# Chemical Denudation in Sweden

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## *Abstract*

Many analyses of groundwater have been made by the Swedish Health authorities. Of those about 10,000 have been used for an attempt to map the geographic distribution of various substances. The factors analyzed are: Total amount of inorganic substances, Ca, Fe, Mn, $NH_4$, $SO_4$, Cl, $NO_3$, $HCO_3$, $PO_4$, pH and oxidation by permanganate. It is found that the water of wells with a depth less than 2 m are more diluted than that of the deeper ones.

Scania and the plains of the later district have rich waters whereas the Highlands of Southern Sweden and the northern part of the country (Norrland) have water with a low salt content. Drilled wells are richer than the shallow ground water wells. The chemical denudation is much stronger than formerly calculated. One can estimate that the topmost metre of the soil has lost about 1/5 of its weight by denudation since the ice age. Great losses are also caused through the sewage waters which are carried away to the sea, by the burning of straw etc.

Very much may be done in order to stop or to counteract the chemical denudation. A well planned crop rotation, planning of a forest culture which improves the soil conditions, taking care of all affalls are some of the roads leading to a decreased chemical denudation of the soil.


The geochemical processes within the various parts of the cycle of the earth are so intimately related to each other that it is hardly possible to say whether an action takes place in the lithosphere or in, for instance, the hydrosphere. This applies above all to the part played by water in weathering. This action also greatly affects conditions within the biosphere, so greatly, in fact, that one is justified in saying that organic life is wholly dependent upon the direction weathering takes. An occurrence to which little attention is paid is that which takes place within that part of the biosphere which might be called the anthroposphere. Human beings interfere with and regulate nature, and their activities have become so potent that in certain cases the results may be compared with geological events.

In the present work the author attempts to give a cross-section of the reaction known as chemical denudation, caused by percolating water, subsoil water and watercourses, and the contribution of man to these processes.

Rain falls, water sinks into the ground, and all the substances in the soil are more or less dissolved. Soil moisture, the source from which all plants derive their nourishment, is formed. Salts are liberated and precipitated as the water sinks farther down. At greater or lesser depths the water collects as subsoil water which in places comes to the surface as springs, wells, watercourses and lakes. Subsoil water carries with it dissolved substances and deprives the top soil of part of its stock of nutrients. This is what is known as the chemical denudation of the land.

This impoverishment of the land has up to now been measured by examining the amount of dissolved substances carried by rivers into the sea (9, 15, 21). This is in itself a very important phenomenon as it consists of a transport of substance from the lithosphere to the hydrosphere. But more important from a biological point of view is the transport of dissolved substances from the upper layers of soil to those below.

To illustrate these problems we have an extensive material consisting of analyses of water collected at our chemical stations and by the State Institute of Public Health. The material at our disposal includes water from deep wells, lakes and watercourses, water-pipes, shallow wells and springs. It is only the two last named which in the present work are taken as being representative of subsoil water.

Analysis instructions are to be found in Meddelande från Kungl. Medicinalstyrelsen, 1950. (31).

This material suffers from one drawback, viz. the samples were in the main taken from populated areas. Thus these districts rather than the great uninhabited areas are represented. Some samples, however, were taken from unpopulated areas. In addition there is a very extensive material consisting of conductivity determinations from Vattenfallsstyrelsens' main power-lines through Sweden. By means of these investigations a belt taxation of the soil conductivity within large parts of the uninhabited areas has been carried out, the results of which are in good agreement with the maps based on water analyses.

The results are given below in mg/l. As far as Ca is concerned, this is calculated from the total hardness, but the result is given in mgCa/l.

**Depth**

The samples of water were taken from wells of different depths.

The deepest wells are to be found in the clayey plains (Upsala, Kristianstad, Malmöhus, Skaraborgs län) and in Kopparbergs län and Västerbotten. The least average depths are found in Blekinge, Halland and Värmland. It is to be expected that the salt content of the water should vary with the depth. Table 1 shows the variations in water from wells of different depths. The total salt content, as well as Cl and Ca, is doubled in the first two metres.

The consumption of permanganate, on the contrary, is greatest in shallow wells, probably on account of the relatively greater amount of organic substance in both the water and the surface soil.

It is of great interest to ascertain whether the relationship between the different ions and the total content of inorganic matter is constant or not.

In Table 2 the total salt content has been fixed at 100.

From this it can be seen that the relative composition of the salts is practically the same at different depths as far as $SO_4$, Cl, Ca, Fe, Mn and $NO_3$ are concerned. On the other hand, the water in wells two metres deep or shallower seems to be more diluted than that in deeper wells.

One explanation of this may be that the water on its way down through the earth attains complete saturation only after a certain period of time. It may also be that the upper

**Table 1. Depths of shallow wells and the content of different substances in the water by mg/l**

| Depth in metres | $SO_4$ | Total salt content | Cl | Ca | Fe | Mn | $NO_3$ | Permanganate consumption |
|---|---|---|---|---|---|---|---|---|
| 1 | 5 | 118 | 13 | 3.7 | 0.7 | 0.57 | 3.6 | 21 |
| 2 | 4 | 122 | 13 | 4.1 | 1.0 | 0.08 | 5.4 | 20 |
| 3 | 5 | 194 | 26 | 6.2 | 1.2 | 0.15 | 9 | 25 |
| 4 | 7 | 199 | 25 | 6.6 | 1.6 | 0.21 | 13 | 27 |
| 5 | 7 | 231 | 32 | 7.5 | 1.2 | 0.18 | 14 | 19 |
| 6 | 8 | 237 | 29 | 8.2 | 1.1 | 0.17 | 14 | 18 |
| 7 | 9 | 227 | 29 | 7.7 | 1.4 | 0.18 | 11 | 23 |
| 8 | 10 | 245 | 32 | 7.5 | 1.2 | 0.23 | 9 | 20 |
| 9 | 9 | 235 | 36 | 7.1 | 1.0 | 0.09 | 12 | 15 |
| 10 | 9 | 211 | 23 | 6.5 | 3.2 | 0.36 | 6 | 18 |
| 11 | 15 | 209 | 19 | 6.7 | 0.8 | 0.12 | 10 | 18 |
| 12 | 8 | 226 | 21 | 8.5 | 0.7 | 0.13 | 12 | 9 |

**Table 2. Figures in Tab. 1 referred to total salt content = 100.**

| Depth in metres | $SO_4$ | Total salt content | Cl | Ca | Fe | Mn | $NO_3$ |
|---|---|---|---|---|---|---|---|
| 1 | 4 | 100 | 11 | 31 | 0,6 | 0.05 | 3 |
| 2 | 3 | 100 | 11 | 34 | 0.8 | 0.07 | 4 |
| 3 | 3 | 100 | 13 | 32 | 0.6 | 0.07 | 5 |
| 4 | 3.5 | 100 | 13 | 33 | 0.8 | 0.10 | 6 |
| 5 | 3 | 100 | 14 | 32 | 0.5 | 0.08 | 6 |
| 6 | 3.5 | 100 | 12 | 34 | 0.5 | 0.07 | 6 |
| 7 | 4 | 100 | 13 | 34 | 0.5 | 0.08 | 5 |
| 8 | 4 | 100 | 13 | 31 | 0.5 | 0.09 | 4 |
| 9 | 4 | 100 | 15 | 30 | 0.4 | 0.04 | 5 |
| 10 | 4 | 100 | 11 | 31 | 1.5 | 0.17 | 3 |
| 11 | 5 | 100 | 9 | 32 | 0.4 | 0.06 | 5 |
| 12 | 3.5 | 100 | 9 | 37 | 0.4 | 0.06 | 5 |

layers are as a rule so exhausted that the soil moisture in them is weaker than that in the deeper layers.

## The Factors Examined

The factors usually investigated when water is analysed are sulphate, total dissolved inorganic substance, called below total salt content, chlorine, bicarbonate, Ca, iron, manganese, nitrate, nitrite, ammonia, phosphate, permanganate consumption (oxidizing capacity) and pH. As the samples have, in some cases, to be transported rather long distances one is justified to a certain extent in doubting the value of the pH determinations.

Not all the samples, however, have been examined with regard to the above mentioned substances. In some cases sulphate determinations have been omitted, in others Mn, and so on.

In Table 3 all the figures have been grouped according to the total salt content and averages have been made for each group and factor. For each of the factors $SO_4$, Cl, bicarbonate, Ca, Fe, Mn, $NO_3$, $NO_2$, $NH_3$, permanganate

**Table 3. Total salt content compared with the content of other substances. The figures give mg/l.**

| Total salt content | $SO_4$ | Cl | $HCO_3$ | Ca | Fe | Mn | $NO_3$ | $NO_2$ | $NH_4$ | Perm. con. | $PO_4$ | pH |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 13.7 | 1 | 1.6 | 10 | 6 | 0.3 | 0.06 | 0.1 | 0.01 | 0 | 25 | 0.06 | 5.9 |
| 22 | 2 | 2.5 | 15 | 9 | 0.4 | 0.12 | 0.9 | 0.1 | 0.1 | 20 | 0.01 | 5.9 |
| 34 | 2 | 3.6 | 20 | 10 | 0.6 | 0.03 | 1.1 | 0.1 | 0.1 | 18 | 0.04 | 6.0 |
| 42 | 3 | 7 | 24 | 12 | 0.4 | 0.03 | 2.5 | 0.1 | 0.4 | 20 | 0.1 | 6.1 |
| 52 | 5 | 6 | 30 | 15 | 0.9 | 0.08 | 2.9 | 1.0 | 0.2 | 15 | 0.4 | 6.2 |
| 61 | 5 | 6 | 34 | 19 | 0.9 | 0.11 | 4.0 | 0.7 | 0.1 | 16 | 0.07 | 6.1 |
| 72 | 5 | 8 | 39 | 21 | 1.5 | 0.10 | 5.0 | 0.7 | 0.2 | 20 | 0.3 | 6.1 |
| 82 | 6 | 9 | 46 | 24 | 1.3 | 0.07 | 5.5 | 0.9 | 0.4 | 16 | 0.1 | 6.3 |
| 92 | 6 | 11 | 51 | 32 | 0.8 | 0.04 | 8 | 3 | 0.1 | 14 | 0.7 | 6.4 |
| 112 | 6 | 13 | 63 | 34 | 1.5 | 0.15 | 8 | 4 | 0.9 | 24 | 0.6 | 6.6 |
| 134 | 6 | 13 | 81 | 42 | 1.5 | 0.14 | 9 | 4 | 0.5 | 22 | 0.5 | 6.7 |
| 159 | 8 | 18 | 95 | 51 | 1.5 | 0.31 | 11 | 4 | 1.2 | 24 | 0.4 | 6.5 |
| 183 | 8 | 19 | 107 | 59 | 1.1 | 0.20 | 13 | 4 | 1.2 | 22 | 0.5 | 6.6 |
| 209 | 8 | 20 | 146 | 72 | 1.2 | 0.14 | 11 | 6 | 0.6 | 24 | 0.7 | 6.6 |
| 226 | 8 | 23 | 156 | 77 | 1.4 | 0.13 | 11 | 3 | 1.3 | 22 | 0.6 | 6.5 |
| 260 | 8 | 23 | 182 | 91 | 1.5 | 0.16 | 11 | 4 | 1.4 | 22 | 0.6 | 6.8 |
| 287 | 9 | 25 | 211 | 104 | 1.5 | 0.18 | 11 | 10 | 1.2 | 22 | 0.3 | 6.9 |
| 309 | 10 | 25 | 223 | 111 | 0.8 | 0.15 | 13 | 6 | 1.3 | 22 | 0.8 | 6.9 |
| 334 | 14 | 34 | 227 | 120 | 1.3 | 0.32 | 16 | 7 | 3.2 | 22 | 0.9 | 6.9 |
| 356 | 10 | 29 | 266 | 126 | 1.1 | 0.83 | 11 | 4 | 3.1 | 30 | 1.0 | 7.0 |
| 382 | 9 | 38 | 279 | 134 | 1,3 | 0.23 | 13 | 17 | 2.4 | 28 | 1.3 | 6.9 |
| 409 | 23 | 38 | 294 | 139 | 2.0 | 0.18 | 14 | 7 | 3.3 | 19 | 1.1 | 7.0 |
| 435 | 25 | 41 | 258 | 146 | 1.4 | 0.20 | 23 | 2 | 1.8 | 26 | 2.7 | 7.0 |
| 457 | 10 | 60 | 293 | 151 | 2.0 | 0.25 | 19 | 18 | 3.1 | 28 | 2.0 | 6.9 |
| 484 | 10 | 82 | 266 | 141 | 0.9 | 0.37 | 17 | 35 | 6.8 | 23 | 0.8 | 7.0 |
| 518 | 23 | 64 | 312 | 154 | 2.0 | 0.20 | 12 | 7 | 4.4 | 27 | 0.8 | 6.8 |
| 567 | 25 | 92 | 295 | 159 | 2.4 | 0.68 | 21 | 39 | 18 | 38 | 2.1 | 7.0 |
| 736 | 42 | 176 | 341 | 192 | 1.3 | 0.47 | 29 | 15 | 9 | 25 | 1.2 | 7.2 |
| 1,620 | 30 | 644 | 324 | 308 | 3.0 | 1.09 | 25 | 3 | 6 | 34 | 2.1 | 7.1 |

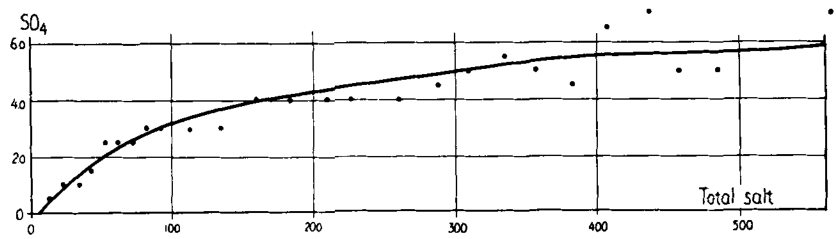


Fig. 1. Sulphate and total salt content.

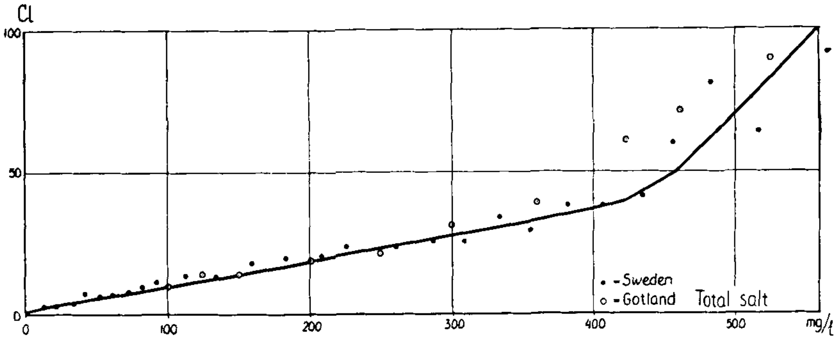


Fig. 2. Chlorine and total salt content.

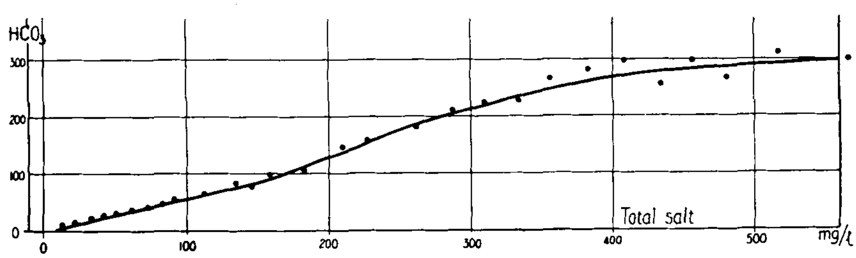


Fig. 3. Bicarbonate and total salt content.

consumption, $PO_4$, and pH a curve has been plotted showing the relationship between the total salt content and the respective factor.

Fig. 1 shows the relationship between the total salt content and sulphate. It is seen that the $SO_4$ content increases in proportion to the salt content to between 300 and 400 mg/l. After that the curve becomes very irregular.

Fig. 2 shows the relationship between the total salt content and the chlorine content. The figure shows that a linear relationship exists up to the salt content 400—450, after which the curve changes its direction abruptly and the chlorine content increases more rapidly than before. This is probably due to the basic substance, calcium carbonate, increasing its solubility very slowly at this concentration, and to the fact that the increase of dissolved salts is due to an increase of chlorides.

Between the bicarbonate content and inorganic substance (Fig. 3) the relationship seems to be that the increase in bicarbonate content takes place somewhat more rapidly than that of inorganic substance.

Ca (hardness), Fig. 4, shows a slight decrease with a high total salt content. This is in agreement with what has been said above concerning Cl-total salt.

A comparison of the Ca/Cl relationship shows that the chloride content increases more rapidly than the calcium content. Gripenberg's (23) values for the waters of the Gulf of

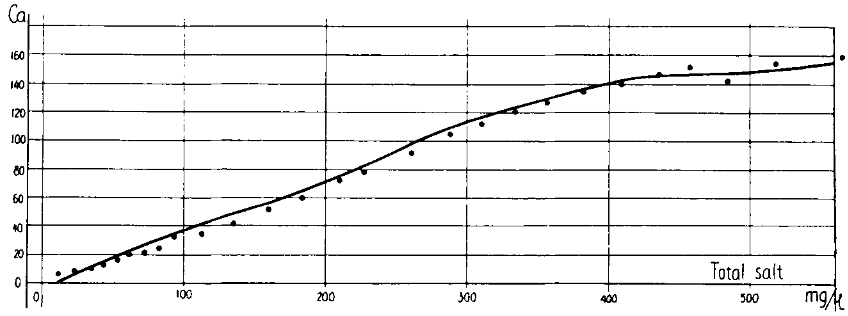


Fig. 4. Calcium and total salt content.

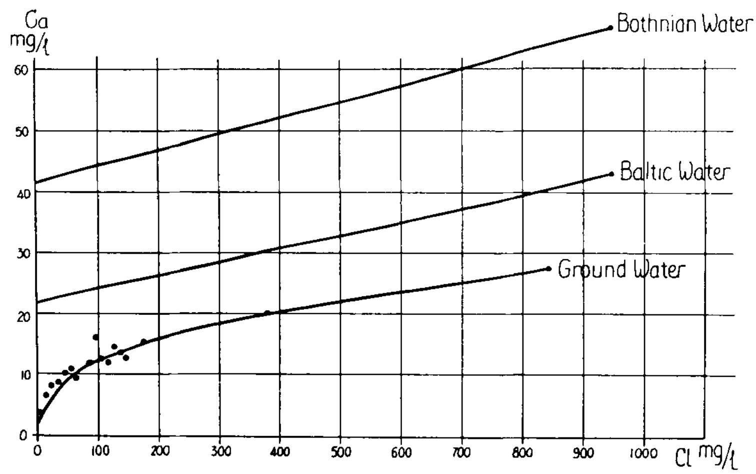


Fig. 5. Relation between calcium and chlorins in ground water and Bothnian and Baltic Waters.

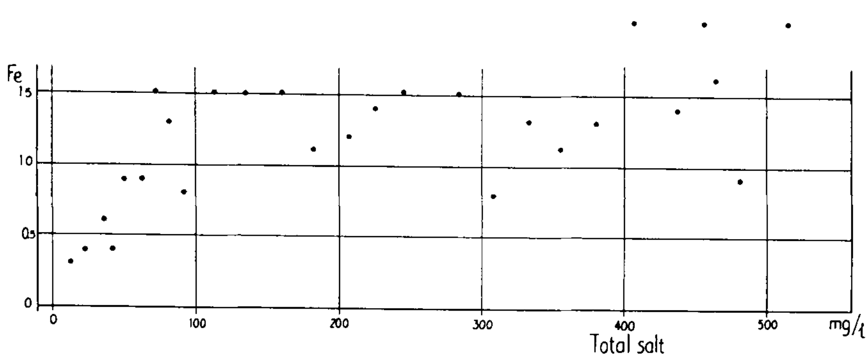


Fig. 6. Fe in relation to total salt concentration.

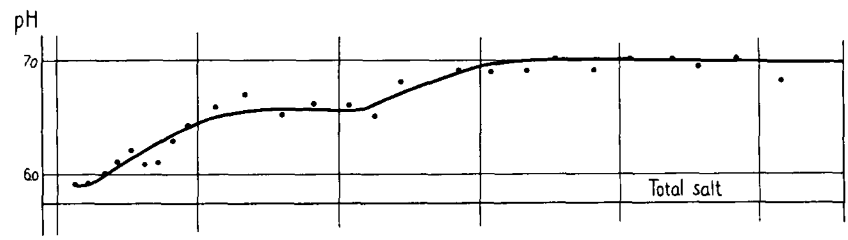


Fig. 7. pH and total salt content (Units as in fig. 6).

Bothnia and the Baltic are included for comparison. From this we perceive that subsoil water contains relatively more Cl than seawater at high concentrations (Fig. 5) while conditions are contrary at low.

The connection between the total salt content on the one hand and Fe and Mn on the other is not particularly marked. This is illustrated in Fig. 6. Other conditions, such as pH and oxidation-reduction potential etc., are decisive here.

No connection between the total salt content and the permanganate consumption can be traced, but on the other hand there exists some relationship between Fe and Mn.

There seems, however, to be some connection between acidity (pH), so that the greater the acidity of the water, the lower is the salt content (Fig. 7). If this is due to the acid soils being poorer or to their exhaustion must be investigated later.

The relationship with $PO_4$ seems to be good, but there are so few analyses that the results should be used with caution.

The averages indicate that up to 300—400 mg/l total salt content the composition of the water is the same, although diluted in varying degrees.

## Geographic Distribution

Maps have been compiled of the different characteristics $SO_4$, total salt content, Cl, Ca, Fe, Mn, $NO_3$ and permanganate consumption. In order to facilitate the work somewhat, parish averages have been calculated and these form the basis of the compilation of the maps. (The maps are found at the end of this issue.)

The picture of the total salt content obtained shows that the country can be divided into four regions: Norrland, the Central Swedish agricultural area, Småland and Skåne. (Map 1.)

The Norrland region is bounded in the south by a line drawn from the mouth of the River Dalälven to the southern part of Lake Vänern. The country to the west of this lake connects to the Småland region. There are a number of small districts in the Norrland region with a rather high total salt content. The largest of these is the district round Lake Storsjön.

The Central Swedish region shows great variation, and the plains proper have high contents.

The Småland region is bounded roughly in the north by a line running from east to west through the southern part of Lake Vättern and to the south by a line drawn from Hallandsås through Eslöv and Knislinge to Mörrum. The coastal areas in the east and west have somewhat richer water. In the inland districts the western half is considerably poorer than the eastern.

The Skåne region has exceptionally rich water, particularly in the coastal areas.

The distribution of the calcium content is on the whole about the same as that of the total salt content. In the north the districts round Lake Storsjön and Lake Siljan are outstanding. Only in small areas is the calcium content in Halland high. (Map 2.)

There is a striking difference between the provinces of Upland and Södermanland. It is of interest to compare this picture with that which LUNDQUIST's investigation give of the calcium content of the clays in the district of Stockholm (3). There, too, the southern part of the district with its deficiency of calcium is in sharp contrast to the northern part, which has a particularly high calcium content, due to the Gävle limestone.

The geological explanation of the variations in calcium content can be arrived at only after a careful study of all the details.

The water of Skåne is rich in nitrates (Map 6) but, except for a small increase in the Östergötland plain, their occurence diminishes towards the north. The production of nitrates may be assumed to be very dependent on the climate. Romell has collected figures from the State Forestry Research Board which show that the farther north one gets the lower is the nitrogen accumulation in woodland soil. The nitrate and nitrogen producers are clearly dependent upon the temperature of the soil and the length of the growing season. (Oral information.)

The ammonia content of water seems to be in co-ordination with that of nitrate. It cannot be proved that nitrogen in water is in any way inherent to coastal areas. This material, therefore, gives no support to the theory that nitrogen is chiefly a cyclic element produced by the sea (34, 41).

Curiously enough, the consumption of permanganate (Map 8) is greatest along the Baltic coast. These waters seem thus to be more deficient in oxygen than those in other parts of the country. An explanation of this may be that the coasts of the Baltic are flat (stagnating waters).

The content of iron and manganese (Map 7 and 5) is also higher in these parts. The subsoil waters of Skåne are usually poor in manganese.

The occurrence of sulphate (Map 3) is not following the distribution of calcium. It is true that Skåne is extremely rich in sulphates but a relatively high sulphate content is also characteristic of southern Småland. The Central Swedish region has high values too, extremely so in certain alum-slate areas. It is of interest to note that the two most northerly provinces show a somewhat higher sulphate content than the two lying immediately to the south (cf. the alum soils frequently occurring there).

Finally there remains the chlorine content of the subsoil waters (Map 4). As is the case with sulphate, Skåne (tertiary and other sediments in the moraine) is also rich in chlorine, and the area rich in Cl stretches into southern Småland. The chlorine content is also rather high in the Central Swedish region. Particularly high contents are to be found round the southerly point of Lake Vänern.

The waters of Södermanland are richer in chlorine than those of Upland.

The coastal area of Halland has subsoil water considerably richer in chlorine than the waters of the inland districts. The chlorine content diminishes very rapidly with the distance from the coast.

Härlin has (31), in connection with corrosion investigations, made analyses of rainwater on the west coast of Sweden.

The results of this investigation are shown in Table 4.

**Tab. 4. The occurrence of Cl and $SO_4$ in rainwater and its conductivity (according to Härlin).**

| Distance from sea in km | Cl mg/l | $SO_4$ mg/l | Sp. conductivity | Total inorganic substance (calc. by the author) |
|---|---|---|---|---|
| 0 | 22 | 13 | $165 \times 10^{-6}$ | 116 |
| 2 | 5 | 9 | 71 | 49 |
| 12 | 1.8 | 5 | 46 | 32 |
| 135 | 0.7 | 6 | 29 | 20 |

Similar results have been arrived at in Holland.

This demonstrates how rapidly wind-borne salt decreases towards the interior of the country.

Only 10 per cent of the samples have lower or the same chloride content as two kilometres from the coast. If for the rest of the country we calculate with 0.7 mg Cl/l it will be found that this figure is a few per cent of the amount found in subsoil water. It seems hardly probable, therefore, that the chlorides in subsoil water are carried from the sea by wind.

The following part will deal with deep waters, i. e. those obtained from the bedrock by boring. There we shall see that where the bedrock is rich in chloride, the subsoil water is also rich in chloride. It must therefore be assumed that there exists a rather good circulation between subsoil and deep water, and that this is the most important source of the chloride content of the soil.

It might be thought that urine and manures would affect the chloride content of subsoil water. This, of course, often occurs purely locally. In very many cases the surface water runs into the water supply, but generally speaking the addition of chloride emanating from human beings is so small that it cannot be of any significance. Every human being emits about 5 kg Cl per annum (46). Thus the whole population of Sweden should produce about 35,000 tons of Cl. Our import of potassium salts is the equivalent of about 60,000 tons of Cl (39), making a total of about 100,000 tons. This is equal to 2.5 kg per hectare a year. This would, assuming that about one-third of the precipitation became percolating water, be the equivalent of about 1 mg/l. For the country as a whole the addition is negligible It might be considered that the high chloride content of Skåne water is due to the density of the population and the intense use of manures. It can be assumed that a farmer with one hectare of land, growing sugar beets and kitchen produce, would use 200 kg potash. His family consists of five persons. Together this gives 125 kg Cl/hectare and year or about 80 mg/l in the subsoil water. It is only in such extreme circumstances that the amount of Cl found locally in normal Scanian subsoil water can have been contributed by human agency.

### Water from drilled deep wells

Water from drilled deep wells gives information of the composition of water in mainly unweathered parts of the crust of the earth. The influence of cyclic elements, organisms and so on is much reduced at these depths. The type of bedrock must be of primary importance. The material obtained from the State Institute of Public Health included analyses of water from about 2,000 deep wells. A compilation has been made in the form of maps (Maps 9—14). On account of the limited extent of the material the results have been collected by "härads" and the average calculated.

This material shows that all the ions with the exception of $NO_3$, $NO_2$, $NH_4$ and $PO_4$ occur much more richly than in subsoil water. In order to give a better survey of the relationships a table has been compiled giving the averages by provinces for both deep wells and shallow wells (Table 5). Water from deep wells is much richer in chloride. Nitrogen compounds, on the contrary, occur in smaller amounts. It is impossible on the basis of this material to say whether they originate from percolating surface water or from the bedrock.

### Chemical Denudation

People of today seem to be of the opinion that lakes and watercourses were created so that all kinds of filth can be deposited in them. This is what is known as modern hygiene. What is commonly called filtered sewage contains large amounts of nutrients that disturb the balance for the flora and fauna of watercourses and lakes. At the same time large amounts of nutrients are transferred from the lithosphere to the hydrosphere, and are thus withdrawn from that part of nature's economy upon which human beings are dependent for their livelihood.

When modern hygiene has become universal we can assume that all refuse from man will go into the watercourses.

Sewage from the food-producing industries, the waste of the timber industry, the destruction of straw and humus by fire must cause the loss of valuable substances.

An attempt has been made to draw up a survey of how people in Sweden waste nutrients.

**Survey of losses and gains of nutrients in tons per annum.**

| | N | $P_2O_5$ | $K_2O$ |
|---|---|---|---|
| Refuse from human beings[1] | 28,000 | 8,000 | 7,000 |
| Household water (assessed) | 7,000 | 2,700 | 2,300 |
| Starch factories (42) | 250 | 140 | 480 |
| Dairies (rinsing water) (20, 42) | 238 | 60 | 70 |
| Slaughter houses (swilling water) (47) | 20—200 | 8—50 | 4—80 |
| Silo fodder (press water) (12, 29) | 130 | 60 | 410 |
| Bark on floated timber[2] (19, 37) | 1,350 | 380 | 790 |
| Export timber and cellulose (19, 37) | 20,000 | 2,000 | 25,000 |
| If all straw is burned (36) | 21,000 | | |

[1] Assuming that all Swedish homes are fitted with W.C. and drainage.

[2] Timber is to an increasing extent barked before floating.

The export of grain and foodstuffs causes loss of nitrogen, potash and phosphorus.

**Table 5. Averages for provinces and characteristics (D = deep wells: S = shallow wells).**

| County | $SO_4$ | Total salt content | Cl | $HCO_3$ | Ca | Fe | Mn | $NO_3$ | $NO_2$ | $NH_4$ | $PO_4$ |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Stockholm | D 42 | 377 | 88 | 213 | 89 | 1.2 | 0.13 | 4.3 | 5.3 | 1.5 | 0.54 |
| | S 5 | 248 | 34 | 82 | 94 | 1.2 | 0.10 | 6 | 6 | 1 | 1.64 |
| Upsala | D 37 | 326 | 80 | 252 | 121 | 1.9 | 0.10 | 4.9 | 4.9 | 2.0 | 0.61 |
| | S 10 | 293 | 31 | 236 | 117 | 1.1 | 0.16 | 7 | 7 | 4 | 1.10 |
| Södermanland | D 42 | 349 | 70 | 202 | 85 | 2.5 | 0.22 | 8.8 | 5.7 | 1.7 | 0.22 |
| | S 15 | 277 | 32 | 177 | 92 | 2.1 | 0.19 | 12 | 6 | 2 | 0.91 |
| Östergötland | D 55 | 374 | 48 | 245 | 124 | 1.4 | 0.18 | 9.5 | 1.1 | 0.6 | 0.30 |
| | S 18 | 263 | 34 | 165 | 93 | 1.1 | 0.20 | 16 | 8 | 1 | 1.13 |
| Jönköping | D 15 | 170 | 17 | 109 | 60 | 1.5 | 0.59 | 3.7 | 18.3 | 1.6 | 0.00 |
| | S 9 | 132 | 19 | 46 | 34 | 0.5 | 0.08 | 18 | 2 | 1 | 1.63 |
| Kronoberg | D 34 | 177 | 20 | 107 | 57 | 1.1 | 0.52 | 2.8 | 0.7 | 1.0 | 0.75 |
| | S 18 | 139 | 23 | 36 | 32 | 0.7 | 0.08 | 21 | 5 | 1.0 | 0.37 |
| Kalmar | D 15 | 361 | 93 | 141 | 76 | 2.6 | 0.19 | 3.3 | 1.5 | 1.7 | 0.11 |
| | S 18 | 213 | 36 | 98 | 57 | 1.2 | 0.68 | 11 | 3 | 3 | 0.89 |
| Blekinge | D 42 | 652 | 249 | 129 | 148 | 1.4 | 0.17 | 7.7 | 2.1 | 1.7 | 1.00 |
| | S 46 | 404 | 109 | 79 | 88 | 0.6 | 0.15 | 63 | 2 | 0.4 | 6.45 |
| Kristianstad | D 37 | 378 | 33 | 310 | 162 | 1.9 | 0.11 | 15.6 | 1.9 | 0.4 | 0.65 |
| | S 46 | 334 | 52 | 130 | 104 | 0.5 | 0.09 | 62 | 4 | 1 | 1 |
| Malmöhus | D 30 | 549 | 103 | 355 | 159 | 5.4 | 0.33 | 6.2 | 1.4 | 4.5 | 2.50 |
| | S 60 | 527 | 66 | 280 | 178 | 0.7 | 0.13 | 58 | 6 | 5 | |
| Halland | D 42 | 225 | 138 | 105 | 53 | 3.8 | 0.33 | 7.0 | 3.3 | 3.2 | 0.50 |
| | S 15 | 236 | 68 | 80 | 54 | 1.9 | 0.47 | 14 | 4 | 6 | 1.39 |
| Göteborg & Bohus | D 22 | 304 | 91 | 119 | 42 | 1.8 | 0.11 | 0 | 0.1 | 1.5 | 0.00 |
| | S 3 | 190 | 29 | 111 | 43 | 2.2 | 0.38 | 6 | 37 | 1 | 1.11 |
| Älvsborg | D 34 | 217 | 29 | 108 | 62 | 0.9 | 0.45 | 5.7 | 2.4 | 0.5 | 0.26 |
| | S 10 | 171 | 26 | 93 | 47 | 0.8 | 0.38 | 12 | 2 | 2 | 1.58 |
| Skaraborg | D 42 | 680 | 313 | 279 | 139 | 1.1 | 0.26 | 8.0 | 4.5 | 4.5 | 0.62 |
| | S 30 | 292 | 61 | 185 | 94 | 1.0 | 0.15 | 11 | 2 | 1 | 1.70 |
| Värmland | D 18 | 237 | 45 | 156 | 71 | 1.1 | 0.29 | 2.3 | 2.5 | 0.6 | 0.25 |
| | S 3 | 103 | 14 | 61 | 28 | 0.8 | 0.13 | 6 | 2 | 1 | 0.25 |
| Närke | D 18 | 363 | 85 | 180 | 96 | 1.4 | 0.28 | 2.2 | 2.8 | 1.4 | 0.20 |
| | S 10 | 163 | 17 | 103 | 60 | 1.5 | 0.18 | 11 | 2 | 1 | 0.56 |
| Västmanland | D 30 | 318 | 88 | 187 | 88 | 0.6 | 0.21 | 6.0 | 4.6 | 0.5 | 0.65 |
| | S 10 | 94 | 20 | 129 | 70 | 1.8 | 0.29 | 9 | 4 | 1 | 1.00 |
| Kopparberg | D 26 | 160 | 16 | 132 | 62 | 1.6 | 0.45 | 3.9 | 3.5 | 2.6 | 0.46 |
| | S 18 | 130 | 15 | 80 | 41 | 1.2 | 0.25 | 11 | 5 | 2 | 0.2 |
| Gävleborg | D 34 | 274 | 58 | 531 | 52 | 1.9 | 0.16 | 3.0 | 1.6 | 1.2 | 0.18 |
| | S 6 | 119 | 18 | 58 | 31 | 2.3 | 0.20 | 8 | 6 | 2 | 0.23 |
| Västernorrland | D 15 | 187 | 19 | 115 | 52 | 3.4 | 0.37 | 0.2 | 1.5 | 1.1 | 1.81 |
| | S 6 | 110 | 12 | 61 | 34 | 1.4 | 0.15 | 5 | 3 | 2 | 0.40 |
| Jämtland | D 26 | 219 | 12 | 212 | 105 | 0.7 | 0.22 | 5.3 | 4.1 | 4.1 | 0.08 |
| | S 5 | 150 | 10 | 128 | 64 | 0.7 | 0.08 | 8 | 1 | 1 | 0.03 |
| Västerbotten | D 26 | 190 | 35 | 100 | 45 | 3.0 | 0.28 | 2.5 | 3.2 | 3.0 | 0.86 |
| | S 7 | 81 | 13 | 32 | 22 | 0.9 | 0.14 | 5 | 5 | 1 | 0.12 |
| Norrbotten | D 10 | 202 | 24 | 137 | 48 | 2.6 | 0.18 | 1.0 | 9.7 | 3.0 | 2.90 |
| | S 1 | 129 | 50 | 53 | 41 | 2.5 | 0.73 | 7 | 4 | 6 | 0.50 |

**Import in tons per annum.**

| | N | $P_2O_5$ | $K_2O$ |
|---|---|---|---|
| Oilcake (39) | 900 | 340 | — |
| Artificial manures (39) | 50,000 (15,000 from the atmosphere) | 90,000 | 30,000 |

This survey shows that the loss of nutrients in industry is of subordinate importance (even if it may be extremely important locally).

The great losses are in sewage and in agriculture and forestry.

We waste more nitrogen than we import, we import seven times as much phosphoric

**Table 6. Concentration of soluble inorganic substances, sulphates, chloride and nitrate in some Swedish rivers, and in the water which flows into the different rivers.**

No information about the nitrate in the rivers is available, but judging from other (28, 13, 38) investigations the occurrence of nitrate in river water seems to be very low and is given in this table = 0. It is easy to see that it is not only the total inorganic substance that decreases on the way from subsoil water to the river mouth, but also the $SO_4$, Cl and $NO_3$.

| River | | $SO_4$ | Totalt salt content | Cl | $NO_3$ | Ca + Mgl |
|---|---|---|---|---|---|---|
| Skellefte älv | river water | 0.9 | 21.2 | 3.1 | 0 | 5 |
| | subsoil water | 1.0 | 8.0 | 13 | 7 | 26 |
| Ume älv | river water | 1.5 | 20.9 | 3.3 | 0 | 6 |
| | subsoil water | 6.0 | 102 | 14 | 9 | 16 |
| Öre älv | river water | — | 26 | 3.2 | 0 | 4 |
| | subsoil water | 6 | 54 | 3 | 0 | 6 |
| Ångermanälven | river water | 1.7 | 20.9 | 2.5 | 0 | 8 |
| | subsoil water | 4 | 107 | 11 | 9 | 32 |
| Indalsälven | river water | 2.1 | 32.6 | 4.5 | 0 | 15 |
| | subsoil water | 5 | 170 | 9 | 3 | 74 |
| Ljungan | river water | 1.2 | 28.4 | 3.0 | 0 | 12 |
| | subsoil water | 5 | 131 | 15 | 0 | 45 |
| Ljusnan | river water | 1.6 | 24.6 | 2.5 | 0 | 8 |
| | subsoil water | 2 | 54 | 7 | 5 | 16 |
| Dalälven | river water | 2.0 | 25.3 | 2.8 | 0 | 7 |
| | subsoil water | 28 | 150 | 10 | 0 | 30 |
| Närkes Svartå | river water | 9.6 | 43.9 | 4.9 | 0 | 10 |
| | subsoil water | 10 | 103 | 9 | 5 | 30 |
| Nyköpingsån | river water | 12.7 | 58 | 6.2 | 0 | 22 |
| | subsoil water | 26.0 | 258 | 31 | 12 | 92 |
| Mjölnaån | river water | 27.9 | 138.4 | 9.6 | 0 | 71 |
| | subsoil water | 35 | 416 | 58 | 28 | 134 |
| Stångån | river water | 7.9 | 49.6 | 7.1 | 0 | 20 |
| | subsoil water | 9 | 233 | 31 | 17 | 83 |
| Emån | river water | 7.1 | 40.1 | 6.8 | 0 | 14 |
| | subsoil water | 9 | 153 | 21 | 12 | 41 |
| Mörrumsån | river water | 5.3 | 30.6 | 7.9 | 0 | 8 |
| | subsoil water | 16 | 157 | 28 | 18 | 43 |
| Helgeå | river water | 7.4 | 51 | 11.7 | 0 | 14 |
| | subsoil water | 35 | 215 | 33 | 38 | 46 |
| Tommarpsån | river water | 33.6 | 202.7 | 14.2 | 0 | 89 |
| | subsoil water | 50 | 410 | 39 | 58 | 159 |
| Kävlingeå | river water | 30.7 | 210.7 | 18.7 | 0 | 95 |
| | subsoil water | 50 | 498 | 74 | 35 | 170 |
| Rönneå | river water | 14.9 | 94.1 | 15.0 | 0 | 36 |
| | subsoil water | 45 | 316 | 51 | 27 | 93 |
| Lagan | river water | 4.9 | 27.9 | 6.8 | 0 | 7 |
| | subsoil water | 9 | 126 | 20 | 17 | 25 |
| Nissan | river water | 6.9 | 33.3 | 7.0 | 0 | 9 |
| | subsoil water | 9 | 105 | 21 | 13 | 22 |
| Ätran | river water | 5.3 | 36.8 | 7.4 | 0 | 15 |
| | subsoil water | 5 | 97 | 15 | 19 | 25 |
| Viskan | river water | 7.9 | 48.7 | 10.9 | 0 | 14 |
| | subsoil water | 9 | 116 | 9 | 9 | 33 |
| Klarälven | river water | 2.5 | 22.6 | 3.2 | 0 | 6 |
| | subsoil water | 5 | 59 | 9 | 5 | 17 |
| Ölman | river water | — | 49.5 | 5.5 | 0 | 11 |
| | subsoil water | 4 | 163 | 27 | 7 | 49 |
| Gullspångsälven | river water | 2.9 | 21.8 | 4.3 | 0 | 7 |
| | subsoil water | 5 | 95 | 8 | 8 | 31 |
| Tidan | river water | 13.4 | 81.6 | 9.6 | 0 | 28 |
| | subsoil water | 20 | 213 | 28 | 19 | 63 |
| Lidan | river water | 37.9 | 193.2 | 16.6 | 0 | 74 |
| | subsoil water | 44 | 370 | 50 | 18 | 115 |

acid as we throw away and a certain balance exists with regard to potash.

And we consider that we can afford to waste one or two hundred million kronor a year for the pleasure of enriching the sea with nutrients.

At the same time we destroy our water-courses with our waste matter so that the fish die out, our water supply is contaminated and our opportunities for swimming are limited. In order to remedy some of these drawbacks we add chemicals to the water, which then becomes sterile. The equilibrium of our waters is disturbed, and they lose their ability to purify themselves.

We have seen above how much the subsoil water carries away. On an average for the whole country every litre of percolating water removes from the upper layers of the soil:

| Totalt salt content | $SO_3$ | Cl | Ca | Fe | Mn | $NO_3$ | $PO_4$ | |
|---|---|---|---|---|---|---|---|---|
| 132 | 9 | 13 | 40 | 1.2 | 0.17 | 7.0 | 0.5 | mg |

If we calculate that one-third of the precipitation evaporates, one-third runs away and one-third soaks into the ground, and an average precipitation of 600 mm it makes per square metre (200 l):

| Total salt content | $SO_4$ | Cl | Ca | Fe | Mn | $NO_3$ | $PO_4$ | |
|---|---|---|---|---|---|---|---|---|
| 26.4 | 1.8 | 2.6 | 8 | 0.24 | 0.034 | 1.4 | 0.1 | gr |

For a square kilometre the figures will be the same but will then indicate not gr but ton. If we calculate that denudation began 10,000 years ago and that it was not greater then than now (in reality it was probably 2—4 times as great then, and has since fallen to its present values), we arrive at the following figures for leaching (in 1,000 tons per square kilometre):

| Total salt content | $SO_4$ | Cl | Ca | Fe | Mn | $NO_3$ | $PO_4$ |
|---|---|---|---|---|---|---|---|
| 264 | 18 | 26 | 8 | 2.4 | 0.34 | 14 | 1 |

A square kilometre one metre deep contains about 1,500,000 tons of soil. Since the Ice Age, therefore, at least one-fifth of the total weight of the soil has been washed away, and only the least soluble materials remain.

For the whole country the annual loss should be (in 1,000 tons):

| Totalt salt content | $SO_4$ | Cl | Ca | Fe | Mn | $NO_3$ | $PO_4$ |
|---|---|---|---|---|---|---|---|
| 10,800 | 740 | 1,070 | 3,280 | 99 | 14 | 575 | 41 |

These figures represent incredible amounts. The fertility of the soil is continually diminishing.

## Leaching

Stone recently ground down by the ice naturally produced a much more concentrated water-solution than does the present denuded stone-powder, the soil. As a minimum of the salt content of the soil-moisture in those days we must take the concentration of water from deep wells. On account of the great surface of finely-ground powder exposed to the action of water it was probably even greater. Leaching has continued since then. An example of how leaching progresses is given below. Different kinds of rocks were ground in a colloid mill and an attempt was made to extract phophorus acid from them. Extraction was carried out once by means of HCl, 3—6 times by 2 % citric and 3—6 times by 0.01 % NaCl solution. The sum is given for the first two extraction mediums. The results of the various extractions is given for the water extractions. Averages are given for the different types of rocks. (5).

From this it is clear that water dissolves only a small part of what citric acid and hydrochloric acid can do in the same time. But the

**Extraction from different types of rocks (average) by means of HCl and citric acid, and fractionated with water (0.01 % NaCl solution).**

The figures give: $P_2O_5$ in 1/1,000 per cent of dry weight

| | HCl | 2 % citric acid | Water | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | I | II | III | IV | V | VI |
| Gneiss | 138 | 97 | 0.91 | 0.22 | 0.19 | 0.20 | 0.06 | 0.07 |
| Granite | 145 | 129 | 0.63 | 0.39 | 0.52 | 0.24 | 0.11 | 0.05 |
| Limestone | 353 | 20 | 0.22 | 0.12 | 0.41 | 0.15 | 0.0 | 0.0 |
| Sandstone | 49 | 17 | 0.25 | 0.13 | 0.38 | 0.10 | 0.10 | 0.0 |
| Slate | 165 | 115 | 1.23 | 0.15 | 0.45 | 0.35 | 0.15 | 0.20 |
| Hälleflinta | 125 | 94 | 0.15 | 0.0 | 0.15 | — | — | — |
| Porphyry | 73 | 65 | 0.12 | 0.20 | 0.60 | 0.0 | 0.0 | 0.0 |
| Diorite | 286 | 271 | 1.20 | 0.73 | 0.40 | 0.6 | 0.06 | 0.06 |

gradual decrease in the yield of phosphoric acid is of the greatest significance.

In the previous part we gave a Table illustrating losses in the upper layers of soil. The rivers carry much smaller quantities to the sea (6). Table 6 gives a comparison of the concentrations of river water near the mouth of the river, and the subsoil water concentration in the precipitation areas of the rivers (32).

No information about the nitrate in the rivers is available, but judging from other (28, 13, 38) investigations the occurrence of nitrate in river water seems to be very low and is given in this table = 0. It is easy to see that it is not only the total inorganic substance that decreases on the way from subsoil water to the river mouth, but also the $SO_4$, Cl and $NO_3$.

The total amount of salt washed out is 3—4 times greater in subsoil water than in river water (Table 7). On its way to the sea the water must, by precipitation, absorption, the action of organisms and so on loss large amounts. It is of interest to note that this applies also to such easily dissolved ions as $SO_4$, Cl and $NO_3$.

**Table 7. Relation Subsoil water: River water.**

| River | $SO_4$ | Total salt content | Cl | Ca + Mg l |
|---|---|---|---|---|
| Skellefte älv | 1.1 | — | 4.2 | |
| Ume älv | 4.0 | 4.9 | 5.2 | |
| Öre älv | | 2.1 | 0.9 | |
| Ångermanälven | 2.4 | 5.1 | 4.4 | 4.0 |
| Indalsälven | 2.4 | 5.2 | 2.0 | 4.9 |
| Ljungan | 4.1 | 4.6 | 5.0 | 3.8 |
| Ljusnan | 1.3 | 2.2 | 2.8 | 2.0 |
| Dalälven | 14.0 | 6.0 | 3.6 | 4.3 |
| Närkes Svartå | 1.0 | 2.4 | 1.8 | 3.0 |
| Nyköpingsån | 2.1 | 4.5 | 5.0 | 4.2 |
| Mjölnaån | 1.3 | 3.0 | 6.0 | 1.9 |
| Stångån | 1.1 | 4.6 | 4.4 | 4.1 |
| Emån | 1.2 | 3.8 | 3.1 | 2.9 |
| Mörrumsån | 3.0 | 5.1 | 3.5 | 5.4 |
| Helgeå | 4.7 | 4.2 | 2.8 | 3.3 |
| Tommarpsån | 1.5 | 2.0 | 2.7 | 1.8 |
| Kävlingeån | 1.6 | 2.3 | 4.0 | 1.8 |
| Rönneå | 3.0 | 3.3 | 3.4 | 2.6 |
| Lagan | 1.8 | 4.4 | 3.0 | 3.6 |
| Nissan | 1.3 | 3.1 | 3.0 | 2.4 |
| Ätran | 1.0 | 2.7 | 2.0 | 1.6 |
| Viskan | 1.1 | 2.4 | 0.8 | 2.3 |
| Klarälven | 2.0 | 2.6 | 2.8 | 2.8 |
| Ölman | — | 3.3 | 4.9 | 4.4 |
| Gullspångsälven | 1.7 | 4.4 | 1.8 | 4.4 |
| Tidan | 1.5 | 2.6 | 3.0 | 2.3 |
| Lidan | 1.2 | 1.8 | 3.0 | 1.5 |
| | 1.9 | 2.5 | 3.3 | 3.1 |

Generally speaking it can be said that lime is precipitated most effectively in the large rivers of Norrland. Nyköpingsån, Stångån, Mörrumsån, Ölman and Gullspångsälven also show great precipitation.

The three rivers of northern Halland, Mjölnaån, Tommarpsån and Kävlingeån, and Tidan and Lidan in Västergötland, on the other hand, show only little precipitation.

The shorter a watercourse is, the smaller is the difference between subsoil water and river water.

As far as sulphateion is concerned, there is no more to be said than that Tidan, Lidan, Tommarpsån and Kävlingeån show high content and little loss. The same applies to the inorganic substance.

With regard to chloride, no conformity can be found, but it is surprising to find that this, too, diminishes so greatly when subsoil water becomes river water. Nitrate and phosphate, two materials so important to organisms, decrease particularly rapidly, which is, of course, quite natural, for plants take up with great avidity every trace of these substances in the water.

If we take into consideration the disappearance of the various substances from the subsoil water we find that the sulphateion undergoes the least change, while chloride, Ca + Mg and the total salt content disappear in about the same proportions.

We see therefore that denudation is particularly great. If only the conditions during the most recent decades are taken into consideration we find that about 10 times as much lime and nitrogen disappear as is added to the soil. Equilibrium seems to exist with regard to phosphoric acid.

As regards the removal of calcium, a calculation was made on the basis of two extensive investigations, one made in 1930 and the other in 1940 (7). It shows that the sugar-beet area of Skåne, which on an average is given 120 kg CaO per hectare and year, has become 0.13 pH units more acid. If it is calculated that the soil of Skåne requires on an average 3,000 kg CaO to change the reaction one pH unit, it would mean that 60 kg would disappear per hectare and year. The plants take away 90 kg and denudation about 100 kg. This would mean a loss of 190 kg and an addition of about 120 kg. A deficiency of 70 kg as against a calculated 60 kg.

If we consider the figures for leaching during 10,000 years we find that 2,600 tons of easily dissolved nutrients have disappeared per hectare or, as mentioned above, at least one-fifth of the total weight of the top metre of the soil.

The yield of a cultivated plant is usually considered to be an indication of its well-being and within small areas, where the climate can be ignored, it is the available plant food that is decisive (Map 15). A study of the map of the yield per hectare of winter wheat in Sweden (8) shows that it is identical with the one giving the distribution of calcium in the water. There is every reason for assuming a relationship between soil rich in plant food and greater yields (Fig. 8).

If the yields of parishes, for which water analyses are available are compared with the calcium content of the water, it is found that there is excellent agreement (Fig. 8). This does not mean that the calcium content is the deciding factor with regard to the fertility of the soil, but rather a sign of how much the soil is impoverished.

A similar distribution: occurring sparsely in the Norrland and Småland regions and very frequently in Skåne and the Central Swedish region is found in most grove plants, our finest deciduous trees and most of the inhabitants of herbaceous slopes (örtbackar).

The localities occurring sporadically in the Norrland region are to be found as a rule on what Gunnar Andersson called "south mountains". HALDEN (24, 25), GRAPENGIESSER (22) and WISTRAND (48) have all shown that the name "south mountain" is misleading, for many of the localities where "relicts" are found slope towards other points of the compass, even towards the north. Their main characteristics are extreme weathering and water rich in nutrients.

Gunnar Andersson has taken the retreat of the oak and the hazel towards the south as the basis of a theory on the deterioration of the climate.

The present writer has shown that the lower parts of peat layers are richer in mineral nutrients than the upper parts of the same kind of peat (4). This indicates that formerly the peat was growing and deposited in richer water than is the case at present.

Sandegren has been able to demonstrate that in certain deposits in Bohuslän only the oldest are rich in calcium. Sandegren has provided, orally, the following information: "During S.G.U.s peat survey, samples from Bohuslän often contained freshwater calcium mud in the deepest layers of the bog. All such occurrences were at a high altitude, and according to pollen analysis they belong to the oldest of the post-glacial periods, the Boreal period."

HESSLAND (27) has found similar cases.

The retreat of certain plants towards the south may just as well be explained as being caused by a change in the factors of the habitat as by a change in the climate.

In view of the fact that agricultural research has produced certain races of plants suitable for different climates, particularly winter wheat, one can say with regard to this plant

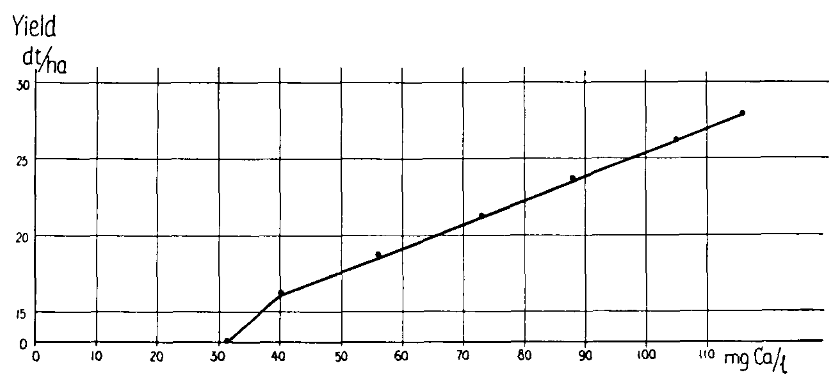


Fig. 8. The calcium content of the ground water and the yield of winter wheat in the lake district of Sweden.

that it is the soil factors that are responsible for its varying degrees of thriving.

Thus the retreat towards the south and the present "climatic limits of plants" can no longer be advanced as a proof that the climate has deteriorated. The proof must be sought elsewhere.

**What can be done to counteract denudation?**

Denudation affects most seriously countries with humid climates, that it to say the world's best arable areas, and is therefore a great, if invisible danger, probably greater than the visible mechanical erosion (10).

The question rises involuntarily: Can anything be done to counteract this destruction of the soil? If nothing is done, the soil of the country will gradually become waste. Instances of such soil devastation may be found in many places. Rome's campagna, which, during the early years of the history of Rome was its granary, was neglected more and more, the soil was denuded and the pH value sank to 5. It was not until the present century that the land could be cultivated anew. In Scotland and England the forests were laid waste, arable land was turned into pasture for sheep with the result that in some parts the cultivation of the land again seems impossible, while in other parts it is costing enormous sums. During the sixteenth century in western Java flourished the Sultanate Bantam. The Deutch described the country as very fertile, but now the soil is exhausted and to a large extent covered with brushwood and the country continues to decline.

This is what will happen in Sweden, although more slowly, if nothing is done to prevent impoverishment of the soil.

One practicable way is to increase evaporation so that less water percolates through the soil. We have done this unconsciously. Our yields, both of agricultural and forests, have increased. These consume more water. BERGSTEN's (11) investigations have shown that the discharge of our rivers has diminished considerably during recent years. In many places farmers are of the opinion that wells are running dry and that the subsoil water is subsiding.

This is a very dangerous development, for although we may prevent leaching, we may at the same time cause a general aridity.

Another, perhaps more difficult but better and more certain solution is to seek help from plants to a greater extent than hitherto. As is well known, plants have an incredible ability to collect the food necessary for them from very diluted solutions (26). Thus BURD (14) has shown that plants in both good and bad soil reduce the concentration of soil moisture to the same low level and keep it there. If the land is then allowed to lie without vegetation the amount of dissolved substances increases rapidly. If plants are allowed to keep the land free from nutrients, the percolating water cannot take much away.

During summer hardly any water soaks through the soil (no water runs through underground drains then), and when the ground is frozen no percolation can take place. Spring and autumn are the seasons when leaching takes place.

Such crops as winter cereals, winter rape and pasture are some of the plants that might be used. Bare land should clearly be avoided during the winter. Investigations must be made to find out which ways are most practicable.

A shorter period of rotation in the forests and more frequent thinning out would probably be an effective way of preventing unwanted leaching, perhaps it might even be replaced by an accumulation of plant foods and better nutrients conditions and an increase in fertility. It appears as if the number of needles produced by a spruce attains a maximum when the tree is 50—60 years old, after which it decreases (19). If a tree is allowed to live 60—70 years it need never pass through the later period, when its needles become fewer and it requires more nourishment, without being able to produce enough needles to enrich the soil.

If a wood is allowed to remain undisturbed only dead needles will fall to the ground and become humus. When trees are felled living needles are mixed with litter and humus.

EBERMAYER (19) has shown the relationship between the different kinds of needles.

| | Living | | Dead |
|---|---|---|---|
| | Current year % | Previous year % | % |
| Total ashes | 1.55 | 1.89 | 1.52 |
| K | 0.62 | 0.41 | 0.14 |
| Ca | 0.19 | 0.49 | 0.44 |
| P | 0.30 | 0.24 | 0.06 |

The living needles contain about five times as much of the important plant foods potash and phosphorus as the dead ones.

If we can grow trees with large crowns, the falling needles will be reduced to a minimum, and when the trees are felled the living needles will be incorporated into the ground. Birches and other deciduous trees contribute more to the soil than do pine trees. An admixture of leaves is necessary to keep up the productivity of the soil.

Trees derive their nourishment from the lower layers of soil, and are thus able to redeem nutrients that have sunk down below the reach of the roots of herbaceous plants.

Finally it must be stressed that the ground must be kept occupied with trees in order to prevent leaching.

It may be said, therefore, that forest, properly cared for can do much to eliminate the harmful effects of chemical denudation.

We must also cease our present waste of refuse. Modern techniques are moving in the right direction by trying to utilize all the byproducts of manufacture.

But town waste matter, too, must be made use of, for it represents great values, and at the same time the threatened contamination of our water can be avoided.

This may be done by spraying meadowland with sewage, as is done at Lund. In this way the plant food is effectively saved, and the water continues on its way completely purified (44, 45).

At Munich (35, 47) the Hofer system has been applied since 1912. After the sewage has been roughly filtered and diluted it is led into dams containing plants and fish. Bottom vegetation develops rapidly and serves as food for the fish. The water runs out completely purified.

For about seventy years so-called rieselfelder (47) have been in use in Germany. The sewage is led on to these fields where it sinks through the soil. After a certain time the fields are sown and the plants absorb the plant food.

These are some ways to solve the problem of how to extract the greater part of the nutrients from sewage and at the same time purify the water so that it no longer destroys the watercourses.

The burning of forest land and straw is a great waste of nitrogen.

The waste water from our pulp mills should also be saved.

Bark should not be allowed in the rivers, but should remain in the forests.

Much effort must be expended at once to solve all these and allied problems, so that our most valuable heritage, our soil, shall not be laid waste.

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