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RESULTS OF INVESTIGATIONS INTO CYCLIC SALTS ON THE EAST COAST OF THE ADRIATIC (SPLIT)

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SPLIT 1952

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(with 9 graphs)

By

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and

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INTRODUCTION

This paper gives data which for the first time present a picture explaining how salt from the sea water, owing to the influence of the wind, is spread into the atmosphere, and how it is transported to the land in the regions of the East Coast of the Adriatic.

The paper is dealing, then, with cyclic salts. This term applies to salt circulating between the sea water and the atmosphere and between the atmosphere and the land. The sea is being agitated by the wind which, if strong enough, as in the case of the Bora Wind (NE) and the South Wind (SSE) may easily carry away fine droplets of sea water emerging when the crests of the waves are bursting. The range of the transport of that water dispersion depends upon its extent and upon the strength of the wind. While bigger drops will fall down on the sea surface or somewhere on the seashore after a shorter flight, finer ones may be carried farther away, and the finest ones will remain suspended in the air and are likely to reach great distances. That transport is facilitated by the fact, that, under favourable conditions due to dry or warm air, water evaporates from the droplets, leaving behind only crystals of salts or a highly concentrated solution of salts, thus diminishing the bulk of the droplets and the speed of their fall (Boguslawski and Krümmel, 1907). A thin crystallic dust of that kind or sufficiently fine doplets of sea water may be carried very far away. It is known that the amount of those cyclic salts, carried to the land by air-currents, is rapidly decreasing at the beginning of the transport, which process is later slowed down (Cauer, 1932). The salts are finally brought down to the ground through the medium of precipitations. If these had fallen on land, they will — either in a shorter or in a more indirect way — mostly reach the sea again, being carried off by streams.

The opinion has also been expressed that not only a mechanical transport of salts from the sea water is here involved, but that there are also chemical processes of oxidation at work as in the case of halogenes according to Cauer's theory of oxidation of chlorides from the sea water by ozone.

Investigations of this kind are important not only from the point of view of an oceanographic balance of salts in the sea water, but also in regard to the transfer of considerable quantities of various salts from the seawater to the land, where they can play their rôle in the metabolism of land organisms.

These data may as well be of some interest and practical use in the study of meteorological phenomena. The knowledge of quantities of those salts in the atmosphere has been helpfully applied to the studies dealing with the nuclei of condensation and with the origin of precipitations. (Cauer, 1932; see also Lipp, 1932). It is certain that the data relative to the amount of salts, particulary of some of them (J), have contributed toward the determination of origin of some body of air (Jesser and Thomas, 1943; Cauer, op. cit.).

THE METHOD

Our investigations were carried out from October 15th 1948 to November 30th 1949. The locality of investigations was the Cape of Marjan Peninsula (The Institute of Oceanography and Fisheries) near Split. The Institute has a meteorological station of its own, whence rainwater and the data relative to it were obtained. The meteorological box lies 20 metres away from the sea-coast, 12 metres above the sea level. Its site is such that it is partially sheltered from the NE winds by the Mount Marjan ridge (see inset in the map, Figure 1). The data relative to the winds have been obtained from our meteorological station and have been checked with those given by the

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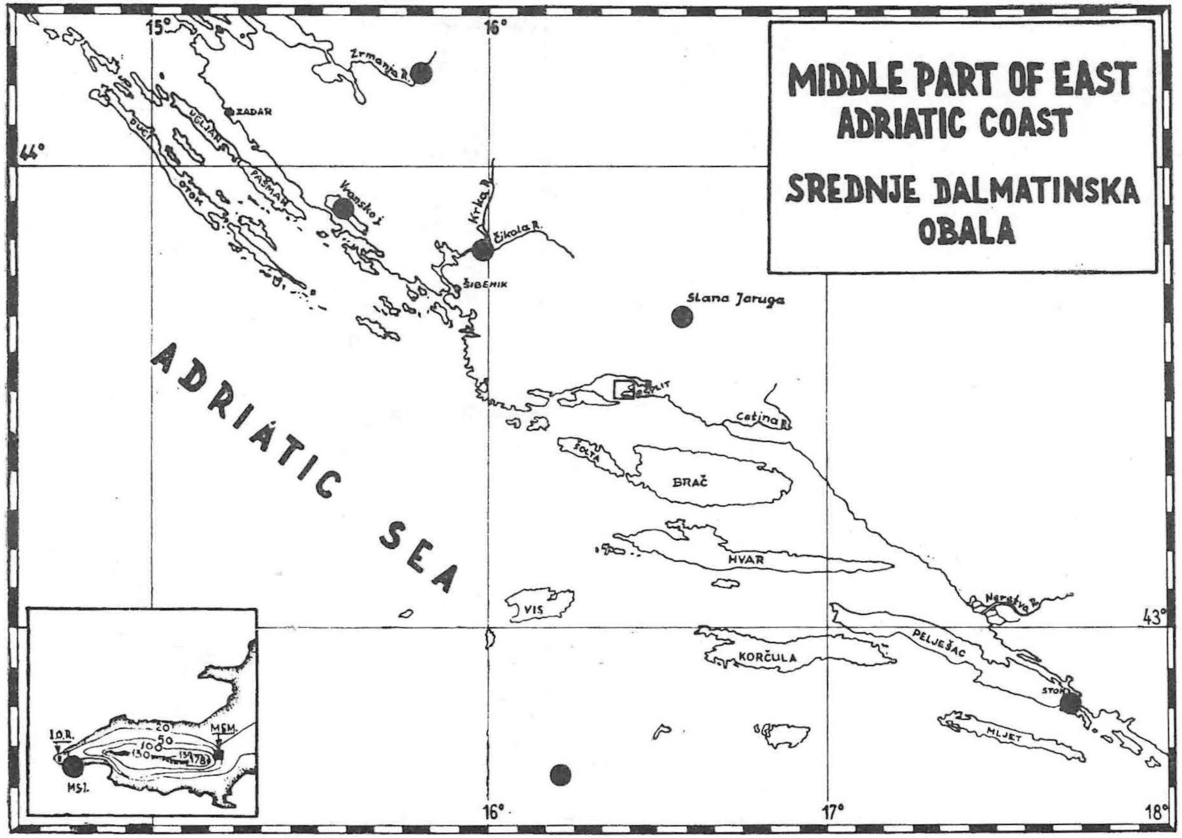
MIDDLE PART OF EAST ADRIATIC COAST
SREDNJE DALMATINSKA OBALA
ADRIATIC SEA
15°
16°
17°
18°
44°
43°
ZADAR
Zrmanja R.
Vransko j.
Krka R.
Čikola R.
ŠIBENIK
Slana Jaruga
SPLIT
Cetina R.
ŠOLTA
BRAČ
HVAR
VIS
Neretva R.
PELJEŠAC
KORČULA
STON
MLJET
UGLJAN
PAŠMAN
DUGI OTOK
I.O.R.
M.S.M.
MSJ.
20
50
100
130

Fig. 1.

Split Hydrometeorological Service, whose station lies on the eastern slopes of the Mount Marjan (see also at the map), and which is in the position to measure all the winds alike as it commands the very top of the hill. Samples of rainwater were taken from the pluviometer every morning at 7 o'clock, the total quantity of precipitations for the past twenty-four hours being found out by that opportunity.

Chlorides were determined by the Mohr method improved by Winkler (M a u c h a, 1932). In order to obtain a higher concentration of chlorides and, consequently more accurate data, we started by evaporating the samples of water before the titrations took place, but the method proved precise enough even without that supplementary measure, provided the Winkler's correction had been applied. Where the volume of the sample allowed, two analyses were carried out at the same time. By this method have also the present Br' and J' actually been included into chlorides. But if taken into consideration that the ratio of Cl:Br in the seawater is 292:1, and the ration of Cl:J about 379600:1, we shall find that the difference between our data relative to »chloride« and the actual quantity of chloride is smaller than the sensitiveness of the method itself, that is to say that the difference was without significance in our work.

Sulphates existing in the rainwater were determined in the gravimetric way in the form of $BaSO_4$ (T r e a d w e l l, 1943). A 5% solution of Ba Cl_2 was gradually added during boiling, and then the liquid was kept quiet during night-time. The filtration and ignition of sediment followed the next day.

THE RESULTS

In Table 1 (see Appendix) are given the data relative to the days of the period of investigation. Table 2 shows the data relative to the months of that same period.

It results from those data that the amount of Cl' (to make it simpler, chloride ion will be marked by »Cl« only) existing in rainwater varied from its lowest value of 1.38 mg Cl/l in June 1949 to its highest value of 156.4 mg Cl/l during a rainstorm in January 1949. B. Kinch at Cirencester (Southeast

England) recorded after a storm the value of 100 mg Cl/l of rain water (Boguslawski — Krümmel, op. cit.). Israël, on the other hand, found at Leiden the value of 171 mg Cl/l (Israël, 1934).

A high value of chlorides in the rain water was recorded by W. Irwin who found 123 mg Cl/kg of rain water when the sea has had a few days of storm, and N. H. J. Miller collected the rain water having a maximal content of 3.920 mg Cl/kg on Outer Hebrides, Scotland (K. Rankama and Th. G. Sahama, 1950).

The mean value of the content of chloride during the period of our investigation was 9.65 mg Cl/l, this corresponding to the average of 72 analyses. Israël found at Leiden a mean value of 4.18 mg Cl/l in the rain water obtained at the meteorological station lying 4 kilometres away from the seacoast.

Whilst working on this subject our interest was attracted not only by the concentration of chlorides in rain water, but also by the amount of chlorides contained in the fallen quantities of rain water. We give, therefore, the values of the total amount of chlorides fallen with rain water per unit of surface during the period of our investigation.

Those values are shown in Table 2, columm 4. January and March 1949 were the months with higher amounts of chlorides in the precipitations (see Table 2, columm 4), whilst the maximum (0.2027 mg Cl/cm^2) was reached in November that year.

Table No 2

Months	mm of rainfall l/m²	Average amount Cl mg/l	Precipitated Cl mg on a cm² of soil
Second half of October 1948	60,2	6,98	0,0420
XI	47,6	6,82	0,0324
XII	9,6	21,58	0,0207
I 1949	82,2	13,6	0,1119
II	—	—	—
III	49,7	21,2	0,1051
IV	—	—	—
V	125,1	7,32	0,0915
VI	55,7	5,72	0,0319
VII	9,2	7,28	0,0067
VIII	18,5	14,44	0,0268
IX	46,5	4,07	0,0189
X	128,0	3,29	0,0422
XI	157,6	12,83	0,2027

That very month, at the same time, particularly abounded with precipitations which amounted to 157.6 mm. If February and April 1949 are excepted, as those months were rainless, the minimal amount of chlorides fallen per unit of surface occurred in July that year.

THE RATIO BETWEEN THE AMOUNT OF RAIN WATER AND THE AMOUNT OF CHLORIDES IN IT

1) The Regularity of Several Days' Periods

There is a regularity to be recognised from our data relative to the ratio between the amount of chlorides in rain water and the amount of rain water itself.

When a rainless period is followed by one showing a relatively higher number of rainy days without strong winds, or, to put it in a more precise way, with winds being less than 6 Beauforts strong, then the first rainfall from that series of rainy days is the most abundant with chlorides, whilst the contents of chlorides in rain water shows a gradual decrease on the following days. For example: December 31st, 1948, January 23rd, May 11th & 20th, June 2nd, August 13th, 1949. On the next rainy days of each of the series rain water was found to contain less chlorides. That course is followed down to a minimum, which usually proves to be a turning point when a windy weather sets in. This regularly applies to a series of successive rainy days, but sometimes also to a series of rainy days with intermediary rainless days without strong winds, as it was the case, for example, from August 19th to September 10th, 1949. Some of such cases are shown in graphs (Figures 2 to 7).

It results that the air is enriched with salts during the rainless periods. When rains set in, the atmosphere is being purified and left with a scarce quantity of salts, so that the rain water deriving from rainfalls occuring after a few rainy days usually shows minimal quantities of »chloride«. But if during a series of rainy days a strong wind intervenes, the regularity is then disturbed, as it occurred from November 5th to 9th and 18th to 27th, 1949, when strong winds — measuring

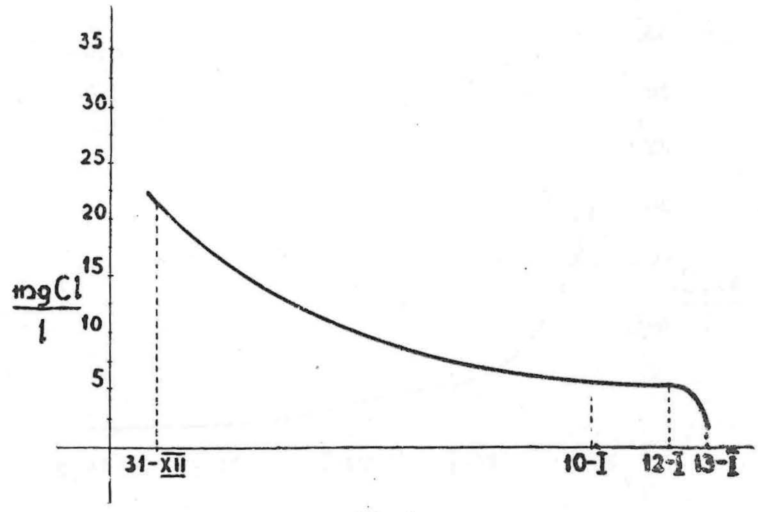
35
30
25
20
15
10
5
mgCl / l
31-XII
10-I
12-I
13-I

Fig. 2.

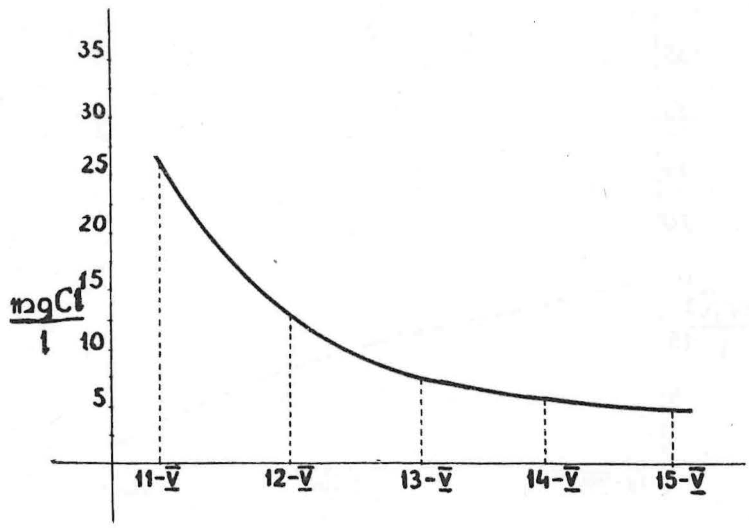
35
30
25
20
15
10
5
mgCl / l
11-V
12-V
13-V
14-V
15-V

Fig. 3.

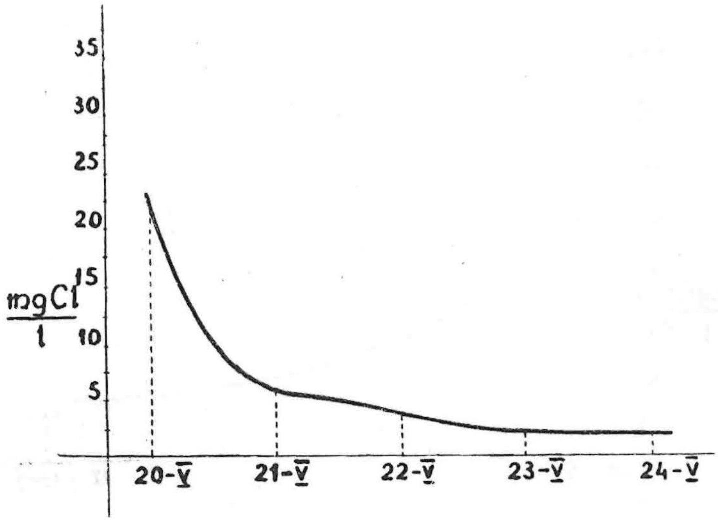
35
30
25
20
15
10
5
mgCl / l
20-V
21-V
22-V
23-V
24-V

Fig. 4.

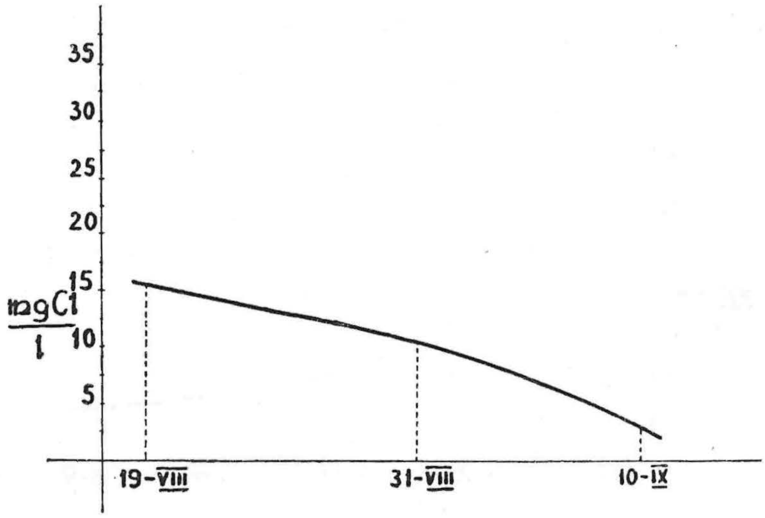
35
30
25
20
15
10
5
mgCl / l
19-VIII
31-VIII
10-IX

Fig. 5.

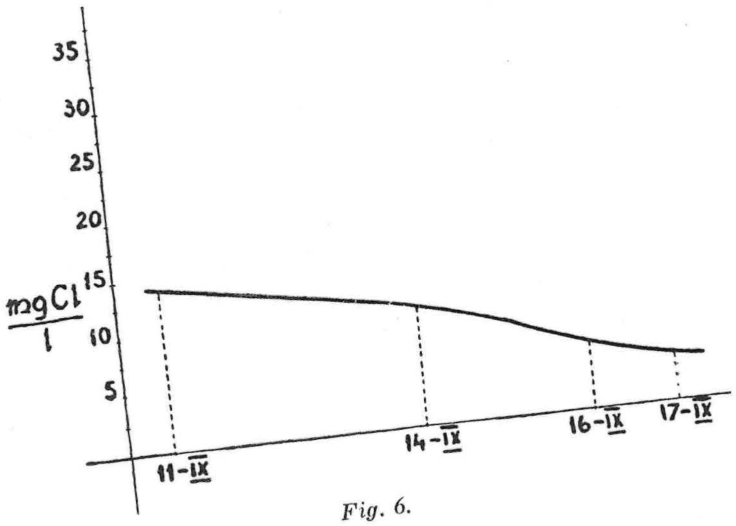
35
30
25
20
15
mgCl / l
10
5
11-IX
14-IX
16-IX
17-IX

Fig. 6.

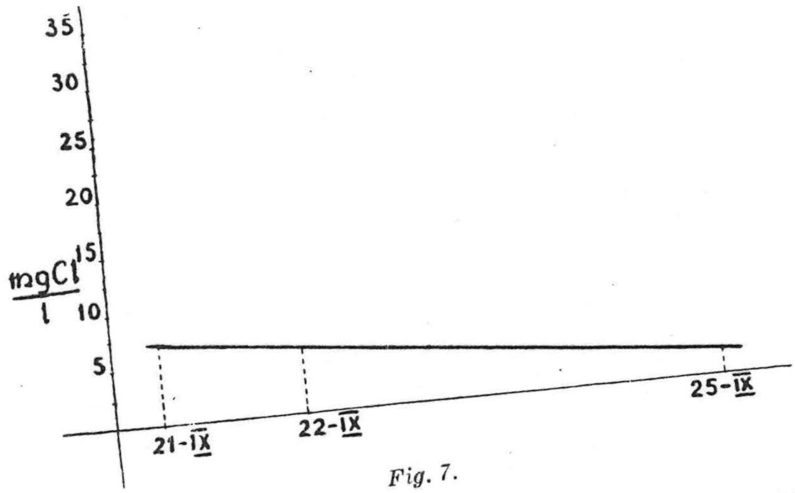
35
30
25
20
15
mgCl / l
10
5
21-IX
22-IX
25-IX

Fig. 7.

over 6 degrees of the Beaufort's scale — happened to blow during those rainy days.

The case recorded from May 18th to 20th, when there was an increase of the content of salts, but no gain in strength of the wind was registered, remains outside of that regularity.

A regular decrease of Cl mg/l in the rain water is then a normal phenomenon during the absence of a strong wind within a short series of rainy days. But the fact should be emphasized, however, that the regular decrease of concentration of Cl in the rain water is by no means connected with the amount of precipitations on those days (see circumstances from January 9th to 10th, from March 12th to 14th, from May 11th to 15th, and 20th to 24th etc.).

This regularity may be called the Regularity of Several Days' Periods.

2) The Regularity of Longer Periods of Time

Another fact resulting from our data consists in the observation that the amount of rain water falling down on one day and the content of chlorides in it underlie a regularity which could be formulated as follows: Seen in the course of longer periods of time, we find that the greater the amount of rain water fallen down on some day, the lower the value of Cl mg/l present in it, and vice versa, the smaller the quantity of rain water, the higher the concentration of chlorides in it. That phenomenon may be called The Regularity of Longer Periods of Time.

All that becomes rather evident when a sufficient number of data, obtained over a longer period of time, is arranged into a system of coordinates (see graph, Figure 8). In spite of considerable departing and scattering of points, the tendency of their grouping along a line still may be presumed. That line is approximately following the course of a hyperbola.

The two regularities, as stressed above, are actually in opposition with each other and exactly that is the reason for the departing of data from an ideal hyperbola in graph 8. The course suggesting a hyperbola might be explained by the folowing hypothesis. The lower part of the troposphere, between the region of rainbringing clouds and the earth has the capacity of holding a certain amount of dispersed salt but that quantity is unable to reach its maximal value of »saturation« during frequent rainfalls. When rain passes through that part of the

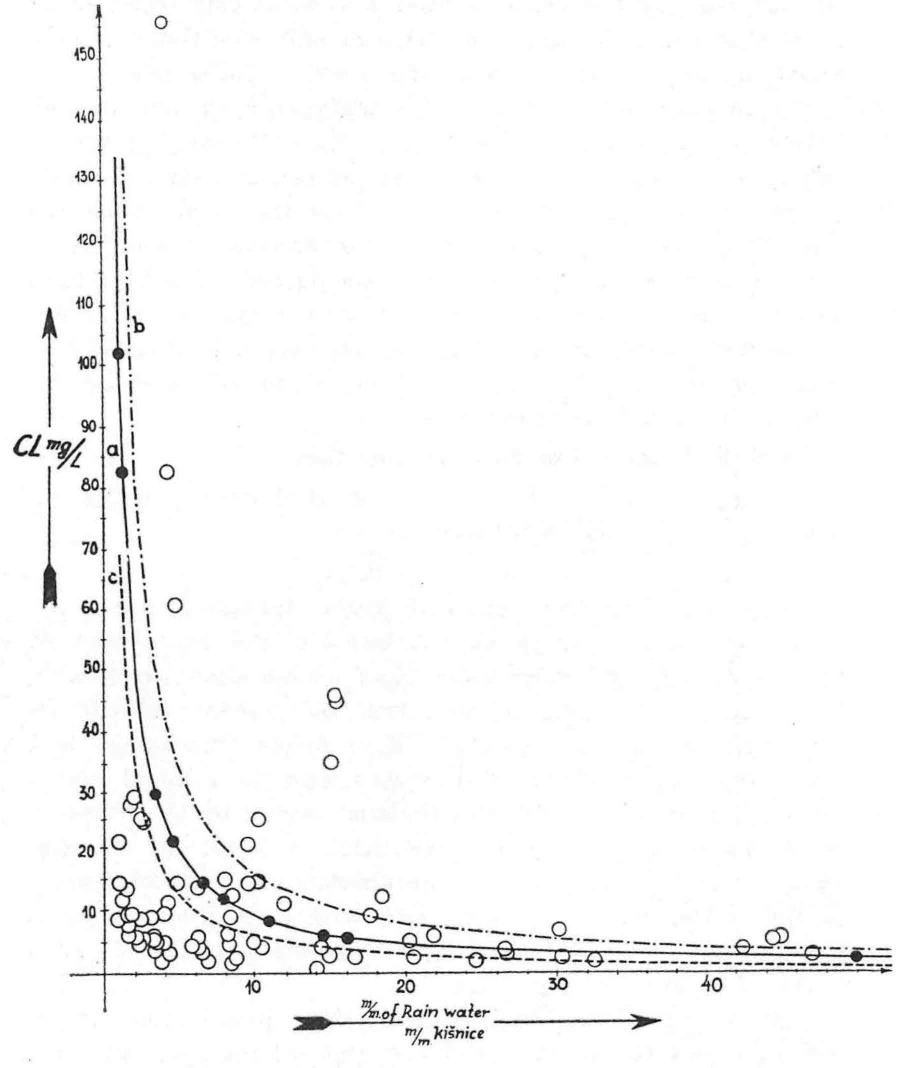

Fig. 8.

troposphere, it takes with the chlorides and other salts. The larger amount of rain water, the smaller the concentration of Cl to be found in it, as the disposable amount of chlorides in the atmosphere is limited, and vice versa, a precipitation of a few milimetres will accumulate a relatively higher amount of Cl mg/l. That is facilitated by the fact that the actual amounts of salt in the atmosphere are very small and that never can the value be reached which is needed to make rain water satureted with salts. Our maximal value of chlorides found in rain water during a period extending over a little more than thirteen months was 156.4 mg Cl/l, which corresponds to about 1/1000 of the value of saturation of Na Cl in distilled water, while our annual mean value, amounting to 9.65 mg Cl/1, scarsely corresponds to about 1/20000 of the value of saturation. It is likely, however, that in the process of solution of salts in the atmosphere there are some factors at work which influence the speed of dissolving of salts from the air in the atmospheric water. A part may also be played by the electric charge of particles that might in some circumstances delay the process of solution of those salts.

On the basis of our data we take that

Cl mg/l x mm of rain water = K, this actually being the equation for the equilateral hyperbola:

$$x \times y = K$$

The departing from an ideal curve (graph 8, curve a), noticed in our case, might be attributed to the inconstancy of the constant K (the mean value K of all our data amounts to 101.7), or, if according to definition the constant should be unchangeable, then the amounts of Cl in the atmosphere had many times a lower value if compared with the value of »saturation« (in the air). That was perhaps caused by too frequent rains that occured in our coastal region in 1949, not allowing big quantities of chlorides to be accumulated in the atmosphere, as far as the value of »saturation« with salts would make it possible. Here may lie the reason for coming together of points in the very corner of the graph.

An average K = 165,6 is obtained if we choose from among our data only those occurrences of rain which were preceded by a rainless period of 10 or more days.

On the other hand, if we choose out of those data only the rainfalls which were preceded by rainless periods lasting from 1 to 3 days, an average K = 69,2 is obtained (provided that from 43 data two ones were eliminated owing to a wind of hurricane speed — 7—10 degrees of the Beaufort's scale — occurring on November 6th and 29th, 1949).

These data enable us to draw two new hyperbolas: curve *b* for K = 165,6 and curve *c* for K = 69,2 in the graph 8. Each of them lying on its own side of the basic hyperbola *a* for K = 101.7 in that graph. In that way we arrive at a system of hyperbolas in which each of them is characteristic for the respective group of rainfalls.

The fact that the rain water belonging to rainfalls preceded by short rainless periods shows a lower value for K, is in full accordance with the hypothesis that salts dispersed in the atmosphere are being brought down by rain, as well as with the hypothesis that a certain period of time is needed until the atmosphere becomes saturated with salts again.

The values of the constant K (the value of all data obtained during a longer period of time, corresponding to the basic hyperbola) may differ in the cases of some regions lying in the vicinity of the seacoast and of those situated farther inland. It is also most likely that the values of K will mutually differ if a desert region is compared with one abounding with precipitations. In that case it is likely that K would be a characteristic constant for the climate of a given region.

3rd Regularity: The Decrease of the Transport of Chlorides During a Rainfall

One day was the minimal interval of time within which our observations were being carried out during our work. H. Israël (1934), however, gives data on the content of chloride covering a single rainfall. Rainwater was being collected at following intervals succeeding the beginning of a rainfall: after 3 hours and 15 minutes, 3 hours and 30 minutes, 3 hours and 45 minutes, 4 hours, and 4 hours and 15 minutes. The author presents data relative to amounts of each fraction including the amount of water and of Cl mg/l as well.

We were interested in those data being anxious to see whether there was some regularity in them according to our Rule of Several Days' Periods, as the obtaining of rain water involved short periods of time. Whilst our data refer to days, those data (Table 3) cover hours.

Table No 3

1 Time of taking the rainwater	2 ccm of rainwater	3 a $Cl\,\frac{mg}{l}$	4 b mm of rain	5 a. b=K	6 K calculated according to formula: $k = \frac{2.303}{t_1 - t_2} \log \frac{K_1}{K_2}$
$6—9^{15}$	465	0,8	16,25	12,96	12,96
$9^{15}—9^{30}$	180	0,47	6,30	2,97	2,61
$9^{30}—9^{45}$	49	1,57	1,71	2,68	2,25
$9^{45}—10$	35	1,69	1,22	2,06	1,99
$10—10^{15}$	32	1,58	1,12	1,77	1,77

Remark: Data under 1, 2, 3 have been taken from Israël, (op. cit.); the remaining ones have been deduced from them.

K = mg Cl that fell on 1 m^2 of the surface of the ground.

It seems that the amount of chlorides was decreasing during the rainfall in the above case so that the amount of precipitated chlorides was gradually diminishing with the later fractions of the rain. Let us suppose that the decrease of the product mg Cl/l and of the quantity of rain have some functional connection with time on the basis of the equation:

$$- \frac{dK}{dt} = kK$$

where $- \frac{dK}{dt}$ represents the speed of the decrease of the above product in the course of time, and k represents the specific constant. The above equation enabled us to calculate the values of the product K (Table 3, Column 6). We can deduct from the calculated values, and from the analytically obtained ones (Column 5) which agree to a certain extent (Column 6), that the amount of chlorides (K) precipitated on the ground within fractions of one rainfall lasting for several hours is depending upon time according to the rule of the exponential function. Here is, then, the case of salts being brought down from the atmosphere by rain. The amount of salts precipitated on the ground will grow smaller and smaller toward the end of a longer rainfall.

The same explanation has likewise been applied when dealing with the hyperbola relative to the Regularity of Longer Periods of Time (II regularity), so that these two regularities do really express the one and the same phenomenon, that is to say the bringing down of salts from the atmosphere, with the difference that only o n e rainfall is involved with the III regularity (»Israël's« case), whilst m o r e rainfalls, extending over s e v e r a l months, are comprised by the II regularity (The Regularity of Longer Periods of Time).

The case taken from Israël is in fact an example illustrating the departing of data from the ideal hyperbola belonging to the Regularity of Longer Periods of Time, owing to the possibility of replacing the content of salts in the atmosphere, the time being too short for its balance to be restored there. Our cases of September 10^{th} and 11^{th}, and October 29^{th} and 30^{th}, 1949, belong also here, as those rainfalls showed to contain a higher concentration of chlorides per liter on the second day of both cases, whilst the product K decreased regularly.

DEPENDENCE OF THE AMOUNT OF CHLORIDES IN RAIN WATER UPON THE STRENGTH OF WINDS

To make the insight into this relation possible, the graph in Figure 9 has been drawn. By making use of the data relative to winds from table 1 we chose from among the data covering the strength of winds that one showing the highest number of Beaufort's units during the three last days preceding the rainy day (Table 1, last column), supposing that it was chiefly responsible for the transport of salts into the atmosphere.

Among the factors causing the scattering of points in graph 9 there is also the way in which the data on winds were being collected. Notes on wind occurrences were made every day at 7 a. m., 2 p. m., and 9 p. m. Rainwater was collected at 7 a. m., although, for the major part, it really belonged to the preceding day, as it has been pointed out in the remark following Table 1.

There is a permanent perturbance among the data owing to that fact. The wind, moreover, often used to gain in strength during the intervals between the hours of making notes, as it frequently happened with the Bora Wind (e. g. the data for January 22^{nd}, 1949).

The graph reveals some direct relationship between those two factors within somewhat wide limits. The data relative to the Bora Wind are grouped in the steeper belt of the graph (with the exception of two ones) whilst the gently sloped belt of it contains almost all the data covering the winds from the remaining directions. A further conclusion to be deduced from

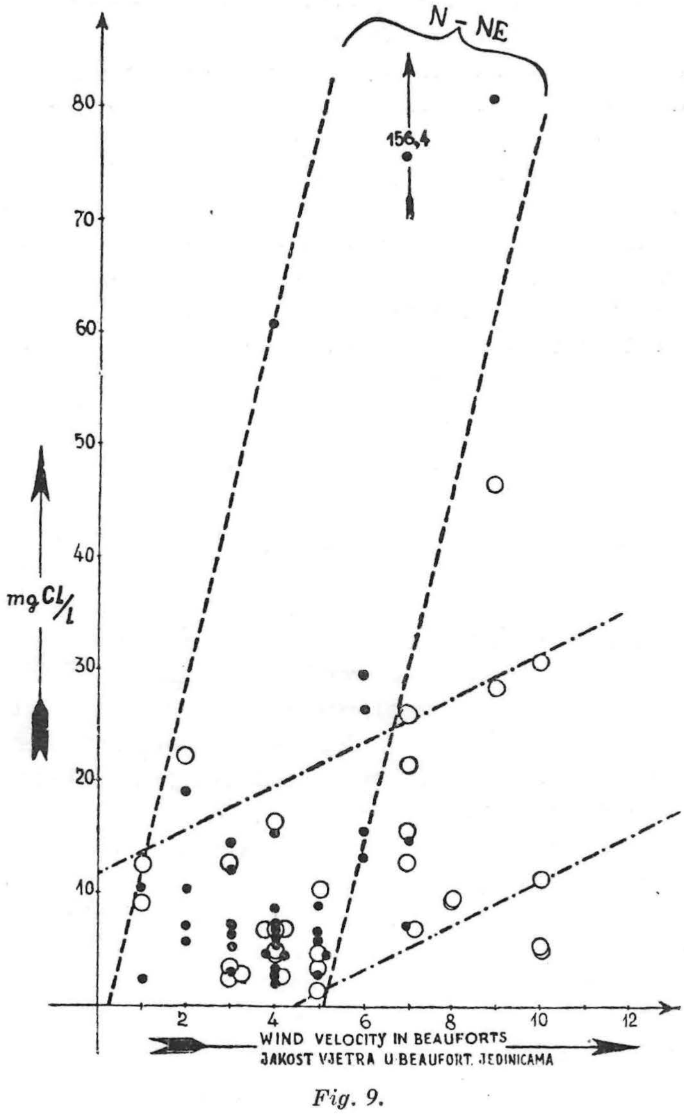

Fig. 9.

that graph is that all the winds blowing with uniform regularity, i. e. all except the Bora Wind (direction N-NE), are less responsible for the increase of chlorides in rain water, whilst the Bora Wind shows the property of accumulating chlorides with the substantial growth of its own strength as evident from the steeper belt belonging to it in the graph. That fact is explainable by the characteristic way the Bora Wind uses to blow, bursting irregularly in violent blasts, and making thus the spraying of the sea water possible, which, being a characteristic of the Bora Wind, produces a considerable increase of the amount of chlorides in rain water. (The spray — or »pulverisation« of sea water, as the Dalmatians use to call it — is the phenomenon following the Bora Wind, when, under its gusts small clouds of sea water droplets arise here and there from the crests of smaller waves — and, of course, of bigger ones too). The degree of declivity of the coast from which the Bora Wind blows is also likely to play a role in it. But some other factors may likewise contribute toward the said spraying.

From the inclination of the curve in the graph we see that the Bora Wind has an eightfold higher influence upon enrichment of rain water with chlorides than any other wind. This, however, should be taken only approximately, not overseeing the above limitations of the exactness in preparing that graph.

THE CONTENT OF SULPHATE IONS IN THE RAIN WATER

Several analyses relative to the content of sulphate in rain water were carried out during our work. The number of analyses was limited by the quantities of disposable rain water. The data are given in Table 4.

The maximal value of sulphates deriving from those data is 29.7 mg/l, and the minimal value 2.4 mg/l. The ratio Cl/SO_4 amounts to 0.101 and the highest one 0.672. The mean ratio Cl/SO_4 is 0.314. To make comparisons possible, some other data relative to the content of SO_4 in other waters have been added.

It is necessary, however, to point out the great difference between the ratios Cl/SO_4 for rain water and for the waters either of the Adriatic Sea or of the Oceans for example. Whilst that ratio amounts to 7.20 for the Oceans and about 7.24 for the Adriatic, it falls to 0.314 in the case of our rain water. Similar values for that ratio with regard to rain water were noticed for some other regions too (K a l l e, op. cit.). The ratios

Cl/SO_4 for the waters of the Krka River (up the Skradin waterfall) and the Zrmanja River (up the waterfall Jankovića Mlinica) are still lower and amount to 0.075 and 0.100 respectivelly, proving a relatively higher content of sulphates in those waters. Layers of gypsum are really not uncommon there. Data covering two American rivers are also given for comparison, wherefrom we see that their waters contain less sulphates and more chlorides than that two Yugoslav rivers that were examined.

Here is also a datum showing an extremely low value of that ratio found in the water of the spring Slana Jaruga near Sinj. We give it as an interesting detail. The value of the ratio for that water amounts to 0.0082. The name of the spring, meaning Salt Gully, does not refer to common salt being possibly contained by it, but to gypsum which is called »slanica« or »slana stina« (salt stone) in that region.

Table No 4

Origin of water	Cl mg/l	SO_4 mg/l	Cl/SO_4	References
Rain water on 16 XI 1948	—	2,4	—	This paper
„ 9 I 1949	5,8	12,1	0,479	„
„ 12 I	2,0	7,1	0,283	„
„ 12 III	12,9	19,2	0,672	„
„ 12 V	7,5	17,7	0,395	„
„ 22 V	2,0	18,6	0,104	„
„ 24 VI	5,8	21,0	0,276	„
„ 9 IX	3,0	29,7	0,101	„
„ 8 X	2,7	21,0	0,128	„
„ 5 XI	6,4	16,4	0,390	„
Krka 19 VI 1949	4,7	62,9	0,075	Buljan
Zrmanja 22 VI 1949	3,4	34,0	0,100	„
Colorado	19,92	28,61	0,696	Sverdrup & al. (1946)
Mississippi	6,21	15,37	0,405	„
Slana Jaruga 15 VII 1948	11,0	1341,0	0,0082	Buljan
Stonsko vrelo (Ston spring) IX 1947	1002,0	128,0	7,83	„
The Adriatic, SSW of Dubrovnik 20 Nm, 310 m deep, 20 IX 1948	21420,0	2945,0	7,28	„
The Adriatic, S of Vis Island 20 Nm, 100 m deep, 24 II 1949	21340,0	2963,0	7,20	„
The Oceans	—	—	7,2	Kalle (1943)

The low value of the ratio Cl/SO_4 for the water of Slana Jaruga is due to copious quantities of gypsum being dissolved in it. The highest value of that ratio has been found in the water of a brackish spring at Veliki Ston where it reaches 7.83, representing the only value surpassing that of the sea water. The appearance of such a high ratio of Cl/SO_4 in the latter case needs a special explanation which lies beyond the province of this paper.

The low value Cl/SO_4 found in our rain water corresponds to those estabilished for rain water by other authors. The reason for such a low ratio is perhaps to be sought in the transport of sulphates into the atmosphere by means of combustion, particularly of coal which always contains greater or smaller quantities of sulphur, the major part of which finds its way into the atmosphere in the form of sulphuric acid to which it is turned by oxidation. The amount of chlorides in the smoke is, on the other hand, an insignificant one. That possibility is the more likely as our meteorological station is situated not far from suburban industries and from a busy sea-port.

Kalle, op. cit. has it that vulcanisms also add to the decrease of the value of that ratio.

The same author gives further W. D. Collins' and K. T. Williams' (1933) data for rain water on Wailuku (Hawaiian Islands) where the ratio Cl/SO_4 amounts to 3.15, coming next to the value found for our rain water according to the data we have at our disposal. With regard to the isolated position of that region as to influences of man, the case might serve as an example for the first mentioned opinion explaining why the ratio for rain water departs so much from that one for sea water.

It is interesting to note that the succession of ratios runs as follows:

Table No 5

Sea Water	Rain Water Hawaii	Rain Water Split	Yugoslav Rivers	A Spring rich with gypsum
7,2	3,15	0,314	0,087	0,0082

Rain water, according to the value of its ratio, lies somewhere between sea water and land fresh waters, and it seems that the value of the ratio Cl/SO_4 of rain waters provenient from different regions is also the result of the degree of the influence of land or marine factors upon rain waters.

A FEW FACTS ABOUT THE GEOCHEMICAL AND BIOCHEMICAL SIGNIFICANCE OF CYCLIC SALTS FOR THE ADRIATIC COAST

Yoshimura (1936) made investigations into the influence of the cyclic salts on some lakes situated not far from the sea, which were never relict mountain lakes, and whose distance from the sea vary from 0,6 to 2,7 km. Chlorides in quantities from 21 to 49 mg per liter were found in those lakes. The same author quotes A. Delebecque's works dealing with a French lake and F. W. Clarke's ones for some lakes in Florida which possess high contents of chlorides of cyclic origin.

The extent of the transport of salts through the atmosphere aided by the wind is illustrated by the event that happened lately in the region of the Saratoff district (Popova, 1951).

During the first days of April, 1950, there blew a strong wind from the region of the Caspian Sea, carrying such a quantity of salts with, that houses, trees, etc., were plastered with them. As resulted from the analysis, those salts consisted of $CaSO_4$, NaCl, Na_2SO_4 and of clay. Records from the same time reveal that the stormy wind in the region of the Caspian Sea reached the velocity of 20 metres per second. The transport of salts in the Saratoff district derives, in the opinion of the mentioned author, partly from salt lakes along the Caspian coast and partly from salts contained in the water of the Caspian Sea itself. The distance between Saratoff and Astrahan amounts to about 580 km.

There is, however, an older datum on a considerable transport of salts caused by the wind in the region of the East Adriatic. Gavazzi A. (1904), quoting Partsch, has it that during a storm in Southern Dalmatia raging on the 8th of January 1825, all the windows at Dubrovnik were »mit Salz wie mit einer Eisrinde beschlagen«.

That fact suggests the thought that also the Vrana Lake (See map, Picture 1) might owe one part of its salts to the sea, wind being the medium of their transport. That is facilitated by the fact that the Vrana Lake lies lengthwise in the direction of the sea coast, being separated from the sea by a ribbon of land 1—3 km wide. The front exposed to the influence of the

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We must not forget, however, that the Vrana Lake shows a relatively high content of chlorides. According to our measurements in June 1948, carried out on sixteen different points of that Lake, both on the surface and at the bottom, the content of Cl varied from 1080 to 1460 mg/l, corresponding to a total amount of salts from 1,98 to 2,67 gr per liter of water from that lake. It is, therefore, that the cause of such a high content of salts should, for its major part, be sought in the direct influence of the sea, made possible by subterranean connections between it and the lake, and for a minor part only in the cyclic origin of those salts. We have here a partition consisting of Karst limestone which, owing to its porosity, allows subterranean connections.

The presence of eels in the Vrana Lake may strenghten that hypothesis. It is supposed that eels do not avail themselves of the artificially cut Prosika Canal but that they travel by the intercommunicating subterranean cavities through the body of the land partition between the sea and the lake (See Plančić J., 1948).

It is obvious, of course, that the water of the Vrana Lake owes its enrichment with chlorides in a considerable extent to the Prosika Canal, as, after Gavazzi (op. cit.) the amount of salts in the water of that lake has increased after the canal had been cut. According to the same author, the influence of the wind-borne marine salts is felt in several lakes of Croatia, all lying in the vicinity of the seacoast, e. g. Blato, Blatina, Prožura (Mljet Island), Site (near Šibenik).

*

The folloving table contains an annual review (from December 1st 1948 to November 30th 1949), of the data relative to cyclic salts in the Split region:

Table No 6

mm of rainfall	Average content of Cl in the rain water	It fell on 1 cm^2	
682,1	9,65 mg Cl/l	68,2 cm of rainfall	0,658 mg Cl

The total quantity of salts fallen upon a unit of surface of the soil can be obtained from the above data by applying the usual hypothesis (which is subject to criticism) that the total amount of salts in the rain water is:

$$S = 1.835 \times Cl,$$

as it is the case with sea water.

According to that hypothesis, 1.207 mg of salts fell on 1 cm^2 of soil in the region of Split in 1948 and 1949. That quantity of salts is not a small one. Supposing that it had been falling on an undrained area or on a desert region, it would amount to 1.2 gr per one square cm in one thousand years.

By taking the specific weight 2.2, the height of that column would be 5.49 mm. That is a considerable quantity from the standpoint of geochemistry, surpassing three times the average speed of sedimentation in the ocean water, which, according P. H. Kuenen (1938) amounts to 0.001 to 0.002 mm a year (K a l l e, op. cit.).

The mentioned amount of salts (1.207 gr) fallen per 1 square cm of the investigated region, was about 50% higher than that one which was found by Pierre (1851), for the region of Normandy (quoted from K. R a n k a m a and Th. G. S a h a-m a, op. cit.). It is not excluded that the proximity of our meteorological station to the seacoast played a part in our case resulting in a higher amount of found chlorides.

By making a very rough approximation that the stated facts relative to cyclic salts apply to the entire Yugoslav coast-belt, taken as 5 km wide, we obtained the following picture:

Length of the mainland coast-line from Sušak to the Albanian frontier (R u b i ć, 1927)	1563 km
Length of the coast-line belonging to Dalmatian islands, the Istrian ones excepted (R u b i ć, op. cit.)	3607 km
Approximative length of the coast-line of Istria, Cres and Lošinj Islands	500 km
	5670 km
Minus, small radii on curves	1670 km
	4000 km

We arrive thus at 4000 km of seacoast with a minimal hinterland of 5 km.

The five kilometres wide coastal zone includes, then, an area of about 20 000 square kilometres of the Yugoslav Adriatic region. As an amount of 12 tons of salts is being precipitated yearly upon one square kilometer of surface (10^{10} cm^2), it follows that the coastal zone is receiving as much as 240.000 tons of salts per annum.

The major part of those salts is being brought down from the atmosphere and very soon streamed back into the sea, which is proved by the fact that the soil of the coastal zone is not oversalted. But a part of the precipitated salts, e. g. the main part of occurrring K and of some rarer salts, happen to be bound to the soil and to remain in it. As potassium represents 1.1% of the total amount of all the salts occuring in sea water, we find that a quantity of about 2500 tons of K is being brought down every year on the land of the said coastal zone, which would yield 8000 tons of potassium fertilizer (containing 40% K_2O). The main part of that amount of K is being highly adsorbed by the particles of the soil, where it is allowed to enter the biological cycle. The amount of potassium precipitated yearly on the said region is certainly not unimportant also from the economic point of view.

The amount of boron transported by means of rain water taken as H_3 BO_3 would yield something about 180 tons of that compound assuming that the ratio B/Cl maintains the same value in both sea and rain water. Rankama and Sahama (op. cit.) have it that boron is notably concentrated from sea water in the coastal soils which may contain from 10 to 50 times as much Boron as inland soils do.

Judging from the above facts, a deficiency of that biological element as a plant nutrient is rather improbable in the Yugoslav coastal region, having especially in mind the leguminous and bulbous plants which are particularly sensitive to deficiency of boron (Monier-Williams, 1950). Similar results would be obtained if other thallassophile elements were taken as the subject of calculation.

It is a great pleasure to express our thanks to Professor Dr. J. Goldberg of the Zagreb University for his criticism on the paper, and Professor A. Hruš, of the Split Higher Pedagogic School, for helpful discussion.

We are much indebted to Lieutenant C. Duplančić, chief of the (Naval) Hydrometeorological Service of Split, who most kindly placed at our disposal all the data regarding to winds we required.

Our thanks go also to our colleague Professor A. Vuletić who kindly procured a sample of water from Slana Jaruga.

SUMMARY

The content of chlorides in rainwater was investigated into during a period of time extending over more than thirteen months (in 1948 and 1949). The content of sulphate in rain water was also the subject of those investigations. The data thereon are given in tables covering days and months. The lowest content of Cl' was 1.38 Cl/l, and the highest one was 156.4 mg Cl/l.

December 1948 showing 21.58 mg Cl/l and March 1949 showing 21.2 mg Cl/l were the rainy months with the highest concentration of chlorides in rain water. Among the months with rain October 1949 showing 3.29 mg Cl/l and June 1949 showing 5.72 mg Cl/l were the ones with the lowest content of chlorides in rain water. The yearly average, as resulting from 72 analyses, was 9.65 mg Cl/l.

The amount of Cl, precipitated on 1 m^2 of surface during a day's period was 7.7×10^{-4} mg Cl/cm^2 (24. V. 1949), and the greatest one was 7.04×10^{-2} mg Cl/cm^2 (8. XI. 1949). The year's average precipitation was 6.58×10^{-1} mg Cl/cm^2. Expressed in a year's total of (dry) salts a height is reached amounting to 5.49 μ.

A regularity has been stated consisting in the fact that in cases of rain water belonging to rainfalls occurring during several subsequent days, in absence of winds being over 4-6 degrees Beaufort strong, the concentration of Cl/l decreases regularly with time. (Rule of several days' period).

It has been stated further that the points, resulting from data on mm of rain water and mg Cl/l of all the rainfalls which occurred during a year, if placed into a system of coordinates, will produce almost a hyperbolic curve. There results that the product obtained by multiplying mm of rain water by mg Cl/l represents one, to some extent constant, quantity (K). This is the Regularity of longer time periods.

The opinion has been expressed that K might possibly be a characteristic of single climatic regions.

By dealing with the data on Cl and mm of fractions of a single rainfall lasting for 4¼ hours there has been found that

the amount of mg Cl precipitated on the ground (mg Cl/l x l of rain water) decreases with time following the law of the exponential function.

Data are also given on the content of SO_4 found in several rain waters at different season of the year, the average content of Cl/SO_4'' amounting to 0.314.

The possibility of an influence of cyclic salts upon the salinity of the Vrana Lake water was also dealt with.

Approximate values of the amounts of salts precipitating during a year on the 5 km wide coastal belt of the Yugoslav Adriatic Littoral are given. The total quantity of salts amounts to 2.4×10^5 tons.

The probable influence of some compounds of the rain water salts on the living world of the coastal belt has also been considered.

BIBLIOGRAPHY

BOGUSLAWSKI G. & O. KRÜMMEL (1907): Handbuch der Oceanographie, Stuttgart.

BULJAN M.: Sulfati u Jadranskoj vodi (Sulphates in the Adriatic Sea Water — an unpublished paper).

CAUER H. (1932): Das Jod der Luft im Hochgebirge. XL. Jahresbericht des Sonnblick-Vereines 1931 Wien.

GAVAZZI A. (1904): Die Seen des Karstes, I. Teil. Abhandlungen der K. K. Geogr. Gesellschaft in Wien, V. Bd. 1903/04, No. 2.

ISRAEL H. (1934): Über den Chlorgehalt des Regenswassers. Bioklimatische Beiblätter der Meteorologischen Zeitschrift 1934. Bd. Hf. 2.

JESSER H. & E. THOMAS (1934): Jod Luftuntersuchungen. Zeitsch. Analyt. Chem 125, 89—93 iz Chem. Zentrbtt. 1943. I. 1557.

KALLE K. (1943): Die Stoffhaushalt des Meeres. Leipzig.

LIPP H. (1932): Über die Chemische Zusammensetzung des Nebelfrostes auf der Zugspitze. XL. Jahresbericht des Sonnblick-Vereines 1931. Wien.

MAUCHA R. (1932): Hydrochemische Methoden in der Limmologie. Stuttgart.

MONIER-WILLIAMS G. W. (1950): Trace Elements in Food. London Chapman & Hall Ltd.

PLANČIĆ J. (1948): Privredni značaj Vranskog jezera. (The Economic Importance of the Vrana Lake) Ribarstvo Jugoslavije III, 15.

POPOVA R. K. (1951): Gips i solj iz atmosfere. (Gypsum and Salts from the Atmosphere.) Priroda, No. 2, p. 65. Moscow.

RANKAMA H. & TH. G. SAHAMA (1950): Geochemistry. Chicago.

SVERDRUP H. U., M. W. JOHNSON & R. H. FLEMING (1946): The Oceans, their Physics, Chemistry and General Biology. New York.

TREADWELL F. P. (1943): Kurzes Lehrbuch der Analytischen Chemie II. Bd. Quantitative Analyse.

YOSHIMURA S. (1946): The Effect of Salt-breeze on the Chemical Composition of Freshwater Lakes near the Sea. — Arch. f. Hydrobiol. Bd. XXX. s. 345—51.

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APPENDIX

Table No 1

Date	mm of rainfall	Cl mg/l	kg Cl/km²	Direction and velocity of wind at 07.00		at 14.00		at 21.00		The strongest wind
1948										
14 X				NE	(2)	SW	(0)	SSE	(1)	
15				NNE	(2)	SW	(0)	ESE	(0,4)	
16				NE	(2)	ESE	(4)	ESE	(5)	
17	42,5	4,6	196,3	NNW	(2)	SSW	(1)	SE	(2)	5
26				SE	(4)	SSW	(6)	SSE	(7)	
27				SSE	(7)	SE	(7)	SSE	(6)	
28				SSE	(7)	SW	(6)	ESE	(3)	
29	9,4	15,4	144,8	NNE	(1)	S	(0)	ESE	(2)	7
30				ENE	(3)	S	(6)	ESE	(8)	
31	8,3	9,44	78,4	SE	(4)	SE	(6)	E	(3)	8
1 XI	17,4	9,54	166,1	ENE	(2)	NE	(2)	NNE	(1)	8
14				NE	(2)	WNW	(1)	W	(1)	
15				NE	(1)	SE	(0)	N	(0)	
16				NE	(1)	ENE	(4)	ESE	(3)	
17	21,8	6,48	141,3	NE	(2)	NNE	(3)	NNE	(3)	4
18	8,4	1,99	16,7	NNE	(6)	NNE	(7)	NE	(7)	
28 XII				NE	(1)	NE	(0)	N	(1)	
29				NE	(2)	SE	(1)	ESE	(1)	
30				NE	(1)	ESE	(3)	SE	(7)	
31	9,6	21,58	207,3	SE	(5)	SSE	(6)	S	(6)	7
1949										
7 I				NNE	(2)	NE	(0)	NNE	(1)	
8				NE	(2)	ENE	(0)	SE	(2)	
9	44,5	5,84	259,9	SE	(3)	NE	(1)	NNE	(3)	2
10				NE	(3)	NE	(1)	NE	(1)	
11				ENE	(2)	ENE	(2)	E	(2)	
12	8,1	5,39	43,65	SE	(0)	NE	(1)	NNE	(4)	3
13	24,7	2,0	49,4	NNE	(10)	NNE	(12)	NNE	(10)	4
20				NE	(0)	ENE	(0)	ENE	(1)	
21				SE	(3)	SE	(0)	NE	(1)	
22				NE	(0)	NE	(6)	NE	(7)	
23	4,9	156,43	766,0							7
28 II				NE	(3)	NNE	(8)	NNE	(9)	
1 III				NNE	(5)	SW	(1)	NE	(2)	
2	4,2	82,8	347,5	SE	(1)	NNE	(9)	NNE	(11)	9

Table No 1 (continued)

Date	mm of rainfall	Cl mg/l	kg Cl/km²	Direction and velocity of wind at 07.00		at 14.00		at 21.00		The strongest wind
9				NE	(4)	SSW	(1)	SSW	(1)	
10				ENE	(0)	SE	(1)	NE	(2)	
11				NE	(1)	SE	(3)	E	(3)	
12	2,5	60,81	152,0	SE	(3)	SE	(1)	SE	(2)	4
13	18,4	12,87	236,5	ESE	(4)	SE	(3)	SE	(3)	3
14	6,2	6,87	42,6	NE	(0)	W	(0)	N	(0)	4
15				ENE	(1)	ESE	(4)	SE	(2)	
16	7,9	16,16	128,0	NNE	(2)	SW	(1)	ESE	(1)	4
17				SE	(1)	ESE	(1)	NE	(3)	
18	4,3	12,21	52,5	NE	(1)	S	(1)	SW	(2)	3
19				SE	(5)	NNE	(5)	NNE	(7)	
20	6,2	14,84	92,0	NNE	(7)	NNE	(6)	NNE	(9)	7
9 V				NNE	(6)	NNE	(2)	NNE	(5)	
10				NNE	(4)	SSE	(3)	NE	(3)	
11	10,2	26,3	268,3	NE	(3)	SW	(1)	SW	(0)	6
12	8,7	13,44	117,0	SE	(0)	W	(1)	NNW	(3)	6
13	30,5	7,5	228,7	S	(0)	SSW	(3)	NE	(1)	4
14	2,3	6,08	14,0	NE	(1)	SW	(1)	NW	(1)	3
15	10,6	4,87	51,6	N	(0)	SSW	(1)	NW	(2)	
16				ENE	(1)	SSW	(1)	NW	(0)	
17				SW	(0)	SW	(0)	NE	(0)	
18	1,2	12,84	15,42	ESE	(1)	S	(1)	SW	(1)	1
19				E	(1)	SSW	(2)	SW	(1)	
20	1,1	22,19	24,4	NE	(0)	SE	(4)	SE	(2)	2
21	10,0	6,28	62,8	SE	(1)	SE	(4)	SSE	(3)	4
22	14,3	4,1	58,6	NNE	(1)	E	(1)	E	(1)	4
23	32,4	2,05	66,3	NE	(0)	S	(1)	S	(1)	
24	3,8	2,05	7,77							
30				E	(1)	SSW	(2)	SSE	(2)	
31				SE	(3)	ESE	(5)	SW	(0)	
1 VI				ESE	(1)	SSW	(1)	NW	(2)	
2	1,8	10,24	18,43	NE	(1)	SW	(1)	WNW	(1)	5
3				NW	(1)	WNW	(3)	NE	(1)	
4	14,1	1,38	19,45	SE	(1)	SW	(1)	—		5
10				SE	(1)	SW	(1)	S	(0)	
11				SE	(0)	SW	(1)	SE	(3)	
12				WNW	(2)	NE	(2)	SE	(2)	
13	4,5	3,87	17,41	NNE	(2)	NNW	(2)	NW	(1)	3

Table No 1 (continued)

Date	mm of rainfall	Cl mg/l	kg Cl/km²	Direction and velocity of wind at 07.00		at 14.00		at 21.00		The strongest wind
16				SE	(0)	SW	(4)	SE	(0)	
17				NE	(0)	SW	(1)	NNE	(3)	
18	3,2	6,1	19,5	NNE	(5)	SSE	(3)	NE	(2)	4
19				NE	(4)	SW	(1)	NE	(3)	
20				NNE	(2)	SE	(1)	NNW	(2)	
21				NNE	(1)	SW	(3)	SSW	(1)	
22	2,6	9,3	24,2	NE	(1)	SSW	(2)	NNE	(4)	4
23				NNE	(2)	SE	(2)	ESE	(2)	
24	3,8	5,5	20,9	NE	(2)	NNE	(1)	NE	(3)	4
25	20,5	5,8	118,9	E	(2)	SSW	(3)	NW	(1)	
26	5,2	15,4	80,0	NE	(4)	SW	(2)	NW	(1)	
28				SE	(0)	SSW	(1)	SW	(1)	
29				NE	(0)	SW	(2)	NW	(2)	
30				ESE	(1)	SE	(1)	NNE	(2)	
1 VII	8,2	7,0	57,4	N	(3)	N	(3)	NNE	(4)	2
15				SE	(0)	SSW	(1)	NW	(0)	
16				SSW	(1)	SW	(1)	NW	(1)	
17	1,0	9,6	9,6	SE	(0)	SSW	(1)	SW	(1)	1
10 VIII				NE	(1)	SW	(1)	NE	(4)	
11				NE	(4)	SW	(2)	SW	(1)	
12				NNE	(1)	NNW	(5)	NNE	(6)	
13	1,9	29,8	56,6	NNE	(7)	NNE	(7)	NNE	(7)	6
14				NNE	(4)	SSE	(2)	NE	(1)	
15	3,3	6,7	22,1	NE	(1)	SSE	(3)	NNE	(2)	7
16				NE	(1)	SW	(2)	E	(1)	
17				SW	(0)	SSW	(1)	NNE	(3)	
18				NNE	(5)	NNE	(6)	NE	(4)	
19	10,2	15,4	157,1	NNE	(6)	NNE	(4)	NNE	(1)	6
29				N	(0)	SSW	(0)	SSW	(1)	
30				NW	(0)	SW	(1)	S	(0)	
31	3,1	10,4	32,2	NNE	(1)	SSW	(1)	S	(0)	1
8 IX				NE	(3)	SW	(2)	SE	(1)	
9				SE	(0)	SW	(2)	SE	(2)	
10	26,8	3,0	80,4	ENE	(1)	SSW	(1)	NE	(0)	3
11	1,5	14,1	21,15	NE	(1)	SW	(1)	NNE	(2)	3
13				NE	(1)	S	(1)	NE	(2)	
14	1,5	10,5	15,75	E	(2)	SE	(5)	ENE	(2)	2
15				NE	(1)	SSE	(1)	SW	(1)	
16	2,0	6,3	12,60	NE	(1)	SSE	(1)	NNE	(1)	5
17	3,3	4,4	14,52	NE	(3)	NE	(2)	NNE	(2)	5

Table No 1 (continued)

Date	mm of rainfall	Cl mg/l	kg Cl/km²	Direction and velocity of wind at 07.00		at 14.00		at 21.00		The strongest wind
19				NNE	(1)	SW	(1)	NE	(2)	
20				NNE	(1)	S	(1)	SW	(0)	
21	1,4	7,0	9,8	N	(1)	SE	(2)	ESE	(1)	3
22	3,2	6,0	19,2	NE	(1)	SW	(1)	W	(0)	2
23				SW	(0)	SSE	(1)	NW	(1)	
24				NE	(1)	SW	(1)	NNE	(4)	
25	6,8	2,3	15,64	NE	(4)	SW	(1)	NNE	(2)	4
1 X				ESE	(2)	SE	(5)	SE	(5)	
2				SE	(5)	SE	(5)	SE	(5)	
3				NE	(3)	SE	(1)	NE	(1)	
4	15,1	3,1	46,81	NE	(1)	SE	(1)	NE	(2)	5
5				NE	(3)	SE	(1)	E	(1)	
6				NE	(1)	S	(1)	NW	(1)	
7				ENE	(2)	ESE	(3)	NNE	(2)	
8	20,6	2,9	59,74	ENE	(4)	SSE	(4)	SE	(3)	3
9	46,7	2,7	126,09	ESE	(4)	NW	(1)	N	(1)	4
10	26,4	4,2	110,88	NNE	(4)	NNE	(4)	NE	(4)	4
17				NE	(1)	SSW	(1)	NNE	(1)	
18				NNE	(1)	NNE	(3)	NNE	(5)	
19	1,6	8,86	14,18	ENE	(1)	SW	(1)	NNE	(2)	5
27				ENE	(2)	SE	(3)	ESE	(3)	
28				ENE	(4)	ENE	(4)	NE	(4)	
29	16,6	2,93	48,64	NE	(2)	NW	(1)	NE	(3)	4
30	1,0	15,84	15,84	NNE	(3)	—		NE	(1)	4
1 XI				NNE	(5)	SW	(1)	NNE	(4)	
2				NNE	(5)	NE	(3)	NNE	(4)	
3				NE	(3)	—		NNE	(4)	
4	2,1	5,99	12,58	NNE	(5)	NE	(5)	NE	(4)	5
5	30,6	2,7	82,62	NNE	(3)	ENE	(6)	SE	(7)	5
6	45,0	6,42	288,90	—		E	(1)	S	(4)	7
7	11,9	12,51	148,87	ESE	(1)	SSE	(7)	SSE	(9)	7
8	15,3	46,02	704,11	SE	(3)	SW	(1)	N	(1)	9
9	1,6	28,07	44,91	NNE	(3)	N	(7)	NNE	(1)	9
12				ENE	(1)	SE	(1)	ENE	(1)	
13				SE	(1)	ESE	(4)	SE	(4)	
14				SSE	(3)	SSE	(4)	SSE	(7)	
15	2,4	25,9	62,16	SSW	(1)	SE	(2)	ENE	(2)	7

Table No 1 (continued)

Date	mm of rainfall	Cl mg/l	kg Cl/km²	Direction and velocity of wind at 07.00		at 14.00		at 21.00		The strongest wind
16	6,3	4,69	29,08	NE	(1)	ESE	(4)	NNE	(3)	
17	6,3	4,69	29,08	NE	(4)	—		NNW	(1)	7
18	8,7	2,97	25,84	NE	(1)	SSE	(1)	ESE	(3)	4
19				ESE	(4)	SE	(4)	SE	(7)	
20				SE	(5)	SE	(5)	SE	(4)	
21				ESE	(10)	SE	(4)	SE	(3)	
22	3,9	11,24	43,84	ESE	(3)	SSW	(1)	SSE	(4)	10
23	5,9	5,1	30,09	SSW	(5)	SSE	(5)	WNW	(2)	10
24	6,4	4,15	26,56	SSE	(7)	S	(7)	SSW	(6)	10
25	2,4	26,1	62,64	S	(4)	SE	(4)	SE	(7)	7
26				SE	(7)	SE	(7)	SE	(10)	10
27	15,2	30,6	465,12	SSW	(6)	NE	(5)	SSW	(7)	

Remark: The dates contained in this Table belong to the wind and rain water data, but as rain water was being taken at 7 o'clock in the morning some reserve is here necessary. As the main part of the rain water could have fallen on the previous day (from 07.00 to 24.00 hours), those data should be logically taken as belonging to foregoing days, although the dates, to make it shorter, were put, for instance, 13. III. instead of 12.—13. III.

REZULTATI ISPITIVANJA CIKLIČNIH SOLI U KIŠNICI NA ISTOČNOJ OBALI JADRANA (SPLIT)

(sa 9 slika u tekstu)

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KRATAK SADRŽAJ

Ispitivan je sadržaj klorida u kišnici u toku više od 13 mjeseci (1948 i 1949 god.). Osim toga je ispitivan i sadržaj sulfata u kišnici. Podaci su dani tabelarno po pojedinim danima i po mjesecima. Najniži sadržaj Cl' bio je 1,38 mg Cl/l, a najviši je bio 156,4 mg Cl/l.

Mjeseci sa kišnicom najjače koncentracije klorida su bili XII. 1948 sa 21,58 mg Cl/l i III. 1949 sa 21,2 mg Cl/l. Od mjeseci sa kišom su najmanje sadržavale Cl mg/l kišnice X. 1949 sa 3,29 mg Cl/l i VI. 1949 sa 5,72 mg Cl/l. Godišnji prosjek iz 72 analize je bio 9,65 mg Cl/l.

Najmanja količina mg Cl, koja je pala na 1 cm^2 površine u toku jednog dana je bila $7,7 \times 10^{-4}$ mg Cl/cm^2 (24. V. 1949), a najjača je bila $7,04 \times 10^{-2}$ mg Cl/cm^2 (8. XI. 1949). Godišnje obaranje Cl' je bilo $6,58 \times 10^{-1}$ mg Cl/cm^2. Preračunano na ukupne soli (suhe) godišnje padne soli visine $5,49 \mu$.

Konstatirana je pravilnost da u kišnicama kiša palih u toku nekoliko dana u otsustvu vjetrova jačine veće od 4—6 Beaufortovih jedinica, svakim slijedećim danom opada koncentracija Cl mg/l (p r a v i l n o s t v i š e d n e v n i h p e r i o d a).

Dalje je nađeno da točke podataka mm kiše i mg Cl/l svih kiša u godinu dana stavljene u koordinatni sustav se grupiraju približno u hiperboličnu krivulju. Izlazi da je mm kiše x mg Cl/l jedna, donekle konstantna, veličina (K) (p r a v i l n o s t d u g i h v r e m e n s k i h p e r i o d a). Izneseno je mišljenje da postoji mogućnost, d a b i K m o g a o b i t i z n a č a j a n z a p o j e d i n a k l i m a t s k a p o d r u č j a.

Tretirani su podaci Cl i mm frakcija jedne kiše trajanja 4¼ sata i nađeno da količina mg Cl palih na zemlju (mg Cl/l x l kišnice) opada sa vremenom po zakonu eksponencijalne funkcije.

Dani su podaci sadržaja SO_4'' u nekoliko kišnica u razno doba godine. Nađen je Cl/SO_4 prosječno 0,314.

Tretirana je mogućnost upliva cikličkih soli na slanost Vranskog jezera.

Dane su približne brojke količine soli, koje padnu u toku godine na 5 km uski obalni pojas jugoslavenske obale. Količina ukupnih soli iznosi 2.4×10^5 tona.

Razmotren je mogući upliv nekih komponenata soli kišnice na živi svijet obalnog pojasa.