OCHRE AND SUBSURFACE DRAINAGE IN FINLAND

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Abstract

The risks of ochre deposition in subsurface drains are common on the sandy and peaty soils of Central and Northern Finland. The iron concentrations of ground water on sandy soils, the mean for 14 fields with subsurface drainage being 23.2 ppm, were found to be high compared with the threshold values for the risk of ochre deposition in Central Europe. The problems have, however, been small, which can be assumed to be due to the climatic conditions and the method of underwater drainage, which has been applied systematically.

1 Introduction

In the history of subsurface drainage in Finland, the ochre problem has been present and acknowledged for several decades. The different alternatives to deal with this problem were analyzed in the early 1950's (Puustjärvi and Juusela 1952). In practice, the method that has been used almost exclusively to prevent ochre deposition in Finland has been underwater drainage. The experiences obtained with it have been favourable. The formation of deposit has decreased notably, with the consequense that there has been hardly any need for maintenance. Over the past ten years, subsurface drainage has become increasingly common on the sandy and peaty soils of Central and Northern Finland, while the previous focus used to be on the clay-containing soils of Southern Finland (Figure 1). On the basis of the soil type distribution, it can be postulated that the risk of ochre deposition will continue to increase, as subsurface drainage has only been begun on the sandy soils of the northern coastal area and the morainic and peaty inland soils.

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The number of subsurface drains non-functional because of ochre deposits has been quite small. Their number is increasing, however, and the percentage of non-functional drains out of the total annual new drainage over the past few years has been of the order of 0.5 %, i.e. 100 - 200 hectares/ year. Applying the classification presented by Kunze (1982), the coastal sandy areas can be classified as areas of temporary risk and the peaty soils as areas of permanent risk.

The recent development has provided new ways of prognosticating the risk of ochre deposition. Also, washing equipment to remove the deposits from the drains have been developed. The widespread application of flushing equipment has also made it possible to replace the expensive construction of underwater drains with cheaper subsurface drainage that can be kept functional by means of continuous maintenance.

2 Iron in ground water

Water supply arrangements have revealed that the excessively high iron concentrations of ground water in Finland are bound to bring about problems (Hatva and Niemistö 1973). The data on **the** iron concentrations of ground water on the cultivated fields in Finland are scant, however. The data to be presented here are based on the water samples collected from the northern coastal area during 1980 - 1984 (Table 1).

The sampling points were located on fields with subsurface drainage of a known history and with observable deposits in the drainage pipes. The water samples were collected from a ground water pipe installed for this particular purpose. In addition to laboratory analyses, the total iron concentrations were also monitored with field measurements[1].

One goal of the project was to find out the possibilities of applying the field measurements of ground water iron concentrations to estimate the local ochre problem. The total iron concentration was selected because it is easy to determine. It was known, moreover, that the ground water table is close to the drainage depth, which means that the water sample can be obtained as unaerated as possible, and that the iron concentartions may be relatively high. No attempt was therefore made at this stage to carry out Fe^{++} assays.

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1. Iron test kitt, model IR-18B, cat No 1.464-01 Hach Company P.O.Box 389 Loveland, Colorado 80593 U.S.A.

As it can be seen from the summary on Table 1, the Fe concentrations were high, the mean for 33 samples being 23.2 ppm and their range 1.0 - 111.0 ppm. As the material is so small, it is not expedient to try to explain the factors responsible for the wide range of variation. It could be pointed out, however, that the ground water status seems to have an obvious effect in such a way that the deeper the ground water table was, the higher was the iron concentration. The mean pH of the water samples was 5.5 and the pH range 3.3 - 6.6. The Mn concentrations assayed for part of the samples were 1.3 ppm and 0.29 - 4.3 ppm, respectively.

3 Functional state of drainage

The subsurface drainage on the farms presented in Table 1 varied from 3 to 22 years of age. No drains that were completely non-functional or clogged were found. The drainage on eight farms was of the underwater type, and six farms lacked submerged outlets. If we pick out of the material the cases with identical conditions, i.e. the farms with pure sandy soil and no artesian ground water, we can see that after five years more than half of the pipe cross-section was filled by deposits in the drains lacking submerged outlets. The Fe concentrations of the water samples collected from these areas were 12 - 26 ppm. Where underwater drainage had been used, the precise amount of deposition was difficult to estimate, because part of it could have been eliminated by the removal of back-flooding, but even in these cases signs of deposition were detectable at the bottom of the pipes of corresponding age. As to the minimal iron concentrations, it was not possible to point out in Table 1 the iron concentration at which the ochre risk would be non-existent. Field measurements carried out in other connections suggest that in pure sandy soils the Fe concentration can be 2 - 3 ppm without there being any need for special measures in the construction of subsurface drainage.

The deposits mainly consisted of reddish amorphous mass, which was pulverized when dry. The ochre deposits in Finland are mostly pure, i.e. they seldom include soil matter, which is due to the liberal use of filtering gravel. Large mare's tail-type occlusions (Ivarson and Sojak 1978) caused by micro-orgamisms have also been rare.

4 Discussion

It is generally known that ochre formation is essentially due to the concentration of soluble iron in the ground water and the bacterial activity associated with its precipitation (Ford 1985, Kuntze 1982). It remains unknown, however, to what extent the different physical, chemical and biological factors are responsible for ochre formation. The essential raw material can be said to be ferrous iron. The determination of ferrous iron concentration has therefore been adopted as a prognostic measure of the ochre risk.

Kuntze (1982) reviewed Central European findings where the ochre risk had been classified relative to the Fe^{++} concentrations. The concentrations at which the risk is termed as 'slight' are 0.5 - 5 ppm, while in the class of 'very great' risk they range from 6 ppm to more than 14 ppm. The concentrations presented above for the Northern Finnish conditions are quite high compared with the Central European values despite the differences in the methods of analysis. On the basis of the practical experience acquired by the Field Drainage Centre, it can be claimed that in the northern coastal area there are several thousands of hectares of drained fields where the iron concentrations of the ground water exceeds 10 ppm. Some hypotheses can be presented concerning the relatively small number of cases of ochre glogging.

Of the microbes that have been found to be present in ochre formation, the analyses of ground water in Finland have revealed e.g. Leptothrix, Gallionella and Thiobacillus (Hatva and Niemistö 1973, Carlson et al. 1980), and drain deposits have been found to contain Leptothrix and Gallionella (Ford 1984). The explaining factor thus cannot be an absence of microbes, but climatic factors may contribute to microbial activity. The average depth of subsurface drainage in Finland is 1.0 - 1.2 m and the soil temperature at this depth is near $0^{o}C$ for a large part of the year (Figure 2). The soil is also frozen throughout the winter months, when there is only minor flow in the drains. In addition to this, the summer months of June and July typically have sub-average precipitation, which also results in sub-average drain flow at this time of the year.

As regards the drainage tehnique, the underwater system compined with abundant gravel around the pipes as well as the clay piping that was used in a majority of the drainage systems until the mid-1970's have been factors that have been found to minimize the problems due to ochre deposition (Kuntze 1982).

On the basis of the survey that was made, it appears that the classifications of ground water iron concentrations made in Central Europe for prognosticating the ochre risk are not as such applicable to the conditions prevailing in Nothern Finland. In the ligt of the experience so far obtained, it seems that the principles being applied in the Leningrad region on the Soviet Union are partly more compatible with the present findings. In the Leningrad region subsurface drainage requires no special measures if the Fe concentration of ground water is below 3 ppm (Peltomaa 1984).

It would be of primary importance to diagnose the presence of the ochre problem at the planning stage. A method for this purpose is being developed in Finland on the basis of findings made by Ford (1982). The major difficulty seems to lie in the application of the international concentration threshold values to different soils and climatic conditions. In addition to this, there is a need, even within Finland, to create different scales for the drainage of sandy and peaty soils. The risk levels will probably be lower for peats than for sands (Tanskanen 1985). In addition to these two types, there are an estimated 50 000 hectares of acid sulphate soils in Finland, where ochre deposits will be a true problem because of the abundant and easily soluble pyrite contained in the soil.

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References

Carlson, L., Vuorinen, A., Lahermo, P. and Tuovinen, O. 1980. Mineralogical, geochemical and microbiological aspects of iron deposition from groundwater. Biogeochimistry of ancient and modern Enviroments. Berlin p. 355-364.

Ford, H.W. 1982. Estimating the potential for ochre clogging before installing drains. TRANSACTION of the ASAE 25(6):1597-1600.

Ford, H.W. 1984. Professor Ford's visit in Finland, personal discussions.

Ford, H.W. 1985. Iron ochre and related sludge deposits in subsurface drain lines. Circular 675 University of Florida. Institute of Food and Agricultural Sciences.

Hatva, T. and Niemistö, L. 1973. Examination and removal of iron in ground water. Agua Fennica 1973:82-92.

Ilmatieteen laitos 1979. Havaintoja maan lämpötilasta Suomesta 3 p. 59.

Ivarson, K.C. and Sojak, M. 1978. Microorganisms and ochre deposits in field drains of Ontario. Canadian Journal of Soil Science 58(1):1-17.

Kuntze, H. 1982. Iron clogging in soils and pipes - analysis and treatment. Pitman Publishing Inc., 1020 Plain Street, Marshfield, MA.

Peltomaa, R. 1984. Personal discussions with Russian experts in Leningrad. Summary published in Finnish Vesitalous 1/1984.

Puustjärvi, V. and Juusela, T. 1952. On rust precipitates present in drainage pipes and on the means of preventing their formation. Acta Agriculturae Scandinavica II(2):131-152.

Tanskanen, S. 1985. Finnish Field Drainage Centre, unpublished data.

Table 1. Fe, Mn and pH of the water samples, soil type of the sampling site and difference between the water level in the sampling vial and the ground surface.

Sampling site		Fe^{totl}/laborat. ppm	Fe/field assay ppm	Mn ppm	pH	Water table m	Soil type	N.B
Kalajoki	Rauhala	13.0-111.0			5.5-6.5	0.4-0.7	sand	
	Kivioja	53.0-66.0		1.3	6.2-6.4	0.9-1.0	sand	
Pyhäjoki	Pirkola	34.8			5.7	0.6	sand	
Ruukki	Agr.Res.St.	2.3-22.8		0.43-4.3	5.3-5.9	0.7-1.1	sand	
	Isohuumola	2.8	2.5	0.29	4.5	0.8	sandy loam	artesian water
	Roppola	3.5	3.8	0.67	5.7	0.7	silty clay loam	
Liminka	Heikkilä	14.0-46.0		0.96	6.1	0.7-1.2	sand	
	Jurvala	1.0-11.8	1.0	1.3	4.5	0.9-1.0	silty clay loam	
Tyrnävä	Potato Res.St.	14.3-26.0	13.0	1.0	4.5-4.7	0.8-0.9	silty loam	
	Kotila	1.6	2.5		5.9	0.5	sand	
	Jokela	7.4-50	9-50		3.3-3.5	1.0	silty loam	
	Eriika	1.3			6.6	1.0	silty loam	
Paltamo	Hannila	9.4-22.2			3.5-4.8	0.2	silty clay loam	artesian water
Tornio	Mörtti	2.3-25.8			5.2-6.6		silty loam	
Average		23.2			5.5	0.7		
Range		1.0-111.0	1.0-50	0.29-4.3	3.3-6.6	0.2-1.2		

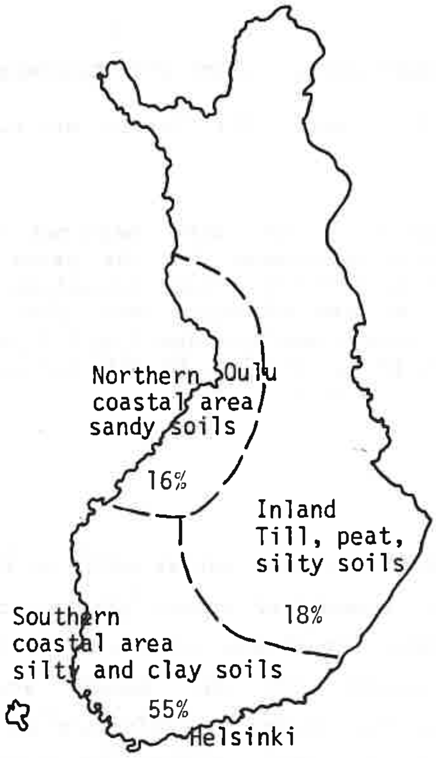

Figure 1. The main soil and types the percentage of subsurface drainage fields in the different parts of Finland

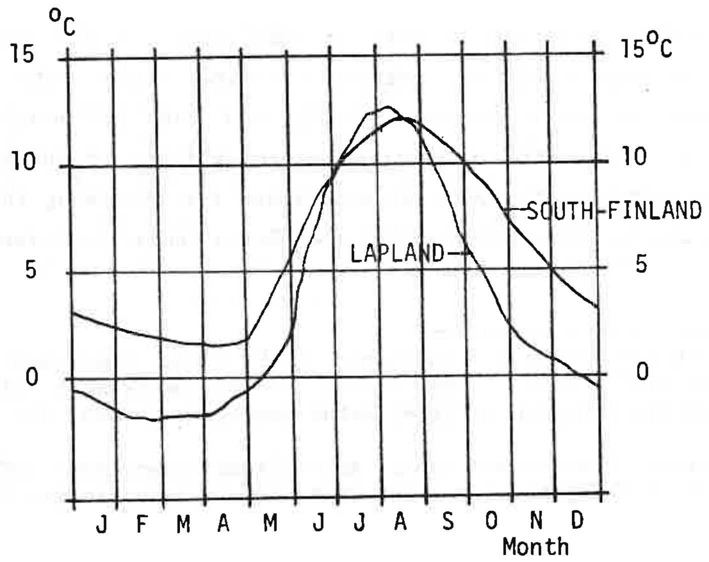

Figure 2. Soil temperature at a depth of 1 meter in Southern and Northern Finland