

RECLAMATION OF ACID SOILS

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Summary

Acid soils occupy approximately 60 percent of the land area of the Earth. They arise under humid climate conditions from carbonaceousless soil-forming rocks in all thermal belts of the Earth. Soil acidification is partly a consequence of the depletion of calcium and magnesium. This occurs through the leaching of cations of calcium and magnesium by infiltrating water and through their uptake by crops. Acidification of soils is intensified by the application of mineral fertilizers, primarily nitrates as well as by acid rains and climate change. Acidic soil reaction and the associated negative characteristics reduce the productivity of the soil and the quality of crops as well as adversely affecting ecological balance in farmland.

Liming of acid soils plays a key role in increasing their fertility. By now various methods of calculating lime dosage have been worked out, and specialized machinery and liming technologies have been developed. For this purpose industrial wastes containing calcium are of considerable current use, including ash.

To promote sustainable land use, a set of models descriptive of the dynamics of environmental reaction as well as of the attendant processes in the agricultural systems should be made; the liming dose should be determined very carefully; GPS should be used for its application and new varieties of plants suitable for acid soils should be developed.

1. Introduction

Acid soils occupy approximately 60 percent of the area of the Earth. They arise under humid climate conditions from carbonaceousless soil-forming rocks in almost all thermal belts of the Earth. Acidic soil reaction and the associated negative characteristics reduce the productivity of the soil, the quality of crops, and the efficiency of fertilizers and plant protection methods, as well as adversely affecting the ecological balance in farmland.

Long-term field experiments and agricultural practice have demonstrated that soils have been constantly acidified and depleted of calcium and magnesium. This occurs through the leaching of chemical element from the upper layers of alkaline-soils by infiltrating water as well as by the uptake and subsequent removal of these elements in crops. Acidification of soils is intensified by the application of mineral fertilizers primarily nitrates, as well as by acid rains. The process of acidification affects not only cultivated

soils but also forests and water resources. Soil reaction in its turn influences both microbiological and biochemical processes in the soils and on the chemical composition of plants. Liming of acid soils plays a key role in increasing their fertility and is vital to the success of agricultural operations. But liming is an expensive measure and sometimes it does not work efficiently. To provide sustainable and ecologically friendly development of both agriculture and forestry, the long-term dynamics of soil reaction and its attendant properties should be predicted and properly managed.

2. Soil acidity and its indices.

Acidity is defined as the ability of chemical compounds to split out of protons in solution. Correspondingly the concept of the “acidity of soils” may be defined as soils’ peculiarity to sustain a certain number of protons in solution or the concentration of hydrogen ions in the soil moisture.

The concentration of hydrogen ions comes in units of milligram-equivalents and is measured on the pH scale. pH is defined as the negative logarithm of hydrogen ion activity (this is closely related to concentration) in a solution. The pH of a soil solution is normally measured by an electrochemical method with aid of a glass electrode. Several types (indexes) of soil acidity are distinguished.

2.1. Actual acidity.

This is the soil solution acidity determined by the components dissolved in it.

Soil solution may be defined as the liquid phase of the soil including dissolved salts, organic and organo-mineral compounds, gases and colloids. The acidity of soil depends on:

- mineral acids (such as sulfuric and nitric acids); normally they are contained in small quantities in soil;
- carbonic acid (derived from dissolved carbon dioxide which is produced when microorganisms or roots “breathe out”);
- organic acids (these are secreted by microorganisms and plants and can also be produced during decomposition of organic matter);
- aluminum, iron and manganese ions that manifest acidic properties.

Under real conditions reaction and composition of soil solutions are rather dynamic. To standardize analysis conditions current acidity is determined by water extraction or suspension, prepared as a ratio of soil:water ratio to 1:2.5. For organic soils this ratio is 1:25.

Normally values of actual soil acidity vary in the pH range from 3...4 (that of the very acid soils) to 8...9 (alkaline and saline soils). Most agricultural crops have a narrow range of soil solution reaction, from the pH being between 5.5 to 7.5..

2.2. Potential acidity.

This type of acidity emerges in the interaction of soil with salt or basic solutions. A

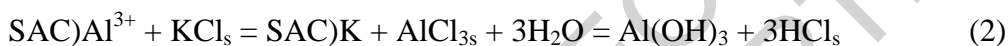
dynamic balance is maintained between the concentrations of ions that are held in the soil solution and those that are adsorbed by a solid phase of the soil (soil absorbing complex). The “soil solution – soil absorbing complex” system is responsible for the buffering of the soil, i.e. its capacity to resist change in soil reaction.

Soil absorbing complex (SAC; ППК – Russian abbr.) may be defined as the totality of mineral, organic and organo-mineral components of the solid phase of a soil, that have the property of cation [positive ions] exchange.

The equivalent exchange of SAC's ions into the positive ion [=cation] of salt occurs in a salt solution. Ions of hydrogen and aluminum generated during the process in the soil solution provide its acidification and may be defined as the form of potential acidity of soil.

2.2.1. Exchangeable acidity.

This is calculated during the treatment of soil with a neutral salt solution.

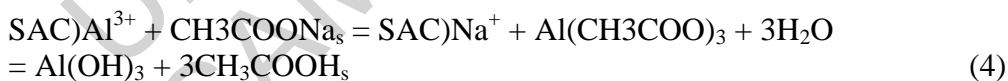
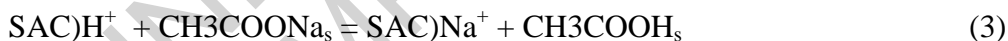


s – soil solution

The acidity of the soil solution is determined by pH size or by alkali solution titration.

2.2.2. Hydrolitic acidity.

This is determined during the treatment of soil with hydrolytically alkaline salt. The most frequently used type of its determination is the one-normal solution of vinegar sodium. The exclusion of hydrogen and aluminum ions out of SAC takes place more completely in the process.



s – soil solution

2.3. Cation (positive ion) exchange capacity and saturation with bases.

Cation exchange capacity (CEC; ЕКО – Russian abbr.) or cation absorption may be defined as total amount of cation, capable of equivalent exchange with cations contained in a solution that interacts with soil. It comes in units of mg-eq per 100 gram of soil or per 1 kg of soil.

The principal media of exchangeable position in soils are clay and loamy minerals and organo-mineral-compounds.

Changeable positions of loamy minerals are formed mainly through isomorphic substitution Si^{4+} for Al^{3+} and Al^{3+} for Mg^{2+} . Their quantity does not depend on the medium reaction. CEC (EKO) of montmorillonit may run between 100 and 120 mg-eq per 100 g of soil, of illit – between 10 and 40, of caolinit – 5 and 15 mg-eq per 100 g of mineral.

Organic substance comprises carboxil-, phenolic and other functional groups being ionized at different pH values. CEC of organic substance may run as high as 600-800 mg-eq. and up per 100 g of substance. CEC of a certain soil is formed according to its mineralogical and humus content. CEC may vary from ones to tens of mg-eq per 100 g of soil (See Table 1).

Type of Soil According to:		Cation Exchange Capacity (mg-eq/100 g of soils)
FAO Soil Classification	Russian Soil Classification	
<i>Dystric Cambisols</i>	<i>Sod-podsolic sandy</i>	3,5
<i>Vertic Cambisols</i>	<i>Sod-podsolic loam</i>	7
<i>Chernozem ordinary</i>		28
<i>Dystric Leptisols</i>	<i>Mountain-meadow</i>	38

Table 1. Cation exchange capacity of various soil (powering layer)

The content of exchangeable cations in SAC is varies across a wide range, depending on soil type. Practically all soils contain exchangeable calcium and magnesium normally with calcium predominating. Potassium cations are contained in all soils as well but their amount in SAC is not large. SAC of soils with a leaching regime and acid reaction of media contains ions of hydrogen and aluminum. The degree of saturation with bases is defined as a portion of CEC that is occupied by cations of alkaline and alkaline-landed elements and can be determined by Equation 5.

$$V = (S / T) \times 100 \quad (5)$$

V –Degree of saturation with bases (as a percentage of CEC),

S – Sum of exchangeable bases,

T –Cation exchange capacity.

3. Natural reasons for increasing soil acidification

Acidic soils occupy more than 60 percent of the land surface of the Earth (Figure 1). There are three main reasons for their natural spread:

- The leaching regime;
- The absence of carbon in the upper layers of soil;
- Forests in the present and in the past.

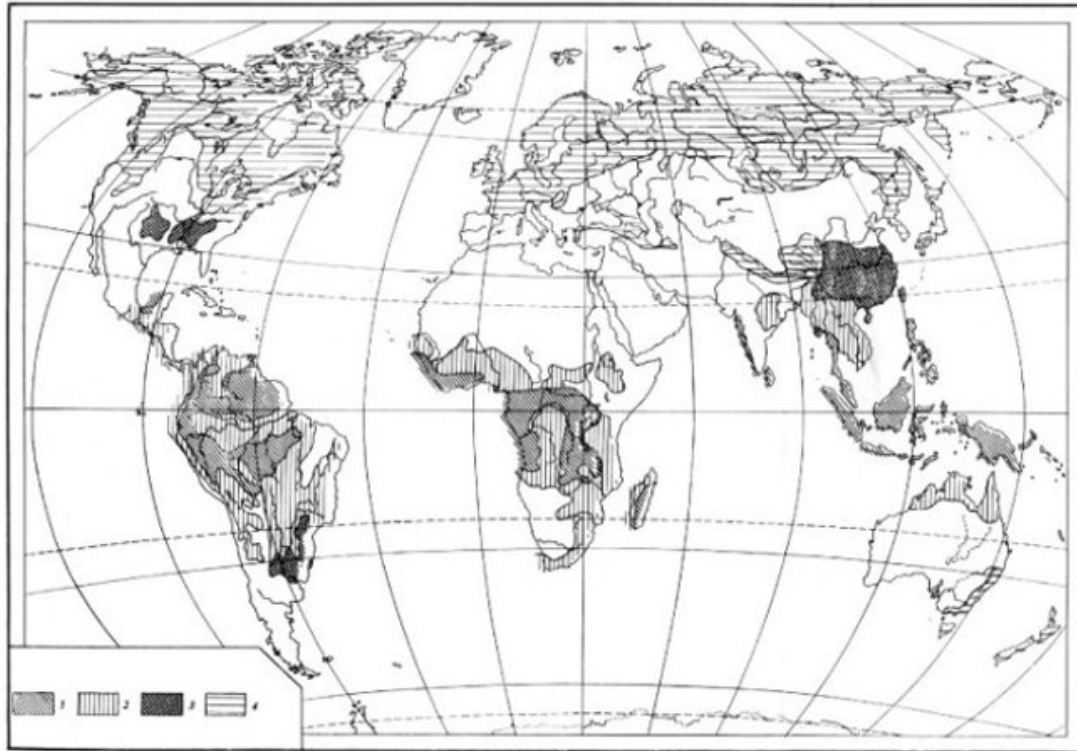
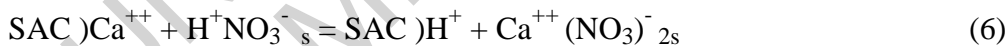


Figure 1: Acidic soils

3.1. Leaching regime.

A leaching regime is created on drained plains under conditions of the excess annual precipitation over evaporation (humid climate conditions). A portion of the precipitation leaches the soil so that it washes away all the compounds dissolved in the soil moisture. As a result of the exchangeable processes with hydrogen ions in the soil solution (there is normally a weakly acidic reaction) the cations of base elements from SAC go into solution and are leached by the downward movement of water until they are beyond the reach of plant roots.



In due course, the degree of soil saturation with exchangeable bases reduces to a quasi-steady-state degree where the removal of calcium and magnesium from the soil is balanced by their input from precipitation and destruction of soil minerals. This balance normally occurs when the soil reaction is highly acid. Lysimeter studies in many countries, have shown that the average annual losses of calcium and magnesium in the surface layer of soil account for 100-250 kg/ha per year, but may amount to as much as 400-500 kg/ha in limed soils. Washing out of alkaline-ground elements is highly dependent on the granular-metrical contents of soils (See Table 2).

Indexes	Type of Soil		
	Sandy	Carbon loamy	Loamy
Total annual leaching of Ca	374	431	325

Ca leaching in April-September	184 (49%)	116 (27%)	88 (27%)
Ca leaching in October-March	190 (51%)	336 (78%)	237 (73%)
Total annual leaching of Mg,	64	58	73
Mg leaching in April-September	32 (50%)	14.5 (25%)	19 (26%)
Mg leaching in October-March	32 (50%)	43.5 (75%)	54 (74%)

Table 2. Calcium and Magnesium losses by leaching from the agricultural soils of different granular-metrical content, (kg/h, the average value over 6 years)

3.2. Soil-forming rocks and plants.

The characteristics of the soil-forming rock dictate the mineralogical contents of soil and the contents of alkaline-ground elements in it. Acidic soils have been formed on acidic non-carbon rocks such as granite and others. These soils provide favorable conditions for the appearance of large amounts of moveable compounds of hydrogen (H), aluminum (Al), manganese (Mn), iron (Fe), copper (Cu) and zinc (Zn). Nevertheless, the content of alkaline ground elements in it is very low.

Vegetation plays an essential role in creating soil acidity. In the northern climatic regions coniferous-trees are widespread. The deposition and decomposition of foliage and branchwood in coniferous forests, on non-carbon soils, produces a rich variety of organic acids and aggressive fulvic acids. Under these conditions the podzolic process causes the destruction of primary and secondary loamy minerals and the appearance of large amounts of exchangeable forms of hydrogen and aluminum.

As a result of the intensive migration of loamy minerals within the soil and due to the washing-out of organo-mineral compounds and mineral salts, a characteristic podzolic layer (A₂) is formed in the soil. It is characterized by light color, a plate-like structure, weak absorbing capacity, high acidity and low fertility. In the lowlands and particularly in poorly drained areas of low relief, long-term water-logging may occur. This leads to the gley formation process as well as to the accumulation of regained, moveable forms of manganese and iron.

3.3. The distribution of acid soils.

Because of the variety of combinations of such factors as soil-forming rocks, vegetation, climate, and relief, against a background of a leaching regime a great range of acid soils types can be found on Earth. They are widespread in different thermal belts and cover most of the continental landmasses. About 30 percent of the cultivated land in India has an acid soil reaction. There are also many acid soils in the USA, Canada, South America, Africa, and Asia (See Figure 1).

According to the Russian classification for the acid reaction of media, the high degree of non-saturation with bases and the high necessity of periodical liming are characteristic for different soil formations (such as podzolic, sod-glyaic, peats, red, yellow, brown soils and so on).

Acid soils, with a pH of less than 7.0 may be grouped as follows (according to FAO classifications):

- PD – PODZOLUVISOLS
- PZ – PODZOLS
- HS – HISTOSOLS
- FL – FLUVOSOLS
- GL – GLEYSOLS
- LP – LEPTOSOLS
- CM – CAMBISOLS

In recent years it became obvious that the acidification of soils that were naturally neutral was occurring, e.g. chernozem soils. The results of recent research in agrochemistry have shown that intensification of agriculture on chernozem soils, together with acid precipitation (See: Acid Precipitation) and changes of climate, resulted in increasing soil acidity. This is the reason for the deterioration of agrochemical characteristics and degradation of soils, as well as chernozem productivity loss. This brings us to the question of chernozem liming.

4. The reasons for anthropogenic acidification of soils. The phenomenon of “Environmental Acidification”.

The soil covering of the Earth and the distribution of acid soils took shape long before the arrival of industrial and agricultural acidity. In every region a distinct ecosystem of plants, ground microflora and microfauna, and larger animals adapted to the environment, was formed. At the same time global circulation of the elements was taking place and a quasi-balance of their input and output was sustained. Man's activity broke down the natural circulation of the elements, created non-compensated output of certain elements and the accumulation of others. Under conditions of humid climate there was an acceleration of the processes of acidification of soil and environment. The acidification of the environment may be defined as the totality of the processes and phenomena in the ecological environment of the regions where there is leaching and acidification of the upper layers of the soil, and further changes in the physical-chemical, biological and agrochemical characteristics of the soils, in the structure and productivity of the ecosystems, and in the physiology and biochemistry of animals and human beings.

Several types of human activity lead to acidification.

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