THE BIOLOGICAL BACKGROUND TO INTERNAL SOIL EROSION

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ABSTRACT

Soil erosion is one of the most deleterious form of soil degradation. The effects of wind and water soil erosion on topsoil are well discribed types of soil erosion. Nevertheless there exists suuficient data about different form of soil erosion, which changes the soil structure and water regime in subsoil. The term internal soil erosion is primarily characterized by strong reduction in soil microbial activities followed by the breakdown of soil aggregates and decrease soil aggregate stability which caused the leaching of fines soil particles by the percoleting water. The term of this phenomenon is only scarely used. The importance of the soil microbial activities, the role of soil organic matter and plant roots as key players of stability of soil aggregates are in the article emphasized.

Key words: internal soil erosion, soil aggregation, soil microorganisms, root exudates

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INTRODUCTION

Soil erosion is one form of soil degradation. It´s one of the problems of soil degradation in Europe (BORMAN and POESEN, 2006). Erosion with the loss organic matter, compaction, buil-up area, acidification and contamination by polutants overall causing degradation of soil. Moreover various types of deleterious effects are in interaction and resulting synergic effect can be much worse. When 1 cm of soil is washed off, the total loss per 1 hectare amounts to 300 kg of soil nitrogen. The resulting chain reaction could be diicult to eliminate through the return of the once eroded soil its origin place (BUKOVSKÝ at al., 2012). The soil degradation leads not only to a reduction of productive capacity of the soil, but its economic and environmental effects often cross the boundaries of the affected area (PODHRÁZSKÁ, 2009).

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1. Erosion

There are two main types of the erosion on the agricaluture land in Czech Republic: water erosion and wind erosion. Water (or rainfall) erosion is caused by eroding of the land surface by the raindrops and consequent runoff of topsoil particles. Wind erosion affects the soil surface by mechanical force of wind. Soil particles are than blowing away and store elsewhere. About 50% of agricultural land is threatened by water erosion and about 7,5% wind erosion. So it´s evident that it´s necessary to deal with the issues of erosion (JANEČEK 2002, BOARDMAN and POESEN, 2005, PODHRÁZSKÁ, 2009). Suprisingly there are not many references the strong link between disturbed soil condition for living soil creatures and the susceptibility of the soil to the all types erosion. The aim of this article is to explain and to emphasize the preventing role of undisturbed soil biota aginsta soil erosion.

1.1 Internal erosion

JANEČEK et al. (2008) reported, that rainwater erosion oprates not only in surface runoff, but also in subsurface runoff. This effect is known as **internal soil erosion**. The internal erosion includes mechanical leaching of fine fractions with different dispersion by the gravitational water between soil coarse. The internal erosion involves selective loss of fine particles within the matrix of coarse soil particles under seepage flow which affects the hydraulic and mechanical behavior of the soil (CHANG and ZHANG, 2013). Fine particles can be cohesionless particles or clay particles (MAROT et al., 2012). The exteme type of surface runoff is called introskeletal erosion. Introskletal erosion is defined as vertical down-wards gravitation movement and/or percolation of small organic as well as inorganic soil particles into spaces – soil skeleton – of weathered rock cover. There are 45,5 thousand hectars of soil affected by this types of erosion in the mountains of Czech Republic (JANEČEK et al., 2002, VACEK et al., 2003).

The internal soil erosion starts usually by deterioration the stability of soil aggregates from which are than the fine fraction leached down by the raindrops. This effect changes soil behavior which is caused by higher soil density, because the finest soil particles are washed out from upper soil horizons into available soil interspaces and fulfilling them. Such changes take place usually in subsoil at agricultural land, which normally low in content of soil organic matter (SOM). This type of soil degradation is less in soils where soil aggregates are well cemented by microbial and fungal byproducts. Changes in the upper soil horizons and subsoils have detrimental effect on soil water regime, and, with corresponding synergy, also on other soil properties.

There are two scenarios of how the water erosion could damage subsoil. In the first case, if the exposed subsoil has higher **clay content**, the total volume of pores increase, but the size of pores decrease. Capillary pores starting dominate. It means that total water capacity increases, but capacity of water avaible for plant is reduced, because water is bound more strongly by capillary forces. So there is enough water, but water isn´t accesible for plant, infiltration is decreasing and other surface runoff is incerase. The aggregates in the expose subsoil start to lose stability and they eroding (JANEČEK, 2002). These factors have a significant effect to soil retention capacity of rainfall water as well as to soil water available to plants and finally to the nature of soil fertility. As a consequence the topsoil depth is reduced. This leads to adding more clayey subsoil material by the tillage into the topsoil layer. Such topsoil have low content of available soil water, reduced soil air, increased of soil density, increased soil compaction, increased formation of anaerobic environment. By all of these factors the density and aktivity of soil organisms decreased. In the second case, if the exposed subsoil has a **higher content of sand**, the total volume of pores decrease, but the pores size increase. The soil water availability is reduced by different mechanism. Not because the water is kept by capillary forces, but mainly evaporation and seepage into the soil increase. Although soil with higher sand content have a lower surface runoff, erosion at this soil is still problem. The soil is degraded in both cases. The internal erosion is a silent factor. The question is why the fine particles are leaching from soil (JANEČEK et al., 2002, BOT and BÉNITES, 2005, PRAŽAN, 2007, PODHRÁZSKÁ 2009).

2. Aggregation of soil

The internal soil erosion is closely linked to the soil composition and to type of dispersive clays. For soil stability is desirable to preserve as high as possible status of aggregation of soil particles. A soil aggregate is a complex of mineral and organic soil particles, which are associated by cementing substances (KOSTELANSKÝ et al. 2004). Typical cementing substances include calcium carbonate, humus, and oxides or silicon, iron, and aluminium. Various other chemicals, especially certain organic compounds, such as polysaccharides and lipids, glue soil particles. Some organic materials exert forces through surface tension or electrical charge; others, like roots and fungal hyphae, adhere to soil as part of their natural function. A soil aggregate is represented by soil particles that cohere to each other and these are involved in the formation of soil structure. The strength of interparticle cohesion depends on a variety of soil physical, chemical, and biological influences. Some of the most important of these are air-water surface tension, intermolecular attractive forces between water and solids, cementation by precipitated solutes, holding by roots and fungal hyphae, as well as by the various chemical phenomena. The forces of soil cohesion depend strongly on water content and other conditions. So aggregate stability refers to the ability of soil aggregates to resist disintegration when disruptive forces associated with tillage and already mentioned erosion are in action (NIMMO, 2004).

2.1. The aggregate stability

Aggregate stability is highly dependent on organic matter and biological activity in soil, and it generally increases as they increase. Fungal hyphae, thread-like structures used to gather resources, bind soil particles to form aggregates. Other soil organisms, like earthworms, secrete binding materials. Soil particles are also aggregated and stabilized by organic “glues” resulting from biological decomposition of organic matter. Physical disturbance, e.g. tillage, accelerates organic matter decomposition rates, and destroys fungal hyphae and soil aggregates. Soil biota help create aggregates and use them as habitat or refugia to escape predation (DEAN, 2008).

Changes in aggregate stability may serve as early indicators of recovery or degradation of soils. Aggregate stability is an indicator of organic matter content, biological activity, and nutrient cycling in soil and it´s critical importance to soil fertility. Generally strongly than to other surrounding particles the particles in small aggregates (<0.25 mm) are bound by older and more stable forms of organic matter. Microbial decomposition of fresh organic matter releases products (that are less stable) that bind small aggregates into large aggregates (>2-5 mm). These large aggregates are more sensitive to management effects on organic matter, serving as a better indicator of changes in soil quality. Greater amounts of stable aggregates suggest better soil quality. When the proportion of large to small aggregates increases, soil quality generally increases. Stable aggregates can also provide a large range in pore space, including small pores within and large pores between aggregates. Pore space is essential for air and water entry into soil, and for air, water, nutrient, and biota movement within soil. Large pores associated with large, stable aggregates favor high infiltration rates and permeability for water and air and resistant to compaction. Soil with stability structure allow penetration of the roots and organisms living in soil profile and their developing. Conversely unstable soil aggregates are leaching by water to individual soil particles. Such soil has bad structure, partices are joining together, soil is compacting and create crusts which is impermeable to water and air (RAJCHAR, 2002, DEAN, 2008).

2.2 The role of soil microorganisms, soil organic matter and roots

As already mentioned the aggregate stability is closely linked to content of soil organic matter and biological activity. The amount of SOM influences the physical and chemical properties of soil much more than would be corresponding to its relatively low content in the soil. The content and quality of organic matter have significantly affects to the stability of soil aggregates, also the soil organic matter is main source of essential nutrients for plant growth, substrate for microorganisms and allows a number o chemical reactions. So the biogeochemical cycles of nutriens in soil are closely linked to microbial activity (PODHRÁZSKÁ, 2009, ŠIMEK, 2003). Another important factor of stability is a growth of the roots. Roots affects to soil structure not only mechanically, but also through the secretion and receiving of various substances. Roots can act as a reservoir of mineral nutrients transported to aboveground plant part by the flow mass and difussion, but also roots accept ions or water, so the content of ionts are accumulated or reduced. Roots also secrete H^+ or $(HCO_3)^-$ and CO_2, which could changes the redox potencial. The low molecular weight root exudates could mobilize nutrients directly or indirectly, through supplying energy for microbial activity in the immediate vinicity of the root. The name of thin layer of soil adjacent into the roots is rhizosphere. The role of exudates will be desribed at the next section (BALÍK, 2009).

2.2.1 *Root exudates*

Root exudates are the low or high molecular weight substances, which are secreted by the plant roots. This substances are a small molecules (organic acids, amino acids, sugars), the secretions (enzymes), the lysates of death cells and mucilage, which is layer of musuc in the root cap. Just the mucilage has many biological functions. They are: protection apical root zone against from drying, enhanced mechanical resistance for ingrowing the plant roots into the soil, facilitate or prevent the reception of ions, the interaction with the soil particles and soil, which support the soil aggregation. There are released a degreable carbon compounds in this proces (BALÍK, 2009, ZÁHORA, 2012). The exudation is one of the most important sources of carbon in soil, which are available to soil microorganisms. In this way plants stimulated high spontaneous activity of rhizosphere microorganisms. Once multiplicated, microbes quickly exhausted the key available nutrients in rhizosphere, and are competing about them with plants. At this threshold are microorganismus stimulated to produce appropriate extracellular enzymes that plants cannot produce for making limiting nutrients available from surrounding soil (especially from SOM). Profiting are both, plants which are able to reach the available nutrients via mass flow, and microorganisms, wich are key players in this interaction (ZÁHORA et al., 2011).

2.3 The creation of soil aggregates

The structure of the soil is measured by the individual soil particles. This particles occur in soil alone only rarely. Particles create a larger or smaller clusters which are called aggregates (JANDÁK, 2009). Aggregates can broadly classified into macroaggregates (>250 µm) and microaggregates (20-250 µm). An aggregate is a naturally formed assemblage of sand, silt, clay, organic matter, root hairs, microorganisms and their "glue" like secretions mucilages, extracellular polysaccharides, and hyphae (filaments) of fungi as well as the resulting pores. Soil aggregates often contain fine roots that grow into soil pores associating aggregates with the rhizosphere. Persistent binding agents like organic matter and metals stabilize microaggregates. The temporary binding agents (polysaccharides and hyphae) produced by soil organisms aid in the formation of macroaggregates contained within the more stable microaggregates (FORTUNA, 2012).

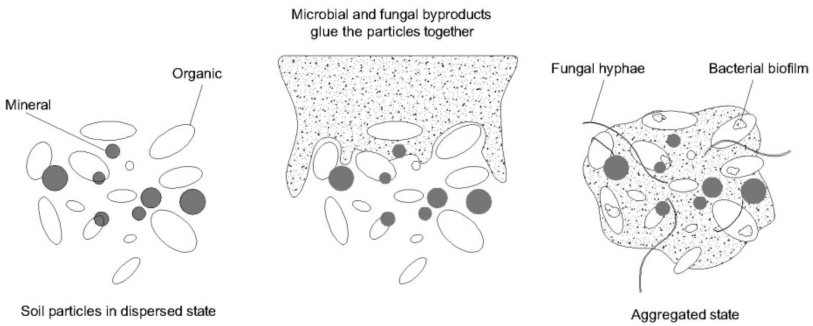

Fig.1. The biological background to creation of soil aggregates

MATERIAL AND METHODS

The area of interest – Water protection area Březová nad Svitavou is located in the Pardubice region in the vulnerable area of water resources, which according ihe Directive of Nitrate (NOHELet al., 2008). We will sample pattern of soil from different ecosystems and sites: meadow, forest, arable land with different way of management and degraded land.

The soil structure and texture will be analyzed in samples. The pipett method will be used. It is a method of gravitational sedimentation. In the pipette method, concentration changes are monitored by extracting samples from a sedimenting suspension at known depths and predetermined times (JANDÁK et al., 2003). We´ll observe differences between samples and will try to find a suitable method of management for maintain soil structure.

CONCLUSION

These data show how the soil biota is important for maintaining the soil structure. Our working group deals the issues of soil degradation and quality in Březová nad Svitavou. The area of our interest Březová nad Svitavou is main source of drinking water for about 500 000 people in Brno and its neighbourhood. It´s very good source of drinking water, however, despite the radical reduction of using of mineral fertilizers in the second half 20-th years, the concentration of nitrates slightly but steadily increase (NOHEL et al., 2008).

There were observed some unintentional changes in soil properties in area of our interest, which directly or indirectly affected basic properties and quantity of ground water (composition, structure, terrain morphology, infiltration, the annual course of temperatures, soil microbial activity, immobilization of nutrients etc.). The most determining factor is a human activity; fertilization, land use, pesticides, dry atmospheric deposition, changes in crop rotations etc. (NOHELet al,. 2008, PODHRÁZSKÁ, 2009). After prolonged time of the conventional agriculture practice in this region there are clear changes in soil quality in sense of above mentioned soil degradation. For the understanding and explanations of the destabilization of soil aggregates is necessary to describe the biological background of **soil internal erosion.**

REFERENCES:

BALÍK J., (2009): *Význam rhizosféry v životním prostředí*, VĚDECKÝ VÝBOR FYTOSANITARNÍ A ŽIVOTNÍHO PROSTŘEDÍ, VÝRV Praha

BOARDMAN, John a Jean POESEN. *Soil erosion in Europe*. Chichester, England: Wiley, c2006, 855 s. ISBN 978-0-470-85910-0.

BOT Alexandr, BÉNISE José, (2005): *The importance of soil organic matter*, FAO SOIL BULLETIN, Rome, isbn 92-5-105366-9

BUKOVSKÝ J. a kol. (2012): *Situační a výhledová zpráva PŮDA*, MZE, Praha 1, ISBN 879-80-7434-088-8

CHANG D.S., ZHANG L.M. (2013)*: Critical hydraulic gradients of internal erosion under complex stress states,* Journal of Geotechnical and Geoenvironmental Engineering, vol. 139, P. 1454-1467

DEAN, James E., 2008, *Soil Quality Indicators*, USDA Natural Resources Conversation Service

FORTUNA Anny-Marie (2012): *A 'biological universe' exists in a gram of soil. Find out how the soil biota within this tiny universe transform energy, create and modify their habitat, influence soil health, and aid in the regulation of greenhouse gases,* The soil biota, Nature Education Knowledge 3(10):1

JANDÁK, Jiří, Eduard POKORNÝ a Alois PRAX. *Půdoznalství*. 1.vyd. Brno: Mendelova zemědělská a lesnická univerzita, 2001, 140 s. ISBN 80-7157-559-3.

JANDÁK Jiří 2003: Cvičení z půdoznalství. 1. vyd. Brno: Mendelova zemědělská a lesnická univerzita v Brně, 2003, 92 s. ISBN 80-7157-733-2

JANEČEK, Miloslav. *Základy erodologie*. Vyd. 1. Praha: Česká zemědělská univerzita v Praze, 2008, 165 s. ISBN 978-80-213-1842-7.

KOSTELANSKÝ, František. *Obecná produkce rostlinná*. 1. vyd. Brno: Mendelova zemědělská a lesnická univerzita v Brně, 1997, 121 s. ISBN 80-7157-245-4.

MAROT D., BENDAHMANE F., NGUYEN H.H. (2012): *Influence of angularity of coarse fraction grains on internal erosion*, Houille Blanche, vol. 6, P. 47-53

NIMMO J.R. (2004): *Aggregation: Physical Aspects, in Hillel D., ed.*, Encyclopedia of Soils in the Environment, London

NOHEL P., ZÁHORA J., MEJZLÍK L. (2008): *Sledování úniku minerálního dusíku z půd různých ekosystémů v OPVZ II. st. Březová nad Svitavou*, SOVAK, 7-8: 48-51

PODRHÁZSKÁ, Jana (2009): *Protierozní ochranná opatření v zemědělské krajině* (studijní materiály k akci), Vzdělávání podnikatelů v zemědělství, lesnictví a potravinářství na modelových lokalitách, Místní akční skupina Moravský kras

PRAŽAN J., KAPLER P., PICKOVÁ A. (2007): Analýza adaptačních opatření na změnu klimatu na území ČR v oblasti zemědělství, výstup funkčního úkolu MZe ČR č. 4228, VÚZE

RAJCHARD, Josef. *Ekologie III.*: *struktura a funkce ekosystému, produkční ekologie, biogeochemické cykly, chemické faktory prostředí, základy ekologie půdy, ekologie vodního prostředí, aktuální celosvětové ekologické problémy*. 1. vyd. České Budějovice: Kopp, 2002, 197 s. ISBN 80-7232-191-9

ŠACH, František a Vladimír ČERNOHOUS. *Metodické postupy ochrany lesních pozemků proti erozi*: *recenzovaná metodika*. Strnady: Výzkumný ústav lesního hospodářství a myslivosti, 2009, 28 s. ISBN 978-80-7417-004-1

ŠIMEK M., (2003): *Základy nauky o půdě, 3. Biologické procesy a cykly prvků*, České budějovice. ISBN 80-7040-630-5, s.11-24

VACEK S., PODRÁZSKÝ V.V., MIKESKA M., MOSER W.K. (2003): *Introskeletal erosion threat in mountain forest of the Czech Republic*, Journal of forest science, 49, 2003 (7): 313-320

ZÁHORA, J. *Interakce mezi půdou a organismy*. In: VOPRAVIL, J. *Vzdělávací modul ochrana životního prostředí v oblasti půda.* 1. vyd. Náměšť nad Oslavou: ZERA, 2012. s. 119--151. ISBN 978-80-87226-15-5

ZÁHORA J., NOHEL P., KINTL A. (2011): vyplavování minerálního dusíku z orných, lučních a lesních půd v OPVZ II. st. Březová nad Svitavou. In Voda Zlín 2011. 1. vyd. Zlín: Moravská vodárenská, a.s., s. 49-54