Spatial-temporal Variation of Reclaimed Soils Filled with Fly Ash [1]

Zhenqi Hu[2] Yinli Bi, Jitao Si, Xuelin Xu, Xianfeng Yue and Bo Zhang

Abstract. Reclaiming subsided land with fly ash is an effective reclamation method in China. The paper studied spatial-temporal variation of the reclaimed soil filled with fly ash. Reclaimed soil samples were collected from Anhui Province. This research was conducted on four different reclaimed lands with different reclamation years (1, 4, 8 and 12 years) for their temporal variation. Samples from different profiles were chosen for their spatial variation analysis. The results indicated the significant difference of physical and chemical properties between reclaimed soil and normal soil. Water infiltration of reclaimed soil was lower than that of normal soil, but their water infiltration increased with reclamation years. Bulk density of reclaimed soil was higher than that of farmland, but it was improved with time. The 12-year-old reclaimed soil had the most similar value of bulk density to normal soil. It was helpful to plant growth. The pH of reclaimed soil was higher than normal soil because of fly ash. The pH value of reclaimed soil was decreased after 12 years. The topsoil's OM contents were increased with reclamation years. The total N and Olsen-P contents of reclaimed soil were lower than those of normal soil, but total N and Olsen-P and available K contents of topsoil were increased in the 12-year-old reclamation land. The results showed that soil properties had been improved with time. Properties of topsoil were much sensitive than that of subsoil. The physical and chemical properties of reclaimed soil were worse than that of normal soil. They need a long time to adjust soil fertility for similar to normal soil and application of some suitable fertilizers is needed in reclaimed soil.

Additional Key Words: reclaimed soil, fly ash, physical and chemical properties

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Introduction

Coal is the most attractive energy resource in China, accounting for approximately 75% of consumption. Underground mines in China excavate more than 96% of coal output. With the excavation of coal from underground, the severe land subsidence is often resulted, which always causes huge losses of cultivatable lands. According to statistic, the area of subsiding and subsided land from coal mining totals more than 400,000 hectares with a increase of 22,000 hectares each year (Hu 1998). It is well known that China has a very large population and the cultivatable land shortage is very serious. The mean of cultivatable and permanent farmland per person in China only equals about one-third of the average value in the world. This situation makes the reclamation of subsidence land become an urgent task for our Country.

Filling subsidence land with some filling materials such as coal wastes and fly ash is a practical method for reclaiming subsided land in China. In China, 83.7% of Electrical power is come from coal-fire power station (1999 national statistic data from the Internet). Thus a large amount of fly ash is produced by coal-fire power station. Using fly ash as filling materials into the subsided area is good reclamation method, which could make use of wastes, restore the disturbed lands and reduce land losses due to all kinds of waste piles, and the environmental pollution could also be eliminated. This method has been applied to some subsided sites such as Huaibei (Anhui province), Yanzhou and Xingwen (Shangdong province), Pingdingshan (Henan province), Xuzhou (Jiangsu province) for more than 20 years.

The general procedures of reclaiming subsided land with fly ash are: (1) removing the topsoil from the subsidence lands for forming a circle bank, which results a large pit called ash stockyard; (2) filling the ash stockyard with the coal ash by use of hydraulic transportation; (3) draining the water and settling the coal ash; (4) replacing the topsoil (0.2m-0.5m) on the coal ash.

Fly ash is not real soil. SiO_2 and Al_2O_3 are key chemical components of the fly ash. They occupy about 83.85 percent. Fe_2O_3 and CaO occupy 7.2 percent, and MgO and TiO_2 only 1.86 percent. Whether could the reclaimed soil with fly ash be suitable for farming? What are the

characteristics of the soil? This paper tries to answer these questions.

Material and Method

Experimental site was located in Huaibei city, Anhui province. Most area of Huaibei city is plain. Average temperature of years is 14.5° C and the elevation is ranging 24m~34m. The annual rainfall is 500~900mm. Evaporation is 1800~1900mm. Local climate is suitable for farming. Major crops are wheat, corn, rice and soybean. The average farmland is 0.0667 ha. per person.

Huaibei city is rich of coal resources. The Huaibei Coal field is 9,600 m^2. The proven recoverable reserves reach 2.726×10^{10} tons of coal with three to seven coal seams. So far, 34 mines have been established, among which 15 mines are state owned and 19 mines are local owned. The annual output of coal surpasses 2.1×10^7 tons. The total output of coal has come to about 3.8×10^8 tons since 1958 when the mine began its operation. A large area of land is subsided due to coal mining. So far, more than 13,333.3 ha land have subsided and has increased at the speed of 533 ha. per year. Therefore, subsidence land reclamation in Huaibei is extremely important.

Experiment site was in Renwei village of Huaibei city, east of Huaibei, where Xiangcheng mine and Zhuzhuang mine operated. The subsided land was filled with fly ash can covered with about 30 cm soil in different years. We choose four plots with 1, 4, 8 and 12 year's old respectively for soil sampling (i.e.: plot 1 – reclamation after 1 year, plot 2 – reclamation after 4 years, plot 3 – reclamation after 8 years, plot 4 – reclamation after 12 years). Since topsoil was about 30 cm and the thickness of topsoil was not exactly same, thus sampling depths were 0~20 cm (soil), 20~30 cm (soil), 30~40 cm (fly ash), 40~60 cm (fly ash) and 60~80 cm (fly ash) (see Fig. 1, the sampling position in the soil profile). Major tested soil properties were soil bulk density, infiltration rate, soil water content, pH, and content of OM, N, P and K.

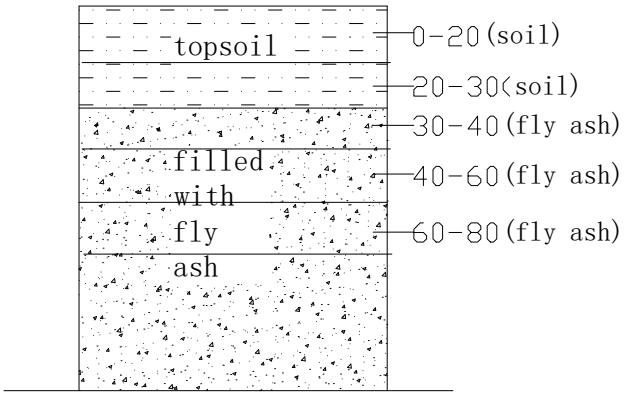

Figure 1. Soil sampling position in the profile.

Results and Discussions

Soil bulk density

Table 1 listed the results of average soil bulk density in different depths. Fly ash had lower bulk density than cover soil, although fly ash was filled in the deep of the subsided land and underlined the topsoil. The newly reclaimed land had compaction problem, which had the largest values of bulk density. Exception of plot 4, the depth of 20~30 cm had slight larger bulk density than the topsoil. Comparing different plots, inspection of the data it is obvious that the bulk density was improved with time. When the reclamation after 8 or 10 years, the soil

Table 1 Average soil bulk density (g/cm^3)

Depth (cm)	plot 1	plot 2	plot 3	plot 4
0~20 (soil)	1.55	1.44	1.38	1.39
20~30 (soil)	1.61	1.48	1.43	1.38
30~40(fly ash)		0.85	0.91	0.89
40~60 (fly ash)		0.84	0.92	0.90
60~80(fly ash)		0.84	0.89	0.90

Note: plot 1 --- reclamation after 1 year, plot 2--- reclamation after 4 years
plot 3 --- reclamation after 8 years plot 4 --- reclamation after 12 years

conditions may reach the normal soil condition. But, the bulk densities of fly ash in different depths and different plots showed the steady state, which could not be changed with time.

Soil moisture content

The soil moisture content is the important factor affecting the plant growth. Numerous other soil properties depend very strongly upon moisture content (Hillel 1982). Table 2 listed the soil water contents in different plots and different depths. Since there was rainfall five days ago before sampling, tested soil moisture contents were high. The results showed that fly ash had much higher moisture contents than soil, which was mainly because of the rainfall. But it also indicated that fly ash might be able to holding some water. The soil moisture contents were increased with time, which showed that soil physical condition was improved with time.

Table 2 Soil moisture contents (%)

Depth (cm)	plot 1	plot 2	plot 3	plot 4
0~20 (soil)	16	21	27	29
20~30 (soil)	20	26	27	28
30~40(fly ash)		58	58	53
40~60 (fly ash)		59	54	56
60~80(fly ash)		56	51	56

Infiltration

As the reclaimed soil had high moisture content and clay content, the infiltration should be lower than that of farmland. The tested results (see Fig. 2) by single ring method revealed that the infiltration rate of the farmland was larger than that of reclaimed soil. Infiltration rates in plot 2, plot 3 and plot 4 were 0.11 mm/min, 0.15 mm/min and 0.25 mm/min, respectively, which showed that the properties of infiltration were improved with time. The reclaimed soils with 4 and 8 years' old had much lower infiltration than that of farmland. The newly reclaimed soil usually had the slowest infiltration, which might lead to the severe erosion and nutrient losses in the reclaimed soil.

pH value.

Fig. 3 listed all pH values in different plots. All reclaimed soil were alkaline. Their pH values were within 8.16~9.2, which showed that the pH did not change with time. Thus some treatments for modifying the pH should be taken for good harvest.

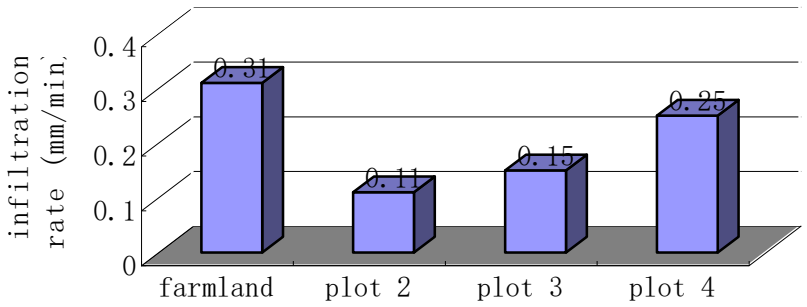

Figure 2. Infiltration rate in reclaimed soils

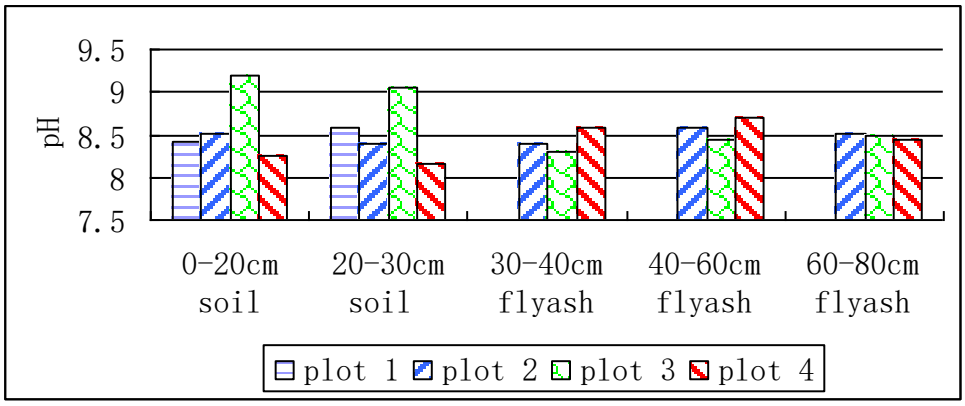

Figure 3. pH values in different plots

Organic matter content

The Organic Matter (OM) is one of the important fertility factors. Farmland in Huaibei usually has 1.2~2.0 % organic matter. The results (see Fig. 4) proved that the newly reclaimed soil had much lower organic matter content than farmland. And the OM content were increased with time 12-year old soil (plot 4) had similar OM content of farmland. Usually, the upper layer (0-20 cm) of farmland soil has a higher OM content than the underlying layer (20-30 cm), which is a typical characteristic of agricultural soils. But in the reclaimed soil the upper layer (0-20cm) had similar OM content to the underlying layer (20-30cm), and sometimes the upper

layer had a lower OM content than the underlying layer. The tremendous difference in the vertical distribution of OM content revealed that the reclamation method led to the mixture of original soil layers, and sometimes the original underlying layer was covered cver the original upper layer. Therefore, soil amendments are needed.

Total N

The total N content in normal farmland is usually ranging from 0.05~0.3 %. If soil has lower total N content than 0.05%, then the soil is deficient in nitrogen. Exception of 8-year old soil in 0-20 cm layer, all the tested soil in 0-20 cm layer had less than 0.05 % of total N contents (see Fig. 5). Thus, the reclaimed soil with fly ash was deficient in nitrogen. However, the total N content had a tendency to increase with reclaiming time.

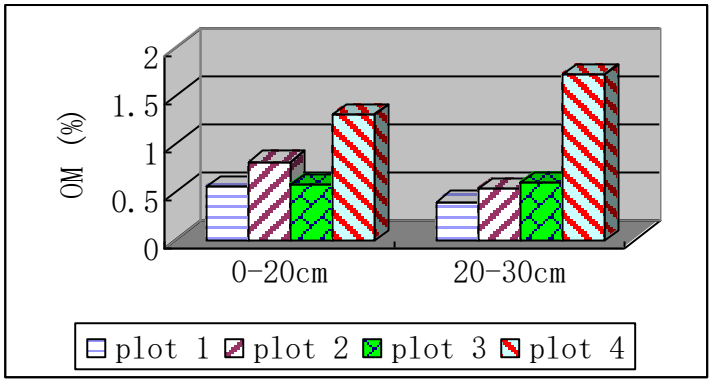

Figure 4. Organic matter contents in reclaimed soils

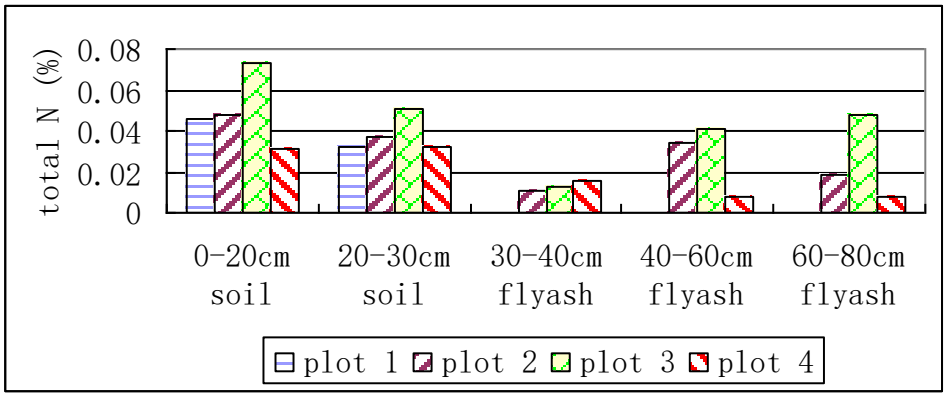

Figure 5. Total N in reclaimed soils

Olsen P

Olsen phosphorus is important for plant growth. It is reported that the classification of Olsen P is classified as being low when less than 5ppm, middle when 5-10ppm, and is considered as being high if larger than 10ppm. Test results (see Fig. 6) show that newly reclaimed soil had the least Olsen P content, which was in low level. The Olsen P content in 8-year-old and 12-year-old soils was higher than the other reclaimed lands and were in the middle level. It also showed that soil condition had improved with time. After having been reclaimed for 12 years, some phosphorus had accumulated in the soil, which raised the reclaimed-soil to a higher lever of phosphorus. It indicated that phosphorus is not a limited factor for plant growth after reclaiming 8 years.

Plant available K

The content of readily available K to plants in China is usually ranging 40-200 ppm (Zhu 1992). The tested results in reclaimed soil were 80-200 ppm (see Fig. 7), which showed that K was not a restrict factor for plant growth in the reclaimed soil. Test results also show that the content of plant readily available K were increased with time. Soils in 8-year-old and 12-year-old had higher content of plant rapidly available K.

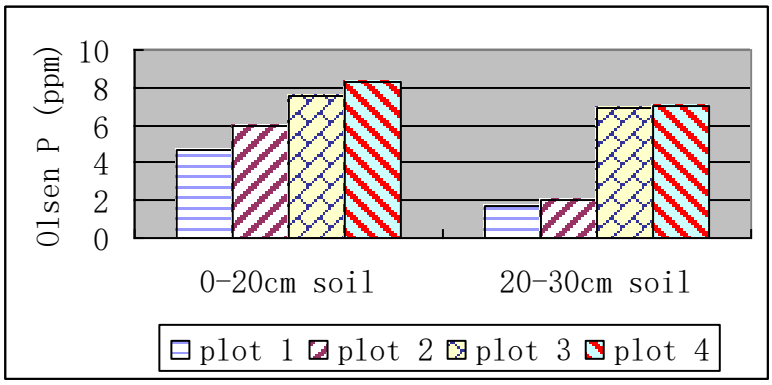

Figure 6. Olsen P in reclaimed soils.

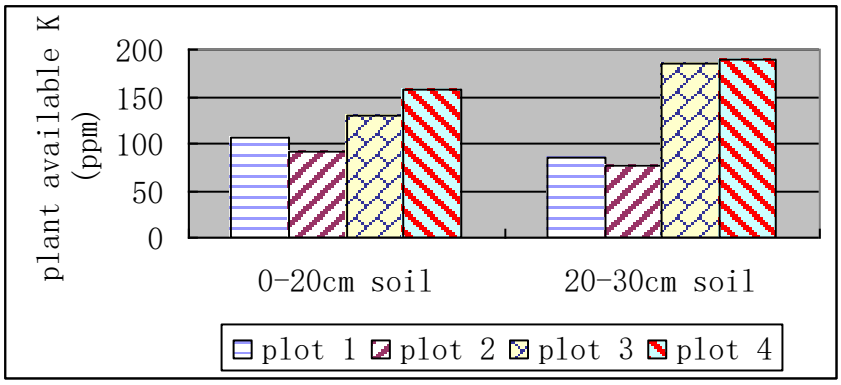

Figure 7. Plant readily available K in reclaimed soils

Conclusions

(1) Reclaiming subsided land with fly ash is a good reclamation method. Due to the poor characteristics of fly ash, soil cover is needed.

(2) Covered soil had higher bulk density and lower soil moisture content than fly ash. Physical properties of fly ash were in steady state, which were not changed with time. Soil physical properties were improved with time tremendously. The 12-year-old reclaimed soil had similar physical properties to farmland.

(3) Reclaimed soil and fly ash had high pH values (over 8), which did not change with time. Thus some treatments are needed for adjusting pH.

(4) Newly reclaimed soil had lowest contents of OM and N, P, K, which showed the deficient of nutrients. Total N content did not change with time obviously. But OM, Olsen P and plant readily available K were improved with time. The reclaimed soil with 12-year-old had similar contents of OM and readily available K to farmland and middle level of Olsen P, which showed that soil fertility of reclaimed soil could be improved to similar level of normal soil after reclaimed 12 years

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