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# Soil properties of special interest in connection with health problems

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## *1. Some historical data*

For as long as medical science has existed, there has been knowledge of certain human illnesses related to particular geographical districts. In this connection Hippocrates' observations have often been mentioned[2,3]. Some knowledge of the geographic distribution of sickness in domestic animals is also very old. Marco Polo noticed cases of disease in the Far East, which may now be attributed to selenium poisoning. In the nineteenth century, such toxicity was discovered in the USA. Endemic goitre due to iodine deficiency has been known for a long period of time and this is often set forth as a geomedical example. As a lesser known example the discovery of phosphorus deficiency in domestic animals in Norway may be mentioned.

In certain districts in southern Norway, osteomalacia in cattle was very common. In the seventeenth century, farmers informed an official interested in botany (Jens Bjelke, 1580–1659) about this illness and Bjelke in turn named a plant species, very common in the pastures in the afflicted districts, *Gramen ossifragum* or, 'the grass that breaks bones' (systematic name: *Narthecium ossifragum* (L.) Huds.). Thus, very early on the species came to be identified by this name[10]. More than two hundred years later, it was proved that the osteomalacia (which farmers had tried to prevent by mixing crushed bone into the cattle fodder) was related to the extremely low phosphorus content in the bedrock, soil and plants. A geologist confronting the problem had found that the content of the phosphorus mineral apatite was extremely low in districts with osteomalacia, and deduced that phosphorus deficiency could be the cause of the sickness[21].

The etiology of osteomalacia could, however, be determined only after knowledge in medicine and natural sciences had reached a certain level. While the plant species

*Narthecium ossifragum* was common in districts with phosphorus deficiency and osteomalacia, it was not the direct cause of the disease. It does seem, though, that the sheep disease 'alveld' is related to this plant[18].
More than 350 years ago the Norwegian clergyman Peder Claussøn Friis wrote about scurvy and the use of the plant *Cochlearia officinalis* as a prophylaxis[19].
Many other diseases with special geographical distribution have likewise been studied; however, a comprehensive understanding of these diseases must draw on contributions from various sciences. The name 'geomedicine' has been introduced to identify this large and special field of study[9]. A present definition describes geomedicine as the science dealing with the influence of natural environmental factors on the geographic distribution on problems of human and animal health.

## 2. *Chemical changes in parent material during soil formation*

The chemical composition of bedrock may, to a certain extent, be used as a basis for estimating the elements available to plants in a specific area. However, we sometimes find great differences between the total content and the quantities available to the vegetation. An example may illustrate this. To obtain satisfactory harvests in agriculture it is often necessary to use fertilizers. Potassium is one of the elements added. The total potassium quantity in the plough layer in one hectare may be as large as 50,000 kg, but a wheat harvest will only take up approximately 50 kg, i.e. 0.1%. A great increase in the harvest is often obtained nevertheless by using potassium fertilizer.
Chemical changes continuously take place in the surface deposits covering the bedrock. Processes depending on climatical and biological factors cause alterations. With time the upper layers acquire a different chemical composition and other physical properties than the lower soil material. Physical and chemical weathering of the mineral material, addition and transformation of organic matter, and transportation take place between the different layers in the soil profile. We differentiate between soil material and soil; we can define *soil* as the part of the material where plants have their roots.
Under like conditions, the changes are in direct proportion to the length of time soil formation has lasted. Furthermore, the soil properties are dependent on climate, living organisms, topography, and on the parent mineral material.
In a climate with high precipitation, relatively large quantities of soluble material are removed from the soil. If the topography is heavily dissected, comparatively greater amounts of water will run off from the surface, i.e. without leaching too much from the soil. Such surface water may cause soil erosion. Where the precipitation is scarce in relation to evaporation, we may find salt accumulation in the soil. The organisms are in interaction with the soil, depending on, and influencing it.
There are great differences in the chemical qualities of various groups of soils. In most parts of the world percolating water carries away soluble material from the soil. Increasing salt content in the sea during the geological periods bears a relationship to this carry-off from of the land.
Changes in pH during soil formation influence the possibilities of the plants to take up nutrients. Many essential elements will be more readily available when pH decreases. There are, however, exceptions; for example, plants will, as a rule, have a better supply of molybdenum and selenium with increasing pH.
Humus accumulation and clay formation are factors of importance in plant nutrition. Absorption and release of necessary elements are greatly influenced by these components.

## 3. *Essential elements for plants, animals, and human beings*

The list of elements known to be necessary for organisms continues to be enlarged. Among plants, differentiation between macro and micro nutrients is usual. Carbon, oxygen, hydrogen, nitrogen, calcium, potassium, magnesium, phosphorus, and sulphur belong the primary group. Micro nutrients are iron, manganese, copper, zinc, molybdenum, chlorine, and boron. Animal organisms need these same elements, with (probably) the exception of boron. Furthermore, animals and humans need iodine, selenium, sodium, fluorine, cobalt, and chromium. Some scientists consider silicium and vanadium necessary for plants; these two elements, as well as nickel and tin, are necessary for animal organisms including man. Even more elements are in the spotlight as possible necessary trace elements.
Many elements have injurious effects in biological processes. Arsenic, lead, and mercury have been emphasized as being toxic for a long time, and lately the dangers inherent in cadmium have been pointed out. Arsenic and cadmium in very small quantities may perhaps have positive influences on animals. As science improves, more elements will be identified as toxic.
When concentration becomes considerably higher than necessary, even the nutrient elements can become toxic. There are great variations in the differences between the concentration limits for deficiency and excess. Examples of elements with relatively small differences are boron for plants, and selenium for animals.

## 4. *Examples of soil properties of geomedical importance*

*Effects of extreme composition of the mineral material.* As mentioned in the introductory section, cases of osteomalacia have been linked to extremely low phosphorus content in the bedrock.
In some districts there is such a low content of calcium and magnesium in the bedrock that it leads to medical consequences. A low fluorine content in particular may result in a greater frequency of caries. For many further examples of trace element deficiencies injurious to animals and human beings see Underwood[20].
Toxic effects due to high concentrations of certain elements in the soil are not seldom. One of many typical examples is selenium in toxication of animals grazing in certain areas in the USA. The sickness was clearly described in the last century. That too much selenium in grazing plants was the cause of the illness was first discovered a little more than fifty years ago.

*Geographical variation in the composition of precipitation.* Earlier it was assumed that rainwater was practically as pure as distilled water. As analytical methods improved, the presence of considerable amounts of dissolved matter was established in the precipitation, even in non-polluted districts. For a long time seawater was considered to add water to the air only by evaporation. Now we know, however, that to a certain extent waterdrops from the waves are brought into the atmosphere.

Analyses of precipitation samples from some Norwegian stations in the period 1955–62 show clearly that there are great variations in the contribution of elements to the soil (figs 1 and 2, and table). Once these differences were evident, it was natural to try to find out whether the deviations had influenced the soil. Determination of exchangeable cations in humus samples from forest soils showed a relative decrease of sodium and magnesium from the coast towards the Swedish border in Nord-Trøndelag, and a further decrease towards the inland counties Oppland and Buskerud. There was a corresponding increase of the element calcium[5]. Chlorine, iodine, and bromine had similar decreases from the coast towards inland as

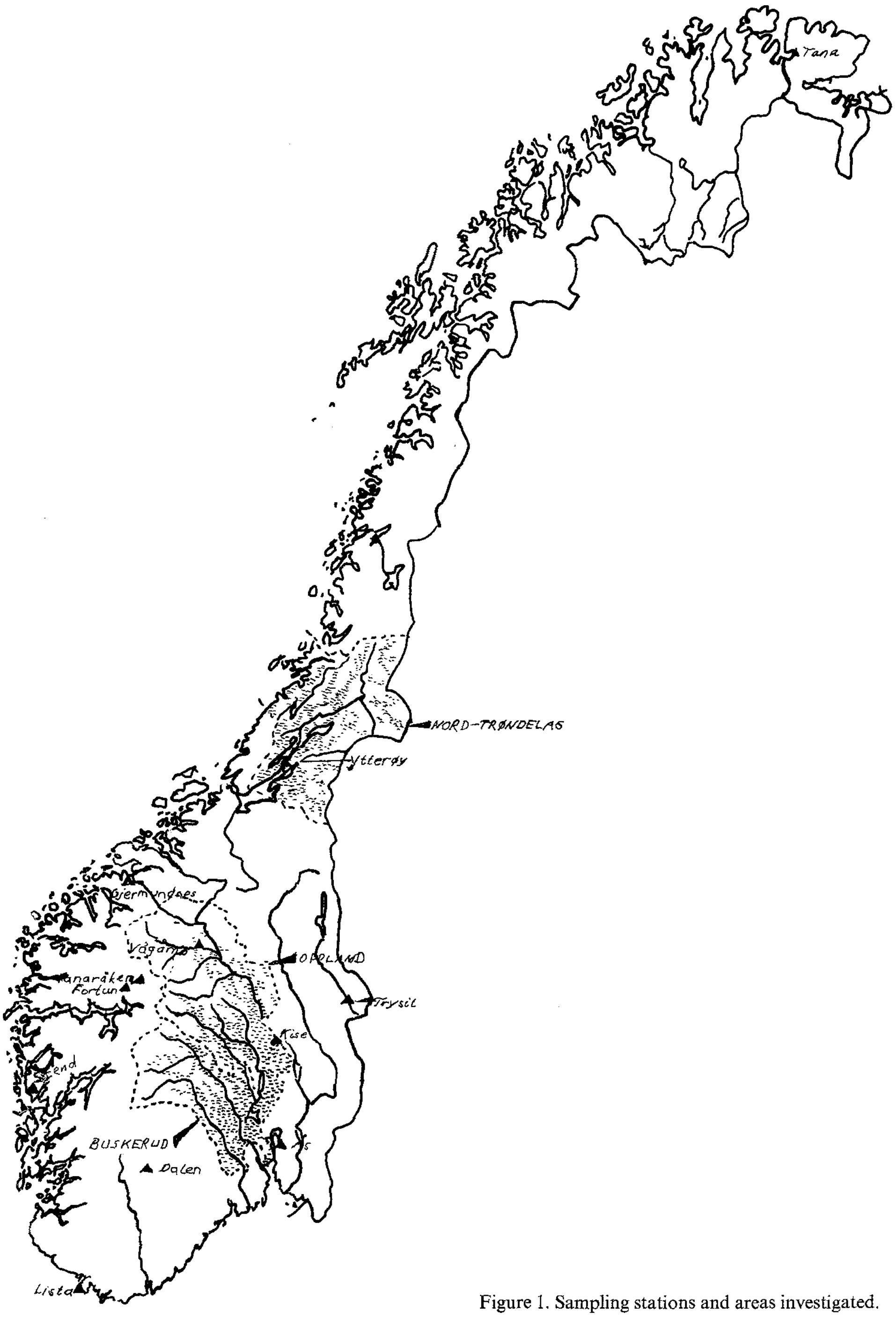


Figure 1. Sampling stations and areas investigated.

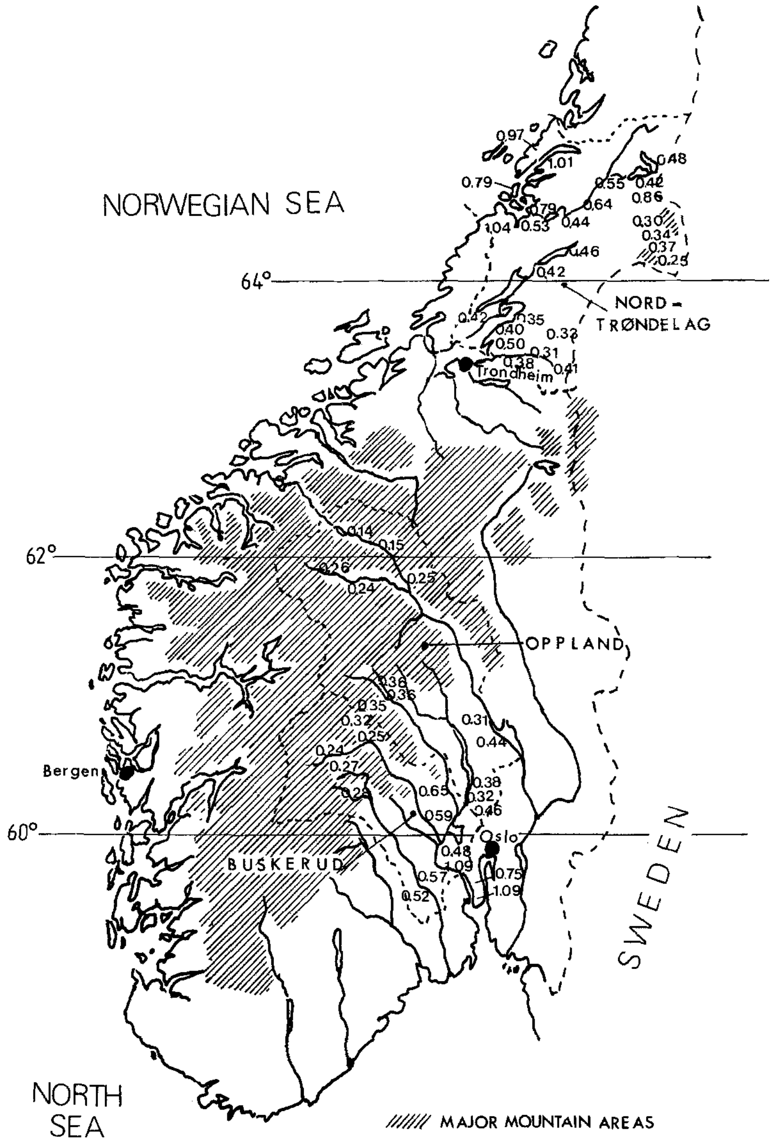


Figure 2. Regional distribution of selenium in humus layers of Norwegian forest soils (ppm).

Analyses of precipitation from Norwegian meteorological stations. Notice the pronounced difference between the inland station Vågåmo and the coastal station Lista regarding Na and Cl

| Station | Year | Precipi-tation (mm) | Yearly amount, mg/m$^2$ S | Cl | $NO_3$-N | $NH_3$-N | Na | K | Mg | Ca | pH (average) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Ås | 1955–62 | 719 | 616 | 697 | 146 | 156 | 488 | 137 | 94 | 536 | 5.3 |
| Vågåmo | 1955–62 | 292 | 294 | 135 | 30 | 46 | 134 | 108 | 50 | 406 | 6.2 |
| Lista | 1955–62 | 1025 | 1871 | 25,742 | 345 | 276 | 14,831 | 839 | 1734 | 1381 | 4.9 |
| Ytterøy | 1957–62 | 640 | 393 | 3,246 | 57 | 75 | 1,820 | 283 | 273 | 561 | 5.9 |
| Tana | 1958–62 | 336 | 409 | 1,613 | 31 | 69 | 966 | 138 | 132 | 413 | 6.0 |
| Gjermundnes | 1957–62 | 991 | 501 | 4,570 | 53 | 106 | 2,785 | 185 | 364 | 584 | 5.9 |
| Stend | 1957–62 | 1116 | 907 | 4,365 | 148 | 209 | 2,491 | 245 | 336 | 643 | 5.4 |
| Fortun | 1957–62 | 622 | 366 | 404 | 51 | 98 | 253 | 123 | 60 | 528 | 6.0 |
| Fanaråken | 1957–62 | 616 | 320 | 424 | 55 | 86 | 363 | 120 | 53 | 264 | 5.8 |
| Trysil | 1957–62 | 673 | 465 | 187 | 88 | 107 | 126 | 81 | 42 | 394 | 5.7 |
| Kise | 1957–62 | 543 | 417 | 141 | 92 | 126 | 104 | 75 | 45 | 491 | 5.7 |
| Dalen,Telemark | 1957–62 | 768 | 504 | 340 | 112 | 90 | 240 | 165 | 66 | 759 | 5.9 |

sodium and magnesium[13]. It was very interesting also to find somewhat corresponding distribution patterns for selenium[12,15].

The figures of exchangeable ions show 4.6 times as much magnesium and 6.0 times as much sodium compared with calcium in the coastal districts in Nord-Trøndelag as in the inland counties Oppland and Buskerud. The content of selenium is about 0.8–1.0 ppm in the coastal areas and 0.15 ppm in the driest inland region.

These chemical differences in the soils can have health consequences. Goitre has from early times been usual in inland districts with low precipitation, where the soils are especially poor in iodine. Analysis of small-grain from these districts showed, as expected, a low iodine content[6]. In the inland districts with extremely low selenium content in the soils, animals have suffered from muscular dystrophy, which is counteracted by selenium preparations[16,17].

When the soil absorbs material from the atmosphere we must take into consideration that it takes a long time for any substantial accumulation to be achieved in this way. Young soils, as in districts glaciated in the Quaternary period or in districts with rapid erosion, may have an extremely low content of such elements. A corresponding explanation for selenium deficiency in animals in Norway, and the Chinese Kechan disease, has been suggested[11].

*Some general comments on soils of the world.* Soil science is relatively young. It was only within the last century that the factors deciding soil formation were recognized. The subject itself is complicated and broaches on many other sciences as well. These conditions are the reason that areas of soil science has not yet reached a mature level. Till now there are only incomplete, scattered surveys of the distribution of various soil groups in the world. The organizations FAO and UNESCO have worked out a worldwide soil map on the scale 1:5 million. In the legend[1] there are 106 soil units divided into 26 main groups. While the presentation is valuable as a general reference, it is obvious that this map does not give a complete picture of the soil conditions of the world.

The International Society of Soil Science has presented a great deal of information on soils. Many countries have worked out more or less detailed national soil maps, and in some nations, intense soil mapping is taking place. With time we shall be armed with improved basic materials that will open the way to the evaluation of special health problems.

*Geomedical problems due to soil pollution.* Human activity has in many cases resulted in soil pollution with geomedical consequences. The best known case may be the cadmium poisoning that led to the itai-itai disease in Japan[4]. Water from a mining district was used for irrigation of rice fields. In time the soil became rich in cadmium and rice had such a high cadmium content that it led to human injury: bone substance and the kidneys were destroyed. The name itai-itai recalls the sound of the patient's lamentation. A large number of cases of soil pollution from mining have been reported elsewhere in the world, but until today none seems to be so well known as the drastic cases of itai-itai illness.

Various industries cause air pollution that, with time, damages the soil. The discharges that result in acid precipitation have been discussed with concern. From incineration plants many elements escape that may cause injurious effects. There are many cases of fluorine poisoning close to aluminium factories. Many metallurgical plants pollute the environment with heavy metals. As an example, one may mention the investigation on soil pollution close to a zinc factory in Odda, Norway[7,8]. Great quantities of heavy metals were found, e.g. of cadmium, in soils and plants. Warnings have been issued to discourage substantial dependence upon food plants grown in the vicinity of the factory.

## 5. *Synopsis and future perspectives*

A few examples of relationships between soil conditions and health problems have been pointed out. Soil science is a relatively young science. Improved analytical methods have made it possible to obtain a more extensive body of information elucidating chemical composition. More intensive interest has arisen concerning the toxic waste exchange within soil-plant-animal-soil cycles. The importance of soil factors in environmental relationships has been emphasized. In recent times, human and veterinarian medicine has given more importance to prophylaxis, and geomedical knowledge can often be valuable in this connection. In turn, developments in the fields of medicine and earth sciences have better prepared us to solve complicated problems within the field of geomedicine.


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