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Part 3

ASH AND SLAG HANDLING

3.2. Ash and slag handling systems at TPPs

3.2.5. Ash and slag disposal sites

3.2.5.4. THE RESULTS OF BIOLOGICAL RECULTIVATION FOR THE SECOND WORKED OFF SECTION OF ASH DISPOSAL AREA OF NOVOCHERKASSK HYDRO

V.V.Biryukov[1], I.V. Gurina[2], N.A. Ivanova[2], V.G. Lukianov[1], Ye.A. Lysenko[1]

Branch office of public company "OGK-6" Novocherkassk Hydro, Novocherkassk, Russia (1)
Novocherkassk state Land Reclamation Academy, Novocherkassk, Russia (2)

ABSTRACT

The results of biological recultivation for the second worked off section of ash disposal area of Novocherkassk Hydro are given. Agrotechnical survey of ash disposal area estimated that its natural overgrowing was lacking and a biological stage of recultivation for forming anthropotolerant phytosenosis is necessary. To determine the most adapted species of plants suitable for forming stable phytocenosis on ash disposal area laboratory experiments in vegetative vessels were carried out. These experiments made it possible to determine the possibility of growing grass mixture of coach grass + awnless brome + Hungarian sainfoin on ash disposal area and to substantiate scientifically seeding rates for grasses, rates of fertilizer usage and sowing terms as well.

Couch grass + awnless brome + Hungarian sainfoin grass mixture was sown in April 2004. Phytomelioration of ash dump surface completely excluded negative impact on surrounding landscapes.

INTRODUCTION

The total area of ash dumps in Rostov region equals 250 ha. More than 40 mln tons of ash slags are housed in them [1]. In perspective areas under ash dumps will be expanded that is connected with the planned growth in power generation on the basis of burning solid fuel.

Ash dumps do great harm to environment and people [2]. Proper placing and adequate development adjusted for a possibility of further use as well as their recultivation prevent and eliminate damage that ash dumps do to landscapes.

At present main directions for recultivation of worked off ash dumps are agricultural, forestrial and hygienic and sanitary [2-4].

Study of experience in carrying out recultivation works on ash dumps of Russian Federation enabled to ascertain that agricultural and forestrial lines of their recultivation are economically and ecologically impracticable. Agricultural crops cultivated on ash dumps accumulate increased concentrations of dangerous for people and agricultural animals microelements in their biomass. Utilization of ash dumps area for cattle grazing can cause disturbance in the surface layer and wind erosion. It is impossible to grow merchantable wood because root system of trees when penetriating into ash dump substratum cannot provide necessary nutrition for the trees. Besides, these lines of recultivation require vast capital investments as for their realization large volumes of fertile and potentially fertile ground as well as increased rate of fertilizer usage are necessary [5].

As utilization of worked off ash dumps in the national economy is economically and ecologically unreasonable predominant direction of their recultivation is hygienic and sanitary, that is biological conservation.

So, the purpose of our studies was to develop technology for biological conservation of ash dump of Novocherkassk Hydro.

Studies on the second worked off section of ash dump of Novocherkassk Hydro have been carrying out since 2004.

AGROTECHNICAL SURVEY

The second worked off section of ash dump of Novocherkassk Hydro with area of 76 ha is in 8 km to the south-east from Novocherkassk between two stanitsas Krivyanskaya and Zaplavskaya.

In 2002 on the ash dump a technical stage of recultivation that foresaw forming recultivative layer 30…40 centimeter thick of loamy and sandy loamy substrata was carried out.

Agrotechnical survey of the second worked off section of ash dump was being carried out in autumn 2003 to study conditions natural self-overgrowing of the disturbed area.

As a result it was established that natural overgrowing of ash dump was practically lacking. Fragmentary plant cover was found only on dam slopes of ash dump, more closed phytocenosis with tree and shrub vegetation being observed on the south slope that is accounted for favourable climatic conditions. Intensive deflation of both drifted substrata and dried fly ash was observed on the surface of ash dump and this caused unfavourable conditions for forming natural phytocenoses. It was found out that self-recultivation of this area is impossible. Because of constant wind impact particles of recultivated layer are removed and ash uncovers itself but plants can not grow on it.

Analysis of samples of recultivative layer made it possible to determine that humus is practically absent in them (table 1). Samples from 20…40 cm horizon have twice as much heavy metals, than samples from 0…20 cm horizon (table 2).

Besides recultivative layer is not provided with nutrients in quantities sufficient for plant growing (table 1). Thus, content of nitrate nitrogen in 0…20 cm layer was 0.38 mg/kg, phosphorus – 0.7 mg/kg, potassium – 12.8 mg/kg. So, the necessity to apply nitrogen-phosphate fertilizer was stated.

Table 1. **The results of agrochemical analysis of samples from recultivative layer of the second worked off section of Novocherkassk Hydro ash dump, 2003**

Horizon, cm	Nitrate Nitrogen, mg/kg	Labile Phosphorus, mg/kg	Exchange Potassium, mg/kg	Humus, %	pH
0…20	0.38	0.7	12.8	0.01	9.49
20…40	0.36	4.0	28.0	0.09	9.51

Table 2. **Content of heavy metals in samples of the recultivative layer of the second worked off section of Novocherkassk Hydro ash dump, 2003**

Horizon, cm	Heavy metals, mg/kg				
	Cu	Cd	Zn	Ni	Pb
0…20	2.858	0.068	9.145	4.687	1.989
20…40	6.161	0.135	17.346	6.616	3.543

The results of agrotechnical survey of the second worked off section of Novocherkassk Hydro permit to make conclusions about the necessity of biological stage of recultivation for forming anthropotolerant phytocenosis on the worked off ash dump. This phytocenosis is to consist of grass and tree and shrub vegetation with well developed root system, drought-resisting, undemanding to soil fertility and having good land reclamation qualities.

LABORATORY EXPERIMENTS

To determine the most adapted species of plants suitable for forming stable phytocenosis on ash disposal area laboratory studies in vegetative vessels were carried out. The experiments foresaw observations for growth and developing 2-, 3- and 4-component grass mixtures on the background of different rates of fertilizer usage on the following scheme:

1. couch grass + alfalfa (no fertilizer);
2. couch grass + alfalfa (optimal rate);
3. couch grass + alfalfa (30 % increase in rate);
4. couch grass + goat's-rue (no fertilizer);
5. couch grass + goat's-rue (optimal rate);
6. couch grass + goat's-rue (30 % increase in rate);
7. Columbian grass + couch grass + alfalfa (no fertilizer);
8. Columbian grass + couch grass + alfalfa (optimal rate);
9. Columbian grass + couch grass + alfalfa (30 % increase in rate);
10. Columbian grass + goat's-rue (no fertilizer);
11. Columbian grass + goat's-rue (optimal rate);
12. Columbian grass + goat's-rue (30 % increase in rate);
13. Columbian grass + amaranth + Hungarian sainfoin (no fertilizer);
14. Columbian grass + amaranth + Hungarian sainfoin (optimal rate);
15. Columbian grass + amaranth + Hungarian sainfoin (30 % increase in rate);
16. Hungarian sainfoin + couch grass (no fertilizer);
17. Hungarian sainfoin + couch grass (optimal rate);
18. Hungarian sainfoin + couch grass (30 % increase in rate);
19. Hungarian sainfoin + Columbian grass (no fertilizer);
20. Hungarian sainfoin + Columbian grass (optimal rate);
21. Hungarian sainfoin + Columbian grass (30 % increase in rate);
22. Hungarian sainfoin + couch grass + awnless brome (no fertilizer);
23. Hungarian sainfoin + couch grass + awnless brome (optimal rate);
24. Hungarian sainfoin + couch grass + awnless brome (30 % increase in rate);
25. couch grass + Hungarian sainfoin + alfalfa + goat's-rue (no fertilizer);
26. couch grass + Hungarian sainfoin + alfalfa + goat's-rue (optimal rate);
27. couch grass + Hungarian sainfoin + alfalfa + goat's-rue (30 % increase in rate).

Diammophoska ($N_{9\text{-}10\%}$; $P_{25\text{-}26\%}$; $K_{25\text{-}26\%}$) was applied as a mineral fertilizer. Rate of fertilizer usage in experimental variants was calculated depending on area of a vegetative vessels and rate of $N_{60}P_{120}K_{90}$ fertilizers kg of active matter (a.m.) per ha.

To test germination ability of examined crops experiments were carried out in multiple replication and then a laboratory experiment was laid. Seeding depth in vessels was 2…3 см.

The first sprouts (15 %) appeared in 25…30 days and in two weeks 75 % of sprouts were recorded. The following crops showed the highest per cent of germination: Hungarian sainfoin – 96 %, couch grass – 75 %, awnless brome – 82 %. These crops had high indices irrespective of rate of fertilizer usage as well as grass mixtures with them. Analysis of linear growth dynamics showed that the following crops had the largest values of height: couch grass – 11 cm, Hungarian sainfoin – 6 cm, awnless brome – 10 cm, alfalfa – 4 cm.

Thus, the laboratory experiments permited to determine the possibility of growing couch grass + awnless brome + Hungarian sainfoin grass mixture on ash disposal area and to substantiate scientifically seeding rates for grasses, rates of fertilizer usage and sowing terms as well.

FIELD STUDIES

Couch grass + awnless brome + Hungarian sainfoin grass mixture was sown in the second decade of April 2004. Seeding rates were 40 %, 40 %, 20 % for couch grass, awnless brome and Hungarian sainfoin, correspondingly.

All grasses are perennial, have quick acclimatization, high resistance to unfavorable conditions of microclimate and to negative physical and chemical properties of ground. They are able to develop a strong root system and have symbiosis with microorganisms. They can grow during 6 and more years.

The weather greatly influenced the growth and development of plants in the grass mixture. During the growing period rainfall was within the norm – 275 mm, air relative moisture was 69 %. Analysis of meteorological data makes it possible to characterize the year of 2004 as warm and wet. Rainfall was enough to exceed field moisture deficiency that is important for the plant growth.

Total sprouts of grass mixture appeared in the early May, and in the late July sodding of ash dump surface was observed, that fully excluded forming of sand storm on its area. In the late August additional fertilizing of the grass mixture with ammonium nitrate in the rate of N_{60} kg/ha a.m. In the early October complex fertilizer – ammophos was applied.

To restore the disturbed plot forest reclamation practices were used as well. In autumn 2004 tree and shrub vegetation was planted on the recultivated area: three-row forest reclamation belt – diagonally and four-row forest belt is meant for reducing negative influence of the eastern winds. Four-row forest belt planted on the slopes and along perimeter of the ash disposal area is meant for fixing its surface. In total, more than 10,000 trees and shrubs of 17 species were planted on the restored area.

Inspection in the early spring 2005 showed that grass mixture plants passed the winter well. As for the growing period in 2005 it can be defined as arid. Rainfall was in the form of heavy showers and this volume was 15 % less than mean annual. Relative moisture was 64 % and mean daily air temperature exceeded greatly mean annual indices during the whole growing period.

During the grass mixture vegetation monitoring on the dynamics of linear growth and the depth of root system penetration had been carrying out. The data received indicated that the mean height of plants was more than 80 cm and the depth of root system was 30 cm.

Nutritive regime for grass mixture was stimulated by additional nitrogenous fertilizing in the rate of $N_{60\text{-}90}$ kg/ha a.m. in spring while at the end of the growing period complex fertilizers were applied.

The autumn inspection of the landscape formed established successful growth both cultivated plants of grass mixture and associated weeds. The mean number of species on 1 m^2 was 3…5.

The inspection of forest belts created indicated 80 % taking roots for shrubs. The best taking roots was observed for dog roses, snowberry bush, silverberry, sea buckthorn, spindle tree and spindle bearded tree.

In spring 2006 good wintering of plants was also recorded. After the winter period mean safety of grass mixture plants was 93.6 %.

Analysis of meteorological data made it possible to characterize the year of 2006 as arid. Rainfall was 16.8 mm less than the norm. Within the months of the growing period rainfall was distributed unevenly, August being the driest month (2.4 mm). The mean daily air temperature in the growing period was 19.4°C, 1.6°C higher than the mean of many years. Relative air moisture was 62 % but wet May and June (51.1 mm and 103.2 mm of rainfall, correspondingly) made it possible for both the cultivated plants and weeds to grow well on the ash disposal area. Fertilizer applying in rates $N_{90}P_{90}K_{60}$ kg/ha a.m. favoured good growth and development of grass mixture plants.

In 2007 field studies on the ash disposal area were continued. After the winter safety of grass mixture was over 89 %.

In 2007 there observed little rainfall (84.3 mm less than mean of many years) and increased values of temperatures and relative moisture (3.1°C and 13 % higher than the mean of many years, correspondingly). In general, 2007 growing period was semi-arid.

In the early growing period fertilizers were applied in calculated rate $N_{90}P_{90}K_{90}$ kg/ha a.m. By the end of the vegetation mean height for Hungarian sainfoin had been 82 cm, that for couch grass and goat's-rue had been 123 cm. By the end of growing period 2007 the depth of root systems had been 38…46 cm and penetrated into ash dump substratum.

After the winter 2007-2008 mean safety of plants was 85 %. In general the year of 2008 can be called arid. According to meteorological data for the growing period total rainfall was 306.4 mm that is 30.4 mm more than the mean of many years. Mean daily air temperatures were close to mean annual values, but relative moisture for the same days was much higher than the mean annual values.

At the end of vegetation 2008 average plant heights of grass mixture were: for Hungarian sainfoin 95 cm, for cereals – 137 cm. The depth of penetration for root systems was 48…53 cm for Hungarian sainfoin and 45…56 cm for couch grass and awnless brome.

To study influence of phytoreclamation on agrochemical properties of recultivative layer samples of sand substratum were taken and sent for analysis to analytical laboratory of the Russian Research Institute of Reclamation Problems (RosNIIPM) in autumn 2008. The results of analyses are given in tables 3, 4.

Data in tables 3 show that in the layer of 0…20 cm nitrate content increased by 0.52 mg/kg, while in the layer 20…40 cm it increased by 2.14 mg/kg as compared to the samples taken in 2003. Decrease in content of labile phosphorus as compared with the original one is accounted by its assimilation by the plants of grass mixture. Content of exchange potassium in the layers of 0…20 cm and 20…40 cm was 20 mg/kg and 48 mg/kg, correspondingly, showing its increased content in sand substratum. It should be pointed out that after phytoreclamation of considered area humus content was increased.

Table 3. **The results of agrochemical analysis of samples from the recultivative layer of the second worked off section of Novocherkassk Hydro ash dump, 2008.**

Horizon, cm	Nitrate Nitrogen, mg/kg	Labile Phosphorus, mg/kg	Exchange Potassium, mg/kg	Humus, %	pH
0…20	0.9	no	20.0	0.07	8.48
20…40	2.5	44.6	48.0	2.69	8.32

Table 4. **Content of heavy metals in samples from the recultivative layer of the second worked off section of Novocherkassk Hydro ash dump, 2008.**

Horizon, cm	Heavy metals, mg/kg				
	Cu	Cd	Zn	Ni	Pb
0…20	2.32	0.008	8.76	1.53	3.12
20…40	6.47	0.25	18.45	9.17	6.23

The results of table 4 show sufficient decrease in content of heavy metals in the layer of 0…20 cm. Their increased content in 20…40 cm layer of sand substratum indicate that the plant root systems reached ash.

The results received allow to speak about positive processes favouring increasing of organic matter in sand substratum in the form of biomass and root systems of plants in grass mixture that can be achieved only with the help of crops-phytomeliorants. Decrease in content of heavy metals in the upper 0…20 cm layer of sand substratum is also a positive factor that was reached as the result of phytoreclamation on the recultivated ash disposal area.

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