UDC 504.064.36:621.182.94

Part 3

ASH AND SLAG HANDLING

3.5. Applications of ash and slag from power coals

3.5.4. Use of ash and slag for improving the properties of soil

3.5.4.7. Monitoring of recultivated ash dumps of SDPPs

I.V. Gurina, N.A. Ivanova, P.A. Mikheyev, Novocherkassk State Land Reclamation Academy, Novocherkassk, Russia

V.G. Lukianov, A.N. Antonenko, Novocherkasskaya SDPP – a branch office of the "WGC-2", Novocherkassk, Russia

ABSTRACT

A system of monitoring indices for biological recultivation that includes observations of phytocenosis forming processes and changes taking place in the recultivative layer is proposed. The results of monitoring of biological recultivation for the second section of Novocherkasskaya SDPP ash disposal area using the proposed system of indices are given. For the period of 2005-2012 the successful growth and development of plants in grass mixture "Hungarian sainfoin + coach grass + awnless bromegrass" used for grassing down as well as substantial increase in biotic diversity of vegetation and settling down of fauna that was lacking earlier were stated. The monitoring results allowed to make a conclusion about proceeding positive processes stimulating accumulation of organic matter in the recultivative layer. Decrease in pH values and the content of heavy metals in the recultivative layer was established that is a positive factor achieved as a result of biological recultivation being carried out.

INTRODUCTION

Ash dumps of SDPPs removed from service occupy sizable areas and have a negative impact on the environment. To accelerate their restoration and sanitation of ecological situation in the regions of their location it is necessary to carry out biological recultivation. The restoration process for disturbed areas does not complete after implementing recultivative works, it is necessary to conduct monitoring to predict changes in the state of restored components of the disturbed landscape.

On disturbed lands, as a rule, biological monitoring is carried out and its aim is observation of biota state [1]. The most complex problem of monitoring is to choose observation parameters which are developed for separate biological components or certain levels of their organization [2]. Observations must be conducted in accordance with the standard methods, criteria and evaluations.

Such studies were carried out on Yuzhnouralsk SDPP, Verkhnetagilsk SDPP and others after their biological recultivation. Monitoring of phytodiversity was carried out since vegetation communities being formed are considered to be the most available and informative component of the formed landscape [3].

However, apart from vegetation communities being developed on recultivated territories, soil cover is also classified as an environment component of the landscape. Soil cover forming takes place as a result of a long soil-forming process. At the same time all the landscape components take one or another part in the soil forming, with vegetation being its major factor. In this connection monitoring on recultivated lands including ash dumps must insert observations of changes taking place in the recultivative layer apart from studies of the processes of phytocenosis forming.

MONITORING CHARACTERISTICS

Methodical basis for monitoring of recultivated ash dumps is the proposed system of characteristics that forsees:

1. Keeping in the recultivative layer in dynamics: nitrate nitrogen, labile phosphorus, exchange potassium, absorbed sodium, absorbed calcium, absorbed magnesium, pH of water extract, salt composition in water extract, organic matter, heavy metals, granulometric composition and microaggregate one. Sampling from the recultivative layer is carried out every 3-5 years. The results of analyses in dynamics permit to judge about nutritive regime and changes taking place in the recultivative layer.
2. Root system depth of perennial grasses in dynamics. Observations of root system depth and accumulation of root system mass for perennial grasses in dynamics permit to judge about tearing away of organic mass along horizons of the recultivative layer and about soil forming process that takes place. These observations are carried out every year at the beginning and end of the growing period.
3. The growth, development and productivity of perennial grass mixture used for creating phytocenosis during biological recultivation. Observations for the growth, development and productivity of a grass mixture are conducted annually at the beginning and the end of the growing period. The results obtained allow to determine a value of biological mass for teared away plant residues to supplement the recultivative layer with organic matter as well as to judge about the processes of humus formation in it.
4. Density of planting of perennial grass mixture in dynamics. Observations of grass-cover thickness of perennial grass mixture in dynamics make it possible to determine plant loss for concrete crops and plant density thinning of grass mixture on the recultivated area. They are carried out every year at the beginning and the end of the vegetation.
5. Number of weeds and types of predominant weed vegetation. Observations of weed dynamics and types of predominant weed vegetation permit to judge about types of weeds and plant tolerance within the formed

phytocenosis. They are carried out annually at the beginning and the end of the growing period.

6. Content of nutrients and heavy metals in biomass of the cultivated grass mixture. Sampling of plant mass of grass mixture for a total analysis including the content of heavy metals is carried out every 3-5 years at the end of vegetation. The results of analyses allow to make a decision to utilize biomass out of the bounds of a recultivated object or to replenish the recultivative layer with organic matter at the expense of plant biomass teared away.

7. Photosynthesis activity of sowing of a perennial grass mixture. Observations of photosynthesis activity of sowings during the growing period permit to determine how effectively the energy of solar radiation is used under the conditions of recultivated area.

MONITORING RESULTS

The proposed system of monitoring characteristics for biological recultivation was tested at the second section of Novocherkasskaya SDPP ash dump. Biological recultivation for the second section of ash dump using phytomelioration technology was carried out in 2004 [4]. Since 2005 and up to the present time monitoring of the recultivated ash dump has been carrying out [5].

Inspection of plant cover at the recultivated section of ash dump being conducted in the early spring of 2012 revealed that safety of sowing for the grass mixture “Hungarian sainfoin + coach grass + awnless bromegrass” averaged 68 %. Plant heights for Hungarian sainfoin averaged 49.0 cm, for grasses (coach grass and awnless bromegrass) it averaged 58.0 cm. Root system depth of Hungarian sainfoin averaged 63.0 cm, that of grasses averaged 69.0 cm. In 2012 a random displacement of Hungarian sainfoin at the recultivated section with forming locations of sufficiently dense placement of plants was gone on.

Some thinning of grass mixture sowings was observed, especially on plots where machinery moved, but loss of crop plants was replaced by appearance of weed vegetation that was freely displaced at the recultivated section. Weed number of sowing averaged 25 plants per m2 and bringing of seeds from the recultivated in 2011 first section contributed to this. To the end of 2012 vegetation height of Hungarian sainfoin averaged 85.0 cm, that of grasses was 90.0 cm. Plants of grass mixture formed strong root system that allowed them to grow and develop under the conditions of very drought 2012. Root system depth of Hungarian sainfoin averaged 66.0 cm, that for coach grass and awnless bromegrass was 72.0 cm.

The highest indices of grass mixture biomass productivity were observed when the calculated rate and that increased by 30 % of fertilizing were applied. In average for 2005-2012 biomass productivity under the improved nutritive regime showed 22 % exceeding over the indices obtained for the calculated rate of fertilizing and 30.5 % exceeding without fertilizing. Fertilizing influenced positively on photosynthesis activity of grass mixture sowings. Maximum values of photosynthesis potential and pure photosynthesis activity was observed when the increased by 30 % rate of fertilizer – 4760.4 thousand m2/ ha per days and 6.5 g/m2 daily were applied correspondingly.

In accordance with the order of monitoring realization sampling of plant mass and recultivative layer was carried out at the second section. Analyses were conducted in the certified laboratory of FSBSI “Russian Research Institute of Reclamation Problems” (RosNIIPM).

Sampling of plant mass for the grass mixture “Hungarian sainfoin + coach grass + awnless bromegrass” was carried out in 2008. The results are presented in tables 1 and 2.

Their analysis showed that the content of heavy metals in root dry mass greatly exceeded their content in the above ground mass. In this way Cu content in roots of awnless bromegrass is 2.4 times more than in biomass, those of Cd, Zn and Ni are more by 2.2, 2 and 3 times, correspondingly. It was established that Pb content in biomass of awnless bromegrass was by 1.6 times more than in roots. Coach grass plants had the heavy metals content by 2.3 times more as compared with biomass and only Pb content in roots was by 1.2 times less than in biomass. The content of heavy metals in roots of Hungarian sainfoin like coach grass and awnless bromegrass greatly exceeded their content in biomass. Accordingly, roots of Hungarian sainfoin contained Cu by 1.5 times, Cd by 1.3 times and Zn by 2 times more than in biomass. But contents of Pb and Ni in roots of Hungarian sainfoin were less than in biomass by 3.5 times and 1.8 times, correspondingly. Analysis of plant dry mass for the content of nutrients indicated that biomass of awnless bromegrass contained the least quantity of NPK as compared with coach grass and Hungarian sainfoin. The largest content of total nitrogen was found in biomass and roots of Hungarian sainfoin – 1.92 and 1.54 % and this is by 0.92 and 0.16 % more than for awnless bromegrass and 0.44 and 0.71 % more in comparison with coach grass.

The results of microaggregate and agrochemical analyses are given in tables 3 and 4.

Table 1. **Content of heavy metals (bulk form) in plants of grass mixture**

Sample species	Content of heavy metals, mg/kg of plant dry matter				
	Cu	Cd	Zn	Pb	Ni
Awnless bromegrass (roots)	4.15	0.24	23.50	0.76	5.50
Awnless bromegrass (biomass)	1.70	0.11	11.50	1.23	1.80
Coach grass (roots)	5.30	0.11	21.60	0.90	5.60
Coach grass (biomass)	1.85	0.09	7.25	1.10	2,50
Hungarian sainfoin (roots)	6.00	0.10	19.40	0.19	4.00
Hungarian sainfoin (biomass)	3.90	0.08	9.60	0.67	7.20

Table 2. **Content of nutrients in plants of grass mixtures**

Sample species	Content of nutrients, %				
	K_2O	K	P_2O_5	P	N_{total}
Awnless bromegrass (roots)	1.14	0.95	0.05	0.02	1.38
Awnless bromegrass (biomass)	0.53	0.44	no	no	1.00
Coach grass (roots)	1.01	0.84	no	no	0.83
Coach grass (biomass)	2.18	1.81	0.05	0.02	1.48
Hungarian sainfoin (roots)	1.17	0.97	0.02	0.01	1.54
Hungarian sainfoin (biomass)	1.59	1.32	0.25	0.11	1.92

Table 3. **Microaggregate composition of the recultivative layer**

Horizon, cm	Content of fraction, %, size of fraction, mm						Physical sand	Physical clay
	>0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001		
2008								
0-20	–	89.53	8.91	0.40	1.04	0.12	98.44	1.56
20-40	–	1.28	77.00	11.30	9.84	0.58	78.28	21.27
2011								
0-20	–	87.07	8.19	1.65	2.09	1.00	95.26	4.74
20-40	–	34.62	42.50	9.15	10.79	2.94	77.12	22.88

Table 4. **The results of agrochemical analysis of the recultivative layer samples**

Horizon, cm	Nitrate nitrogen, mg/kg	Labile phosphorus, mg/kg	Exchange potassium, mg/kg	Organic matter, %	pH
2008					
0-20	0.9	0	200.0	0.07	8.48
20-40	5.0	44.6	48.0	2.69	8.32
2011					
0-20	<2.8	9.0	152.4	0.16	8.29
20-40	<2.8	2.6	159.6	3.23	8.13

Analysis of the data in table 3 permitted to establish that in samples of the recultivative layer physical sand is prevailing. As compared with the indices of microaggregate analysis of 2008 the content of physical sand in 0…20 cm and 20…40 cm horizons was decreased by 3.18 and 1.16 %, correspondingly. On the contrary, the content of physical clay in 0…20 horizon increased by 3.18 % and in 20…40 horizon – by 1.16 %.

The results of agrochemical analysis in table 4 showed increase in the content of nitrate nitrogen and labile phosphorus in the recultivative layer as compared with 2008. It was established decrease in the content of exchange potassium by 47.6 mg/kg as compared with 2008 data. That is accounted by its assimilation by plants. In 2011 in 20…40 horizon the content of nitrate nitrogen and labile phosphorus was reduced in comparison with the analysis results of 2008, samples contained high quantities of exchange potassium – by 3.3 times as compared with 2008.

Implemented analysis indicated keeping of tendency for increase in the content of organic matter in substratum at the recultivated section of ash dump. In this way in 2011 it exceeded 2008 data by 0.09 in 0…20 cm horizon and by 0.54 % in 20…40 cm horizon that confirms positive processes to be taking place.

In 2011 decrease in pH values was continued: in 0…20 cm layer – by 0.16 and by 0.19 in 20…40 cm layer. As a whole for the period from the initial sampling before biological recultivation of ash dump with the use of developed technology one of the elements of which was fertilizing decrease in alkalinity of the recultivative layer took place.

The results of salt composition in water extract, exchange bases and heavy metals content in samples of the recultivative layer are given in tables 5, 6 and 7.

The analyses results for salt composition in water extract permitted to point out some increase in ion sum in both 0…20 cm and 20…40 cm horizons in comparison with 2008 data (table 5). The content of absorbed sodium in 0…20 cm layer increased as compared with the results of 2008.

An increase in the content of calcium and magnesium in 0…20 cm and 20…40 cm horizons of the recultivative layer was also established and this is accounted by the fact that the main mass of root system of grass mixture plants is located in ash dump substratum (table 6). The analyses results in table 7 made it possible to establish reduce in the content of heavy metals Cu and Ni by 1.2 times and Pb by 1.6 times in 0…20 horizon of the recultivative layer. The same situation was also observed in 20…40 cm horizon, where the content of Cu, Zn, Ni and Pb was reduced by 17.6, 4.4, 8 and 14.4 times, correspondingly. Such situation is explained by positive influence of phytomelioration.

Table 5. **The results of salt composition analysis of water extract from the recultivative layer**

Horizon, cm	Cl^-, g/mg-eq.	SO_4^{2-}, g/mg-eq.	HCO_3^-, g/mg-eq.	Ca^{2+}, g/mg-eq.	Mg^{2+}, g/mg-eq.	Na^+, g/mg-eq.	K^+, g/mg-eq.	Ion sum, g	Dry residue, g
2008									
0-20	0.002	0.004	0.036	0,010	0.002	0,001	0.001	0.056	0.071
	0.05	0.08	0.60	0.50	0.20	0.02	0.01		
20-40	0.002	0.036	0.036	0.016	0.006	0.002	0.001	0.099	0.113
	0.05	0.77	0.60	0.80	0.50	0.10	0.02		
2011									
0-20	0.004	0.003	0.033	0.013	0.003	0.001	0.002	0.059	0.078
	0.06	0,006	0.56	0.52	0.25	0.021	0.031		
20-40	0.003	0.038	0.034	0.019	0.009	0,003	0.0012	0.102	0.121
	0.059	0.89	0.53	0.86	0.41	0.12	0.024		

Table 6. **The results of exchange bases analyses**

Horizon, cm	Content, mg-eq./100 g of substratum		
	Na	Ca	Mg
2008			
0-20	0.36	4.04	1.56
20-40	–	5.48	2.92
2011			
0-20	0.38	4.19	1.61
20-40	–	5.53	3.08

Table 7. **Content of heavy metals in samples of the recultivative layer**

Horizon, cm	Content of heavy metals, mg/kg				
	Cu	Cd	Zn	Ni	Pb
2008					
0-20	3.0	<0,008	11.1	6.9	2.4
20-40	28.1	0.02	30.4	26.0	15.5
2011					
0-20	2.53	0.05	11.73	5.85	1.53
20-40	1.6	0.03	6.95	3.23	1.08

Thus, the results of monitoring showed successful growth and development of the sown grass mixture. For the considered period substantial increase in biotic diversity of vegetation and setting down of fauna that were lacking earlier were stated. Plant cover greatly influenced the state of recultivative layer. After carrying out phytomelioration on the considered area a tendency for increased in the content of organic matter, decrease in pH values, reduction in the content of heavy metals was established and this is a positive factor achieved as a result of biological recultivation with the use of phytomeliorants being carried out at the ash dump.

REFERENCES

1. **Чибрик Т.С., Глазырина М.А.** Биологическая рекультивация и мониторинг нарушенных промышленностью земель. Екатеринбург, 2008. 195 с.
2. **Дюкарев А.Г., Пологова Н.Н.** Мониторинг и оценка состояния лесных экосистем // Journal of Siberian Federal University. Biology 4. 2008. P. 390-399.
3. **Экологические основы** и методы биологической рекультивации золоотвалов тепловых электростанций на Урале / А. К. Махнев, Т. С. Чибрик, М. Р. Трубина и др. Екатеринбург, УрО РАН, 2002. 356 с.
4. **Результаты** работ по биологической рекультивации второй отработанной секции золоотвала Новочеркасской ГРЭС / В.В. Бирюков, И.В. Гурина, Н.А. Иванова, В.Г. Лукьянов, Е.А. Лысенко // Материалы III Международного научно-практического семинара «Золошлаки ТЭС: удаление, транспорт, переработка, складирование». Москва, 22-23 апреля 2010 г. М.: Издательский дом МЭИ, 2010. С.64-67
5. **Гурина И.В., Иванова Н.А., Михеев П.А.** Система показателей мониторинга рекультивированных золоотвалов (на примере Новочеркасской ГРЭС) // Научная мысль Кавказа. 2012. №3. С. 50-56.

Gurina, N.A. Ivanova, P.A. Mikheyev, etc. Monitoring of recultivated ash dumps of SDPPs // Proceedings of the V Conference “Ashes from TPPs: removal, transport, processing, storage”, Moscow, April 24–25, 2014 — M.: MPEI Printing House, 2014. P. 192– 195.