REVEGETATION POTENTIAL OF COAL WASTE PILES IN NORTHERN CHINA[1]

by

Zhenqi Hu and Qiaoxing Wang[2]

Abstract This study was conducted to determine the revegetation potential of coal waste piles from a coal mine in Northern China. Poor highly porus structure, loose surface with about 5cm - 10cm weathering materials, more than 80% stones, and high ground temperature were typical characteristics of coal waste piles. The physical and chemical properties of the coal wastes were tested in this study. The result showed the coal waste piles had higher bulk density and lower water holding capacity which was half of loess. Infiltration was very rapid, which ranged from 126.4 mm/h to 434.5 mm/h. The pH values indicated that the coal wastes were neutral or slightly alkaline in most cases. Although coal wastes were generally thought to be poor, the tested results showed that the coal wastes had higher contents of organic matter including coal fragments and nitrogen. Based on the results, the authors thought that the coal waste piles not only had some restrict factors, but also had many suitable conditions for revegetation. As long as some improving measures such as recondition of coal wastes pile and plant establishment with irrigation are adopted, revegetation on coal waste piles has potential for some success. Forty-seven plant species planted and growing on the pile reflect this conclusion.

Additional key words: coal wastes, revegetation, mine waste characterization, China

[1] Paper presented at the 10th National ASSMR Meeting: " The Challenge of Integrating Diverse Perspectives in Reclamation", Spokane, Washington, May 16 - 19, 1993.

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Introduction

Coal wastes are generated from coal mining and processing. Wastes do not only occupy land, but also pollute the environment. Almost 1.5 - 2.0 billion tons of old coal mining and processing wastes lie scattered about China; over 150 million tons are generated each year. In China there are a total of about 850 piles, occupying an area of more than 6,700 hectares. Thus, the revegetation of coal waste piles has become the focus of research activities in our country. The efforts can control pollution of coal mining area, allow reuse of the land resources, and result in great economic benefits.

Proceedings America Society of Mining and Reclamation, 1993 pp 300-306

DOI: 10.21000/JASMR93010300

https://doi.org/10.21000/JASMR93010300

Several coal mining areas in China have more than ten coal waste piles revegetated. But, the revegetation potential of coal waste piles has not been intensively studied, which has resulted in high cost and little benefit from the revegetation practice. Therefore, this paper evaluates the revegetation potential of coal waste piles in Northern China so that a rational method of revegetation can be found.

Material and Methods

The experimental site is at the Wangzhuang coal mine in Shangxi province, which is located in Northern China. The coal waste piles are in the shape of an ellipse (see Figure 1), which extended from South-East to North-West. Its length (N-S) and width (E-W) were about 310m and 130m respectively. It was 60m high above the ground level with the slope of 15°-38°; occupying 4 hectares. The mine is in the arid area with temperate continental climate. It has an average annual rainfall of 678.65mm, of which 57% is received in summer. The thickness of weathered layer was only 5 - 10cm. The main constituents of coal wastes were kaolinite and coal, with lesser amounts of Quartz, illite, clasper and pyrite. The ground temperature was high, which led to no freezing in the winter. Based on the landscape of the piles, 8 divisions (A, B1, B2, C1, C2, D, E, F) were selected for study in detail (see Figure 1). In each division, we also chose three parts (top, middle and foot) of the piles for study.

Soil serves as a medium for plant growth and the soil condition directly affects plant growth (Hillel 1982). In the coal waste piles, there were only rocks and weathering materials without any soils. Thus, the characteristics of these coal wastes will determine the potential for revegetation and will also be the key to successful or unsuccessful revegetation of the coal waste piles. This paper reports research on the physical and chemical

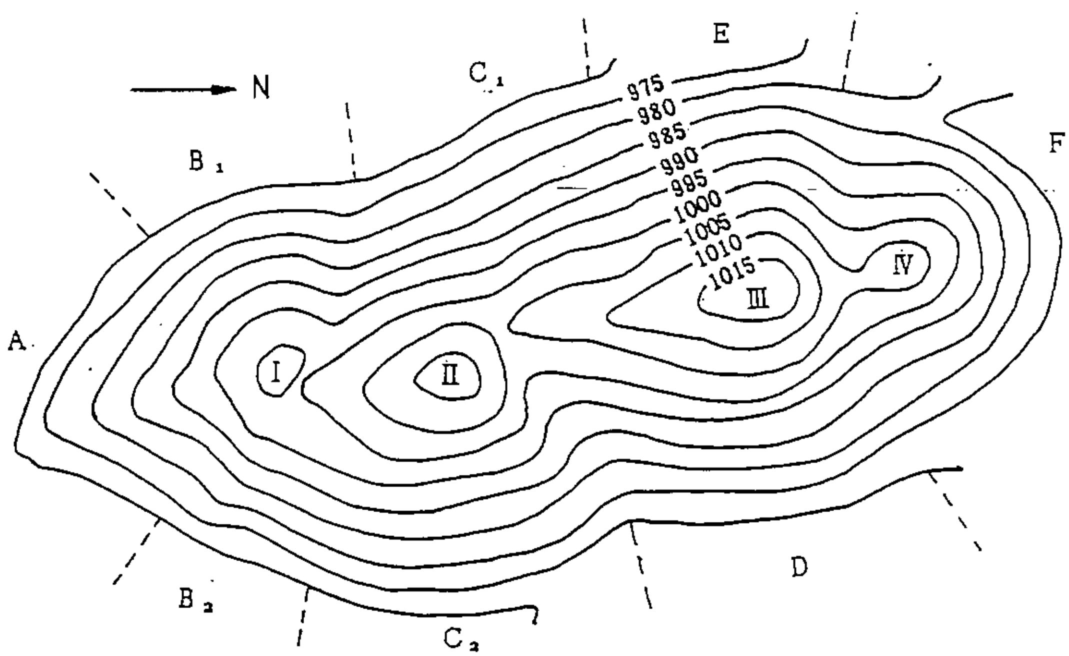

Figure 1. The contour map of the coal wastes pile at Wangzhuan coal mine, Shangxi Province, P.R. China

properties of the coal waste piles such as structure, bulk density, ground temperature, field capacity, moisture content, infiltration, pH, organic matter and macronutrient content. This data helps ascertain whether the coal waste piles have the potential for revegetation.

Results and Discussion

Structure of the coal waste piles

After digging 8 pits in the piles, the profile showed the top 5-10cm layer was weathered materials and the lower layer consisted of mixed and disorderly rocks of different sizes. In the piles, many discontinuous holes were found. We chose six position to take samples from top to 60cm depth in 20cm increment for particle analysis. Results are listed in table 1.

The results showed that the diameter of coal wastes was very large: the content of sand, silt and clay was 20.2% in the top 0-10cm layer, but 79.8% was stone and gravel. With the increase of depth, the diameter becomes larger. In the 40-60cm depth, only 7.3% was sand, silt and clay with the rest (92.7%) being stone and gravel. Obviously, the structure of coal waste piles were much poorer than that of loess, which could lead to poor water holding capacity and the loss of nutrients. But, the capacity of aeration and infiltration might be better than that of loess and plant roots might also more easily penetrate in piles through the holes.

Bulk density of coal waste piles

The tested results are illustrated in table 2 and figure 2.

The results of bulk density revealed that the value of coefficient of variance was in direct proportion to the depth of the pile, thus it could be inferred that the bulk density of coal waste piles varies with depths. The average bulk density in the depth of 0-20cm was similar to that in the depth of 40-60cm, which were all greater than

Table 1. The size distribution of coal wastes. Unit: %

depth	stone		gravel	sand	silt and clay
cm	>20mm	20-10mm	10-1mm	1-0.25mm	<0.25mm
0-20	19.1	20.1	40.6	11.8	8.4
20-40	29.8	23.6	33.0	8.4	5.2
40-60	46.8	21.8	24.1	4.4	2.9

Table 2. Bulk density at different depth

depth	0-20cm	20-40cm	40-60cm
Sample size	6	6	6
Average, g/cm^3	1.616	1.470	1.629
Variance	0.014	0.625	0.115
Standard deviation (SD)	0.120	0.157	0.339
Minimum, g/cm^3	1.447	1.229	1.151
Maximum, g/cm^3	1.815	1.635	2.082
coefficient of variance	0.072	0.107	0.208

Note: Coefficient of Variance (CV) = SD/average

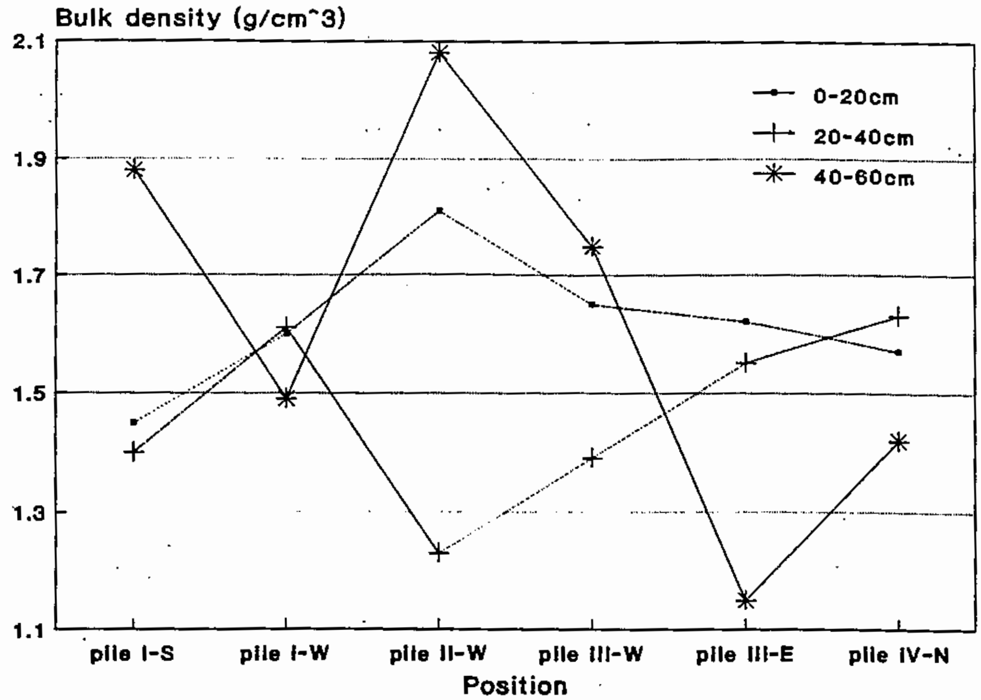

Figure 2. Bulk density of coal wastes

Table 3. Ground temperature of the Wangzhuang coal wastes pile tested in March 1992 Unit: ℃

time	depth (cm)	position along the pile slope: top	middle	foot	air temperature
9:30	0-10	6.14	2.1	1.9	
	10-30	7.7	3.2	3.5	0-3
13:30	0-10	12.7	10.2	9.3	
	10-30	11.6	10.1	7.6	11
16:30	0-10	11.2	9.9	7.5	
	10-30	11.0	9.2	6.5	8

1.6g/cm^3. The bulk density in the depth of 20-40cm was smallest, but it was still close to 1.5 g/cm^3. Therefore, the bulk densities of coal waste piles are usually much larger than that of loess.

Ground temperature

The temperature results listed in table 3 indicated that the ground temperature of coal wastes in the depth of 0-30cm varied with air temperature, which was due to the larger size of coal wastes and better aeration capacity. Along the slope, the ground temperature was increase from the foot of the pile to the pile top. Hence, the surface of the pile top was generally not frozen in winter. This sort of features of ground temperature may lead to: the plants sprouting early in spring and be singed by high temperature in summer.

Moisture content (by weight)

The coal wastes were much different from loess in moisture content because of their tremendous difference in particle size. We took 44 samples in the pile for testing moisture contents. The results listed in table 4 and figure 3 indicated that the moisture content of coal wastes was much lower than that of loess (12.8%). The moisture content was greater than 4% in the drought season, indicating the coal wastes had a certain capacity of holding moisture. Thus some drought-resistance plants could survive on the pile. Furthermore, if loess is covered on coal wastes and irrigated, the plants on the pile could grow very well. The moisture content in the depth of 0-20cm was little lower than that of 20-40cm depth. Among the three positions of the pile (top, middle and foot), the moisture content in the depth of 20-40cm increased from top to foot, indicating good water infil-

Table 4. Moisture Content (MC) of coal wastes

depth	0-20cm			20-40cm		
position	top	middle	foot	top	middle	foot
No.sample	6	6	6	9	9	9
average, %	4.53	4.34	6.35	4.69	5.21	7.83
standard dev.	2.95	1.83	4.64	2.12	2.89	3.54
CV	0.65	0.42	0.73	0.45	0.55	0.45
mean MC, %		5.07			5.91	
mean CV		0.60			0.48	

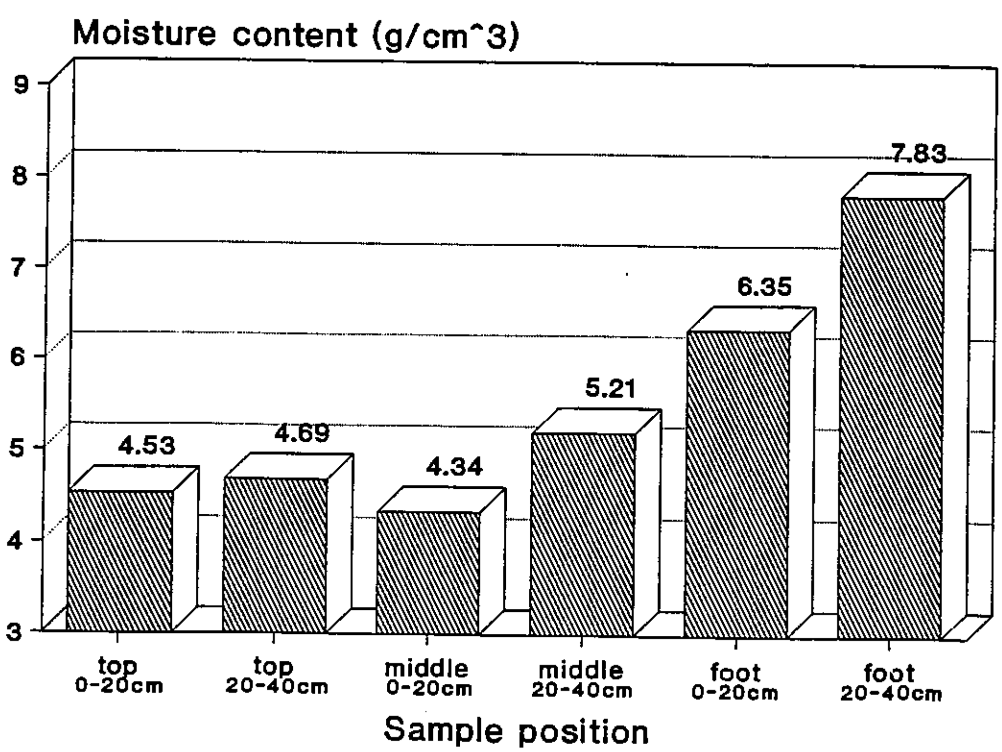

Figure 3. Moisture content of coal waste

tration into the pile. All the values of coefficient of variation were larger than 0.42, which revealed the piles had larger variability in moisture content.

Field capacity

In the piles, three random samples were tested for field capacity. The results were 7.16%, 11.32% and 8.28%, mean value is 8.92%. Comparing with loess which had the field capacity of 20.4%, the field capacity of coal wastes was only 1/2 to 1/3 as much as that of loess. Some treatments for improving the structure of the coal wastes such as accelerating the weathering or covering with loess are needed for revegetation of the piles.

Infiltration

The infiltrated amount of natural rain and irrigation water in soil depends on the infiltrability of soils (Liu and Lu 1990). Random eight infiltration tests were done on the pile. The infiltration patterns were all linear with 95% confidence level and more than 0.99 of correlation coefficient as follow:

$$I = a \cdot t + b \quad (1)$$

where, I = cumulative infiltration, (mm)
t = time, (hour)
a,b = constants

The pattern is much different from agricultural soils. The 8 infiltration rates were: 131.9mm/h, 227.3mm/h, 144.9mm/h, 284.2mm/h, 434.5mm/h, 234.4mm/h, 126.4mm/h and 284.4mm/h respectively. Obviously, they were all in the "rapid" or "very rapid" class (Hossner 1988). Thus, the leaching and percolation might be severe and the moisture and nutrients are easy to leach. According to the feature, sprinking irrigation is needed for the revegetation of coal wastes pile.

Acidity and alkalinity

The pH value of the surface (0-10cm depth) ranged from 6.28 to 8.05, which allows plant growth. But, the pH value in the depth of 10~30cm gave two different results: the 66.7% of all samples were similar to surface (neutrality or slight alkalinity) and the rest (33.3%) are strong acidity. Therefore, although the plants grew well on the pile so far, attention should be paid to potential acidity.

Nutrient of coal wastes

The comparison of nutrients between coal wastes and loess are listed in table 5. The results showed that: (1) the contents of phosphorous and potassium in the coal wastes were similar to loess, which were all deficiency; (2) the organic matter including coal fragments and total nitrogen of coal wastes were abundant, which were 20 and 5.7 times as much as that of loess respectively; (3) the content of rapidly available nitrogen of coal wastes was higher than that of loess, but they were all deficiency. Result shows that rapidly available nutrients in loess were deficiency, but the potential nutrients might not be deficiency in the coal wastes pile. Therefore, some treatments such as increasing moisture content of coal wastes and inoculating with microorganism may produce more available nutrients for plants. Meanwhile, some fertilizers of P and K are needed.

Table 5. Comparison of nutrients between coal wastes and loess

sample	total N (%)	total P (%)	rapidly available nutrients N (ppm)	P (ppm)	K (ppm)	O.M. (%)
loess	0.046	0.090	27	3.7	95.0	0.567
coal waste	0.216	0.080	42	3.1	97.4	11.35

Conclusion

Follow conclusions can be summarized:

(1). The coal waste piles had massive structure and a weathering layer of 5-10cm thickness. The particle size was large (more than 80% were stone and gravel). There were many discontinuous holes in the pile. And it had large bulk density and high ground temperature. The capacity of holding moisture and fertility was lower. Aeration was good and the roots of growing plants could penetrate into the depths of the pile through the large pores.

(2). The coal waste piles had low moisture content and field capacity, and very rapid infiltration. Therefore, irrigation is the key for revegetation on the pile, and the sprinking irrigation are necessary. Furthermore, if gradient terrace is used and some loess is filled in tree pits, the capacity of holding moisture could be increased and the plant in the pile can grow very well.

(3). Generally, the degree of acidity and alkalinity of the coal waste piles were suitable for plant growth, but potential acidity problems exist.

(4). The rapidly available nutrients of coal wastes were deficiency, but the potential nutrients might not be deficiency. Therefore, the treatments for turning nutrients from potential to rapidly available are necessary and some fertilizers of P and K are needed.

The coal waste piles had many special properties. It had not only some restrict factors for plants, but also some suitable factors. As long as some necessary improvements such as recondition of coal waste piles, plant establishment with irrigation, and so on are used, the revegetation of coal waste piles has some success potential. The 47 species of survival plants on the piles, such as locust, weeping willow, elm, pagoda tree, oriental arbovitae, Chinese juniper, Chinese ash, lilac, false indigo, etc., reflect this potential.

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