The Chemical Denudation of the Soil

By O. ARRHENIUS, Kagghamra

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Abstract

The chemical denudation plays a greater role in our climate than the mechanical erosion. The Swedish well waters contain 3—4 times more soluble salts than those rivers which are fed by them. The chemical denudation therefore must be much greater than formerly calculated. A map shows the salt concentration of the well waters of Sweden. The amount of nitrogen accumulated per annum in a district of central Sweden seems to amount to 3—6 kg N per har.

The symposium is supposed to deal with the nitrogen in the atmosphere. It is, however, of great interest to follow up the problems regarding the balance between soil-water and also to try to show the general problem which is of the greatest practical interest: the denudation of the soil.

One of the most discussed items just now is the soil erosion in connection with the possibilities to nourish the ever increasing population of the earth (BENNET, 1939). In all the books published on this subject we find the wind and water erosion, thus the mechanical erosion, mentioned but never the chemical erosion, the soil denudation. In humid climate, like ours, the chemical denudation is more destructive to the soil than the erosion.

Every country which neglects its soil giving it a prey to denudation and erosion is doomed to decline and fall. We may look at the Roman Empire. The country round Rome was a fertile land giving good yields of wheat nourishing the capital. The land was neglected, Rome lived on import goods, and the area turned very acid (pH below 5), denuded of its nutrients, giving low yields. And costing immense sums to reclaim.

About A.D. 400 the farmers of Gotland probably because of a change in rainfall moved their dwellings from the lower, clayey soils to the sandy parts of the island. Within some centuries these soils were depleted and the population had to live as merchants and sailors. When these latter possibilities were throttled in the 12th century an era of poverty and famine was reigning until the lowerlying areas were reclaimed in the 16th century.

On a still larger scale similar things have happened in the U.K. The soils in large districts have been neglected, and denudation has carried away much of the plant nutrients. The food question has been one of the difficulties with which the english people has had to struggle lately.

What is then denudation. The precipitating water percolates the soil layers dissolving the nutrients carrying them down to deeper layers or to the ground water. The ground water feeds the rivers which carry the dissolved salts to the sea. On the way from the well to the sea certain amounts disappear being taken up by plants or precipitated in lakes or rivers.

Certain powers counteract the denudation. The plants evaporating the water diminishes the strength of the down current. Plants have

an ability to take up salts even from very diluted solutions. HARVEY (1926) has shown that organisms living in the sea are able to take up nitrates from solutions at such a low concentration as 10 mg/m³. The plants, thus, take up the nutrients and concentrate them, often thousandfold. When shedding leaves and needles, when the plant dies, wholly or to a certain part, the offall forms the humuslayer on the top of the soil and this layer is rich in light soluble nutrients. In this way the top soil is re-enriched.

By studying the ground water—well water composition and knowing the amount of percolating water it is possible to estimate the amounts of different salts carried away from the upper soil layers. The map shows the concentration of total salts dissolved. The clay districts show high figures, the sand districts and Norrland are on the other hand very poor. From the map is also seen that the deviations within the districts are rather small. (Fig. 1).

The average composition of the water is the same, the concentration only differs. The composition of the percolating water we know but the amount of percolating water is only an assumption. We guess that 30—35 % of the rainfall is not evaporated. And we assume that the percolating water is of the same amount as what we find the rivers carrying off to the sea.

We may therefore compare the concentration of well water with that of river water and that will throw a light on the denudation problem. All earlier investigations on soil denudation have used the amount of salts emptied into the sea by the rivers as a measure of denudation (BAULIG, 1910, ERIKSSON, 1929). In the table we find the amount of total salts, Cl, SO_4 and NO_3 of the well waters of different rivers in Sweden.

From this we see that the amount washed-out of the soil is much greater than that

The concentration of soluble inorganic substance sulphates, chlorides and nitrates in some Swedish rivers and in the well waters feeding the different rivers.

From the rivers we have no data with regard to nitrates. Judged from other analyses the nitrate content in the river waters seems to be very low and would in this table be = 0. It is easily seen that not only the total inorganics diminish from the well to the river waters but also SO_4, Cl and NO_3.

		SO_4	Inorg. subst.	Cl	NO_3
Skellefteälv	River water	0.9	21.2	3.1	—
	Well »	1.0	8	13	—
Umeälv	River water	1.5	20.9	3.3	—
	Well »	6	102	14	—
Öreälv	River water	—	26.0	3.2	—
	Well »	6	54	3	—
Ångerman-älven	River water	1.7	20.9	2.5	—
	Well »	4	107	11	9
Indalsälven	River water	2.1	32.6	4.5	—
	Well »	5	170	9	3
Ljungan	River water	1.2	28.4	3.0	—
	Well »	5	131	15	—
Ljusnan	River water	1.6	24.6	2.5	—
	Well »	1	54	7	5
Dalälven	River water	2.0	25.3	2.8	—
	Well »	28	150	10	—
Närkes Svartå	River water	9.6	43.9	4.9	—
	Well »	10	103	9	5
Nyköpingsån	River water	12.7	58.0	6.2	—
	Well »	2.5	258	31	12
Mjölnaån	River water	27.9	138.4	9.6	—
	Well »	35	416	58	28
Stångån	River water	7.9	49.6	7.1	—
	Well »	9	233	31	17
Emån	River water	7.1	40.1	6.8	—
	Well »	9	153	21	12
Mörrumsån	River water	5.3	30.6	7.9	—
	Well »	16	157	28	18
Helgeån	River water	7.4	51.0	11.7	—
	Well »	35.0	215	33	38
Tommarpsån	River water	33.6	202.5	14.2	—
	Well »	50	410	39	58
Kävlingeån	River water	30.7	210.7	18.7	—
	Well »	50	498	74	35
Rönneån	River water	14.9	94.1	15.0	—
	Well »	45	316	51	27
Lagan	River water	4.9	27.9	6.8	—
	Well »	9	126	20	17
Nissan	River water	6.9	33.3	7.0	—
	Well »	9	105	21	13
Ätran	River water	5.3	36.8	7.4	—
	Well »	5	97	15	19
Viskan	River water	7.9	48.7	10.9	—
	Well »	9	116	9	9
Klarälven	River water	2.5	22.6	3.2	—
	Well »	5	59	9	5
Ölman	River water	—	49.5	5.5	—
	Well »	4	163	27	7
Gullspångs-älven	River water	2.9	21.8	4.3	—
	Well »	5	95	8	8
Tidan	River water	13.4	81.6	9.6	—
	Well »	20	213	28	19
Lidan	River water	37.9	193.2	16.6	—
	Well »	22	370	50	18

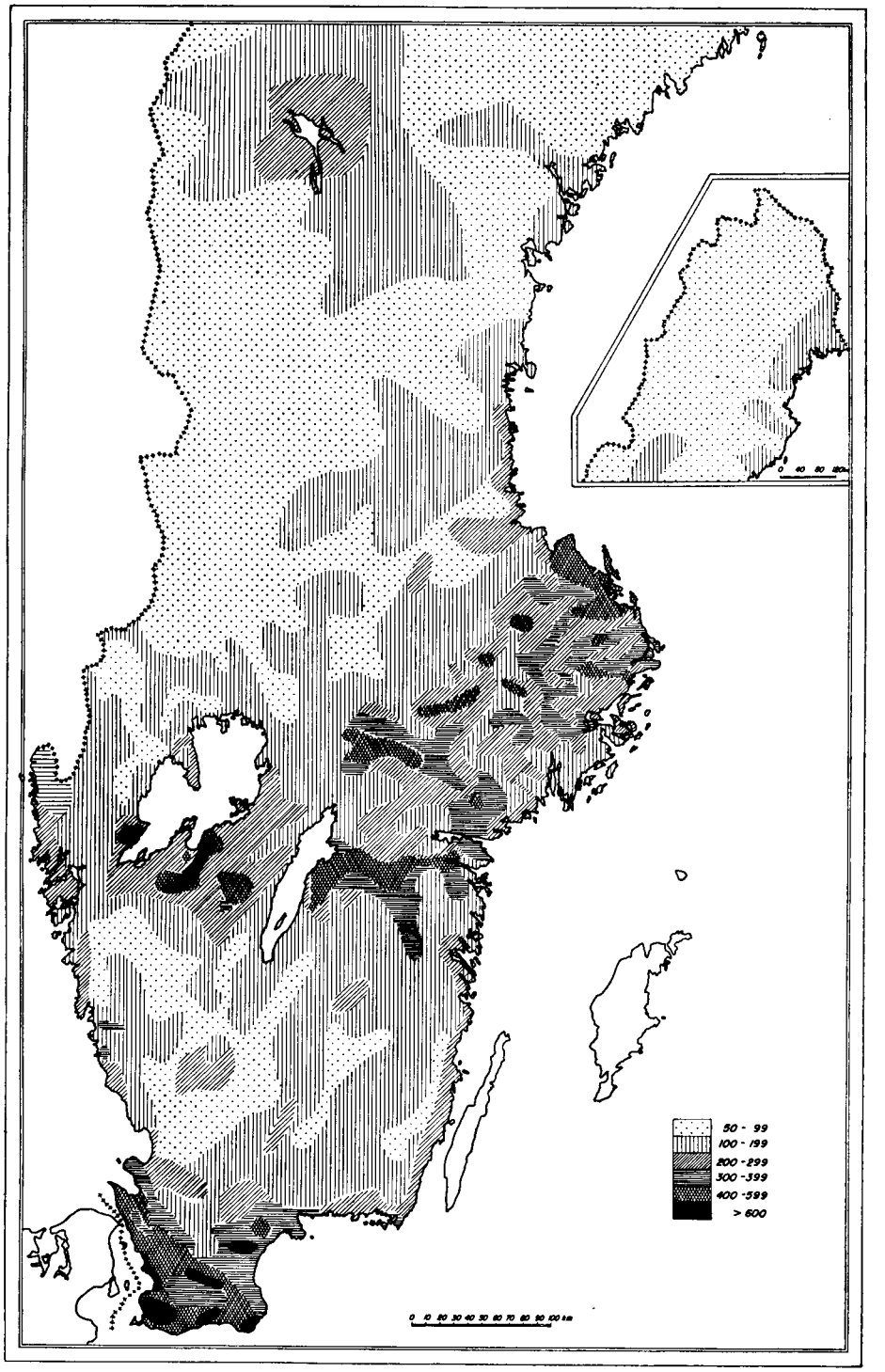

Fig. 1. The concentration (salinity) of well waters of Sweden. The figures give the concentration in mg/litre. The analyses obtained by the courtesy of the Institute of Public Health.

emptied into the sea. The salts must thus be precipitated or absorbed either in the subsoil (the deeper layer) or in the rivers and lakes. It is interesting to see that from the poor waters more is precipitated than from the rich ones.

The total amount of the chemical denudation amounts to about 20 mill. tons a year or 500 kgs per ha.

In the investigations regarding the composition of river water from Sweden by JOEL ERIKSSON (1929), no analyses were made of the content of nitrates. It is therefore impossible to make a comparison like that for the other salts but I have examined all data published by HOFMAN-BANG (1902—03) and SONDÉN (1914) and from this is seen that practically all river waters are free from nitrates. Here probably the organisms of the rivers have assimilated the total amount of the nitrates.

On the other hand the rivers carry large amounts of nitrogen to the sea. It is very probable that this consists of colloidal and suspended peat and humus (ERIKSSON, 1929, HOFMAN-BANG, 1902—03). At least this is often the case in Swedish rivers. But we know rather little of this problem. One may estimate the denudation with the rivers to 3 kg N ha and year. The nitrates of the ground water will amount to 11 kg N per ha. and year.

The question then arises: will there be anything left of nitrogen in the soil or have we to expect a depletion. Dalecarlia has recently been very closely investigated geologically. On the basis of the investigation made we have a humuslayer chiefly in peat bogs in average containing about 30,000 kg N/ha. We may assume that this accumulation has gone on for the last 5—10 thousand years. This would be a net accumulation of 3—6 kg N/ha. and year.

As the nitrogen is the most scarce and most essential nutrient of the soil such an investigation as that discussed here is of the utmost practical interest. Are we able to enrich the soil with nitrogen we may produce more on the soil.

But we still lack essential data about

1) nitrogen fixed

2) the amounts of nitrogen denuded and carried off to the sea

3) the amount of water percolating through the soil.

4) An investigation with regard to nitrogen similar to that which Joel Eriksson has published regarding other water properties must be made.

REFERENCES

BAULIG, HENRI, 1910: Écoulement fleuvial et denudation. *Annales de Géographie* XIX.

BENNET, H. H., 1939: *Soil conservation.* Mc. Graw Hill Book Co. New York and London.

ERIKSSON, JOEL, 1929: Den kemiska denudationen i Sverige. *Meddelanden från Statens Meteorologiska-Hydrografiska Anstalt, 5.*

HARVEY, H. W., 1926: Nitrates in the sea. *Marine Biol. Ass. U.K.*, Plymouth.

HOFMAN-BANG, O., 1902—03: Studien über schwedische Fluss- und Quellwasser. *Bull. of the Geological Institution of the University of Upsala.* VI.

Meddelanden från Statens Meteorologiska Hydrografiska Anstalt 1914—51, 1—14: De svenska vattendragens arealförhållanden.

SONDÉN, KLAS, 1914: Anteckningar rörande svenska vattendrag. I. II. Stockholm.

ULE, WILLI, 1925: *Physiographie des Süsswassers. Encyclopädie der Erdkunde.* Leipzig und Wien.