CHANGES IN THE ADSORPTION COMPLEX OF REKULTISOL UNDERNEATH THE SEEDED GRASSLANDS

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ABSTRACT

The research was conducted on deposol and rekultisol (technosols) in lignite mine Stanari. The main task of the formed grasslands is to improve the mechanical, chemical and biological properties of the rekultisol and deposol in the reclamation process. The fertility of Stanari deposol is extremely low in comparison to the natural soil. Grassland seeding through direct type of reclamation was conducted in 2008, 2011 and 2012 year. The conducted researches include the changes in the adsorption complex in the surface layer of the treated deposol in the reclamation process. Laboratory analysis of this technogenic soil were carried out before the reclamation and sowing started, and then in the process of reclamation at the end of 2012. On the experimental plots where reclamation measures were implemented, there is a slight improvement in most of the chemical characteristics of the rekultisol. Adsorption capacity and saturation degree of base cations in rekultisol were increased. Proper selection of the agromeliorative and other measures is required in the reclamation process. Well based seeding grasslands contribute to the creation of quality rekultisol.

Keywords: *deposol, reclamation, chemical properties, Stanari*

INTRODUCTION

Main objective of the reclamation of degraded areas, caused by open pit mine exploitation of the ore reserves, is to establish the management functions on these newly created technogenic soils (technosols). In order to achieve this objective, it is necessary to implement a number of activities envisaged by the reclamation project. In addition to detailed design, adequate results of previously conducted surveys are extremely important for the successful implementation of reclamation. From this

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reason arises the importance of various field and laboratory studies in biological reclamation of degraded soil.

Deposol (mine soil) in Stanari have middle favorable physical and mechanical characteristics, while their chemical characteristics are bad (Malic, 2010; Malic and Markovic, 2012). Previously projected reclamation methods for Stanari coal basin deposols (of a very low fertility) at formed overburden (unfertile) disposals, were agriculture and forest plantations. The main task of all these man-built terrestrial ecosystems is to stabilize and revive production and ecological functions of a technogenic soil. A significant part of the agricultural reclamation refers to the establishment of artificial grassland. Studies on the methods of grassland establishment in the reclamation process and potential yields have started in 2008 at the deposols of Raskovac open pit external disposal area in Stanari (Malic and Lakic, 2011). Pioneer species in agricultural reclamation include species from the families of *Poaceae* and *Fabaceae*.

Seeding grasslands establishment through seeding grass-leguminous mixtures and pure cultures of certain grass species is significantly present at mine in Bosnia and Herzegovina, Serbia and abroad. Since the earliest reclamation works in the USA, a vast expanse of recultivated areas has been under seeding meadows and pastures (Thorne, 2010; Skousen and Zipper, 2010; Lyle, 1987; Vogel and Berg, 1968).

Normally, most commonly sown species during reclamation process are grasses (family *Poaceae*) because they are producing a large amount of biomass and quickly adapt to specific and harsh environmental conditions. For biological reclamation most commonly used grass species are from the following genuses: *Poa, Festuca, Lolium, Panicum, Agrostis, Phleum, Dactylis* (Malic and Lakic, 2011; Smith *et al*., 2002).

Participation of leguminous in mixtures depends on the type and characteristics of deposols used for reclamation. In addition to the potential yields of forage and hay, multiple significance of all types of grasslands is reflected in the changes of basic physical, chemical and biological properties of deposol through increasing its fertility.

In previously conducted studies, growing annual field crops (sudan grass, rye, wheat and rapeseed) has shown that some positive changes have been identified in deposols, during the reclamation process of technogenic soil in Stanari area (Malic, 2010; Malic and Markovic, 2012; Markovic *et al*., 2012). Such research through agrotechnical phase of reclamation has continued where it was insisted on forming the more fertile surface layer of disposed overburden. A greater production of green mass directly affects increase of content of organic matter in the surface layer of deposol in the reclamation process and rekultisol at overburden disposal (Malic, 2010; Malic, 2015).

The main task of research conducted on the effects that established grasslands had on chemical properties of deposols in the reclamation process, is to condition targeted implementation of the most optimal agrotechnical methods and measures for the

purpose of creation of quality rekultisol in the agroecological conditions of Stanari mine. Basic goal of the researched deposols is to increase the organic matter and humus content in the surface layer, as a foundation for successful reclamation.

MATERIAL AND METHODS

Research the intensity of changes of some chemical properties of rekultisol was carried out on soil samples from the individual experimental plots and surfaces reclamated through grassland establishment. All the deposol and rekultisol samples belong to the disposals formed at Raskovac open pit and Dragalovci zone of the coal mine: "EFT - Rudnik i Termoelektrana Stanari", municipality of Stanari, The Republic of Srpska, B&H.

Laboratory analysis of four average control samples was carried out before the start of biological reclamation, during 2007, 2009 and 2011. The fifth average control sample was taken from the natural soil of the grassland near Stanari mine.

Establishment of the seeding grassland was performed through direct type of reclamation by grass-leguminous mixtures and pure cultures seeding in the processed deposol. Seeding was carried out during the spring sowing period (2008, 2011 and 2012 year). Seeding rate amounted from 30 to 40 kg/ha. During the sowing period, application of fertilizers was performed through the average use of 70 kg/ha NPK, while during the vegetation period supplemental recharge of 50-80 kg/ha N was conducted. When the crops reached their maximum growth, mowing - lawn mulcher was performed.

According to the random schedule, resampling of rekultisol was carried out at the end of the vegetation period in 2012. Six average soil samples were taken from the plots where the seeding grasslands were established during the reclamation process.

Sampling was performed in accordance with the methodology specified for such kind of materials (Resulovic, 1986). The depth of sampling was 0-20 cm. Laboratory analysis of the samples were carried out at the Agricultural Institute of Republic of Srpska in Banjaluka. Characteristics of the soil adsorption complex were determined by the Kappen's method.

Edaphic conditions. Researched substrates belong to deposol before the start of biological reclamation phase and to deposol during the reclamation process (rekultisol). These types were systematized into the first technogenic soil subclass (Resulovic *et al*., 2008), and according to the WRB (2006) reference groups as *Anthropogeomorphic soil material* - nonconsolidated mineral material or *Technosols* (anthropogenic technogenic soil). Samples were collected from two types of disposed material (deposol): sandy-loamy texture with quartz mineralogical composition and clay texture (bentonite clay dominance) with parts of clayish coal. Based on the control results of active and potential soil reactions, deposol samples are classified into a category of highly acidic and moderately acidic reaction. On the basis of organic matter content, deposols

samples can be classified into a soil category of weak and medium content, while pure humus practically does not exist, except for the samples from clayey substrate. According to the available phosphorus (P_2O_5) and potassium (K_2O) content in deposol samples at the beginning of the research, these control samples classify deposol into a category of very poor content of these elements. Sandy loam samples of deposols can be classified into a category of extremely poor total nitrogen content.

Climatic conditions. The average rainfall of the investigated area for the seven-year period (2006-2012) amounted 751,84 l/m^2. The average annual air temperature for the same period was 11,23°C.

RESULTS

Results of the analysis of soil adsorption complex deposols before the biological reclamation, rekultisol, and natural soil are shown in Tables 1–2. Control results of parameters are presented in Table 1. Deposol samples before the start of biological reclamation and natural soil sample were analyzed.

Table 1. Control analysis of soil adsorption complex of deposol before biological reclamation, and of natural soil

Number of samples and subtype of deposol			***Soil Adsorption Complex Analysis***				***Degree of saturation of base cations***
			S	**H**	**T**	**V (%)**	
			cmol/kg				
1.	**sandy loam**	**deposol**	19.60	20.13	39.73	49.33	*moderately unsaturated*
2.			23.60	15.75	39.35	59.97	*moderately saturated*
3.			19.40	14.00	33.60	58.33	*moderately saturated*
4.	**clayey**		17.20	7.47	24.67	69.72	*moderately saturated*
5.	**natural soil**		29.20	1.13	30.33	86.27	*highly saturated*

From the Table 1, shown above it is concluded that based on the total adsorption capacity (T) all the analyzed samples of deposols (samples 1–4) are classified into a category of moderate or inadequately saturated (low to moderate degree of saturation of soil base cations - V). Low adsorption capacity is inherent to all acidic and sandy soils. The natural soil sample has the highest saturation (V) of base cations (S), and very low saturation of adsorbed Hydrogen ions (H), which is a good characteristic.

Results of the analysis of soil adsorption complex - rekultisol after the biological reclamation and during the reclamation process are shown in Table 2.

Table 2. Analyses of soil adsorption complex of rekultisol at the end of 2012

Number of samples and subtype of deposol			***Soil Adsorption Complex Analysis***				***Degree of saturation of base cations***
			S	**H**	**T**	**V (%)**	
			cmol/kg				
1.	2008	**sandy-loamy**	2.40	2.55	4.95	48.48	*moderately unsaturated*
2.	2011		8.00	2.10	10.10	79.21	*highly saturated*
3.	2011		6.40	1.20	7.60	84.21	*highly saturated*
4.	2011		1.60	1.28	2.88	55.56	*moderately saturated*
5.	2011		8.40	1.43	9.83	85.45	*highly saturated*
6.	2012	**clayey**	6.00	1.88	7.88	76.14	*highly saturated*

Reanalysis of soil adsorption complex (Table 2) indicates some positive changes during the period of biological reclamation by methods of seeding grassland establishment. Through the reduction of total amount of adsorbed base cations, reduction of initially adsorbed acidic (Hydrogen) ions is evident.

DISCUSSION

The implementation of biological reclamation gradually leads to the improvement of basic soil characteristics of deposol (both chemical and physical), through the evolution into the ameliorated deposol (Malic, 2010), and the formation of rekultisol, which is the main goal of reclamation of degraded areas. Similar studies confirm this theory on deposols of mine basins (Skousen and Zipper, 2010; Resulovic *et al*., 2008; Lyle, 1987).

It is precisely this difference between the ratios of adsorbed base cations and Hydrogen ions that is highly expressed in this research, particularly among the samples of sandy deposols in relation to clay and natural soil. It is evident that hydrogen ions can predominate over the adsorbed base cations (Table 1, sample no. 1), which implies that such types of soil (in this case sandy deposol with lack of colloids) with their current fertility, practically do not have sufficient adsorption capacity of all the necessary elements of mineral nutrition, which requires the implementation of full agrotehnical measures during the reclamation process. Similar studies indicate that in extremely acidic deposols adsorptive complex of soil is saturated with acidic cations (H, Al, Fe), which explains the high degree of hydrolytic acidity of some samples at copper mine disposals - Bor in Serbia (Golubovic Curguz *et al*., 2010).

Saturation degree of rekultisol with adsorbed base cations (V) shows the growth towards the increase of saturation (Table 2). Applied agromeliorative measures influenced the

release of hydrogen ions from the surface of colloidal particles on samples from both types of deposol textures in reclamation, in a way that these values came closer to the values typical for natural soils. Positive effects on the adsorption of cations are expressed at higher clay content (especially montmorillonite and bentonite clay). The improvement of adsorption conditions on colloidal particles is achieved during research on reclamation with annual field crops on the same deposols (Malic and Markovic, 2012).

In accordance with this research are also studies conducted by Spoljar *et al*. (2006) on the revitalization of Djurdjevac sands, where the higher saturation degree of adsorption complex of the soil with bases, maximum adsorption capacity of base cations and larger amount of bases capable to be replaced on the degraded soil, are explained as a result of increasing the humus content which was accumulated during the implementation of revitalization-reclamation of sandy substrates for a long period of time. Through the application of bentonite and other similar materials, neutralization of the acidity can be conducted, which increases the amount of adsorbed base cations and soil saturation degree (Boskovic Rakocevic, 2003), which was indicated in the results of research performed on the pseudogley soil. This claim can be used for the enrichment of Stanari sandy deposols by the bentonite clay which is partly located at the geological profile of the overburden at the Raskovac open pit.

CONCLUSIONS

In comparison to the natural soil, depending on the type of substrate at specific locations, Stanari mine deposols are more or less of low fertility. In the reclamation process, artificial grasslands are being established to a significant extent, as a part of the agricultural reclamation method. Very important function of the grassland is the improvement of pedological - chemical properties of a technogenic soil. Conducted laboratory analysis before and during the biological reclamation phase indicate the positive changes in the surface layer of rekultisols and deposols in the reclamation process. Enrichment of the organic matter in the surface layer of rekultisols and implementation of other agromeliorative measures induced an increase in the saturation degree of adsorbed base cations, and a decrease in the adsorption of acidic cations.

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