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AN INVESTIGATION OF THE PODSOLATION PROCESSES IN SOILS WITH A HIGH GROUND-WATER-TABLE

BY

H. HOLSTENER-JØRGENSEN

Introduction.

In 1959 the author published a work on the ground-water fluctuations during the year in forest tree stands growing on soils with a high water-table (*Holstener-Jørgensen,* 1959). A representation in a time-series chart of the height of the ground-water (i.e., the distance from the surface of the ground to the water-table) showed that there is a level in the soil below which the water-table does not fall in winter when the water-table is highest.

This level we called the *highest stable water-table.* It is a locality constant, and its position in the soil is determined by the pore condition of the soil. The level coincides with the layer in the soil in which the number of macropores becomes so low that there is no appreciable sideways flow of water towards the ditches. The investigations were made at Bregentved, where the soil is clayey, and here the level coincides with the border between the upper, more or less humous and generally well-oxidized top-soil horizons and the humus-deficient, more or less reduced sub-soil horizons.

Under conditions like those at Bregentved the deep percolation is in reality nil (see also *Holstener-Jørgensen,* 1961). This means that the water fluctuation in the soil below *highest stable water-table* is caused by the water consumption of the vegetation.

Soil investigations show that the limit of the lime stratum in the soil often lies considerably lower than *highest stable water-table* (see analysis figures in *Holstener-Jørgensen,* 1959). Consequently a leaching has taken place. One might imagine that this leaching proves the thesis that there is no deep percolation wrong (cf. *Aslyng,* 1962, verbal information).

However, the podsolation may also be caused by the ions from the layers below *highest stable water-table* being diffused up over this limit and leaving the area with the water that seeps away through the macropores of the soil above *highest stable water-table.* To prove that this is not a mere postulate we made a simple laboratory experiment, which will be reported in the following.

The experimental method.

Tube sections of Plexiglas were assembled watertight to a tube. The inside diameter of the tube sections was 74 mm and each section was 80 mm long. Fig. 1 shows the experimental set-up. In the figure the individual tube sections are numbered. The lowest section (no. 1 in the figure) was closed with a rubber plug into which was inserted a glass connecting branch with a rubber tube. The second tube section from the top was provided with a connecting branch in the middle of the section (no. 7 in the figure).

Water was admitted through the bottom connecting branch, while moraine sand was poured into the tube. This was continued

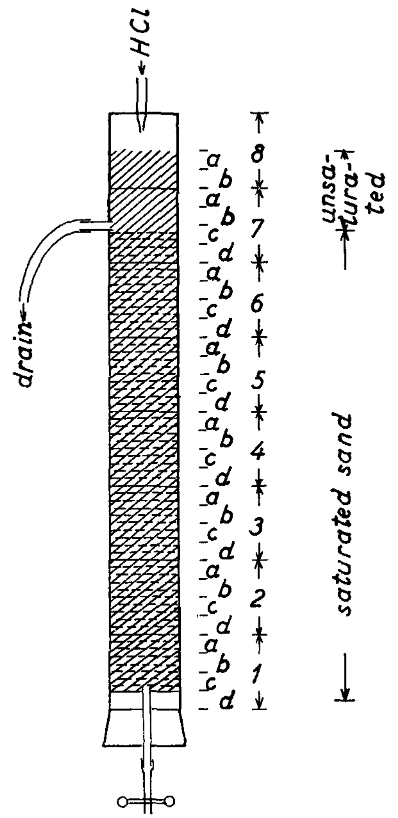

Fig. 1. A sketch of the experimental set-up. For further explanation, see the text.

until tube section no. 8 was half filled with sand. Throughout this process water was added, keeping the sand column saturated, and it was ensured that no air bubbles were caught in the system.

Afterwards the valve at the bottom was closed, and the connecting branch in section no. 7 was opened in order that the water level in the system might adjust itself to the height of this connecting branch. This height corresponded to *highest stable water-table* under conditions like those at Bregentved. Excess fluid in the sand column above this height could be drained off freely through the connecting branch. Below the connecting branch, however, the sand column was constantly saturated throughout the duration of the experiment.

The actual experiment consisted in dripping hydrochloric acid on to the surface of the sand. The rate of dripping corresponded to one litre of hydrochloric acid passing through the system during the ten days the experiment lasted. The normality of the hydrochloric acid was 4.7.

The experiment was commenced on February 4, 1965, and was concluded on February 13.

After passing through the sand column, the hydrochloric acid was caught, and samples were titrated with abt. 0.02 n NaOH to ascertain how much of the hydrochloric acid had been consumed in the sand column by ion exchange and other processes.

The supply of hydrochloric acid having been discontinued, the column was demolished from the top downwards without the fluid in the saturated part of the column having been drained off. The sand in each tube section was divided into 4 layers of equal thickness (cf. the indications by letters in Fig. 1). From each layer two samples were drawn for determination of pH in aqueous suspension and two samples for determination of pH in suspension in 1.0 n KCl-solution. The pH-determinations were made by a mains pH-meter with a glass electrode.

Results of the experiments.

As mentioned, the experiment was commenced on February 4. The first fluid caught from the outlet branch was colourless like the hydrochloric acid fed to the sand column. After the lapse of abt. 2 hours the colour of the drained off fluid had changed. It was now yellow, and during the remaining part of the experiment the drained off fluid had this colour. Throughout the duration of the experiment, however, the fluid was without precipitates.

After less than twenty-four hours a stratum of rust had formed immediately below the level of the outlet branch. During the experiment this B-horizon moved downwards and, at the termination of the experiment, was in the border-area of tube sections 6 and 7.

The pH-values have been brought together in Table 1. As it will be seen, there is some variation between the duplicate analyses. This is due to the fact that all 4 samples (2 for pH · H_2O + 2 for pH · KCl) were drawn individually in each separate layer. Thus, by comparing the individual analyses we get an impression of how much the pH varied in the column after the conclusion of the experiment.

In the bottom line of the table is indicated which pH was found in a mixed sample of the sand from which the column was built.

The figures show a very heavy fall in pH in the upper sand layers down to and including sample 7c. In these layers pH · H_2O has fallen from 7.9 to, on an average, 1.0, and pH · KCl has fallen from 7.7 to, on an average, 0.45.

As mentioned, at the conclusion of the experiment the iron deposit was found to be in the border-area of tube sections 6 and 7. The pH-values show that the abt. 1 cm deep stratum stretched a little bit up into tube section no. 7. Sample no. 7d shows a somewhat higher pH than the sand layers above it.

From and including 6a till the bottom of the column the pH varies considerably. Thus, the average values of pH · H_2O vary between 5.9 (2a and 2b) and 8.1 (4d), while the average values of pH · KCl vary between 5.6 (5d) and 7.5 (4d and 1b). But it will hardly be possible to point out layers as being especially basic or especially acid.

It is evident, however, that, on an average, the pH has also been changed in these deep saturated layers. For the samples 6a to 1d inclusively pH · H_2O is, on an average, 6.7 and pH · KCl, on an average, 6.4. These two values are somewhat lower than the corresponding values for the basic material, 7.9 (pH · H_2O) and 7.7 (pH · KCl) respectively. Consequently, the leaching stretches considerably deeper than the B-horizon.

As mentioned, during the experiment samples were drawn of

Table 1. A survey of the pH-values measured in the various layers of the sand column after the conclusion of the podsolation experiment. (Compare Fig. 1).

Sample No.	Sample Letter	Analysis values pH.H_2O 1	pH.H_2O 2	pH.KCl 1	pH.KCl 2	Average H_2O	Average KCl	Depth cm
								0
8	a	1.2	1.2	0.8	0.8	1.2	0.8	2
	b	1.0	0.7	0.5	0.3	0.9	0.4	
								4
7	a	0.7	0.8	0.5	0.2	0.8	0.4	6
	b	0.8	0.7	0.1	0.3	0.8	0.2	
	Outlet level							8
	c	1.3	1.3	0.3	0.4	1.3	0.4	10
	d	3.8	3.9	3.1	4.7	3.9	3.9	
	Deposit here							12
6	a	5.9	6.3	6.3	6.2	6.1	6.3	14
	b	6.7	6.5	6.5	6.4	6.6	6.5	16
	c	8.0	7.0	6.2	6.5	7.5	6.4	18
	d	6.8	6.4	6.4	7.9	6.6	7.2	
								20
5	a	6.8	6.7	6.1	6.4	6.8	6.3	22
	b	6.8	6.8	8.2	6.5	6.8	7.4	24
	c	6.4	6.6	6.5	5.9	6.5	6.2	26
	d	8.5	6.8	5.4	5.8	7.7	5.6	
								28
4	a	8.1	6.8	5.9	5.8	7.5	5.9	30
	b	6.4	8.2	5.9	5.9	7.3	5.9	32
	c	6.6	6.8	5.9	5.9	6.7	5.9	34
	d	8.2	7.9	8.0	7.0	8.1	7.5	
								36
3	a	6.9	6.5	6.5	6.2	6.7	6.4	38
	b	6.1	6.4	6.4	6.0	6.3	6.2	40
	c	6.5	6.1	5.8	5.9	6.3	5.9	42
	d	6.0	6.0	5.5	8.0	6.0	6.8	
								44
2	a	6.0	5.8	6.3	5.8	5.9	6.1	46
	b	6.0	5.8	6.0	6.0	5.9	6.0	48
	c	6.2	6.1	5.8	6.4	6.2	6.1	50
	d	6.5	6.5	6.1	6.1	6.5	6.1	
								52
1	a	6.4	6.5	6.3	6.3	6.5	6.3	53.5
	b	6.6	6.8	7.5	7.5	6.7	7.5	55.0
	c	6.9	6.5	7.3	7.1	6.7	7.2	56.5
	d	6.9	6.7	6.0	6.1	6.8	6.1	
								58.0
Mixed sample of the basic material		*7.8*	*7.9*	*7.7*	*7.6*	*7.9*	*7.7*	

the drained off fluid, and these samples were titrated with NaOH to pH 7 to get a view of how much of the hydrochloric acid was neutralized by passing the column.

Table 2 represents the results of these analyses. In the last column is shown the difference between the product (ml NaOH) $\times$ (normality NaOH) for the hydrochloric acid supplied and for the fluid that has passed through the sand column. These differences are relative figures for the neutralization of the hydrochloric acid at the individual stages of the experiment.

Table 2. A survey of the relative neutralization of the hydrochloric acid through the effect of the hydrochloric acid on the sand column.

Period of passage	ml NaOH to 1 ml hydrochloric acid passed	NaOH-normality	Consumption $\times$ normality	Mean	Difference supplied — passed
4/2 — 5/2	124.5	0.01794	2.23		
	123.5	„	2.22		
	123.3	„	2.21	2.22	2.52
5/2 — 8/2	159.0	„	2.85		
	159.4	„	2.86		
	160.6	„	2.88	2.86	1.88
8/2 — 9/2	204.0	„	3.66		
	204.6	„	3.67		
	204.0	„	3.66	3.66	1.08
9/2 — 10/2	219.2	„	3.93		
	216.8	„	3.89		
	215.6	„	3.87	3.90	0.84
10/2 — 11/2	232.6	„	4.17		
	232.8	„	4.18		
	230.4	„	4.13	4.16	0.58
11/2 — 12/2	203.4	0.01866	3.80		
	204.2	„	3.81		
	203.6	„	3.80	3.80	0.94
12/2 — 13/2	226.0	„	4.22		
	227.0	„	4.24		
	228.0	„	4.25	4.24	0.50
hydrochloric acid applied	256.2	„	4.78		
	254.0	„	4.74		
	252.0	„	4.70	4.74	

To facilitate the survey, these figures have been represented in Fig. 2 and a free-hand adjustment curve has been plotted.

As might be expected, the first stage of the experiment shows, on an average, the greatest neutralization. In the course of the experiment the relative consumption of hydrochloric acid falls.

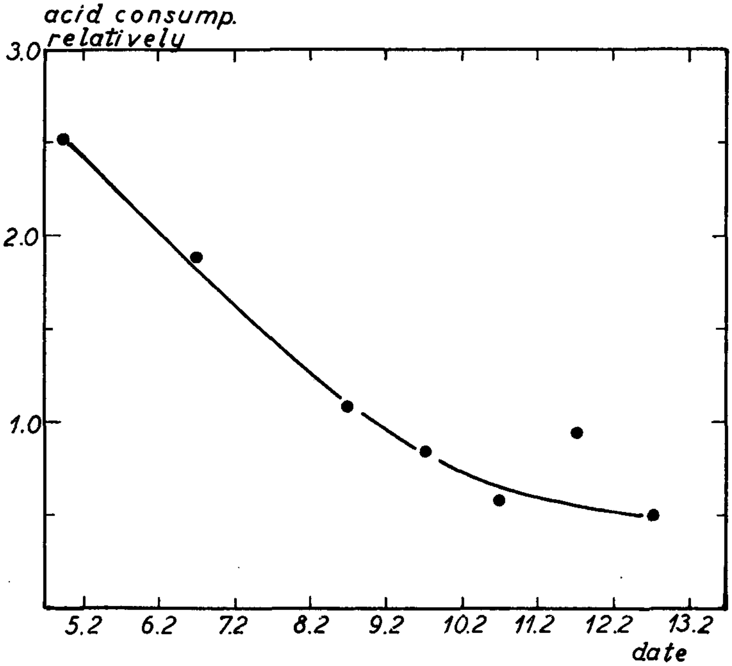

Fig. 2. The relative consumption of hydrochloric acid during the experiment. For further explanation, see the text.

The free-hand curve indicates that the fall in hydrochloric acid consumption is heaviest in the early stages of the experiment.

It is furthermore noticed that the value for the period February 11—February 12 is somewhat higher than might be expected. No explanation can be given of this phenomenon. It should be mentioned, however, that a similar leap was noticed in an experiment made before the one described here. This first experiment miscarried, because one of the lower tube joints became leaky in the last stage of the experiment. The leap may be due to changes in the podsolation process, for instance by the hydrochloric acid liberating other ions in the early stages of the process than in the later ones. To demonstrate this, however, it will be necessary to analyze the ion content of the drained off fluid.

The experiment made simulate the conditions present in soils with a high water-table. In the experimental set-up, *highest stable water-table* is on a level with the outlet branch. The experiment shows that the podsolation processes go much deeper than the *highest stable water-table.* At the conclusion of the experiment, the distinct B-horizon was 4 cm below the drainage level. Below the B-horizon, however, there has been a podsolation, too. It must be presumed that this podsolation below *highest stable water-table* is caused by ion diffusions. The experiment shows that, under conditions like those at Bregentved, we must expect to find the limit of the lime stratum considerably deeper than the *highest stable water-table,* which, in fact, we do.

The experimental set-up was made according to my instructions by Mr. O. J. Larsen, who also carried out all the analyses. For his interest and enthusiasm I should like to offer him my best thanks.

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