5,4	6,4	5,9		
El. conductivity	11,4	11,4	11,3	11,4	11,3	11,3	11,3	30,3	7,36	12,1		
% 20°C. 10 <sup>-5</sup> , cm <sup>-1</sup>	112	104	112	104	112	104	104	435	9	65		
Colour, mg Pt/l	1,0	0,9	0,9	1,0	0,9	1,1	1,1	30	0,4	5,0		1) Conversion to p.p.m. CaCO <sub>3</sub> by multiplication with 5.
Turbidity, mg SiO <sub>2</sub> /l	7,0	7,2	7,4	6,6	7,2	7,4	7,4	35	2,6	8,0		2) Conversion to p.p.m. CaCO <sub>3</sub> by multiplication with 1,79.
Permanganate value, mg O/l	2,3	-	-	2,3	-	-	2,2	-	-	-		
Alkalinity <sup>1)</sup> , ml N/10 HCl/l	12	-	-	12	-	-	12	-	-	-		
Sulphate, mg SO <sub>4</sub> /l	21	-	-	19	-	-	19	-	-	-		
Chloride, mg Cl/l	-	-	0,04	-	-	-	-	-	-	-		
Phosphate, total, mg PO <sub>4</sub> /l	16,2	-	-	17,0	-	-	16,3	-	-	-		
Hardness <sup>2)</sup> , mg CaO/l	8,0	-	-	7,6	-	-	7,3	-	-	-		
Magnesium, mg MgO/l	1,7	-	1,6	1,5	1,6	1,6	1,6	-	-	-		
Iron, mg Fe/l	<0,05	-	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05	<0,05		
Manganese, mg Mn/l	-	9,2	-	8,8	8,8	8,7	8,7	-	-	-		
Oxygen, mg O <sub>2</sub> /l	-	-	-	8,8	8,8	8,7	8,7	-	-	-		

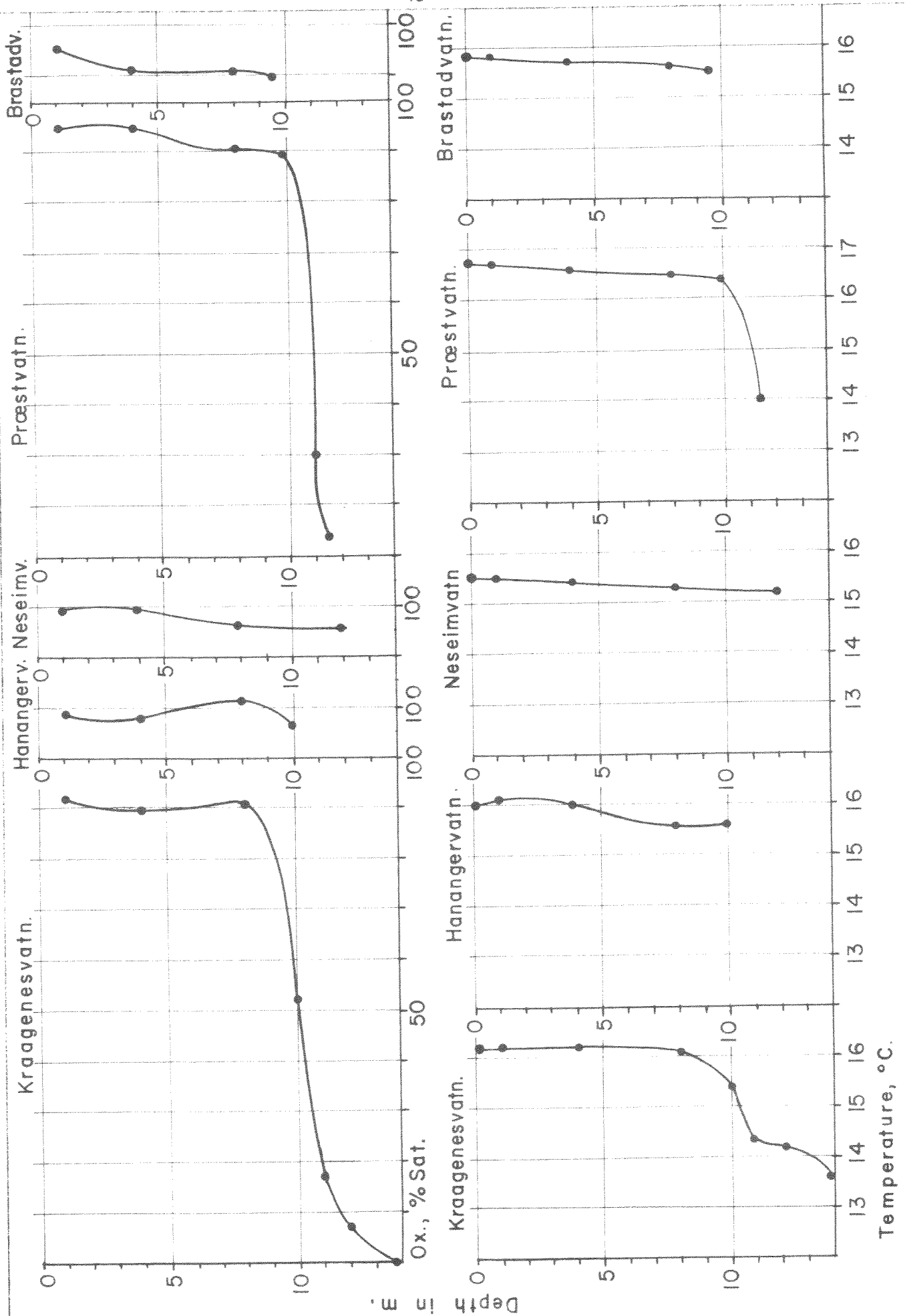
3) St.6: Sample taken in the stream from Brastadv. after discharge of waste water from a dairy.  
St.7: Sample taken in the stream from Præstv.  
St.8: Sample taken after mixing of the stream from Præstv. and the stream from Bra-stadv.

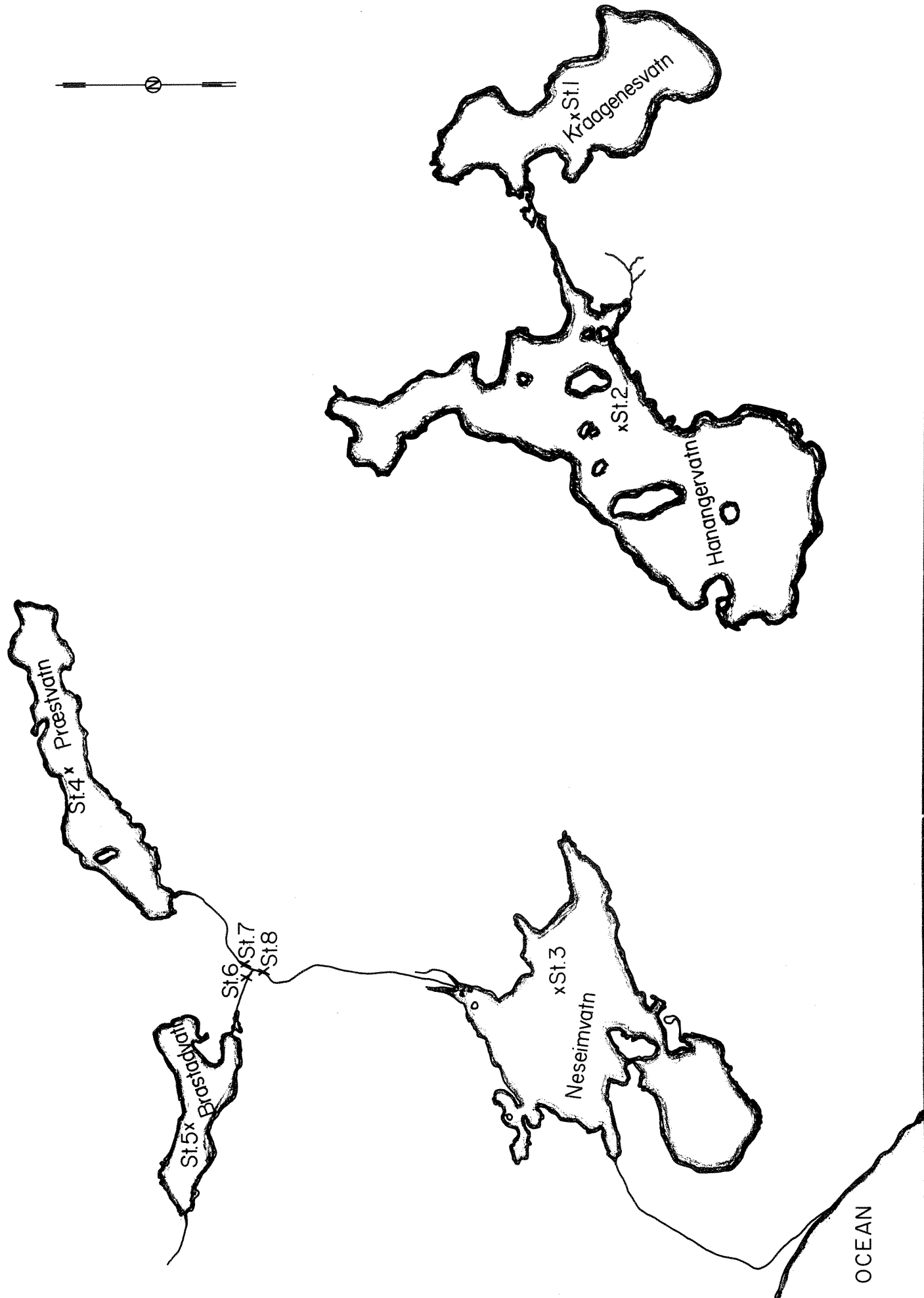
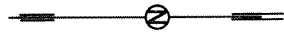
Table 2. 1)

Elektrokemisk A/S.

	Before addition of calciumcarbonate		After addition of calciumcarbonate		Increase in %			
	pH	Alkalinity	Hardness	pH	Alkalinity	Hardness		
Kraagenesvatn	6,9	20	21	8,8	38	30	90	43
Hanangervatn	6,9	19	20	9,2	37	30	95	50
Neseimvatn	7,1	24	22	8,9	44	34	84	55
Præstvatn	7,0	12	14	9,4	36	26	200	86

1) Total alkalinity (pH 4) and hardness in p.p.m. CaCO<sub>3</sub>.





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Sampling Stations (St)

Fig: 2

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Some comments to our report O - 49/62"Water Supply for Industry at Lista".1. INTRODUCTION.

As far as water analyses are concerned, there are many different methods and standards in different countries. In the following we are going to explain the different water quality criteria we have used in our report.

2. WATER QUALITY CRITERIA.

The procedures for the methods we use for our water analyses are, except for permanganate determination (p. 5), to a great extent listed in "Standard Methods" (American Publ. Health Association Inc. 10th and 11th Ed. 1955 and 1960 resp.). Some of the methods in "Standard Methods" are slightly modified to suit our laboratory and the types of water we have in this country.

2.1 pH.

pH is a measure of the strength or intensity of acidity or alkalinity in water. It is expressed as logarithm of the reciprocal of the hydrogen-ion concentration or the hydrogen-ion activity in moles/liter. The pH scale extends from 0 - 14 with a pH of 7,0 corresponding to neutrality; a perfect balance between dissociated hydrogen- and hydroxyl-ions. A pH value below 7,0 means an acid condition or concentration of hydrogen-ions and a pH above 7,0 denotes a concentration of hydroxyl-ion. The lower the value the more acid the reaction, and the higher the value the more alkaline the solution. We have measured pH with a glass electrode.

2.2 Specific electrical conductivity.

Specific conductivity is a measure of the mineral salts in solution, and are closely related to the sum of the anions or the cations which may be determined by specific chemical analysis.

On relatively pure waters, conductivity will usually correlate closely with the dissolved residue present. This determination is



normally applied only as a measure of specific water quality criteria. Specific conductivity is the reciprocal of the electric resistance measured between two electrodes 1 cm apart and 1 cm<sup>2</sup> in cross section. We have measured conductivity with a Phillips Wheatstone Bridge.

### 2.3 Colour.

Colour of water is expressed in mg Pt/l (Hazen units). It is usually defined as the true colour, or that due only to substances which are actually in solution, i.e. colour in filtered water samples. This colour may be caused by natural, mineral or vegetable substances or from soluble inorganic or organic materials. Colour is quite often confused with turbidity. Colour and turbidity together are often named apparrant colour. We have determined apparrant colour with filter photometer (EEL, 10 cm cells), i.e. colour on unfiltered samples. This instrument has been calibrated with a standard platinum cobalt solution. (Hazen solution.)

### 2.4 Turbidity.

Turbidity is a measure of the effect that suspended or colloidal materials have in disturbing clarity or diminishing the penetration of light. It is actually a measure of appearance. Turbid waters means the converse of clear waters. Turbidity is often confused with colour or suspended solids. However, turbidity is a measure of the extent to which the intensity of light passing through is reduced by suspended matter and not a measure of substances in solution (true colour). Also, the degree of turbidity is not equal to the concentration (or quantity) of suspended solids, but only an expression of one effect of suspended solids upon the character of water. We have measured turbidity by the use of Tyndall effect with a Sigris electric Filter Photometer. This instrument is first calibrated with standard silica suspensions, which originally are calibrated with the Jackson candle turbidimeter.

### 2.5 Permanganate value.

Permanganate determination is a method for determining chemical oxygen demand on water samples. It is a laboratory test which measures the proportion of organic matter chemically oxidized

under controlled conditions, and indicates the portion of the carbonaceous matter in water which is reactive to chemical oxidation. For permanganate values determination we have used a method (p. 5) which is standard procedure in this country. This method is based on well known international methods (for example "Standard Methods" 8 Ed. 1936) for chemical oxygen demand tests and in detail the procedure is worked out by the Norwegian State Institute for Public Health, Chemical Department. At present, the standard method for chemical oxygen demand in U.S.A. is the bichromate method, which is assumed to give a more complete oxidation of organic matter in water than permanganate. However, permanganate value is believed to give a fairly good indication of the organic contents in water. It is difficult to correlate permanganate values with corresponding bichromate values, but it is thought and there is some information in literature indicating that a factor between 2 - 5 can be applied for converting permanganate values to corresponding bichromate values.

## 2.6 Alkalinity.

The alkalinity of water can be defined as the capacity of the water for neutralizing acidity. Pure water itself will ionize very slightly with each of the hydrogen ( $H^+$ ) and hydroxyl ( $OH^-$ ) products of dissociation carrying an electrostatic charge. In pure water these charges are equal and opposite. They balance each other and maintain a condition known as neutrality. Other compounds may dissociate in a similar manner and a basic law controls the equilibrium or determines the respective concentrations or activity of ions. When any material is added to disturb this equilibrium with an excess of hydroxyl ions resulting, the water becomes alkaline. The alkalinity of water is usually imparted by the presence of carbonate, bicarbonate, hydroxides and less frequently borates, silicates, phosphates and organic substances. Of these, bicarbonates are the more normal constituents of water and hydroxide or carbonate alkalinity is not often found in untreated waters. Although related, alkalinity should not be confused with pH, as alkalinity is a quantitative measure of the active and reserve power of neutralization, whereas pH represents an intensity of materials in an ionized form. Some materials will dissociate only partially and some natural waters possess a buffer effect. A relatively pure water may exhibit a low alkalinity with a pH

near 7, and a buffered water may exhibit a high total alkalinity at pH 6. Standard procedures for determination of alkalinity are based on titration with standard acid to end points of pH 8,3 and 4,3. (Phenolphthalein and methylorange being indicators resp.) As all natural water samples in our report have a lower pH than 8,3, these samples have no phenolphthalein alkalinity, but only total alkalinity which consists mainly of bicarbonates.

### 2.7 Sulphate, chloride, phosphate, hardness, magnesium, iron and manganese.

All these constituents are normal components in natural water. Hardness expresses the sum of calcium and magnesium ions present in the water.

### 2.8 Oxygen.

Oxygen is present as a normal dissolved component in natural water. The oxygen content is an important indicator on the quality of the water. For oxygen determination we have used a modified Winkler method (Alsterbergs modification).

### 3. HUMIC SUBSTANCES IN WATER:

Most water-types in our country contain a certain amount of humic components which are substances extracted from soil and transported to different lakes and rivers. These humic substances are soluble compounds with a certain colloidal behavior. The character of humic substances in water is to a great extent unknown, but these substances are believed to be complex organic components with a relatively high molecular weight. The humic substances cause a yellowish-brown colour in water. Therefore, colour measurements of water samples together with permanganate determination, are believed to give a fairly accurate and sensitive estimation of the content of humic components.

NORWEGIAN INSTITUTE FOR WATER RESEARCH

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PERMANGANATE DETERMINATION.

APPARATUS: Water bath.  
Stop watch.  
200 mls Erlenmeyer flask.  
10 mls buret.

REAGENTS:  $H_2SO_4$  (1 + 3).  
N/100  $KMnO_4$ .  
N/100  $Na_2C_2O_4$ .

PROCEDURE: 100 mls sample. }  
5 mls  $H_2SO_4$  (1 + 3). } Added to the  
20 mls N/100  $KMnO_4$ . } Erlenmeyer flask.

Put the Erlenmeyer flask in the water bath (boiling) for exactly 20 minutes. Use stop watch. Add 20 mls N/100  $Na_2C_2O_4$  solution and titrate back excess oxalic solution with N/100  $KMnO_4$  solution (to light pink colour).

If the consume is more than 8 mls, the sample must be diluted with distilled water before start.

CALCULATION:

$$10 \cdot (\text{the permanganate consumption of the analysis - blank}) \cdot f$$
$$= \text{mls N/100 } KMnO_4 / \text{liter.}$$

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$$f - \text{standardizing factor of } KMnO_4.$$

EXAMPLE: 20 mls  $Na_2C_2O_4$  20,5 mls  $KMnO_4$  :  $f = \frac{20}{20,5}$ .

Blank: 100 mls distilled water treated in the same way as the sample.

APPENDIX II

Increased evaporation from Kraagenesvatn  
after the discharge of cooling water.

Quite generally, the evaporation from a lake depends on some climatic, variable factors. Without these factors being known, it is difficult to give a true calculation of evaporation. The temperature in the water and the air plays an important part in the heat balance of a lake. Heat of radiation, cloudiness, humidity in the air, wind and also currents in the lake are all of considerable importance in the heat budget of a lake.

Usually, evaporation from a lake is determined by measuring in special evaporation apparatus. However, it is also possible to calculate the evaporation from the following empirical equation:

$$V = \frac{Q_a - Q_l}{L \left( 1 + 0,64 \frac{t_w - t_a}{l_w - l_a} \right)}$$

Here: V is evaporation in cm.

$Q_a$  (Cal/cm<sup>2</sup> 24 h) is heat absorbed as radiation.

$Q_l$  (Cal/cm<sup>2</sup>/24 h) is heat lost as radiation.

$L_w$  (585 cal/g) is heat of evaporation from water.

$t_w$  (°C) is temperature of water.

$t_a$  (°C) is temperature of air.

$l_w$  (mb) is maximum water vapour pressure at temperature  $t_w^{\circ}$ .

$l_a$  (mb) is true water vapour pressure in the air.

The equation is valid for a lake under natural conditions, i.e. heat is either added or removed from the lake in an artificial way.

However, when cooling water is discharged to a lake, there will be an increase in temperature. This increase will be greatest near the outlet of the cooling water; and from here on there will be a decrease depending on mixing conditions etc. Approximate

calculations of the increase in temperature in Kraagenesvatn after the discharge of cooling water can be based on some simplifications and assumptions. We have estimated the total volume of the lake to one million  $m^3$ . The temperature of the water is assumed to be  $10^{\circ}C$  through the whole body of water in a certain time interval. By definition, one calorie is the amount of heat necessary to raise the temperature  $1^{\circ}C$  in 1 g of water. Taking the density of the water as unity, the total, natural heat content in Kraagenesvatn is therefore  $10^{13}$  cal. The average flow of cooling water is  $1 m^3$  per second, and the temperature of this water at the outlet is assumed to be  $20^{\circ}C$ . If the intake water in Hanangervatn has a temperature of  $10^{\circ}C$ , the amount of heat added to Kraagenesvatn in 24 hours is about  $1,7 \cdot 10^{12}$  cal. Hence, the increase in temperature in 24 hours is approximately  $1,7^{\circ}C$  and the heat added to the lake during approximately 6 days will theoretically increase in the same order as the total, natural heat contents. This heat is converted to heat of radiation, evaporation etc. Part of the heat is removed from Kraagenesvatn by water overflowing from the lake. Assuming that maximum half of the heat added is used for water evaporation, i.e.  $0,85 \cdot 10^{12}$  cal., this amounts to an increase in water evaporation of about  $1450 m^3$  per 24 hours, or approximately  $5,3 \cdot 10^5 m^3$  per year. Kraagenesvatn is approximately  $6 \cdot 10^5 m^2$  in area. The natural, maximum evaporation during for example 3 months in summer can be estimated to 0,2 m, i.e.  $1,2 \cdot 10^5 m^3$ . The total evaporation during this time interval is therefore  $1,2 \cdot 10^5 m^3 + 1,25 \cdot 10^5 m^3$ , i.e. approximately  $2,5 \cdot 10^5 m^3$ .

Although the increased evaporation caused by the cooling water is of the same magnitude as the natural evaporation, this change is not significant. As far as chemical factors are concerned, the mineral content will theoretically increase to the same extent. However, this change in mineral content is of minor importance.

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