CZECH SOCIETY OF SOIL SCIENCE

SOIL SCIENCE: PAST, PRESENT AND FUTURE

BOOK OF ABSTRACTS

Joint Meeting
of the Czech Society of Soil Science
and the Soil Science Society of America

and

International Conference
of the Czech Society of Soil Science

Edited by Luboš Borůvka

Prague, Czech Republic, September 16-20, 2001

Conference organized by:

Czech Society of Soil Science

Division of Soil Science of the Czech Academy of Agricultural Sciences

Czech University of Agriculture in Prague

Research Institute for Soil and Water Conservation in Prague

in cooperation with

Soil Science Society of America

ISBN 80-213-0800-1

Welcome to participants

Dear Colleagues,

It is our pleasure to welcome you on the Joint Meeting of the Czech Society of Soil Science and the Soil Science Society of America, organized in the same time as the International Conference of the Czech Society of Soil Science, with a general theme "Soil Science: Past, Present and Future".

The first conference of the Czech Society of Soil Science was held in 1997 and it was decided to organize it regularly. This second conference has been organized as an international meeting in cooperation with the Soil Science Society of America. We thank Professor Miroslav Kutílek and Professor Donald R. Nielsen who came with this great idea. We thank also Professor Donald L. Sparks, the Past President, and Dr. Robert J. Luxmoore, the President of the SSSA, for accepting and encouraging the idea of the joint meeting and for their great help. This meeting should facilitate the exchange of scientific ideas and information and making new contacts and co-operational links in the international scale.

When we started preparing this conference, we were not sure about the form it would get, about the number and composition of participants, etc. We are glad that the returns of the meeting announcement were so good. The conference may not be big by the number of us, but it is certainly big by the names appearing on the list of participants and contributors. We thank you all for coming and sharing your time, findings and ideas with us. We appreciate especially the participation of our colleagues who came from the United States and other distant countries. We thank the convenors and co-convenors for reviewing the papers and for

their help in setting up the scientific program. We hope that each of us will find something interesting among the contributions. We tried to choose up-to-date principal topics, including soil data interpretation, geographic information systems, transport processes in soil, and soil pollution. We see the point of the conference also in making an account of the state of soil science before the 17th World Congress of Soil Science held in Bangkok, Thailand, next year.

Our meeting is held in Prague, one of the most beautiful cities in the world. We hope that you do not regret coming back if you have been here already, and that you will like the city if you are here for the first time. We also hope that you will like the atmosphere on the Czech University of Agriculture and that you will find the campus nice and agreeable. In addition, you will see more of the Czech Republic during the two days of field trips.

We wish us all that the conference be interesting, useful and fruitful.

Josef Kozák
President of the Czech Society of Soil Science
Rector of the Czech University of Agriculture in Prague

Luboš Borůvka
Secretary of the Czech Society of Soil Science

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Opening Remarks on the Occasion of the CSSS/SSSA Joint Meeting "Soil Science: Past, Present and Future"

Dr. Robert J. Luxmoore

President of the Soil Science Society of America

The Soil Science Society of America (SSSA) is honored and very pleased to cooperate with the Czech Society of Soil Science (CSSS) in this International Conference and Joint Meeting of our two scientific Societies. It is a special privilege to meet in Prague. This beautiful city, rich in history and culture, provides a special setting for our meeting as we discuss the past, present and future of Soil Science. Over 1000 years ago as the first inhabitants established Prague, issues of soil were probably of considerable significance to their livelihood as there are issues for us today and will be for future generations. Soil science and soil scientists have had a distinguished past, are having a very active present, and are essential to the future of our Planet. Sixty year ago, Professor Charles E. Kellogg was President of the Soil Science Society of America. Professor Kellogg stated, "*Essentially all life depends on the soil…. There can be no life without soil and soil without life: They have evolved together*". The dependence of life on soil is, directly or indirectly, the basis for all the soil research that we conduct in the agricultural, environmental and earth sciences. We, as Soil Scientists, need to convey the essential message to our citizens that *soils, as the living skin of the Earth, sustain life*. The quality of life in future generations depends on our wise management of soil today. Our Science has lasting significance.

As part of our stewardship, the Soil Science Society of America is developing a position paper on carbon sequestration. The essential message of this position paper is a call for a global increase in soil organic matter as a timely benefit for global well-being. We hope this message will have impact in the United States and perhaps globally. I expect that SSSA will officially adopt the statement at our upcoming Annual Meeting next month. Increasing soil organic matter will benefit humankind by reducing the rate

of increase of atmospheric carbon dioxide and by increasing the productivity of soil, particularly in many areas with degraded soils. There are several challenges to globally implementing this proposal due to limited capital resources in some countries. Effective implementation requires development of a carbon credits trading system and a defensible soil carbon accounting system. These two systems will facilitate the trading of carbon credits from industries and land uses with net carbon dioxide emissions to landowners for sequestration of carbon in soil and plant products. We would be delighted for CSSS to join in partnership with SSSA in this endeavor so we become an international voice calling for enhancement of soil organic matter on Earth.

Our Joint Meeting, including focus on four principal topics of data interpretation, GIS, transport processes and pollutants, will bear many fruits. We address many of the challenges and opportunities important to the future in our presentations and discussions. This meeting will also enhance the relationship between our two Societies as well as provide a wonderful opportunity for personal exchange between our scientists. Some SSSA members have relatives from the Czech Republic and this meeting is of special personal significance to them. One of the former Presidents of SSSA, Professor John Pesek, is of Czech descent. Several of our members have visited Prague before and are pleased to be back. Others are visiting for the first time. For many personal and professional reasons SSSA is delighted to cooperate in this Joint Meeting. In celebration of this special occasion, SSSA presents the eight-volume set of the current SSSA Book Series to the Czech Society of Soil Science with our sincere thanks and appreciation for this wonderful opportunity to share our science.

On behalf of SSSA, I thank Professor Josef Kozak, President of CSSS and the members of the Czech Organizing Committee for the excellent preparation and arrangements for this meeting, and I wish all participants and guests a most exciting and rewarding experience.

TOPIC 1

Interpretation of soil data at different scales in time and space

Convenors:
Luboš Borůvka
Donald R. Nielsen

STATE-SPACE APPROACH TO EVALUATE THE RELATION BETWEEN SOIL PHYSICAL AND CHEMICAL PROPERTIES[1]

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The state-space approach is used to better understand the relation between soil physical and chemical properties in an area cultivated to sugarcane. The experiment was carried out on a Rhodic Kandiudalf at Piracicaba, State of Sao Paulo, Brazil. The sugar cane crop was planted on an area of 0.21 ha, i.e., 15 rows 100 m long, spaced 1.4m, submitted to three management treatments: i. mulching the ratoon crop with trash (cane tips and straw from the last harvest); ii. bare soil between rows after harvest; iii. soil surface covered by residues left by the traditional practice of straw burning before harvest. Measurements of soil water content, soil organic matter, clay content and aggregate stability were sampled along one transect of 84 points, meter by meter. The state-space approach is used to evaluate how soil water content is affected by itself and by soil organic matter, clay content and aggregate stability at neighbor locations, in different combinations, aiming to contribute for a better understanding of the relation between these variables in the soil. The results show that soil water contents could successfully be estimated using this approach, the best performance being found when the estimate of soil water content at locations i was related to soil water content, clay content and aggregate stability at locations i-1. Results open the possibility of underlining influences that cause changes in their relations, stochastically quantifying in a state-space model their changing local behavior, accounting for both, measurement and model errors and the spatial relationships of these variables. This spatial variability is an important factor that affects crop yield and should be considered in planning soil management practices.

INTERPRETATION OF SOIL VARIABILITY ON A RECLAIMED DUMPSITE

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Reclaimed dumpsites created after termination of open-cast mining of brown coal represent an increasing area of anthropogenic soils we have to deal with. Spatial heterogeneity of these soils differs from that of natural soils due to their anthropogenic origin and different reclamation measures, which makes description of their properties more complicated. In the attempt to describe the variability of soil properties on dumpsite Lítov in Northern Bohemia, we applied different pedometric methods on a set of data on 110 soil samples collected in a regular grid 100 by 100 m. The data included soil pH, exchangeable acidity (E_a), oxidizable carbon content (C_{ox}), organic carbon extractable with sodium pyrophosphate (EOC), humus quality parameter (A_{400}/A_{600}), labile aluminum content (Al_{lab}), and content of Al extractable with sodium pyrophosphate (Al_{org}), supposed to be mainly organic. The variability of all the variables was extremely high (Borůvka et al., 1999). This contribution aims in presenting and comparing different approaches to data assessment and interpretation.

First, advanced methods of classical statistics were applied to the data (Borůvka et. al., 1999). In factor analysis, two factors accounting for about 70 % of total variability were selected, since the others seemed to be redundant. The first factor after varimax rotation was interpreted as the factor of soil reaction. The second factor had significant weights for A_{400}/A_{600} ratio and Al_{org} and significant negative weight for C_{ox}. It was interpreted as the factor of organic matter. However, application of geostatistics on the data showed that this interpretation was a little misleading (Borůvka et al., 2001). Kriged maps showed that maxima of Al_{org} and A_{400}/A_{600} were not situated on the same locations. Further investigation suggested that the sources of spatial variability of those two variables were different. A_{400}/A_{600} ratio was influenced mainly by biological reclamation, especially by afforestation with alder trees. Al_{org}, on the other hand, was related rather to the elevation, indicating the influence of the depositing of dumpsite material. This finding led to distinguishing three factors, explaining 83.8 % of total variation, instead of two. The first factor accounted for positive effects of soil reclamation in general, including decreasing soil acidity and labile aluminum content. Spatial distribution of the scores of the first factor, as well as the spatial

distributions of pH, E_a, C_{ox}, EOC, and Al_{lab}, showed high similarity with the map of different reclamation measures used on the area. The influence of afforestation, especially on humus quality and content, was well pronounced in the second factor. The effect of depositing was probably expressed in the third factor influencing Al_{org}. It was shown also that the Al_{org} fraction includes some inorganic forms of Al.

Geostatistics amended to the interpretation of soil variability in an important way. It enabled to distinguish different factors influencing reclaimed soil development, better than classical statistics did. Combination of different methods that complement each other thus provides a good way of soil data assessment even if the basic concepts of the methods are different, as it is the case of statistics and geostatistics. Pedometric methods using combinations of different approaches are useful also for anthropogenic soils on reclaimed areas where spatial distribution of soil properties is determined more by human activity than by natural evolution.

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DEVELOPMENT OF SCALE-SPECIFIC MEASUREMENT TECHNIQUES FOR VADOSE ZONE CHARACTERIZATION

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Variables and parameters required to characterize soil water flow and solute transport are usually measured at different spatial scales with variable measurement volumes. This poses a problem since soil properties are considered to be a function of spatial scale, and their values can differ across scales. Also, when different instruments are used for different soil physical properties, likely their measured values may represent different measurement volumes, thereby making their application to the same soil domain difficult.

Also, the paper emphasizes the need for instrumentation and measurement techniques for specific spatial scales. Examples of soil measurement devices will be presented that provide multiple soil physical measurements within a single sensor design, with similar measurement volumes between measurement types.

The first example illustrates the combination of soil strength, water content and tensiometric measurements within a single probe. A combined tensiometer-coiled TDR was constructed by wrapping two copper around a standard porous cup of a tensiometer. The main advantage of the presented combined probe design is that it provides for the simultaneous measurement of soil water content and soil water matric potential for the same bulk soil volume around the porous tensiometer cup. Although the presented concept and development was tested for laboratory conditions only, a similar combined probe design can be equally applicable for estimation of field soil water retention. A similar design shows that both soil resistance with corresponding soil water content can be measured with a combined sensor, to assess the influence of soil density and water content on soil resistance. This unique combined penetrometer-TDR probe, with paired wires coiled around the cone, allows for simultaneous measurement of both soil resistance and water content, within the same soil volume at the same spatial location, thereby preventing complications that can arise because of soil heterogeneity. Another design is presented that shows how a combined tension-solution sampling probe can be used to measure soil

water matric potential, while allowing soil water solution extraction during or between tensiometric measurements.

A second type of sensor was developed from the principles of heat flow using the dual-needle heat pulse probe. The original dual-probe heat-pulse technique allows, simultaneous measurement of both thermal diffusivity and volumetric heat capacity, and its purposed was extended to estimate soil water content as well. The dual probe consists of two thin needles, representing the heater and temperature sensor probe, which are mounted parallel within a rigid base. A heat pulse is applied, and the sensor temperature response recorded. Modifications of the probe and using four, instead of two needles, allows measurement of the same probe of soil electrical conductivity, thereby providing a means to monitor soil solution concentration. Most recent developments have demonstrated that convective heat transport across the needles may be used to estimate water flow rates. In short, the single probe may allow simultaneous measurement of soil water, solute, and heat transport using the same measurement volume, and might be the instrument of the future for flow and transport studies, in both the laboratory and in the field because of its simple, accurate and versatile design.

It is concluded that soil and vadose zone scientists should collaborate with scientists of other, related disciplines so that various types of measurements are taken at multiple spatial scales. In this way, the relevant physical, chemical and biological processes can be integrated better for an improved understanding of the relationships between flow and transport processes at the microscopic, laboratory and field scale.

THE YIELD INCREASE ON AGRICULTURAL SOILS IN LOWER AUSTRIA

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The major part of food for humans as well as of feed for domestic animals is still being produced on agriculturally used soils. At the same time, precipitations pass through the soil, accounting for about 80% of our drinking water. Thus, the farmer produce not only foodstuff on theses soils, but drinking water as well via these soils. Hence, this land deserves our particular attention in order to preserve it both in substance and function. These tasks become especially urgent when looking at a recent survey according to which 12.000 ha of agriculturally used soil are converted to different purposes in Austria ever year.

It is therefore the imperative to address the question of sustainability of soil uses to ensure that the soils themselves are preserved and their function is maintained.

A review of land valuation (land assessment) in Austria from 1974 to 1997 enables us to draw exact comparisons. The evaluation of the 33 federal reference plots situated in Lower Austria, for example, shows the following as regards valuation index of field and basic grassland number resp.: For the half of the federal reference plots the grading remained the same and about for the half of theses plots received better gradings. Only in a few cases federal reference plots had lower gradings in 1997 compared to 1974.

The reason for this increasing of the soil quality and the soil fertility is a good advice to the farmer by the chamber of agriculture and other agricultural institutions and a logical obeying by the farmer - if you want, a very good collaboration with science and practice.

The exact numbers and the differentiation of the reasons for this favorable trend are summarized in the oral presentation.

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SOIL INTERPRETATIONS FOR SUSTAINABLE FOREST MANAGEMENT IN THE SOUTHEASTERN UNITED STATES

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Managed wetland forests in the southeastern U.S. have become a magnificent component of the landscape, a significant resource for fiber and wood production in the nation, and a unique system for coastal ecological processes, all of which provide numerous benefits to our society. Thus, sustaining long-term productivity and ecological functions of the managed wetland pine forests has been a common goal among forest industry, government agencies, environmental groups, and the general public. The objectives of our long-term research on the productivity of plantation systems are to: (1) identify the determinants of soil, site, and forest productivity for Coastal Plain wetland soils; (2) determine if wetland functions such as soil productivity and site drainage can be restored, if damaged, and at what rate of recovery; (3) determine how intensive forest management affects stand carbon cycling over a forest rotation; and (4) develop a growth model that describes the influence of management, both spatially and temporally, on pine yields based on soil, hydrology, and tree growth processes.

Several rotation-length field studies in several southern states shoed that: (1) wet-weather harvest damage can be minimized by restricting traffic to soils with water contents less than 25%; (2) water table elevation following harvesting is higher on wet-weather harvested sites and hydrologic recovery is slower; (3) bedding partly mitigates soil properties changed by compaction and puddling; (4) site disturbances may increase biomass production by changing species composition; (5) the wetland prevalence index for all species decreases after wet-weather harvesting; and (6) harvest and site preparation initially increases soil carbon pools which could be a significant sink if managed properly. Soil, site, and forest responses to management are very specific; detailed local guidelines are needed for sustainable management.

FOREST SOILS AS A SOURCE OF CO_2

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Soil carbon fluxes are an important component of the carbon cycle in temperate forests being thought to represent 60-80% of ecosystem respiration. Soil CO_2 efflux results from the combination of biological (i.e. the respiration of roots, soil micro-organisms and macro-fauna) and physical processes (i.e. diffusion from sources to soil surface). Of the two compartments, above-ground and below-ground, the below-ground system is the most difficult to evaluate, e.g. only estimates of the contribution of roots to total soil respiration vary from 10-90% (Hanson et al. 2000). The ability of forest soils to sequester carbon through both above-ground and below-ground litter inputs is of particular interest since forest ecosystem potentially represents an increased sink for carbon as atmospheric is increased and photosynthesis stimulated. The flux of current assimilates to roots then can have an impact on soil respiratory losses. On the other hand, temperature increases as result from increasing greenhouse gases in the atmosphere may increase the accumulation of carbon in soils by stimulating the mineralization rate of organic carbon pools in soils by heterotrophic microorganisms. The identification of factors that control C source - sink relations is a prerequisite for understanding the ecosystem C balance and potential effects of raised temperatures, atmospheric CO_2 concentrations and deposition of nitrogen (Högberg et al. 2001). Our objectives were to provide a reliable estimate of soil CO_2, to investigate the effects of seasonal changes in soil temperature on the rate of soil CO_2 efflux and to predict the daily and seasonal dynamics of the soil respiration. We used a field method according to Monteith, Szeicz and Yabuki (1964) modified by Tesařová and Gloser (1976) and Grunda (1980) for the measurement of soil CO_2 efflux. The method was carried out by an absorption balance method using soda lime (Natrocalcite) CO_2 revealed by soil which is absorbed by soda lime granules in Petri dishes under a metal cylinder cut 5–10 cm into the soil. The weight increment of Natrocalcid after exposure in the field represents the amount of CO_2 revealed from the covered surface increased by the weight of water entering into the reaction between CO_2 and absorption agent (conversion by a coefficient of 1.43 (Tesařová and Gloser, 1976). CO_2 release is given in g of CO_2 per m^2 per day and includes also the share of root respiration. The measurement was carried out in the most occurring forest type in the Czech Republic – in a

Norway spruce monoculture of various age and various stand density. Data are evaluated in relation to actual air and soil temperatures and actual soil moisture.

LONG-TERM FOREST SOIL ACIDIFICATION AND NUTRIENT DEGRADATION - LIMITATION TO FUTURE FORESTRY

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The Czech Republic has experienced a serious decline of Norway spruce (*Picea abies*) forests. About 1000 km^2 of spruce stands died during the last three decades. Direct effect of SO_2 on the spruce canopy together with climatic stress was ascribed as a main factor during 1970s and 1980s. SO_2 emissions in the CR peaked in 1987 (2.2 million t yr^{-1}). A desulfurization program was enacted (1992-1998) and emissions declined to 0.3 million t yr^{-1} in 1999, which is 12% of 1987 emissions. This significant change did not improve forest health in the CR. Annual average defoliation of Norway spruce stands in the Czech Republic did not significantly change during 1990s. These observations did not support the hypothesis of direct SO_2 effect as a major cause of the forest decline in the CR. Therefore, soil acidification and related effects can be the major cause of the alarming situation. Depletion of nutrient cation soil pools, (e.g. Ca, Mg and K), and enhanced concentrations of potentially toxic Al in soil solution may contribute to the observed forest dieback. To test mechanisms of forest damage, and estimate time-scale for recovery and spatial distribution of forest soil damage, several methods and their combination was used:

The molar ratios of Ca/Al or (Ca+Mg+K)/Al in the soil solution have been widely used as a criterion for risk of tree damage due to acidification. Intensity and quality of the crown and branch structure transformation due to formation of secondary shoots in successive series is a very sensitive indicator of long-term tree damage, and the subsequent regenerative processes. Soil water chemistry and crown structure transformation of Norway spruce was observed at 17 forest plots in the Czech Republic with following results: All parameters, expressing degradation processes in the crown (defoliation of primary structure), regeneration processes (percentage of secondary shoots) or synthetic stages of crown structure transformation showed a high correlation with soil water (Ca+Mg+K)/Al ratio in organic horizons. Surprisingly, no relationship was found for mineral horizons. Generally, parameters of tree crown status

were considerably better correlated to (Ca+Mg+K)/Al ratio in soil water than to ratio of Ca/Al (Hruška et al. 2001).

Dynamic geochemical model applications of MAGIC (Model of Acidification of Groundwater in Catchments) showed limited prospect for soil recovery in the near future (to 2030) despite substantial reduction of acidic deposition during 1990s. Soil base saturation would increase only very slightly (by ca. 1% during next 30 years). This is because weathering rates become comparable with proton inputs from the atmosphere. Modelled (Ca+Mg+K)/Al ratio in soil water would not increase and estimated atmospheric deposition would keep the most sensitive mountainous ecosystem in chronic stress.

Critical loads and their transcendence for forest ecosystems have been calculated for sulfur and nutrient nitrogen using the simple mass balance method (Anonymous 1996). Critical load is defined as: "The highest deposition of acidifying compounds that will not cause chemical changes leading to long-term harmful effect on ecosystem structure and function". Critical load of acidifying sulfur was exceeded by atmospheric deposition (1998) in almost whole territory of the Czech Republic. Small areas with actual deposition below critical load (ca. 10% of the country) were predominantly located in southwestern part of the country. Critical load of nutrient nitrogen was exceeded in ca. 98% of the territory (Skořepová, unpublished data).

New soil damage classification into four classes was created using geographical information system (GIS) by combining natural factors (climate, geology and soil properties) and actual level of atmospheric deposition of sulfur and nitrogen. The extremely impacted soils were identified on 2 % of territory of the Czech Republic, mostly on high-elevated mountainous areas in northern CR. Strongly impacted soils cover ca. 12%, mostly on higher elevations (ca >700 m a.s.l.) of mountainous areas over whole country. Moderately impacted soils cover 53% and slightly impacted soils 32%. Principles of sustainable forest management, which can support natural soil regeneration, were suggested for all of these classes individually.

Although the main source of problems is acidic deposition, also current forest management practices significantly contribute to soil base cation depletion and acidification, especially at high altitudes. Managed Norway spruce monocultures take up base cations at a rate similar to mineral weathering rate. Since base cations fixed in wood and bark biomass are removed by logging, the internal cycle of base cations is interrupted. Loss of basic cations leads to chronic depletion of the soil exchange complex and aluminum mobilization. Compared to deciduous tree species, Norway spruce canopy captures dry deposition of sulphur

more effectively. As a result, inputs of atmospheric acidity to soil are accelerated as well as leaching of base cations. To improve soil status, we recommend several measures for forest management practice: Specifically important is reducing share of Norway spruce monocultures and promoting mixed or deciduous forest stands instead. Deciduous trees largely reduce the input of atmospheric acidity and create more favorable humus forms as compared to spruce stands.

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THE SIGNIFICANCE OF THE DIFFERENCES IN SELECTED SOIL PROPERTIES OVER 63 YEARS IN MOUNTAIN FOREST SITES OF EASTERN CARPATHIAN

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The comprehensive research in five study plots located at Pop Ivan Mountain, Rakhov District, Pop Ivan Maramureszky-Carpathian Biosphere National Reserve, Carpatho-Ukraina at 24°19,93' E and 47°57,62 N was conducted in both the 1930s and 1990s. Changes over 63 years in the remote mountain area were investigated: the research was designed to compare the pedological, data from the 1930s with the data obtained by the same methodology in the 1990s. To study the changes in soil chemical properties from 1935 to 1998, presenting the soil map of the area and podzolization processes were the main objective. Soil chemical survey played the crucial role. A design of the research was based on the estimation of only internal source of H^+ ions causing an acidifying processes contrasting to a likely role of long distance transport of acidic depositions. The new soil samples were taken in nearly the same positions (difference can reach maximally 2 m) where the soil pits in the 1930s were dug out and stored in the same conditions in the field station. The laboratory analysis based on the identical analytical methods afforded pure findings of the soil chemical survey. The comparison between the data obtained over 63 year was performed by a standard statistical methodology. The changing rate of precipitation in the study plots, role of windthrow disaster and a close to climax steady state conditions were analyzed. The total deposits and concentrations of atmospheric pollutants were taken into account.

The consistent usage of the same field and analytical methods, the precise sampling in the relatively identical soil pits and the broad statistical evaluations were recognized as appropriate research approaches. The roles of natural and likely antropogennous acidification (Ulrich, 1983; Van Breemen et al., 1984, 1996; McLaughlin, 1985; Reuss et al., 1987; Heij et al., 1991) were tried to be distinguished due to different outer and inner parameters of the study plots investigated. The limitations in the data were broadly discussed. The primary effect of internal soil acidification in the site affected by both more light intensity and great accumulation of dead organic matter after a windstorm contrasting with the primary effect of

outer soil acidification in the site affected by the locally highest precipitation rate in the area with dominating wet deposition were described. The conclusions were supported by statistically evaluated data based on information on the significance of the differences in soil properties over 63 years. Due to a mountain character of the study area where a general effect of lower annual precipitation and higher evaporation on forming more concentrated solutions on assimilatory issues in submontane regions and local sources of atmospheric pollutants cannot be expected, the hypothesis was stated clearly: are changes in soil pH and associated properties over a known period of years related to an effect of long distance transport of acidic deposition or an internal soil acidification process?

The role of podzolization was discussed broadly. A presence of Ferro-Humic Podzol (Haplohumods) as an intrazonal soil unit surrounded by Dystric Cambisols (Haplumbrepts) is discussed as a result of joint effects of microrelief, an aquiclude, a rate of accumulation of dead organic matter, a natural low base saturation and high rate of soil moisture. The role of forest tree species (*Picea abies*, *Juniperus communis L., subsp. alpina*, *Alnus viridis*) and herb species (*Deschampsia caespitosa*, *Nardus stricta*, *Luzula sylvatica*, *Festuca picta*, *Carex sp*.) is taken into account, too. Results of chemical analysis were presented. The general meaning of podzolization in the forest mountain sites was discussed.

The forest stands where windstorm opened canopy to more light and triggered off an extensive forest growing are exposed to intense decomposition of organic matter combined with a massive production of organic acids from fast growing seedlings. The natural processes can lead to internal soil acidification which was both measured and indicated by plants. The windstorm led to an increase in biomass entering the soil so that the loss on ignition, total nitrogen content and cation exchange capacity were increased. However, base cation content was lower in the 1990s than in the 1930s, probably because the base cations released by decomposition of the litter were lower than those lost by acid leaching. The total deposition of pollutants in the area was given and shows the real possibility to increase a naturally occurring acidification soil processes in the top area of the mountains. The conditions of the vegetation in the 1930s differ on the open area with the highest annual precipitation which was not fully covered with forest in comparison with the area of close to climax steady conditions and an area of windthrow disaster where the height of the forest reached 45 m in the 1930s.

For the five study plots in the remote mountain area, the comparisons of findings from the 1930s to findings from the 1990s indicate soil acidification. Change in soil acidity over time can be related to an

evaluation of both acidic deposition and natural processes in forest ecosystems. The meteorological data show that there were study plots potentially more influenced by higher rate of precipitation which can be a source of acidic deposition from long-distance transport of atmospheric pollution. One of the study plot was markedly changed by windthrow disaster followed by processes of likely internal proton inputs resulting in acidification of the soils. The last study plot seemed to be close to climax steady conditions and manifests negligible changes.

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NUTRIENT MANAGEMENT GUIDANCE FOR ENHANCING SUSTAINABLE FOREST PRODUCTIVITY

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Guidance on the nutrient management requirement to support enhanced productivity goals for new plantations of loblolly pine (*Pinus taeda*) in the southeastern United States or of Douglas-fir (*Pseudotsuga menziesii*) in the northwestern United States is developed. A suite of Excel spreadsheet calculations, derived by simplification of simulation models, is provided at two Internet websites for use by the Forest Industry in their stand management planning. A three-step procedure is involved.

First, the productivity goal for a new plantation is estimated for a specific site (soil and climate conditions), the selected planting stock and planned management (e.g. planting density, vegetation control, fertilization, thinning). The target biomass projection for each year of the new plantation is determined from growth and yield models available to the forest company or from the 3PG spreadsheet model calibrated for plantation growth. The 3PG model was developed by Landsberg and Waring (1997, Forest Ecol. And Manage. 95:209-228).

The nutrients required to support the target growth are next estimated with the REMMS spreadsheet model. This code determines nutrient requirement from empirical relationships established from the nutrient content of stems, branches, foliage and roots of the two tree species. These calculations determine the time course of nutrient requirements for the target plantation growth.

In the third step, the soil supply of nutrients for the specific soil and climate characteristics of a selected site is determined with the NuCCS spreadsheet model. Soil data from forest company measurements or from estimates provided from soil databases are used to determine the annual nutrient supply from the soil to the vegetation. The difference between the REMSS vegetation nutrient demand and the NuCSS soil nutrient supply provides guidance on the fertilizer requirements to meet the target productivity.

Repeated simulations with the spreadsheet models provide insight on the nutrient management requirements for sustaining enhanced forest productivity through several rotations. The procedures also estimate changes in soil carbon sequestration due to nutrient management.

Supplemental features are included at the Internet websites. The nutrient status at a field site may be evaluated prior to planting by foliar vector analysis with the DIAGNOSIS spreadsheet model. This analysis can be made if foliar mass and nutrient data are available from the previous forest stand. Further, the Crystal Ball software may be used with all Excel spreadsheet models for conducting sensitivity and uncertainty analyses. Sensitivity analysis shows the important variables that contribute significantly to the outputs at each step. Sensitive variables need to be accurately determined. However, variability (uncertainty) of soil, climate and vegetation attributes is often large at field sites. If this variability is known uncertainty analysis may be undertaken with Crystal Ball to estimate plantation nutrient requirements with statistical confidence intervals. These calculation tools are designed for use by the Forest Industry as aids toward sustainable forest management at enhanced productivity levels and for evaluating nutrient management impacts on carbon sequestration.

Acknowledgement: Research sponsered by the Office of Industrial Technologies and in part by the Office of Biological and Environmental Research, U.S. Department of Energy. Oak Ridge National Laboratory is managed by the University of Tennessee-Battelle, LLC, under contract DE-AC05-00OR22752 with the U.S. Department of Energy.

DEGRADATION OF FOREST SOILS USING BULLDOZER SITE PREPARATION IN THE KRUŠNÉ HORY (ORE) MTS. AND POSSIBILITIES OF THEIR RESTORATION

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Bulldozer site preparation was widely used practice in the period of intense reforestation activities in the Krušné hory (Ore) Mts. during 1980 - 90ies. Large areas of forest stands, especially of the Norway spruce, died because of intense air pollution in this region – W and NW Bohemia. Use of the bulldozer soil preparation was based on several ideas:

- Bulldozing enables further mechanization of following reforestation activities – liming, fertilization, plantation, plant protection;
- This process made possible the reforestation of large areas in a short time;
- High expenses were considered advantageous in the deformed economical environment, forest enterprises were evaluated on the base of volume of their activities, not considering their net economical effects;
- "Ecologically" was the using of bulldozers described as a removal of upper, acidified soil layers and making disposable lower, less acidified soil profiles;
- Sometimes, ecological "shelter" of windrows was emphasized.

To describe the impact of such a treatment on the site quality, a research plot was established near the Boleboř village (Ore Mts.), enabling the study of plantations growth, as well as the study of soil and ground vegetation state. Study plot is located on the flat top part of the mountain range, its altitude is 860 m a.s.l., bedrock is formed by acid metamorphites (micaschist), soil type represent Cambisols. Study area is composed by two parts. Both were bulldozed down to the A horizon and planted by the blue (Colorado) spruce (*Picea pungens*). On one part, a birch *Betula verrucosa (syn. alba, pendula)* became the dominant tree species, on the second one, this species is systematically eliminated.

In particular distances from the windrows, i.e. in the 1st row, 2nd row and between 4th - 5th rows of spruces, planted parallelly with them, ground vegetation biomass and composition, surface humus mass and total nutrient content, as well as the soil chemistry and plantation growth were studied.

Plantation was established in the mid 80-ies, plot was studied in the years 1994 and 1999. Results documented a decreasing site quality going from the windrows: this is reflected in the ground vegetation state (biomass and nutrient content), in the holorganic horizons amount and composition, as well as in the soil chemistry.

Biomass of the ground vegetation was decreasing with the increasing distance from windrows, its content of macronutrients decreased as well. Stable state, representing majority of the total surface, was reached between 3^{rd}-4^{th} rows. The same was determined for the holorganic layers, their mass decreased in the same order. Content of macronutrients was more diversified because of other treatments, especially of liming.

The effect of liming as well as the amelioration effects of birch are visible. Site degradation because of further acidification is documented too in the period 1994 - 1999. Especially the nitrogen cycle is degraded.

These soil changes influence the growth and development of plantations considerably. The reason is especially the bad nitrogen and also magnesium nutrition, both in spruce and birch. Bulldozing so represents the deep site degradation by disruption of nutrient cycles and removing the surface organic matter, a vital compartment in forest ecosystems. The poor vegetation on the plot dominated by the blue spruce only can not prevent further site acidification, this process in less pronounced on the plot occupied by birch. This species represents the most favourable soil cover in these conditions, with considerable site improving effects.

Acknowledgement: This presentation was funded by the Research grant MSM 414100009: Restoration of functioning forest ecosystems of the Krušné hory Mts.

SOIL EROSION CONTROL IN URBANIZED AREAS

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The city of Bratislava is by its geomorphologic character divided in two parts:

- One is plainy, lying upon the alluvium of the Danube river;
- Second one is located in undulated terrain of Small Carpathians, mostly with exposition to southwest and in western part with other, variable expositions.

Water erosion is very important problem in the territory between Rača and the Main Railway Station, typical with conglomerate of urbanized areas and vineyards. The problem number one here is water erosion. Very erodible soils composed of weathered granites and vineyards with no anti-erosion protection introduce permanent erosion risk, connected with flooded streets with high quantities of sediments. Possible and viable solution is complete erosion control in form of terraces and grass cover.

Remaining western parts of the city of undulated character are exposed to both water and wind erosion. Water erosion is in most cases successfully controlled with plant cover that has character of the park. However, in small areas (gardens, vineyards, orchards), local problems with water erosion can be serious. These should be controlled locally – by means of plant cover (grass, perennial plants).

Occurrence of sandy soils, as a rule, is connected with wind erosion, particularly in time of winter end and start of vegetation period, and occurrence of western and northern winds of high intensity. Again reliable erosion control is possible in the form of permanent perennial plant cover – grass cover, parks, gardens, orchards and forests.

THE RETROGRADE ACIDIFICATION PROCESSES IN OUR SOILS AS A CONSEQUENCE OF NON-ADEQUATE LIMING

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The objective was to study time development of soil exchange reaction in Czech soils - namely in the soils most endangered by acidification. Two types of multi-annual experiments provided an experimental base:

A) Small-scale field experiments studying the influence of various methods of organic manuring, mineral fertilizing and liming on soil properties;
B) Experimental soil profile amelioration (in the field scale).

Research was aimed at acid unsaturated soils of different texture-in case of the small-scale experiments and at compacted acid semihydromorphic soils - in case of the soil profile amelioration.

The effect of various methods of fertilizing and liming on soil properties was studied in small-scale experiments - mainly with respect to time trends of soil reaction (the development of the pH/KCl-values): stage 1: effect of long-year systematic applications of high doses of fertilizers and ground calcite; stage 2: effect of highly reduced doses of agrochemicals. Liming was systematically applied for eight years, then it was interrupted. Different trends of retrograde acidification were observed in soils with different sorption parameters (various sorption capacity and degree of sorption saturation with bivalent bases). The degree of acidification was not identical in soils of different types after long-term application of compound mineral fertilizer (including superphosphate). When intensive fertilizing was interrupted, pH/KCl values started increasing in stage 2 (where highly reduced fertilizer rates were applied) in relation to soil sorption saturation.

Deep loosening of subsoil was used in experiments with soil profile amelioration followed by incorporation of ameliorating doses of ground calcite and/or mixture of superphosphate and potassium salt (four variants of soil profile amelioration). Subsoil layers of these soils with unsaturated sorption complex were found to be still more sensitive to acidification than topsoil horizons. Single incorporation of ameliorating calcite doses to soil profile substantially increased pH/KCl values on one hand, but acidification trends gradually reappeared in the following years as a result

of fast calcium leaching (acidification rate was related to sorption parameters of soil).

On the base of the results of both experiment types, using mainly the average values of soil exchange reaction and sorption saturation degree and other soil properties, ten groups of soils - so called main soil units (soil types) - were defined with a negligible resistance to acidification effects (insufficient buffering ability). These are most endangered by acidification unless an adequate liming is again introduced. Systematic and sufficient liming should be applied on these soils.

TOPIC 2

Soil geographic information systems

Convenors:

Josef Kozák
Jan Němeček
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THE NATIONAL COOPERATIVE SOIL SURVEY IN THE UNITED STATES: PAST, PRESENT AND FUTURE

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Since 1899, soil surveys in the US have been made cooperatively by Federal and State agencies, and local units of government. This cooperative arrangement is known as the National Cooperative Soil Survey (NCSS). The Natural Resources Conservation Service (NRCS), an agency of the US Department of Agriculture (USDA), is the Federal leader of the NCSS. Federal agencies such as the US Forest Service, National Park Service, and Bureau of Indian Affairs are key cooperators of the NCSS. Several other Federal agencies participate in the NCSS to a lesser extent. State agencies participating in the NCSS include the Land-Grant Universities and Agricultural Experiment Stations. The NCSS has proven to be one of the most successful cooperative initiatives among Federal, State and local units of government ever undertaken in the US.

The past, present, and future direction, and scientific emphasis of the NCSS are assessed in relation to five functional concepts of soil (Dumanski, 1993). These are soil as (1) a natural body; (2) a medium for plant growth; (3) a structural material; (4) a water transmitting mantle; and (5) an ecosystem component. Considering soil in relation to each of these concepts is useful in reviewing the history of the NCSS in the US and developing a strategic plan for soil survey in the 21st century. It is believed the future success of the NCSS will depend, in part, on its ability to maintain its current cadre of traditional cooperators and acquire new ones with diverse backgrounds from all sectors of US society. Progress of the NCSS during the next century will be achieved by combining technology from disparate fields and developing new knowledge and concepts to exploit these combined technologies. There are several important areas in which combining new technology and new concepts will make substantive progress possible. These include: (1) extracting slope factors from digital elevation models (DEM) to locate soil bodies more accurately on the landscape; (2) applying expert knowledge systems to soil mapping; (3) developing and maintaining a database of near surface, use-dependent, and temporal soil properties; (4) shifting from conventional systematic data collection to outcome-oriented project research; (5) conducting studies of soil at the landscape level with no arbitrary restrictions on the depth of

observations; and (6) gaining a better understanding of soil biological processes and their potential impacts on the global ecosystem.

The past and present organizational structure of the NCSS at the field level is reviewed. The types and format of products produced by the NCSS will be discussed. The future success of the NCSS will depend of a field structure that emphasizes conducting soil surveys along natural physiographic boundaries, such as Major Land Resource Areas (MLRA). The MLRA concept will require fewer, but better equipped soil survey project offices. These offices will need to be equipped with the latest computer and information technology. Technologies such as remote sensing, Geographic Information Systems (GIS), and fuzzy logic will be utilized in these offices on a regular basis. Products produced and delivered by the NCSS in the future will be diverse and include CD ROM and web-based versions.

THE STATE AND DEVELOPMENT OF SOIL SURVEYS AND SOIL GIS IN THE CZECH REPUBLIC

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In the Czech Republic systematic soil survey of agricultural lands has been completed at large scale. Within the framework of the typological forests survey soil mapping has been conducted.

There exist two materials for practical use:

- Soil productivity rating of agriculturally used lands at scale 1:5.000, which comprise principal soil forms (76), climate, relief (in digital form);
- Typological system of forests, including 9 forest vegetation zones and 25 edaphic (trophism, hydromorphism) categories.

The following soil maps of both agricultural and soils have been compiled:

- For about and half of the country at scale 1:10.000;
- For the whole territory at scales 1:1.mil and 500.000 for the international cooperation and the soil map at scale 1:200.000; all exist in a digital form.

Two maps of soil regions were compiled at scale 1:500.000 with a broad range of attributes. They reflect not only the characteristics of soil associations (composition, contrastness etc.) and extrinsic characteristics (geomorphology, climate) but also land use, soil rating values and limiting factors, erosion hazards and management conditions (workability, nitrogen behavior).

The digital soil map, which corresponds to the scale 1:250.000 has been completed and is being transformed into the modified SOTER system. This map will serve also for international cooperation.

Because soil surveys of agricultural and forest land were implemented by two separate institutions there were also differences in the soil classification. Nowadays an unified classification system has been completed. Cardinal problems in unifying were:

- To hold analogical soils with different use at the same high taxonomic levels (reference group, soil type, soil subtype);
- To express the differences in topsoils: 0-25 cm (humus forms, micropodzolization etc.) at variety levels;

- To characterize anthropogenic impacts (contamination, erosion etc.) on soils with different use specifically as degradation units;
- To establish Anthroposols.

Soil geographical information system (PUGIS) is being developed. It will be based:

- On the mentioned cartographic soil materials in a digital form, on digitized information concerning geomorphology (slope angles, relief, intensity, isolines, regions), geology, climatology etc.;
- On pedon data from surveys;
- On data of inventories (e.g. pollutants).

PUGIS will dispose of programs for interconnections of polygons (grids) and numeric characteristics and of pedotransfer rules and functions.

Pedotransfer rules represent programmed interpretations. Possibility for interpretation of adsorption characteristics of atrazine in soils of the CR was studied. Our approach was based on exploitation of pedotransfer rules. As a pedotransfer rule we used multivariate statistical methods. K_d value for atrazine estimation was based on the knowledge of data on humus content, soil texture, pH and CEC values, respectively. The results were interpreted in the GIS environment exploiting the digitized soil map of the CR at scale 1:200.000 and the corresponding database of soil characteristics. The spatial distribution of K_d values for the topsoil and the subsoil were computed and presented as soil vulnerability maps.

MAPPING NUTRIENT DISTRIBUTIONS USING GEOSPATIAL TECHNIQUES

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Excessive nutrient inputs from agricultural lands have been linked to environmental degradation and human health risks. In many parts of the world, including the northeastern U.S., high soil phosphorus (P) concentrations are linked to accelerated eutrophication of fresh waters. A large portion of this P comes from a small percentage of the landscape; areas that are high in soil P and transport potential. The mapping of these areas using limited data sets is necessary in order to target pollution prevention measures. In this study, several interpolation methods are used to map soil P distributions in an east-central Pennsylvania 39.5-ha watershed using data collected in 1996 and 2000. Simple field classification, geostatistical, and other geospatial interpolation techniques were compared. Validation was performed using Monte Carlo methods. Slightly more accurate results were obtained with the more complex techniques. However, the added cost and difficulty of the more complex techniques may not be warranted for many environmental applications. The links between nutrient spatial variability structure and transport potential will also be discussed.

USING GIS TO COMPARE WETLAND DELINEATION METHODS IN THE PRAIRIE POTHOLE REGION

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The Prairie Pothole Region (PPR) of North America spans the Canadian provinces of Alberta, Saskatchewan and Manitoba, and extends in to Montana, North Dakota, South Dakota, Minnesota, and Iowa in the United States. The potholes are of glacial origin and lie on rolling till deposits. They are a major landscape feature and provide an example of regionally distinctive wetlands.

These wetlands can function as wildlife habitat, water filters, flood control basins, and groundwater recharge sites. In the past, wetland functions and values were not well understood, and incentives to drain wetlands were offered for agricultural development in the PPR. It is estimated that 89% of wetlands in Iowa, 49% in North Dakota, 42% in Minnesota, and 35% in South Dakota have been drained. Recently the United States has promoted the concept of "no net loss" of wetlands, resulting in the development of many regulatory policies. Policies require wetland definition and delineation for implementation. Government agencies, private organizations, and scientists have written extensively on the difficulty of defining and delineating wetlands.

Most wetland interpretations use three identifiers for delineation: presence of hydrophytic vegetation, hydric soils, and certain hydrology criteria. In agricultural landscapes, hydrophytic vegetation has often been altered or eliminated by intensive management. In these areas, hydric soil is a useful indicator. Examination of soils in zones of frequent inundation shows distinctive chroma and redoximorphic features that are not found in non-hydric soils.

The major complication in evaluating prairie potholes in relation to regulatory identification is the extreme hydrologic variability in the region. The precipitation varies greatly, so that individual wetlands can be inundated for many weeks in the wettest years, to the point that they overflow and form linkages with other, normally isolated, potholes. In the driest years, however, they may be barely moist at the surface. To add to the complexity, potholes may be linked to groundwater and serve as groundwater discharge, recharge, or flow-through sites. Monitoring wetlands to accurately determine hydrology requires wells and automated monitoring equipment. Therefore, indicators of hydrology criteria have been developed.

For depressional wetlands such as the potholes, the Natural Resources Conservation Service (NRCS) has defined 7 primary and 6 secondary

indicators of hydrology. Examples are inundation, soil saturation, watermarks, driftlines, and etc. Many of the indicators are temporal and can easily be missed or are difficult to interpret. An important objective of this study was to investigate alternative and/or supplementary methods for determining the status of wetland hydrology and boundary delineation.

Our approach was to use a Geographic Information System (GIS) to compare wetland areas delineated according to various criteria and methodology. An agricultural field in the PPR of eastern South Dakota was selected for investigation. The field contains a complex of temporary, seasonal, and semi-permanent wetlands. A Global Positioning System (GPS) was used as a mapping tool to delineate detected boundaries and positions.

Hydric soil boundaries were delineated in the field by an NRCS soil classifier. Hydrophytic vegetation boundaries were based on observed wetland vegetation and occurrences of wetland species in tilled areas. An electro-magnetic conductivity meter (EM 31, Geonics Limited, Inc.) was used to measure bulk electrical conductivity in the soil. Readings were taken in a grid system, using GPS to establish location, in 1995 and again in 2000. High readings normally signal high salt concentrations and/or water content. In 2000, soil samples were collected at selected grid-points to a depth of 15 cm and analyzed for electrical conductivity and water content. Soil electrical conductivity and water content were correlated to EM readings and a Pearson correlation coefficient was determined.

Delineated areas for hydric soils were larger than those for hydrophytic vegetation. Vegetation delineation was influenced by tillage that eliminated indicator species traditionally used for wetland determination and may have reduced areas determined from visual inspection.

Interpolated EM data, when contoured, showed delineation similar to hydric soil and hydrophytic vegetation boundaries. Highest EM readings (70-80 mS/m) were in the deepest part of the wetland, with somewhat lower values rimming the wetland. The readings were consistent between years, even though precipitation was highly variable.

Pearson correlation coefficients were highly significant for both electrical conductivity and soil water content. The coefficients for correlation between EM values and electrical conductivity (from soil samples) ranged from .69 to .79. The coefficient for correlation between EM values and soil water content was .64. The results of this study indicate that the use of EM data for wetland delineation has promise. The method is objective, relatively inexpensive, and may show less variability due to temporal weather patterns than other indicator methods. Studies are underway to investigate relationships between EM values and water table levels in order to meet hydrology criteria for wetland delineation.

SOIL INFORMATION SYSTEM FOR SOUTH MORAVIAN ALLUVIAL PLAINS AS KEY TO SUSTAINABLE LAND MANAGEMENT - A USER'S PERSPECTIVE

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Alluvial plains belong to a very common landscape type in Czech Republic. They have important function to mediate the concentrated matter and energy flow by a dominant way in the region. They are known to represent a typical natural environment deeply affecting the selection of human economic activities. In alluvial plains of Dyje and Morava rivers, in the southern most part of South Moravian province of Czech Republic, the soil types limit the extent to which certain land uses are able to occur. The varying processes of different regime of underground water, and sedimentation have mainly developed these soils during flooding of Dyje and Morava, which are the decisive watercourses of the Morava watershed. The landscape, formed in Holocene sediments, had a sustainable and complex spatial pattern of agricultural land grasslands and forests and other land uses resulting from interactions among cultivation, agricultural abandonment, and flood. The interest of agriculture in limiting the flooding of land in the fertile alluvial plain brought about stream-flow regulation in the 20th century. The measures resulted in the cessation of regular floods since 1972. These measures changed the water regime, which in turn brought changes in the properties of soil and its land use capability. There is an urgent need of developing a Soil Information System (SIS) at regional scale for alluvial floodplains of South Moravia. This is important because regional soil management, which combines economic production with ecological protection, requires specific and detailed information about soil. To acquire this information at larger (national and continental) level is time consuming, expensive, complicated and not always error free. Soil Information System is of great use in understanding the dynamics of land use change at regional level, as practical applications in planning and environmental protection need information on soil properties and soil functions. A wide interpretation of soil data and soil maps by planners and other non-geoscientific users may lead to misinterpretation. Therefore prepared information about soil function is needed rather that classical soil maps. Integration on information on land use is one central point in administration and presentation of soil data, as land use is an important factor that affects the social, economic and environmental

makeup of an area. The present paper aims in depicting the terms of development of a regional Soil Information System for South Moravian alluvial plains. Development of such soil GIS, here after referred as Soil Information System (SIS), is through four stages, i.e., logical and physical design, programming, implementation and training. Hence here we deal with the efforts that are being made at Institute of Forest Ecology, Mendel University of Agriculture and Forestry, Brno, in framing the logical design of proposed SIS, from a user's point of view. Proposed SIS should incorporate detailed and specific information on the different indicators and /or properties of soil in order to evaluate the economical and ecological functions of soil. We suggest two types of indicators namely, condition indicator and pressure indicators. The main condition indicators are land use, Drainage, depth of bedrock, climate, elevation and landforms. The main pressure indicators are Changed water regime, land use sustainability, soil erosion, soil acidity, soil salinity and soil pH. The proposed SIS should also be cable of furnishing the prepared information on the land use capability classes and sub classes that exist in the region in question. This is greatly desired as land use capability classes are one way of assessing the limitation of our land and soil, and that what uses it is capable of supporting. Beside this, the information that the proposed SIS should be able to furnish are, information on the soil properties, parameters and functions that enable users to determine the vulnerability of soils to specific hazards, viz., potential susceptibility to compaction, retention capacity for heavy metals, vulnerability to erosion by water, vulnerability to erosion by wind, ground water recharge, nitrate retention capacity, potential agriculture yield and vulnerability to forest soil by acidification; and information on assessment of soil for engineering uses, i.e. deep foundation, shallow foundation, play grounds, local roads and streets, paths and trails, embankment dykes and levees. This can be achieved by having spatial information on related soil properties viz. internal soil drainage, slope, depth of bed rock, flooding, potential frost action, detailed textural classes, alkalinity, geotechnical classification, infiltration rate, salinity, ground water erodibility, surface stoniness and internal stoniness. Also its desirable to have very detailed and specific information on forest soil of the region, because floodplain forest is a dominating and important land cover/ land use in the study region. These hardwood floodplain forests, amounting 15,840 ha, i.e. about 50% of the total area of the floodplain forests in the Czech Republic, are the rarest and the most endangered ecosystems in Central Europe. These are characterized by specific soil conditions, which have mainly been developed by the varying processes of sedimentation during flooding and by different regime of underground water. Other important issues that need to be addressed here are harmonization of information, and use of existing data and metadata base.

USING DRASTIC FOR SPATIAL DECISION SUPPORT AS A TOOL OF RISK MAPPING

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Due to the importance of the subsurface water it is essential to protect the deep water-resources, as it is one of the cleanest sources of drinking water. The major problem is that these subsurface water-resources can be easily and rapidly affected by surface pollution. The danger of pollution is increased by the fact that the exchange of water is slow and as the deep water-resource is one of the major sources of the potable water supply, it will be exploited sooner or later. Environmental impact assessment can help in the environmentally friendly utilization of natural resources.

The aim of the research is to develop a model on a regional scale, which can support an up to date information technological method and can be connected to the DRASTIC methodology, supporting the mapping of vulnerability. As a methodological part of this the aim is to work out such an integrated geographical information system which proves that during a detailed environmental impact assessment it is possible to combine the methodology of the geographical information system with risk-assessment on the potential pollution of subsurface water.

The research includes the following parts:

- The establishment of complex experimental and reference databases, which are needed for detailed environmental impact assessment;
- The comparison of data collecting methods and the comparative analysis of database managing method;
- Detailed methodology of impact analysis and the use and adaptation of models based on the Geographical Information System, which is capable of optimizing resources of many criteria and suitable for taking into consideration the environmental (hydrogeological) buffer-capacity, the minimization of risk and the optimal decision support.

On the basis of DRASTIC method in the data layers each piece of information was given different weight in the decision making process, so each data layer became indexed which made it possible to estimate the risk of the potential pollution of subsurface water on the basis on the different decision factors. Relying upon the results of the examinations the

vulnerability map of the given area was prepared. This map is practical and can easily be adapted to many decision alternatives.

WOODLAND PRODUCTIVITY INTERPRETATIONS FOR AN ALABAMA, USA, NATIONAL PRESERVE USING ADJACENT OLD AND RECENT SOIL SURVEYS AND GIS

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Soil survey maps and attribute data are now available in many countries. Some are available in digital format, however, most in the USA are published as maps and are bound in reports. The maps are often published at different scales in different areas, some use soil names that are obsolete, some are classified according to systems of classifications no longer used. This can be problematic when two or more different adjacent soil surveys are within a project area. In this investigation we evaluated potential forest productivity of a 3504-ha portion of the Little River National Preserve that includes parts of two published soil survey areas, Dekalb and Cherokee counties, Alabama, using digital technologies. The Dekalb survey was intensely mapped and correlated according to the "1938 Yearbook of Agriculture Soil Classification System". The Cherokee county survey, which includes many broad soil association map units, was classified according to criteria in Soil Taxonomy. The Little River is the boundary between the counties. The Preserve area is elongated (north-south) with the Little River roughly dividing the Preserve into two parts. The Preserve consists of highly dissected steep soils covered with mixed hardwoods and pine most of which were destroyed by recent ice storms and selectively harvested. Soil maps were digitized directly from soil atlas sheets published at 1:20,000. For display, the vector based soil polygons were overlain on images of 7.5 minute topoquods with ArcView software®. A field review was conducted to evaluate map quality, study soil profiles, and determine shortleaf pine site indexes at 19 locations distributed over the project area. The 28 mapping units used in the Dekalb County part were re-correlated according to Soil Taxonomy criteria. Similar map units were combined and renamed. All points where data were collected were located with a GPS unit (Garmin GPS III plus®). The soil.shp file was converted to a 5-square meter soil.grd raster file and a reclass tool was used to update the map. The file was converted back to a .shp file and a combine tool used the combine small soil delineations with adjacent similar soils. Large delineations of soil associations on the Cherokee county part (only six mapping units) were split and additional polygons were inserted for soils included in the association. After the soil

map was revised, shortleaf pine site index and woodland suitability group fields were inserted into the soil attribute table. Maps and data tables were obtained using ArcView software®. The USDA-Natural Resource Conservation Service classifies site index for short-leaf pine as: low (<56), moderate (56 – 65), moderately high (66 – 75), high (76 – 85), and very high (>85). Site indexes can range from about 40 to 105. Under this classification 36% of this area has low and 53% has moderate site indexes. The low indexes are caused by shallow to rock, low fertility, droughty soils.

This study indicated that the use of existing soil survey information, topographic maps, GIS, GPS and minimal field investigation can significantly reduce the time required to evaluate areas for potential forest productivity and other uses of soil.

CRITERIA AND AREAS OF PUBLIC INTEREST IN LAND-USE MANAGEMENT IN THE CZECH REPUBLIC

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Land is a multifunctional category in national economy. On the one hand, it has a production function, it is a factor of production and an object of ownership, that means it is goods, on the other hand land is taken as a natural resource and environmental component with ecological function for the landscape water regime, and as a medium for energy generation and for transport and transformation processes. Land is the state territory and it has cultural, historical and social dimensions. Hence it is evident that land ownership and land use are so much associated with public interests that there should exist government supervision of land-use management and a certain level of regulation to protect public interests.

It is evident that optimum land-use management should be defined by evaluating all specific (economic, environmental, cultural) functions of land while taking into account public and government-pursued interests. Evaluation of these functions of land, which were intentionally redefined to set major territorial social preferences, allows to construct a general geoecological map (at an original scale 1 : 500 000). These four main groups of background information were used for its construction:

- Landscape invariants (major reference land classes and their lower taxonomic units, geomorphologic territorial units, climatic regions and subregions);
- Summary background data on agricultural production functions of soil mantle (delimitation of favorable and less favorable areas for agricultural production, classes of farm land conservation);
- Summary background data on environmental, cultural and other functions of soils (special protection of water resources, particularly protected nature areas, zones of cultural monuments, military domains);
- Background data on soil vulnerability (risk of soil erosion, risk of drought).

A total of 13 background layers (maps) were developed, their synthesis resulted in the final map of national and social priorities (public interests) for land-use management.

Four categories of lands were defined to be used for application of public interest to decisions on land-use management:

CATEGORY I includes lands with national priority other than economic use. It involves national parks, national nature reservations, national nature monuments, and protection zones of these particularly protected areas. It also comprises military domains, degree I protection zones of water-supply reservoirs and streams, protection zones of medicinal and mineral water springs, water protection zones of degree I, territorial systems of ecological stability, development areas according to land-use plans and lands for public purposes according to the system of complex reallocation of land. Public land reserve in the region concerned should be included in this category. State-owned land of this category cannot be privatized.

CATEGORY II comprises lands with economic use restricted by public burden declared by generally valid legal regulations and/or lands with real burden in public interest recorded in the land register. On a national level, these are lands in protected landscape areas, in protected areas of natural water accumulation, in protected zones of landscape monuments, in natural parks, in degree II protection zones of water-supply reservoirs and streams, in water protection zones II. State-owned land in this category may be privatized while real burdens in public interest must be entered.

CATEGORY III includes farmlands of highest quality and lands with above-average capability within the climatic regions (classes I and II of farm land protection). Use for agricultural production is a national priority in this category. Their exemption from farmland resources is not permitted, only exceptionally in national interest. State-owned land may be privatized on condition that its agricultural production functions are maintained.

CATEGORY IV comprises lands with average and lower capability, without any real burden in public interest. Economic use other than for agricultural production is admissible. These lands are mostly located in less favorable areas (LFA) in view of agriculture. State-owned land of this category, if not imposed a public burden in its detail, can be privatized to be used in the owner's interest and/or in the interest of the region and commune development.

The concept of public land reserve has been introduced (see Category I): it is 10% of state-owned land in a district or 5 000 ha, and/or the total area of state-owned land in a district if smaller than 5 000 ha. Such state-owned land is going to be used in public interest as a part of land-use management.

A synthetic map at an original scale 1 : 500 000 shows the areas of distribution of four categories of lands with indicated national preferences; it provides framework information on public interest in land in the area

concerned at a national or regional level and on the character of such public interest. With respect to the given level of topographic generalization, the background layers of this synthetic geoecological map are another valuable source of summarily processed information.

Acknowledgements: The paper is an output of Project NAZV QC 0241 "Optimum Management of State-owned Land While Taking into Account Social and Government-Pursued Interests Including the Criteria of Decision-making Process" for the first project year 2000.

TOPIC 3

Transport processes in soil with special reference to preferential flow

Convenors:

Miroslav Kutílek
Svatopluk Matula
Harold M. van Es

MANAGEMENT STRATEGIES TO PREVENT NITROGEN AND PHOSPHORUS LEACHING IN COARSE VERSUS FINE-TEXTURED SOILS

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Current environmental and economic concerns demand improved N use efficiency and many studies have been conducted with this objective. In a recent study, we measured nitrate leaching and performed N budgets on lysimeter plots under three N fertilizer levels, 22, 100, and 134 kg ha-^{1}. Intensive monitoring of crop N uptake, soil N dynamics, and groundwater nitrate concentrations measured under the different N management systems showed that with increasing fertilizer levels, N is efficiently taken up by the crop until a threshold value is reached, after which uptake efficiency dramatically decreases and leaching losses increase. In our case, 43% of the additional 34 kg ha^{-1} N applied between the 100 and 134 kg ha^{-1} rates was accounted for in groundwater. These results show that even minimal overfertilization significantly increases groundwater nitrate levels and precise estimation of crop N needs is critical to reducing leaching losses.

Most current methods for determining fertilizer and manure rates are based on an expected (average) yield response based on information including yield potential, soil type, cropping history, etc. This approach implicitly neglects the annual variations in yield response and environmental losses of N and farmers (being risk averse) tend to apply N based on highest anticipated need, leading to unnecessary excess residual soil nitrate and high leaching losses in most years. We conducted a study that focused on the space-time dynamics of N availability, leaching and denitrification. Drainage class is generally regarded to be the most significant source of variability for N in temperate humid climates. However, our five-year field study involving four rates of N fertilizer and three drainage classes within a 15 ha maize field showed that economic optimum N rates were minimally affected by field variability from drainage class, but strongly affected by annual fluctuations as a result of varying early-season weather. Annual field-averaged economic optimum N rates had a range of 65 kg ha^{-1} with lower rates being associated with years with low early-season precipitation, and vice versa. LEACHMN (Hutson and Wagenet, 1992) model simulations corroborated this pattern that in years with wet early-seasons, soil N availability was significantly reduced as a result of denitrification and leaching. For well-drained soils, most losses

were attributed to leaching, while poorly drained soils mainly experienced denitrification. We concluded that little benefit may be gained from spatially-variable N applications within fields based on drainage class or soil type, but considerable economic and environmental gains are possible from yearly adjustment of supplemental N rates based on model simulations of N dynamics using site-specific weather records, as proposed herein. This will significantly reduce the need for farmers to overapply N fertilizer to assure sufficient plant-available N

N in manure: The fate of N after land application of manure depends greatly on various management and environmental factors. The organic N fraction of manure mineralizes and becomes more gradually plant-available, typically represented by a decay series. However, it is recognized that the rate of N mineralization is strongly affected by variations in soil, climate, manure composition and management. An incorporated fall manure application when soils are warm and crop uptake is nonexistent is likely to result in considerable nitrate leaching losses during the following winter and spring, especially on soils We conducted a field-scale lysimeter study from 1997 to 2000 to investigate nutrient leaching as affected by the timing of manure application, soil type (clay loam and loamy sand), and crop type (maize and orchardgrass). Nitrate levels in drain outflow under the maize system showed that concentrations for fall applications on the loamy sand soil were significantly higher than those for spring applications (21 and 12 mg L^{-1} NO_3-N, respectively). A similar trend was observed or the clay loam (13 and 7 mg L^{-1} NO_3-N, respectively). Higher concentrations (4 mg L^{-1}) in early (Oct. 1) vs. late fall (Nov. 1) application demonstrated the effect of soil temperature on N loss potential. Nitrate concentrations under orchardgrass were much lower than those under the maize system with flow-weighted mean values under 3 mg L^{-1} NO_3-N for both soil types.

P leaching losses were affected by preferential flow processes. Flow-weighted mean Total P concentration were less than 0.04 mg L^{-1} for the loamy sand, but ranged from 0.2 to 1.4 mg L^{-1} for the clay loam, with high peaks mostly recorded in the fall. The risk associated with N and P leaching losses appears to be different for various soil types, primarily due to differences in soil hydrology. Based on the current research knowledge, preferential manure slurry movement can be significantly reduced by better timing and placement of manure application based on site-specific soil and weather information.

Preliminary data from our earlier-mentioned lysimeter study confirm that Total P levels in drain outflow are predominantly governed by spikes associated with preferential flow events. For both the maize and grass systems, short-term concentrations reached above 1 mg L^{-1} on the clay

loam site soon after fall manure application due to preferential flow. They were again briefly elevated during spring snowmelt, but remained below 0.02 mg L^{-1} for most of the time. On the loamy sand site. Total P concentrations remained below 0.02 mg L^{-1} at all times, indicating that soils with little or no preferential flow pose no problems with P leaching as long as saturation levels have not been reached. A component of the proposed work involves better determination of critical soil P levels and assessment of temporally-dynamic critical source areas.

IMMISCIBLE FLUIDS FLOW IN SOILS: NUMERICAL AND EXPERIMENTAL SOLUTION

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The increasing production and use of organic chemicals of the type non-aqueous phase liquid (NAPL) is a serious environmental problem due to leakage of surface and underground storage tanks and eventual disasters which form a hazard of contamination of soils and aquifers. The remediation processes taking place after the soil contamination. We are presenting a computational module – the PollutTransport Module for the analysis of NAPL transport in liquid and gas phase in the vadose zone, in soils unsaturated and saturated with water. The effect of the temperature is taken into account too, thus the heat flow is included. A solution of multiphase fluid and heat flow process posses two main problems:

1. Development of realistic and practical model for fluid constitutive equations;
2. Development of a procedure to solve the problem of multiphase flow governing equations.

Main interest is in improvement of the definition of primary variables namely use of Primary Variable Switching Scheme (PVSS) to switch between volumetric water content θ based formulation and pressure head ψ based formulation. A method for reducing solution oscillations by introducing η "dumping" factor is applied.

The constitutive model has been developed and implemented in the Advanced Tool for Engineering Non-linear Analysis (ATENA) pollution transport module and is based on the two-phase van Genuchten-Mualem model extended to three-phase model upon the assumption of Leverett et al. (1941).

The soil material characteristics have been measured in the systems air-water, air-NAPL and water-NAPL. Leverett assumption is accepted with the development of three phases soil saturation curves based on the curves for two phase condition, as e.g. the soil water retention curve in air-water soil system. Break-through curves are studied for all mentioned phases and the numerical procedure is tested on simplified systems. In the theoretical development at this stage of research a homogeneous soil, called

surrogate soil is assumed as the first approximation of the solution of field environmental problems.

PREFERENTIAL FLOW IN SAND, LOAM, CLAY, AND PEAT SOILS

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Knowledge of the movement of water and solutes through the vadose zone of soils is essential for reliable predictions of pollution risks to groundwater. So far, most models simulating water and solute transport through the unsaturated zone have assumed homogeneous infiltration and a subsequent downward movement of the wetting front parallel to the soil surface. This type of stable flow, however, is uncommon in field soils. Deviations are caused by a variety of mechanisms. Firstly, preferential flow of water solutes may occur in well-structured clay and/or peat soils owing to the presence of shrinkage cracks. Secondly, preferential flow may also occur in non-structured sandy soils, owing to the development of unstable wetting fronts. Fingers or preferential flow paths occur if (1) the hydraulic conductivity increases with depth, as is encountered in soils with a fine-textured layer covering a coarse-textured layer; and (2) the soil is water repellent. Irregular wetting patterns and preferential flow paths have been established in the Netherlands in wettable dune sands and in water repellent sand, clay, and peat soils.

MONITORING AND MODELING OF PREFERENTIAL FLOW IN WATER REPELLENT SANDY SOILS

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Leaching risks of surface-applied agrochemicals in water repellent soils can only be quantified with an acceptable degree of accuracy if knowledge of the underlying principles and an appropriate simulation model are available. The present study aimed to investigate water flow and solute transport processes in a water repellent sandy soil, and to introduce and apply new modeling approaches.

Automated TDR measurements revealed that preferential pathways develop rapidly during severe rainstorms, causing infiltrating water to be preferentially transported to the deeper subsoil. Furthermore, preferred pathways recurred at the same sites during all rain events.

Simulations with a 2-D, numerical finite element flow and transport model indicate that preferential flow paths will only form during infiltration into dry water repellent soils, i.e. in the range below the so-called critical soil water content. Incorporation of hysteresis is essential to generate the formation and recurrence of preferential flow paths with the model. The process of preferential flow and transport has been incorporated in the well-known SWAP model also, and applied to field data of tracer transport through a water repellent sandy soil in the Netherlands. Results indicate early arrival times of bromide in the subsoil in case preferential flow is taken into account.

TIME DEPENDENT HYDRAULIC RESISTANCE OF SOIL CRUST: HENRY´S LAW

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In earlier experiments on steady infiltration into crust topped soil columns, an additional resistance was observed in the vicinity of the boundary between the crust and the soil below. I have performed laboratory experiments in order to check and, eventually, to explain this phenomenon. Crust topped soil was modeled in the traditional way by ceramic plate of high resistance placed on the top of the soil column. Soil was physically modeled once by sand and in other set of experiments by loess. Hydraulic resistance of the plate was by two orders of magnitude higher than the resistance of the soil column in the first set and by 1.5 order of magnitude in the second set. Unsteady infiltration into crust topped soil at low and high water content was repeatedly realized and the plate resistance was measured each time after infiltration. With soil "saturated" by infiltration, flow in the whole system was performed and resistance of the whole system was measured, too. Hydraulic resistance of the plate was rising with time during infiltration. The increase of hydraulic resistance was more expressed when water infiltrated into crust topped dry sand than in experiments with sand of high water content. The effect was less expressed for infiltration into crust topped loess. Hydraulic resistance of the plate was rising with time even in saturated system and the increase of the resistance was dependent upon applied hydraulic gradient. However, the increase of the plate resistance was in this type of experiments less distinct compared to infiltration into dry soil. The process of gradual increase of plate resistance was only partly reversible in de-aired water. Following hypothesis is applicable: High hydraulic resistance of the crust results in steep drop of the water pressure between the top and bottom part of the crust if water flows through the crust topped soil. The concentration of dissolved air in water depends upon the pressure acting on water according to linear Henry´s law. I am assuming that air is released in small, microscopic air bubbles at the bottom part of the crust due to substantial drop of pressure. The microbubbles are blocking the micropores of the bottom part of the crust and on the interface between crust and soil. Consequently, hydraulic resistance increases. This effect exists provided that the crust porous system is uniform and consisting of fine micropores only.

SIMULATION OF WATER TRANSPORT IN HETEROGENEOUS SOILS

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Soil moisture distribution curves after infiltration and redistribution in the layered soil as calculated by mathematical model, are presented. This model is based on numerical solution of Richard's equation. Soil moisture distribution curves were calculated using values of saturated hydraulic conductivity K_{DP}, and K_{GP} measured by disc permeameter, and by Guelph permeameter, respectively, in every soil layer. K_{DP} values represent hydraulic conductivity only of the soil matrix of layers, and K_{GP} values of the soil layers with preferential paths also. Amount of water penetrated into the layered soil of 100 cm depth was less than that applied on the soil surface after every infiltration, for both conductivities. Simulated and measured results closer using K_{GP}- values then using K_{DP}- values of soil layers.

REDUCE ERRORS OF APPROXIMATED SOLUTIONS DUE TO THE UNCERTAINTY OF MOISTURE TRANSFER PROBLEM.

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Deterministic presentation of each transfer problem include two main parts (a) equations and (b) boundary condition. The equations express the mass preservation law, while the boundary conditions derive properly from field (lab) measured data. It is certain that the equations have to be satisfied, but there is a lot of uncertainty concerning determination of the boundary conditions. We propose to look for approximate analytical solution in form that satisfies the equations precisely but perturbs the boundary conditions. These solutions are mass-conservative in contrast to other approximated approaches such as the perturbation method, asymptotic (Galerkin for example) method, or finite difference or finite elements numerical methods. It is proved, on the basis of the maximum principle, that these solutions have the greatest error at the boundary that decreases inside the region.

The power-series method (PSM) is developed following the above principles and applied to solving the saturated and unsaturated seepage problems in anisotropic, layered soils. It found to be available to wide class of transfer steady equation, especially for the process where the expected solutions are smooth, non-periodic function (that are usually the seepage solutions). The PSM fits completely this physical character of seepage problems in contrast to, for example, Fourier series approach (derived usual from variables separation method). Presentation of seepage solutions by Fourier series is difficult and need many members for the appropriated approximation, even worse, in many cases the derivatives of the Fourier series do not converge to derivatives of the solutions (fluxes).

Following PSM the boundary conditions are presented as power series of one variable, while solutions are polynomial of this variable with coefficient as function of other variables.

This way the degree of the differential equations is reduced. The PSM approach is applicable for a continuous boundary condition in many cases, at least on finite segments. A group of solutions is obtained for two-dimensional or three-dimensional axisymmetric medium. Superposition of above meant solutions for linear boundary conditions allows the

development of an important group of solutions with non-continuous (step-like) boundary condition for semi-infinite and finite medium.

TRANSPORT PROCESSES IN HETEROGENEOUS SOIL COVER OF WATERLOGGED SLOPES

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Waterlogged soils on slopes of hilly and mountain areas have specific problems:

- Occurrence of slope springs;
- Periodical surface in flow of „foreign“ water;
- Shallow lateral water flow through soil in different depth of soil connected with usually complicated geological, hydrological, lithological and pedological conditions;
- Transport of many substances with the flowing water;
- Occurrence of inverse semi – and hydromorphic catenas under slope springs.

Relations between the complicated soil cover and shallow lateral water flows through the soil resulting in migration of some substances are the subject of the poster. Directions of lateral subsurface flows were constructed on the basis of soil morphological features and analytical data. Some conclusions could be generalized: the main directions of shallow lateral flows do not follow straight directions down the slope; they do not correspond with the meso- and microrelief of the terrain; a number of substances both natural and foreign origin migrate with flowing (lateral) water; redistribution of these materials (their reduction or environment in area) has some regularities but it combines the result of different processes; redistribution of matter should be taken into account in investigation.

REMARKS TO THE PHYSICS OF WATER MOVEMENT AND SOLUTE TRANSPORT IN SWELLING SOILS WITH CRACKS

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The author confined himself to the cases of swelling and shrinking soils which change their volume more or less periodically and in which the principal type of macropores are planar cracks due to shrinkage at drying. Some basic physical notions are discussed which seem to be critical for a further development of the theory of swelling soils and its applicability in practice. In general, the paper is asking questions rather than offering answers.

The basic notions discussed are:

- the mechanics of swelling and shrinking,
- the geometry of cracks, its describability and predictability,
- the skins (cutans) on the surface of cracks,
- a special role of the surface layer (arable topsoil or grassland sod),
- the multi-scale approach.

The mechanics of swelling and shrinking: Even without the cracks, a simultaneous solution of water, solutes (possibly also air) and solid phase transport may be extremely difficult. The problem becomes simpler when one regards the ongoing processes as reversible and one-dimensional. However, the universal reversibility does not exist. What we may assume is an approximate reversibility within the limits of usual periodic changes to which the soil is exposed. Reversibility is a sort of elasticity and, unfortunately, no realistic elasticity theory can be formulated in one dimension. What seems to be a one-dimensional heaving or sinking of a soil column or profile (semi-space) may be in fact a complicated three-dimensional elastoplastic process. The cracks complicate the case further and their existence can only be reconciled with the reversible theory if we confine ourselves to simple cases, e.g., if we assume that the cracks only arise when the soil tensile strength is exceeded and if their geometry is, to some extent, determined a priori. There seems to exist no high-level theory able to predict the creation of cracks in the soil without such assumptions, even if the soil is regarded as a homogenous semi-space subject to the field of gravity.

The geometry of cracks: Apart from trying to predict or explain when, where and why the cracks appear, we can take their geometry as given and simply try to describe it. Several different approaches exist. The crack pattern may be taken as a regular (e.g., hexagonal) dissection of plane or space or may be regarded as a stochastic point process (e.g., a Voronoi mosaic) or a stochastic surface process, so that what we work with are finally some parameters of stochastic processes, rather than visible pictures of cracks. Other concepts are also possible (some of them arose to describe fissured hard rocks). Most concepts are acceptable enough. The gap between the reality and the model geometry can be bridged over using stereological methods. On a more practical level, the bad thing is that we cannot measure the geometry of cracks in every soil on every field. Hence, the parameters of the crack pattern in a particular soils must be predictable in some way. The factors to be considered comprise the swelling capacity of the soils, its tensile strength, the depth below the surface etc.

The skins on the surface of cracks: We usually cannot neglect the fact that the cracks, as soon as they open, become exposed to external factors and processes such as the crack re-filling with the eroded soil, the deposition of colloids on cracks' surface, the action of biota and the oxidation-reduction processes. These factors make the mechanical and hydraulic properties of the skin on the cracks' surface different from those of the bulk soil. The phenomenon was mostly studied locally (micromorphologically) and very little has been done for its macroscopic averaging..

A special role of the surface layer: In most cases, the cracked subsoil is covered with a ploughed or otherwise cultivated topsoil which behaves differently. It is this surface zone which absorbs rain or snowmelt water before distributing it between the cracks and the soil matrix. This zone is also an intermediary between the subsoil and the atmosphere during the process of evaporation. When left to settle after cultivation, the ploughed topsoil gradually acquires a quasi-stable state more alike to that of the subsoil. The soil in the grassland sod layer is, in addition, reinforced with plant roots which may change its mechanical properties, especially the tensile strength. It is extremely important at, at the same time, extremely difficult to quantify these processes, because of large spatial, temporal and soil, climate and vegetation-wise variability.

The multi-scale approach: The multi-scale character is inherent to any soil with macropores, any porous rock with fissures and even any aggregated soil. The theoretical concept to describe this situation is only obvious on the most abstract level: two (or more) different transport laws are acting in two (or more) separate pore domains and a special constitutive relation(s) express the interaction(s) between these domains. This general

scheme is, however, not easy to formulate for particular cases, especially as regards the interaction term(s). In addition, the transport may take place on different scales in different domains. For example, the transport in the macropore domain may be global, acting over the entire soil profile, while the transport in the matrix may only occur on the scale of individual aggregates.

In conclusion, the author admits that the processes of water movement and solute transport in swelling soils with cracks are only one facet of the complex array of problems associated with the soil and water processes. Practical applications of the above-mentioned concepts, theories and investigations are only conceivable within comprehensive mathematical (or other) models which are capable of simulating all relevant processes, including not only the soil water movement and the solute transport but also the hydrological balance in its entirety, the surface runoff, the soil erosion and sedimentation, the cycles of transformations of organic matter and nutrients, the growth, development and decay of plants, agronomy (tillage, fertilizers, irrigation), groundwater movement, drainage, stream bank hydraulics etc. Some such models already exist and are being applied in practice. However, they have to be permanently improved and the physical concepts on which they are based must be periodically revisited, rather than forgotten.

A MODEL FOR ASSESSING THE LEACHING RISK OF PESTICIDES FROM SOILS CONSIDERING PREFERENTIAL FLOW

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Generally, pesticides have a low mobility in the soil. Despite, traces of many pesticides have been found in the groundwater. This is caused by fast transport due to preferential flow in the soil. Necessary conditions for preferential flow are heavy rainstorms that cannot be predicted on the field scale neither according to their date of occurrence nor to their intensity or duration. As a consequence, it is on principle impossible to predict if, when and to which extent preferential transport occurs at a specific site. However, to reduce environmental pollution, farm management needs an easy tool to estimate the leaching risk of pesticides. Therefore, the aim of this study was to develop such a model for assessing the risk of preferential flow.

To identify factors affecting the preferential transport of pesticides in the soil, we evaluated literature studies investigating the water flux directly or indirectly via the transport of a conservative tracer or a dye tracer in field or lysimeter studies. Furthermore, studies are included investigating the transport of substances with a high affinity to soil, like pesticides, that can be used as tracer for preferential transport. Own studies with pesticides as a tracer for preferential flow and with dye tracers amend the literature review.

The literature review shows that (1) the number and connectivity of macropores (e.g. made by earthworms), (2) the soil water content, and (3) the time and the intensity of tillage are the most important factors influencing the preferential flow. Furthermore, drainages reduce the risk of groundwater pollution directly under the site under study, but increase the risk for contaminating surface water.

The input parameters for the risk assessment are expected to be easily available in the field and must be complete to enable a judgment of the preferential flow risk. To consider the risk of heavy rainstorms, the yearly number of days with rainstorms must be considered additionally. While static parameters (e.g. texture) characterize the site itself, dynamic parameters (e.g. soil water content) allow a time-dependent judgment of the risk potential. The development of the model was scientifically accompanied by the expert group „Preferential transport in soils“ of the Deutsche Vereinigung für Wasserwirtschaft, Abwasser und Abfall e.V. (ATV-DVWK, German Association for Water, Wastewater, and Waste).

TOPIC 4

Heavy metals and organic pollutants in soils

Convenors:
Milan Sáňka
Jack E. Rechcigl

LEAD AND ZINC BIOGEOCHEMISTRY IN A HARDWOOD FOREST

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In the 1970s, the U.S. Congress passed legislation restricting the sale of gasoline with alkyl-lead additives. In the intervening years, the amount of lead (Pb) consumed in gasoline has declined sharply, resulting in lower rates of atmospheric Pb deposition. At the Hubbard Brook Experimental Forest (HBEF) in New Hampshire, USA, the input of Pb in precipitation has declined by more than 97% since 1976. Despite this decline, Pb continues to accumulate in the forest ecosystem of the HBEF due to extremely low losses in drainage water. However, between 1977 and 1997 the Pb content in the forest floor has declined by approximately 30%. Lead now appears to be accumulating in the mineral soil.

Much of our understanding of the long-term patterns of lead accumulation in ecosystems has been shaped by paleo-ecological studies, in which inputs of lead are assumed to be irreversibly retained. Using a regression model and historical information concerning Pb consumption in gasoline, we estimated Pb inputs to the HBEF ecosystem during the period 1926-1989. Based on this analysis and our field observations, it is clear that Pb is more mobile in soils and aquatic sediments than previously reported. The potential for Pb pollution in drainage water may therefore be greater than suspected in regions with continued high rates of atmospheric Pb deposition.

Soil processes play a critical role in the fate of trace metals in forest ecosytems. To explore the nature of soil-trace metal interactions, we estimated five fractions of Zn and Pb in Spodosols at the Hubbard Brook Experimental Forest, in central New Hampshire: (i) soluble + exchangeable (EX); (ii) inorganically bound (IB); (iii) organically bound (ORG); (iv) amorphous-oxide-bound (AMOX); and (v) mineral-lattice, or residual (RES). Organic matter is a critical factor in trace metal fractionation in Hubbard Brook soils; it provides most of the exchange capacity of the soil, and readily complexes trace metals. Strong linear correlations were observed between loss-on-ignition and EX Zn ($r = +0.91$) and Pb ($r = +0.85$), and ORG Zn ($r = +0.57$) and Pb ($r = +0.89$). The Oa horizon accounted for only 1.9% of the soil mass above the C horizon, but contained 23% and 77%, respectively, of the EX Zn and Pb in the soil.

The fractionation of Zn and Pb differed, with Pb more tightly held in the soil than Zn. Among the "labile" fractions (all except RES), ORG Pb was the largest fraction in all horizons except the Bs2 and C. In contrast, EX Zn was the largest labile Zn fraction in the Oa, E, and Bh horizons. Also, the percent of total metal in the EX fraction was greater for Zn than Pb in all horizons. Biocycling of Zn, a micronutrient, provides a mechanism through which labile Zn is returned to the forest floor, helping to maintain labile pools in upper soil horizons. Nevertheless, the EX Zn pool in the soil (6.03 kg ha^{-1}) is insufficient to replace the pool of Zn in above-ground tissues (6.87 kg ha^{-1}). Lead leached from the O horizon between 1926 and 1991 can account for 30% of the EX+IB+ORG Pb, or 14% of the labile Pb in the mineral soil.

CONTENTS, SOURCES AND POSSIBLE ASSESSMENT METHODS OF HEAVY METALS AND ORGANIC POLLUTANTS IN AGRICULTURAL SOILS OF THE CZECH REPUBLIC

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Introduction

Soil survey, monitoring and inventarization programs are inevitable tools to define soil properties for a given area (country), including the status of pollution. Two such programs are conducted under the Ministry of Agriculture of the Czech Republic: Basal monitoring of agricultural soils and Agrochemical testing of soils, both as a part of legislation (Act on fertilizers No. 156/98 S.B. and connected decrees, in wording of later regulations). There is a special database called "Register of contaminated sites" in the framework of Agrochemical testing of soils, in which results of risk element contents are stored.

In order to make a profound assessment of results, also fluxes and balances of substances is necessary to observe. For this reason, monitoring of atmospheric deposition and inspection of sewage sludge are conducted, as programs observing major sources of inputs of substances in soils.

Evaluation and continuous assessment of the specified programs is carried out by the Central Institute for Supervising and Testing in Agriculture and results are submitted to the Ministry of Agriculture and Ministry of Environment.

Method and materials

Soil and atmospheric deposition monitoring program

The program of monitoring on agricultural soil is being realized in the network of 190 representative monitoring plots on arable land, grassland and on special crops since 1992. On chosen monitoring plots atmospheric deposition is monitored simultaneously in one-month period. On the special subsystem of 27 monitoring plots, designed in highly polluted areas, parameters of pollution are investigated (level of pollution, sources, translocation in soil profile, transfer in plants).

Register of contaminated sites

In the period of 1990 - 1993 the survey of risk element contents (Cd, Pb, Cr, Hg) in agricultural soils in the network of 1 km^2 was implemented.

The four elements were successively supplied by analyses of Be, Co, Cu, V, Zn. That survey laid down the database that has been continuously filled by results of supplementary sampling. Geographical co-ordinates and a plot number identify each sample in the database. Affiliated are the results of risk elements contents in soil in 2M nitric acid extract or aqua regia extract. Other risk substances can be analyzed in soil samples based on the requirements of the Ministry of Agriculture.

Inspection of sewage sludge

About 200 water treatment plants from which sewage sludge is applied on agricultural soil are inspected every year. From one to four samples of sludge are taken and analyzed for risk elements contents and, in some cases, also for nutrients and organic pollutants.

Results

The results of the monitoring and inventarization programs can be used as statistical numbers for several purposes (legislation, state administration, soil protection programs, practical farming, different research programs). The programs serve as a base for counting the soil pool of the substances, but also the inputs and outputs can be either counted from the real data (atmospheric deposition, sewage sludge), or using experimental formulas (fertilizers, plant uptake, leaching, weathering).

According to Nicholson et al. (1999), there are following major sources of risk substances in soil: manure, sewage sludge, industrial wastes, atmospheric deposition, fertilizers and lime, agrochemicals, irrigation water. Basically, only fertilizers (including manure), sewage sludge and deposition are of areal importance. Although the fertilizers and especially sewage sludge are applied locally, for statistic purposes the inputs of substances are expressed for the whole area of agricultural land.

In order to asses the potential danger coming from risk substances inputs, it is useful to express sewage sludge application separately, for the fields where applied only.

The pools and fluxes make the necessary data available to assess ecotoxicological risks. The soil pool ($g.ha^{-1}$) is counted for the plough layer based on the soil concentration of a substance. Also inputs and outputs of a given substance are calculated in ($g.ha^{-1}$ $year^{-1}$). Balances, and when compared to limit values, also critical loads for individual substances can be defined. For the time being, the critical loads for Cd, Pb, Cu, Cr, Zn, and Ni were expressed for the agricultural soils of the Czech Republic.

Table 1. Calculated inputs of selected substances in agricultural soils

	Inputs of substances in agricultural soil ($g.ha^{-1}.year^{-1}$)								
	As	Cd	Cr	Cu	Ni	Hg	Pb	Zn	PCB
sewage sludge	0.20	0.06	4.20	3.70	0.75	0.06	1.76	24.15	0.0025
fertilizers	0.71	0.68	8.28	117.73	4.64	0.00	1.78	222.24	
atm. deposition	5.69	1.01	8.79	32.53	11.86	-	31.00	436.11	
sewage sludge-where applied	64.63	18.25	1336.9	1179.0	239.76	18.75	562.40	7696.0	0.79

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HEAVY METALS AND MICROELEMENTS CONTENT OF HUMUS FORMS IN DIFFERENT REGIONS OF THE CZECH REPUBLIC

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Heavy metals and some microelements are considered as an important part of anthropogenic pollution of the environment. Their content indicates long-distance transport and deposition of pollutants in ecosystems, including the forest ecosystems in particular regions - this fact is used for the human impact description. These elements possess different character and mobility in the ecosystem compartments, usually they accumulate in some of them. One of important microelement sinks with considerable indication value are forest soils, especialy their most dynamic part - humus forms.

Presented study documents the content of some microelements including some of heavy metals in holorganic layers and in the uppermost part of forest soils. Examples are demonstrated of localities in regions with differently intense pollution - the Krušné hory (Ore) Mts. and Krkonoše (Giant) Mts., as well as from a region considered as slightly polluted - Šumava (Bohemian Forest) Mts. Analyses were done of L, F, and H holorganic layers and A mineral horizons. Surface humus and mineral soil samples were collected in the year 1999, total element analyses were performed. Results allow to consider the accumulation of studied microelements during the humification process, they can represent a basis for other studies, done by corresponding specialists. Regional differences can be described too, as well as the ecological transects were studied - the effect of altitude, species stand composition, geological bedrock and site preparation.

Acknowledgement: This presentation was funded by the Research project of the Academy of Sciences of the Czech Republic No. A3012905/1999 – Magnetic mapping and analysis of contaminated recent soil sediments

BIOLOGICAL AND CHEMICAL INDICES TO EVALUATE (BIO)AVAILABILITY OR NATURAL ATTENUATION OF METALS IN SOILS

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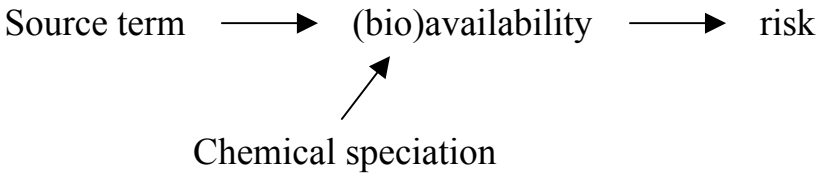
One of the emerging paradigms during the 1990's revolves around the relationships,



The source term heavily influences the chemical form and subsequent (bio)availability of trace elements. Source term generally can be grouped into: natural and anthropogenic. Natural source include the geological parent material of soils and volcanic eruptions; anthropogenic sources such as mining and smelting, chemical manufacturing (tetraethyl lead, fertilizers, batteries, etc.), sewage sludge and livestock manure, fossil fuel combustion residues, etc.

Coupled with (bio)availability is natural attenuation, which corresponds to the "plateau" of uptake of metals (response curve) by plants or other suitable biological indicators. Natural attenuation can be enhanced by remediation in which the (bio)availability of trace elements is minimized (i.e., risk-based remediation). Many researchers have resorted to using abundant, rather inexpensive natural minerals (e.g., apatite) and industrial by-products (e.g., alkaline fly ash, alkaline composted biosolids).

(Bio)availability or natural attenuation can be determined by using biological or chemical indicators (or indices). A common chemical index is the determination of the "available" fraction by extracting the soil in question by a neutral, weak electrolyte (e.g., $MgCl_2$, $Ca(NO_3)_2$, NH_4HOAc, etc.), which soil chemists put into practice in the 1950's to diagnose micronutrient requirements by crops (Mortvedt et al. 1991). This single-step extraction can be integrated with a more detailed multi-step scheme, i.e., sequential extraction procedure. In essence, the latter scheme delineates the solid phase association of the trace element in question --- from medium to highly recalcitrant fractions (i.e., residual). The solid phase association is largely dependent on the soil constituents and redox

potential. In arable soils, the predominant solid phases may include the clay minerals, OM, oxides of Fe & Mn, carbonates, etc. In wetland solids, however, the sulfides and OM may predominate. Successful progress has been made recently to optimize (or standardize) multi-step extraction procedures (Rauret et al. 1999; Ahnstrom and Parker 1999).

Biological indicators of (bio)availability include the plants themselves as probably the most common biological indicator, and microbe-based biosensors. "Indicator" plant species should be favored over the "hyperaccumulator" or "excluder" species.

Promulgation of environment policy relative to trace element content by land use has been, by inlarge, based on the total content in the soil. However, there has been, although sparse, some move within the EU to adopt the "available" fraction in tandem with the total content. Perhaps for certain limited source terms as those in arable soils where the fertilizer, manure, and sewage sludge are common, the "total content basis can be adopted, but probably not so adaptable for other land uses.

It is then apparent that the risk of a certain trace element is proportional to its (bio)availability (or lability). This proportionality should then be integrated with a much larger picture of the relationships above.

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MAGNETIC MINERALS AS TRACERS OF INDUSTRIAL POLLUTION IN SOILS

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Magnetic properties of soils and recent sediments are sensitive to presence of ferro(i)magnetic minerals. Present instruments and methods enable very sensitive determination of concentration of strong ferrimagnetics (for instance magnetite), in the order of ppm. Ferrimagnetics in soils are of both primary (e.g., lithogenic magnetites) and different forms of secondary origin.

Possible mechanisms of magnetic enhancement of soils due to increased concentrations of secondary ferrimagnetic minerals are discussed in, e.g., Mullins (1997), Maher and Taylor (1988), Stanjek et al. (1994) and Singer et al. (1996). Besides pedogenic and biogenic processes, atmospherically deposited ferrimagnetic particles of anthropogenic origin contribute to a great deal to concentration-dependent magnetic properties of top soils, such as low-field magnetic susceptibility (e.g., Thompson and Oldfield, 1986; Petrovský and Ellwood, 1999). The highest concentration of anthropogenic ferromagnetic particles was found in humic or fermentation layers, located right under the litter (Strzyszcz, 1989).

Practically all industrial fly ashes contain significant fraction of ferrimagnetic particles. Most important sources of anthropogenic ferromagnetic particles include fly ashes produced during combustion of fossil fuel (e.g., Flanders, 1994; Kapička et al., 2000). Moreover, other sources, such as iron and steel works, cement works, public boilers and road traffic contribute to contamination by anthropogenic ferrimagnetics (e.g., Heller et al., 1998; Scholger, 1998; Hoffmann et al., 1999). Despite particles of pedogenic origin, anthropogenic ferrimagnetics are characterized by specific morphology and distinct magnetic properties. They are most often observed in the form of spherules, with magnetic phase frequently sintered on aluminium silicates (e.g., mullite) or amorphous silica (Maher and Thompson, 1999). Prevailing ferro(i)magnetic phases are Fe-oxides, namely magnetite and maghemite, with Fe ions very often substituted by other cations (e.g., Strzyszcz et al., 1996).

Recently, rock-magnetic methods have been applied to modern soils in several environmental studies (for overview see, e.g., Petrovský and Ellwood, 1999). Application of comparatively simple technique of measurements of magnetic susceptibility enables to outline areas with

concentrations of deposited anthropogenic ferrimagnetics significantly above the background values. Magnetic mapping represents thus a rapid, sensitive and cheap tool of targeting areas of interest. Afterwards detailed, more time consuming, expensive and laborious chemical analysis should be carried out in order to quantify the pollution levels. Measurements of low-field magnetic susceptibility of surface soils have been applied recently around local pollution sources (e.g., Strzyszcz, 1993; Kapička et al., 1999; Petrovský et al., 2000; Hoffmann et al., 1999). On larger, regional scale, mostly areas in Poland and Great Britain were investigated (Dearing et al., 1996; Hay et al., 1997; Strzyszcz 1991; Heller et al., 1998). These studies proved that in polluted areas magnetic susceptibility of surface soil layers is considerably elevated and, at the same time, typical ferrimagnetic particles of anthropogenic origin were identified.

Up to now, magnetic methods have been primarily used in areas with rather high concentration of anthropogenic particles in soils. For example, in areas with high concentration of industry, the annual amount of atmospherically deposited dust reaches several thousands of tons. A single coal-burning power plant can produce hundreds of tons of fly ashes per year (e.g., Heller et al., 1998). Considering the fact that such power-plant fly ashes contain some 10% of ferro(i)magnetic particles (Kapička et al., 1999), it is obvious that these particles influence significantly magnetic properties of soils in the surrounding areas. However, the problem of reliability of magnetic mapping remains unclear in relatively unpolluted areas or areas where the ratio between the anthropogenic and lithogenic or pedogenic contributions can be less favorable.

It is obvious that industrially derived magnetic minerals share an origin and existence with heavy metals and thus magnetic properties can be used as tracers of pollution. Several studies provide a sound basis for understanding the relationship between concentration of magnetic minerals and heavy metals in soils and sediments. Pre-industrial sediments, modern soils, saltmarsh material and atmospheric dust were studied by, e.g., Georgeaud et al. (1997). Clear correlation between concentration-dependent magnetic parameters and contents of Zn, Cd and Cr were found. Significant correlation between magnetic parameters and certain heavy metals was found also in contaminated fluvisols by Petrovský et al. (2000, 2001). Industrially-polluted area in Austria was examined by Scholger (1998), showing clear links between magnetic susceptibility and concentration of As. High correlation between magnetic susceptibility and several heavy metals in atmospheric dust was reported by, e.g., Strzyszcz (1993).

In our contribution, we intend to introduce magnetomineralogy, its benefits and limitations, as a tool for proxy determination and outlining areas exposed to industrial pollution. Spatial soil magnetic mapping and

vertical soil profiles measured in different areas will be used to demonstrate the suitability and easiness of the method

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INFLUENCE OF HYDROXAMATE LIGANDS ON Pb(II) DESORPTION FROM Fe(III) OXIDES

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The very low solubility of Fe(III) minerals in aerobic soil environments restricts the activity of $Fe^{3+}_{(aq)}$ to extremely small values. Although these concentrations are too low to meet microbial demands, it is precisely in such environments that microorganisms are most abundant and diverse. Given these very low concentrations of Fe, and its essentiality in biochemical reactions, aerobic and facultative anaerobic microorganisms have evolved Fe acquisition mechanisms involving the secretion of highly Fe(III)-specific bidentate ligands known as siderophores (Holmen et al., 1999). More than 200 siderophores have been isolated, the majority of which are either carboxylates, catecholates, or hydroxamates. Siderophores are ubiquitous in aerobic soil environments and exhibit 1:1 stability constants with Fe^{3+} near 10^{30} (Neilands, 1981). These Fe chelators possess similarly large stability constants with Pb and the actinides and for this reason have been proposed as important agents in the mobilisation of these potentially-toxic elements. The aim of this study was to quantify the desorption of Pb and Fe from goethite in the presence of common hydroxamate siderophores: desferrioxamine, ferrichrome, and rhodotorulic acid (Fig. 1).

Goethite was prepared by standard methods (Schwertmann, Cornell, 1991) and identified by x-ray diffraction. Nitrogen multipoint BET analysis of the goethite indicated a specific surface of 36 m^2 g^{-1}. Adsorption experiments were conducted between pH 4 and 8 using a batch method by first suspending the goethite (1 mg ml^{-1}) in 0.01 M $NaClO_4$. Lead (10 μM) was combined with the goethite suspension, either before or after siderophore addition. Desferrioxamine, ferrichrome, or rhodotorulic acid were added to give a final siderophore concentration of 10, 20, or 40 μM. After 18 hr reaction, Pb and Fe in solution were measured by ICP.

Desferrioxamine Ferrichrome Rhodotorulic acid

Fig. 1. Structures of the three siderophores.

In the absence of siderophore, Fe is present in solution at concentrations near the analytical detection limit but appears to increase near pH 4, in response to proton-promoted dissolution of the oxide (Fig. 2). Desferrioxamine presence greatly increased soluble Fe concentration over the pH range 4 to 8, with the amount of Fe solubilised increasing approximately linearly with desferrioxamine concentration. Moreover, the amount of Fe released to solution depended strongly on the addition sequence (i.e. whether Pb or siderophore was added first). Where Pb was the first reagent added, the amount of Fe solubilised was only about one-half that which was released when desferrioxamine was added prior to Pb. The reasons for this strong dependence on addition sequence cannot be determined with certainty without first obtaining molecular level information of the surface complexes through the use of appropriate spectroscopic techniques. However, the influence of addition sequence on total soluble Fe over the pH range 4 to 8 suggests that Pb is blocking sites of preferential attack by desferrioxamine.

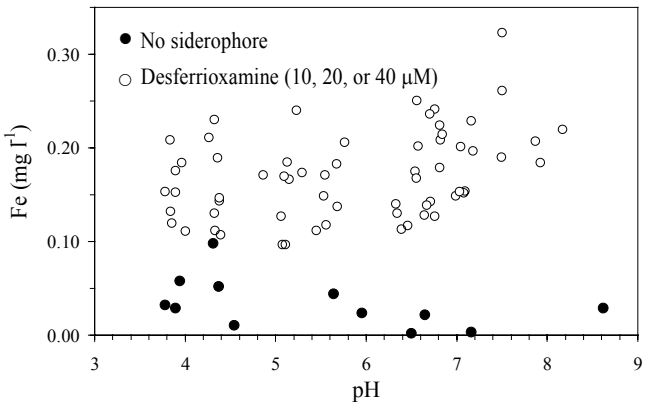

Fig. 2. Effect of desferrioxamine presence on soluble Fe concentration.

In the absence of an organic ligand, Pb adsorbs strongly to goethite with increasing pH (Bargar et al., 1997). The presence of desferrioxamine significantly increased the amount of Pb in solution over the pH range 5.5 to 8. The fungal siderophore, ferrichrome, increased soluble Pb concentrations similarly between pH 6 and 7, a range common in soils and sediments. The amount of Pb in solution increased with increasing ferrichrome concentration. The third siderophore examined in this study, rhodotorulic acid, also decreased Pb adsorption. However, rhodotorulic acid had a weaker effect on Pb adsorption than ferrichrome. At pH 6.5, 20 μM rhodotorulic acid desorbed approximately as much Pb as 10 μM ferrichrome. The greater affinity of Pb for ferrichrome than for rhodotorulic acid was anticipated, in view of their different 1:1 stability constants: $10^{33.1}$ and $10^{28.7}$, respectively (Gopalan et al., 1993). Desferrioxamine, ferrichrome, and rhodotorulic acid have, even at concentrations as low as 10 μM, a significant effect on the adsorption of Pb(II) by goethite. This indicates that commonly occurring siderophores can substantially influence the mobility of Pb and other trace metals in soils and sediments.

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EFFECTS OF FORMER POLYMETALIC ORE MINING ACTIVITIES ON SOIL CHEMICAL PROPERTIES AND CHOSEN PLANT SPECIES

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This paper presents general findings from research conducted near the town of Zlaté Hory, northern Moravia. This part of Czech Republic, and the surroundings of this town in particular, are well known for their ore deposits which have been used since the Middle Ages. The most intense mining activities in the region, those connected with increased pollution, began in the 1950's and ended in 1993. An ore flotation technique was used to obtain a final polymetalic concetrate. One by-product of this process was 6.8 million tonnes of metalliferous tailings. During the four decades of intensive production the adjacent forest area was contaminated by wind-blown pyritic dust particles.

The aim of the research was to characterize the soil environment of the area to determine the major stress factors resulting from aerial transport, and, to analyse both the most abundant and characteristic plant species with the aim of confirming literature data on the behavior of toxic elements in plant biomass.

The experimental profile was located in a spruce monoculture down wind of the tailings. Samples of both soil and plants were taken at 50m intervals. Eleven soil probes (3 samples each) were dug and soil samples from the artificial top layer of deposited metalliferous dust, as well as from the organic and mineral horizon, were taken. In addition, samples of both Norway Spruce (*Picea abies*) branches and European birch (*Betula pendula*) seedlings were collected for analysis.

The soil samples were dried and the sieved fine soil was then mineralized in a microwave digestion unit (BM-1S/II). A mixture of mineral acids (3ml HNO_3: 2ml HCl: 1ml H_2SO_4) were used to obtain total heavy metal content for Cu, Zn, Pb and Cd. The digested soil samples were analyzed using AAS (1GBC AAS Avanta Σ). To distinguish active forms of Al and Fe, soil samples were treated with 0.01M $CaCl_2$, filtered, and then analyzed. The contents of accessible nutrients (Mg, Ca and K) were measured, as well as the content of organic carbon and the ratio of phosphorus retention. Both the active and exchangeable soil pH (1:5 H_2O, $CaCl_2$, respectively) were measured. Five categories of plant tissue were distinguished: Norway Spruce samples were divided into branches and

needles while the birch seedlings were divided into roots, stems, and leaves. These samples were digested in 4ml HNO_3 and analyzed for both heavy metal content and absorbed nutrients.

StatGraphics was used for performing statistical analyses. General characteristics as well as correlations among particular subjects were calculated. In contrast to the original hypothesis the concentration of the studied elements increases rather than decreases with increasing distance from the tailings. However, this phenomenon is balanced by the fact that the final thickness of the deposited material decreases with distance.

Our results show that the main problem is not only heavy metal contamination per se, but rather severe acidification. The oxidization of pyrite has resulted in a profound decrease in pH (pH_{H2O} ranging from 3.09 – 4.12). The final values for Al and Fe fall within either the aluminum or iron buffering range. Such severe acidification has led to increased toxic Al and Fe, heavy metal mobilization, the serious leaching of mineral nutrients (average values for anthropic, organic and mineral horizon: Mg: 1.6, 13.2, 2.5 mg kg^{-1}, Ca: 34.1,120.7,27.3 mg kg^{-1} and K: 19.5, 53.2, 13.2 mg kg^{-1}) and a high degree of irreversible retention of phosphorus (90-95%).

The results of the plant tissue analyses show that for Norway Spruce, there is a significant difference in the content of several elements (Zn, Cu, K, Mg, Ca) between the branches and the needles. The final levels of all studied elements, except K, are significantly higher in Norway spruce branches. Average values (in mg kg^{-1}) in Norway Spruce branches and needles are: 54.5, 16.3 (Zn); 27.3, 6.8 (Cu); 17.5, 11.7 (Pb); 0.5, 0.4 (Cd); 247.1, 122.8 (Al); 176.5, 292.9 (K); 30.3, 21.5 (Mg); 95.6, 68.3 (Ca). Except for K, the final amounts of all analyzed elements are higher in the branches that in the needles. This trend of advancing physiological barriers can also be observed in the European birch seedlings where the concentrations of Cu, Pb, Al are highest in the roots, Cd content is slightly higher in the stems than in the roots, and the concentration of Zn is highest in the stems while the levels of nutritial elements (K, Mg, Ca) are highest in the leaves.

The research results may act as a source of data for improvement of the current situation. Restoration efforts should be based on increasing both soil pH and available soil nutrient supply while simultaneously locating suitable species for reforestation and management.

SPATIAL MULTI-OBJECTIVE DECISION MAKING IN PHYTOREMEDIATIOM OF MINING AREAS

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The aim of our research was to work out a spatial multi-objective decision making process for developing phytoremediation technologies applicable on sites contaminated with mining and industrial wastes containing heavy metals in high concentrations.

The process includes developing models on the total and bio-available concentrations of heavy metals and their spatial distribution and ceonological survey by using GPS/GIS technique to represent the relationship between contaminants and plant associations as potential tools for remediation. The applied method allows of integration of different aspects such as topographical, hydrological and soil characteristics in addition to the contamination as well.

As a representative experimental site an area contaminated with heavy metals located in Gyöngyösoroszi, Hungary was chosen where wastes resulted from different mining technologies. Evaluation of distribution of contaminants – lead, zinc, copper and cadmium exceeding the limit values – has been carried out by geo-statistical methods for qualitative and quantitative characterization of the site having inhomogeneous contamination.

Measuring the total and bio-available heavy metal contents (dissolution and digestion with HNO_3-H_2O_2 and Lakanen-Erviö extracts, respectively) by using ICP-OES and carrying out ceonological survey, contamination and plant models have been developed and the correlation between contamination and vegetation was examined.

The method allows of the identification and selection of phyto-associations having ability to stand extreme heavy metal concentrations and that of potential hyperaccumulators, indicators and excluders, with the help of which phytoextraction and phytostabilization can be realized.

Acknowledgements: Our research is sponsored by the Educational Ministry of Hungary – Biotechnology Research Fund 2000, No.: 02453/2000.

THE SUPRAMOLECULAR STRUCTURE OF SOIL HUMUS

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A number of recent studies (Piccolo et al., 1996; Conte and Piccolo, 1999; Piccolo, 2001) have proved that soil humic substances reveal, instead of a macropolymeric structure, a supramolecular nature in which, at neutral pH, relatively small heterogeneous molecules are self-assembled by weak forces, such as van der Waals, π-π, and CH-π bonds, into large conformations of only apparent high molecular size. The weakly bonded superstructure is easily disrupted in smaller associations by the interactions with natural organic acids. This presentation will illustrate further evidence, by High performance Size Exclusion Chromatography (HPSEC), NMR spectroscopy, and Pyrolysis-GC-Mass Spectrometry, that the behavior of humic substances is that of a self-assembled superstructure.

A confirmation of the supramolecular theory versus the traditional polymeric model is represented by the evidence that the supramolecular conformation can be effectively stabilized into a true polymeric structure. This was achieved by subjecting humic materials to an oxidative reaction catalyzed by the enzyme peroxidase. HPSEC showed that such catalyzed reaction increased the molecular size of humic materials. The formation of real polymers through covalent bonds between the different heterogeneous humic molecules was proved by the chromatographic stability of the polymerized samples even when subjected to treatments with organic acids which are commonly able to disrupt the loose supramolecular conformations of humic substances (Piccolo et al., 2000). Moreover, evidence of C-O-C and C-C covalent bonds formed among humic molecules via a catalyzed radical mechanism was shown by infrared and NMR spectroscopies. Increase of molecular size in humic materials following oxidative polymerization was a function of the pH of the reacting solution and, hence, of the stability of the humic associations (Cozzolino and Piccolo, 2001). The extreme fragility of the catalytic properties of an enzyme, especially in a complex and heterogeneous matrix such the soil, has prompted research on more resistant catalyzers which would mime the peroxidase action. These biomimetic catalyzers were proved to be as efficient as peroxidase in stabilizing humic molecules in polymeric conformations.

The proposed evidence of a supramolecular nature of humic substances and the consequent capacity to stabilize humic superstructures into real polymers by either enzymatic or biomimetic catalysis, not only shows an innovative understanding of humus chemistry but also of the vast potential offered to control the cycle of organic carbon in soils.

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DYNAMICS OF Co, Zn, Cd AND Pb IN SOUTH-EAST PART OF BJELAŠNICA AND UNDER BJELAŠNICA PLATEAU

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Analyzed land areas are located approximately 30 km from Sarajevo to the South. Those areas present two almost separated localities that are separated by a mountain range. Both analyzed areas belong to typical mountainous regions.

The first analyzed area is almost ideal mountain plateau with the range of altitude from 782 m above the sea level near Željeznica river to the east of village Mađari on the furthest east of the plateau, up to the 1237 m above the sea level on the saddle Proskok above village Šabanci, on the furthest western part of plateau.

The other analyzed area is located in south-east parts of mountain Bjelašnica, with interval of altitudes from 1179 m above the sea level at the mouth of river Pijevac and Rakitnica at the furthest south-east part of the mountain, up to 2067 m above the sea level at the peak Bjelašnica, which is the highest spot of this mountain.

Agricultural land surfaces, mostly represented by mountain meadows and pastures, were analyzed. A part of land surfaces on the plateau are high quality plowed fields suitable for row crops and several kinds of cereals.

One of important characteristics of the region is high annual average of rainfalls, respectively 1889.3 mm. Average annual temperature is 0.6^{o} C.

Within analyzed regions, influence of mountain climate is dominant, with the admixture of alpine climate, at the altitude above 1700 m. These are the regions where warm Mediterranean air streams are faced with cold continental air streams, with frequent occurrence of winds with speeds beyond 160 km/h. Such climate elements have influence on duration of vegetation period and present vegetation types.

Presence of different soil types was determined, and among them the most present were shallow soils and medium deep soils on firm triadic limestone and dolomites with the range of depth from 1 cm for litosols up to 60 cm for coluvial soils of hollows. Besides soils on firm rocks, there were also different soil types on flysh and loose geological substrate whose pedon can be deep up to 140 cm.

For the analysis of heavy metals dynamics, soil samples were taken from the depth of 10 cm, using representative sample method. One sample represented surface of 200-400 ha. The sample was formed from at least 10 individual samples that were prepared in the way that they were not in contact with metal parts.

Laboratory analyses of physical and chemical soil characteristics were conducted. Within chemical analyses, concentration of available forms of Co, Zn, Cd and Pb was analyzed, using method of Norvell and Lindsay (1978). Total Pb forms were determined by extraction using 6 mol dm^{-3} HNO_3 on AAS.

By analyzing obtained results, intervals of presence for particular heavy metals and their correlation with humus content and soil pH were determined both for plateau region and south-east region of Bjelašnica mountain.

In discussion of results, values of correlation and its motion are given. Besides, special emphasize was given to whole analyzed areas without separation of heavy metals content, according to present soil types.

High level of total Pb forms was determined on analyzed plateau on one location and in southeast region of Bjelašnica on five locations.

In conclusions, possible causes for increased heavy metals content were given, and directions of actions aimed to protect investigated regions. Possible direction of future agricultural production were marked out as well.

ASSESSMENT OF SOIL CRITICAL VALUES OF HAZARDOUS TRACE ELEMENTS FOR THE TRANSFER PATHWAY SOIL – PLANT

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The prediction of the critical transfer rate of hazardous trace elements (TEs) within the transfer pathway soil-crop can be deduced from the reaching of the critical content of TEs in crops as affected by the TEs soil pool, the content of mobile or mobilizable species content in soils and other soil characteristics. The prediction equation is derived by means of the multiple regression analysis. Transfer functions are preferred to transfer quotients (factors). The substitution of the crop TEs content in the mentioned equations for fodder (food) standard values results in critical soil parameters, interpreted as critical limits for crop quality (marked utilization) and quality assessments.

An attempt has been made to obtain the above mentioned critical soil limits from data collected in two, ways:

- from the pot experiment (fourfold repetition) with 54 soil samples (testing plants radish, triticale),
- from field investigations of 125 pairs soil-plant (testing plants fodder crops).

The sampling sites involve:

- representative taxonomic units of the Czech Republic,
- a broad pattern of soil properties affecting TEs mobilities,
- different kinds and levels of soil contamination, realistic for agriculturally used lands.

The results of our investigations involve:

- testing soil critical values, which represent the derived values, either generic (tab. 1) or resulting from the interaction of two-three (figures 1 - 16, tab. 3) soil parameters (Cd, Pb, As, Cu, Zn, Ni, Mn, Co),
- protective values (tab. 2), which inform us that until this value it has not been possible to prove the hazardous transfer into crops (TEs with low solubility: Hg, Cr^{III}, TEs for which higher contents have not been found in the CR: Tl, Be, V).

Testing value means that the exceeding of these values must be tested on site.

We prefer soil critical values for crop quality and crop yield decreasing derived from interactions among TEs contents, TEs mobilities and another soil characteristics, which affects them.

MICROBIAL RESPONSE TO PERSISTENT ORGANIC POLLUTANTS AND HEAVY METALS IN ALLUVIAL SOILS

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There exists a vast literature on the effect of pollutants on soil microorganisms when grown in vitro. Unfortunately, many of these data have little, if any relevance to the possible effects of pollutants on microorganisms growing in the soil environment, as culture studies omit both complexities of natural ecosystems and the fact, that interactions between different pollutants may have a major influence on the toxicity of a pollutant.

The aim of our study was to characterize functioning and structure of microbial communities in three alluvial soils with different levels of organic pollutants (PAH_s, PCB_s HCH and DDT) and heavy metals (Cd, Hg, Pb, Zn, Cr, Ni). The chemical properties of soils have been partially altered by a heavy flood having occurred in the region (district Zlin, Czech Republic) in 1997. Following microbial parameters were used to identity stress situation in soil: intensity of mineralization and humification of soil organic substances, rate of asymbiotic N_2 – fixation and accumulation of heavy metals in microbial biomass. In addition, diversity of soil bacterial community using both plate-dilution method and method of reassociation of denaturated DNA was studied. The results of statistical evaluation show, that microbiological characteristics of soils belonging to the relatively strongly contaminated ones, differ significantly from those of less contaminated (control) soil. Parameters applied for evaluation of changes in functioning and structure of microbial communities reflect rather sensitively the level of soil contamination.

CHANGES IN SORPTION OF Cd IN SOIL AFTER APPLICATION OF LIMED SEWAGE SLUDGES

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The aim of the trials was to determine changes in sorption of Cd in soil after application of limed and untreated sewage sludges. Three different sewage sludges incubated in advance for eight months at the temperature 20 ^{o}C were used in the trials. The rate was 180 g per 1 kg of sludge dry matter. After application of $CaCO_3$ pH of sludges increased to almost neutral value. In untreated sludges the following Cd concentration was determined: sludge 1 = 5.10 mg $Cd.kg^{-1}$, sludge 2 = 7.08 mg $Cd.kg^{-1}$, sludge 3 = 1.96 mg $Cd.kg^{-1}$. When $CaCO_3$ was applied, the total Cd content was diluted and after analysis the following values were found: limed sludge 1 = 5.09 mg $Cd.kg^{-1}$, limed sludge 2 = 6.56 mg $Cd.kg^{-1}$, limed sludge 3 = 1.59 mg $Cd.kg^{-1}$. Liming of sludges resulted in significant decrease of water-soluble and exchangeable forms of Cd in sludges. The greatest share of exchangeable Cd 10.3 % was in sludge 3 and decreased to 4.7 % by liming. The same trends were also recorded in sludge 2 (decrease from 6.3 to 4.5 %) and sludge 1 (decrease from 9.1 to 7.5 %).

In further stage of experiments new incubation trials were established with sludges treated in this way with three soils (Chernozems, Luvisols, Fluvisols). The rate of the fresh sludge here amounted to 1.665 g of dry matter per 30 g of fine soil. These trials lasted 240 days and extractable amount of Cd was determined five times (0, 14, 30, 60 and 240 days). Three different extract agents were used: 1 $mol.l^{-1}$ NH_4NO_3, 0.025 $mol.l^{-1}$ NH_4EDTA (pH 4.6) and 2 $mol.l^{-1}$ HNO_3. With respect to the fact that in limed treatments total Cd content was lower the changes induced are given in relative expression (in percentage to the total Cd content in soil + sludge). It is evident from all presented results that liming resulted in significantly lower Cd mobility as in sludges only, as in soil after application of limed sludges. Gradual immobilization of Cd has been found during incubation of soil with sludges, as well as control treatments what is in correlation with processes in incubated soils, i.e. with process of gradual mineralization of organic matter of sludges and with subsequent sorption of Cd into more stable humus substances in soil and with the Cd sorption to minerals. Mild extraction agent showed higher relative differences between studied treatments (NH_4NO_3). The incubation decreased differences between untreated and limed treatments, when HNO_3 and NH_4EDTA were

used during incubations. Lime application decreased Cd mobility in all studied sludges. Explanation for reduced Cd mobility of limed sludges can be derived from pH changes of soils. The most pronounced differences were induced after application of sewage sludges on Fluvisols corresponding to the total low sorption capacity of this soil. Average pH value of unlimed treatments amounted to 5.66 and was increased to 6.52 by liming.

Acknowledgement: Financial support for these investigations was provided by Czech Ministry of Education Project No. MSM 412100002.

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SOIL PROPERTIES CONTROLLING HEAVY METAL TRANSFER TO PLANTS – A CASE STUDY

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Transfer of heavy metals from polluted soils to plants and consequent potential input to food chain or to other components of the environment represent an actual danger. The transfer rate depends mainly on the metal content and form in soil, its mobility and bioavailability. These properties are controlled, beside the chemical properties of the metal, by soil characteristics, especially soil pH, humus content and quality, and clay content. Litavka River alluvium represents an area with extreme levels of pollution originating from several sources (Borůvka et al., 1996). The aim of this contribution is to assess the influence of level of soil pollution and soil properties on the transfer of Cd, Pb and Zn to spontaneously grown plants.

Soil (Fluvisol) samples were collected from the topsoil (0-15 cm) on 72 sites in the alluvium of the Litavka River, from sites with different sources and levels of pollution. The samples were air dried and sieved through a 2-mm mesh. Soil pH in 1 M KCl extract (1 : 5 w/v), soil organic carbon content (C_{org}) and other basic soil properties were measured. Content of Cd, Pb and Zn in soil was measured in 2 M HNO_3 extract (1 : 10 w/v) by means of flame AAS. Plants (*Festuca sp.* and *Poa sp.*) were mineralised, shoots and roots separately, in dry mode mineralizer APION, the content of Cd, Pb and Zn was measured also by means of AAS (Borůvka et al., 1997a). Results were treated by step-wise multiple regression analysis using Statgraphics Plus for Windows 4.0 software.

The ranges of metal content in soils were 0.27 to 130.4 mg kg^{-1} in case of Cd, 55.0 to 18,450.0 mg kg^{-1} in case of Pb, and 11.1 to 13,060.0 mg kg^{-1} in case of Zn, indicating extreme pollution of some areas. Respective metal content in plant roots was 0.41 to 89.3 mg kg^{-1} (Cd), 1.2 to 2,507.5 mg kg^{-1} (Pb), and 25.3 to 5,982.0 mg kg^{-1} (Zn). The content in plant shoots was significantly lower: 0.05 to 32.08 mg kg^{-1} (Cd), 0.24 to 378.0 mg kg^{-1} (Pb), and 16.0 to 1,745.8 mg kg^{-1} (Zn).

In the step-wise multiple regression, variables with regression coefficient different from 0 with probability at least 95 % were selected to models. Metal content in plants and concentration factors (C_f), calculated as the ratio between metal content in plant shoots and the content in soil, were analysed (Borůvka et al., 1997b). Clay content and parameters of humus

quality showed only slight and non-significant effect and were not included into the models. Metal content in soil was included in all the regression models, having positive regression coefficient in the models of metal content in plants and negative coefficient in the models of concentration factors. Soil pH was included in the regression models of metal content in roots for all the three metals under study and also in the models of Zn content in shoots and Zn concentration factor; in all cases it showed negative regression coefficient. Soil organic carbon content appeared in the models of metal content in plant shoots and C_f for all the three metals and Zn content in the roots; in all cases with negative regression coefficient. The effect of C_{org} was attributed to forming sorption sites for metals in soil. The models explain a large part of the variability of Zn content in both plant roots (85.09 %) and shoots (77.16 %), and Cd and Pb content in roots (71.91 and 67.73 %, respectively). The explanation of the variability of Cd and especially Pb content in plant shoots was lower (31.02 and 18.01 %, respectively). Some barriers against metal transport from roots to the above-ground plant parts may have taken effect. This supposition is supported by the low C_f values for Cd and Pb (geometric means equal to 0.045 and 0.004, respectively) in comparison with Zn (0.13). Nevertheless, the models of multiple regression provided much better results than simple regression of metal content in plants or concentration factor with soil properties. It suggests that soil properties influence metal transfer to plants in mutual combination and are inter-dependent.

It can be concluded that the level of soil pollution, soil organic carbon content and pH were the principal soil factors controlling heavy metal uptake by plants. These factors influence mainly metal content in plant roots, while the transfer to plant shoots is more influenced by metal mobility in plants. The strongest effect of soil properties on plant uptake was found for Zn, this metal was also the most mobile in plants. The effect of soil properties was relatively lower in the case of Cd and Pb. Lead showed the lowest mobility in plants.

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