Analysis of the Engineering Restoration Effect of Abandoned Yongledian Quarry in Beijing City Based on Soil Physical and Chemical Properties

Liwei CAI *

Administrative Office of Beijing Tongzhou Xihaizi Park, Beijing 101100, China

Abstract The improvement of the soil physical and chemical properties is the most important foundation for mine ecological restoration. The experiment is aimed at undisturbed area, restored area, and damaged area of abandoned Yongledian Quarry in Beijing. Through determination and analysis of soil physical and chemical properties, it shows that there are significant differences in the composite effects of soil physical and chemical properties between restored area, and undisturbed area, damaged area, and engineering restoration effectively improves the composite effects of soil physical and chemical properties in the restored area. The single factor hypothesis test shows that soil pH value, organic matter, alkali - hydrolyzable nitrogen, and total nitrogen traits are the key targets to be restored in this mining area.

Key words Abandoned mining area, Yongledian Quarry, Soil physical and chemical properties, Single factor hypothesis test

Development and utilization of mineral resources have greatly promoted the rapid economic development and urban construction in China, and have long become a strong economic growth point for governments at all levels[1]. However, the irrational exploitation and utilization result in substantial waste of resources, and seriously damage the local ecological environment. In winter and spring, there is often the dust and sand weather; in summer and fall, the bare vegetation and soil damage aggravate the soil erosion, easily leading to landslide and other natural geological disasters[2].

With the rapid growth of China's economy, the ecological awareness of society continues to be enhanced, and people increasingly understand the enormous disaster arising from the irrational exploitation of mineral resources to ecological environment[3]. The goal of building a "world city" has posed higher requirements on Beijing's ecological restoration and construction work. Therefore, in order to effectively improve the ecological environment of Beijing, speed up the pace of ecological system building in Beijing and promote the coordinated development of economy and environment, Beijing City has carried out ecological restoration and comprehensive control on the abandoned mining area in Beijing[4].

The abandoned mining area types in Beijing mainly include coal mines, metal ores, limestone mines, sand pit and quarry, which are 10 districts and counties in the suburbs of Beijing. During the period 2007 - 2010, the Beijing municipal government invested heavily in the engineering restoration of 76400 mu of abandoned mining area in Beijing, and used blasting method to restore 40000 mu of vegetation; the total area of planned vegetation restoration reached 116400 mu[5].

There are mainly two methods for the ecological restoration in Beijing's abandoned mining area[5]: one is to shut down the mining area and use natural forces to carry out ecological restoration of the mining area, which will take a long time; the other is to adopt engineering means to implement artificial ecological restoration of the mining area, which will need huge investments.

Soil is the mixture of minerals, organic matter, gases, liquids and a myriad of micro - and macro - organisms that can support plant life. It is a natural body that exists as part of the pedosphere and it performs four important functions: it is a medium for plant growth; it is a means of water storage, supply and purification; it is a modifier of the atmosphere; and it is a habitat for organisms that take part in decomposition and creation of a habitat for other organisms.

It is the product under the combined action of climate, parent material, vegetation, topography and time[6]. The natural changes in the soil traits are slow, and the natural restoration requires a particularly long time[7]. The engineering restoration means are used to improve the soil physical and chemical properties, which can effectively achieve the restoration effect[8].

For the ecological restoration in the mining area, the improvement of soil physical and chemical properties is the most important basis for the ecological restoration in the mining area. Only when the soil physical and chemical properties are comprehensively improved and restored, can the ecological restoration in the mining area be comprehensively improved.

This experiment determines and analyzes the physical and chemical properties of soil in the undisturbed area, restored area and damaged area in Yongledian abandoned quarry. Through the analysis of the composite effects of soil physical and chemical properties, we study the differences in the composite effects of soil physical and chemical properties between restored area, and un-

Received: January 20, 2014 Accepted: March 31, 2014

* Corresponding author. E-mail: yg - 07@126.com

disturbed area, damaged area.

Through the single factor hypothesis test, we find the bottlenecks limiting the soil physical and chemical properties in the restored area, and propose the key restoration targets, in order to provide a theoretical basis for the artificial restoration in Beijing's abandoned mining area.

1 Materials and methods

1.1 Overview of the study area Yongledian quarry (115°56′49.03″N, 39°49′51.93″E) is located in Tongzhou District of Beijing. The total area is about 42 hectares, and it has a temperate continental monsoon climate, which is characterized by cold, dry and windy winters but hot and rainy summers.

The average temperature is about 11 ℃. The town's average annual rainfall is 613mm, mostly concentrated in June – September. It is often in the form of heavy rain. The main wind direction in the whole year is mainly the northwest wind and north wind, with the annual average wind speed of 2.7m/s.

This experiment studies the undisturbed area, restored area and damaged area in Yongledian quarry of Tongzhou. The undisturbed area refers to the unspoiled natural area; the restored area refers to the area recovered through artificial engineering; the damaged area refers to the area subject to strong artificial interference.

The restored area mainly uses external-soil for the slope surface cleaning and uses seedlings for afforestation. After the leveling of spoil slope, eco-friendly bag protection technology is adopted for slope protection and vegetation restoration.

1.2 Selection of the standard plot Three representative sample plots are selected from undisturbed area, restored area and damaged area, respectively, and 20m × 20m standard plot is set.

Sampling lasts for two years, and sampling is concentrated in May and October, a total of four times. Three sampling points are selected from each area each time, and the values are analyzed and averaged.

1.3 Measurement and analysis of soil physical properties In different areas, 0 – 20cm surface soil samples are selected, and the soil samples are brought back to the laboratory for the measurement of soil water content, field water capacity, density, alkali – hydrolyzable nitrogen, available phosphorus, available potassium, total nitrogen, total phosphorus and total potassium.

The measurement method is based on the national standards and industry standards. Excel 2003 and SPSS data analysis software are used for analysis.

2 Results and analysis

2.1 Variance analysis of soil physical and chemical properties The site conditions of the quarry determine the plentiful gravel contained in the soil before and after shutting down. Table 1 shows that although the gravel content in the restored area is significantly reduced, the gravel content is still high.

Compared with the damaged area, the content of particle and sand grain is significantly improved. Compared with the undisturbed area, the content of gravel is 9.11% more while the content of particle is 10.36% less, indicating that the soil structure of the restored area still needs to be improved.

Table 1 Analysis of the soil texture in Yongledian quarry (international system)

Areas	Gravel//% (>2 mm)	Sand grain//% (0.02 – 2 mm)	Particle//% (0.002 – 0.02 mm)	Clay//% (<0.002 mm)	Soil texture
Undisturbed area	10.98	47.92	41.05	0.03	Heavy stony soil
Restored area	20.09	49.21	30.69	0.01	Heavy stony soil
Damaged area	39.68	36.52	23.79	0.00	Heavy stony sandy soil

As can be seen from Table 2, we can get the following results:

(i) Soil water content. There is extremely significant difference in the soil water content between restored area and damaged area, but there is no significant difference in the soil water content between restored area and undisturbed area.

In terms of the annual average soil water content, restored area is 3.85% higher than damaged area, and there is a difference of 2.17% between restored area and undisturbed area, which is directly related to the reduced gravel content and increased sand grain and particle.

(ii) Soil field water capacity. There is significant difference in the soil field water capacity between restored area and damaged area, but there is no significant difference in the soil field water capacity between restored area and undisturbed area.

The soil field water capacity of restored area is 10.84% higher than that of damaged area, indicating that the soil field water capacity is significantly improved.

(iii) Soil density. There is not significant difference in the soil density between restored area and damaged area, between restored area and undisturbed area.

The soil density of restored area declines to 1.22, but there is still a gap between the soil density of restored area and the soil density of undisturbed area (1.06), so it is necessary to further improve the soil structure, and reduce soil density.

(iv) Soil pH value. There is significant difference in the soil pH value between restored area and undisturbed area, while there is no significant difference in the soil pH value between restored area and damaged area, but this difference is not indicative of improvement.

The soil pH value of restored area is slightly higher than that of undisturbed area, and the alkality is slightly strong, but the pH value falls within the scope of normal growth of plants.

(v) Soil organic matter content. There is significant difference in the soil organic matter content between restored area and undisturbed area, but there is no significant difference in the soil

organic matter content between restored area and damaged area, indicating that the soil organic matter content of restored area is not significantly improved.

The soil organic matter content of restored area is improved unobviously, and there is a large difference in the soil organic matter content between restored area and undisturbed area. Soil organic matter is the material basis of soil fertility, and the important source of nutrition for plants, having a great impact on the soil physical, chemical and biological properties.

Table 2 The significance variance analysis of soil physical and chemical properties of Yongledian quarry

	Treatment	Mean	Standard deviation	Standard error	95% confidence interval		5% significance level	1% extreme significance level
					Lower limit	Upper limit		
Water content //g/g	Undisturbed area	0.153 8	0.007 6	0.003 1	0.069 6	0.085 5	a	A
	Restored area	0.132 1	0.009 2	0.003 8	0.076 7	0.096 0	a	A
	Damaged area	0.093 6	0.015 8	0.006 4	0.043 3	0.076 4	b	B
Field water capacity//g/g	Undisturbed area	0.295 0	0.041 8	0.017 0	0.146 3	0.233 9	a	A
	Restored area	0.285 1	0.035 0	0.014 3	0.184 3	0.257 8	a	A
	Damaged area	0.176 7	0.006 8	0.002 8	0.169 1	0.183 3	b	B
Density //g/cm^3	Undisturbed area	1.06	0.086 4	0.035 3	1.476 7	1.658 1	b	B
	Restored area	1.22	0.083 3	0.034 0	1.069 5	1.644 2	ab	AB
	Damaged area	1.55	0.049 0	0.020 0	1.616 7	1.719 6	a	A
pH	Undisturbed area	7.82	0.049 2	0.020 1	7.965 9	8.069 1	b	B
	Restored area	8.37	0.098 7	0.040 3	8.313 1	8.520 2	a	A
	Damaged area	8.38	0.064 0	0.026 1	7.934 5	8.068 8	a	A
Organic matter //mg/kg	Undisturbed area	21.4	1.871 4	0.764	7.7193	11.6472	a	A
	Restored area	12.65	5.775 3	2.357 8	9.400 9	21.522 6	b	B
	Damaged area	9.84	0.386 8	0.157 9	8.416 9	11.228 7	b	B
Alkali – hydrolyzable	Undisturbed area	29.05	17.662 8	7.210 8	41.486 0	78.558 0	a	A
nitrogen //mg/kg	Restored area	29.54	2.701 6	1.1029	23.310 8	28.981 1	a	A
	Damaged area	14.64	3.217 1	1.313 4	12.539 7	19.292 0	b	B
Available phosphorus//mg/kg	Undisturbed area	6.02	5.381 4	1.196 9	2.887	14.181 9	b	B
	Restored area	9.62	3.452 3	3.409 4	5.889 2	11.135	a	A
	Damaged area	5.14	2.504 5	1.022 5	2.686 9	7.943 5	b	B
Available potassium//mg/kg	Undisturbed area	152.59	31.206 6	12.740 0	90.562 7	186.061 3	a	A
	Restored area	69.67	24.643 9	10.060 8	48.729 9	90.454 1	b	B
	Damaged area	29.27	4.088 4	1.669 1	33.201 4	41.782 5	c	C
Total nitrogen//g/kg	Undisturbed area	0.23	0.041 5	0.016 9	0.094	0.2811	a	A
	Restored area	0.26	0.072 3	0.029 5	0.199 8	0.351 4	a	A
	Damaged area	0.17	0.063 9	0.026 1	0.094 6	0.228 6	b	B
Total phosphorus//g/kg	Undisturbed area	1.58	0.550 9	0.224 9	0.837 5	1.993 8	a	A
	Restored area	1.44	0.356 7	0.145 6	1.0875	1.936 1	a	A
	Damaged area	1.02	0.023 1	0.009 5	0.8275	1.376 1	b	B
Total potassium//g/kg	Undisturbed area	5.11	1.184 6	0.483 6	4.791 3	7.277 7	a	A
	Restored area	5.35	0.934 0	0.381 3	5.116 6	7.076 8	a	A
	Damaged area	3.90	0.650 9	0.265 7	3.272 3	4.638 4	b	B

It is an important indicator for assessing the level of soil fertility. The improvement of soil organic matter content is the next key goal.

(vi) Soil alkali – hydrolyzable nitrogen. There is significant difference in the alkali – hydrolyzable nitrogen content between restored area and damaged area, but there is no significant difference in the alkali – hydrolyzable nitrogen content between restored area and undisturbed area.

The soil alkali – hydrolyzable nitrogen content of restored area is not significantly improved. The alkali – hydrolyzable nitrogen basically represents the level of nitrogen in soil that can be directly absorbed and utilized by the plant, and plays an important role in the plant growth.

(vii) Soil available phosphorus. There is significant difference in the soil available phosphorus between restored area and undisturbed area, between restored area and damaged area. The soil available phosphorus content of restored area is significantly improved.

The available phosphorus content of restored area exceeds that of undisturbed area, and the possible reasons for this are as follows: first, the available phosphorus content of undisturbed area is low in itself; second, in the soil of restored area, there is high level of available phosphorus.

(viii) Soil available potassium. There is extremely significant difference in the soil available potassium between restored area and undisturbed area, between restored area and damaged area, indicating that the soil available potassium content of restored area is significantly improved, and it is still necessary to continue

to be improved.

(ix) Soil total nitrogen. There is significant difference in the soil total nitrogen between restored area and damaged area, but there is no significant difference in the soil total nitrogen between restored area and undisturbed area, indicating that the soil total nitrogen content of restored area is significantly improved.

(x) Soil total phosphorus. There is significant difference in the soil total phosphorus between restored area and damaged area, but there is no significant difference in the soil total phosphorus between restored area and undisturbed area.

The soil total phosphorus content of restored area is significantly improved, mainly because of high total phosphorus content of soil in itself.

(xi) Soil total potassium. There is extremely significant difference in the soil total potassium between restored area and damaged area, but there is no significant difference in the soil total potassium between restored area and undisturbed area.

The soil total potassium content of restored area is significantly improved. The soil total potassium content of restored area is higher than that of undisturbed area, mainly because of high total potassium content of soil in itself.

The physical and chemical properties of the soil are essential for plant growth. Only when the physical and chemical properties of the soil are effectively improved, can the plants thrive, vegetation coverage improve, plant communities be gradually built, species diversity be improved, and abandoned quarry's ecological environment be restored, thereby ultimately achieving the purpose of ecological restoration.

2.2 Composite effects analysis of soil physical and chemical properties After the engineering restoration, the soil physical and chemical properties in the restored area of Yongledian quarry are greatly improved, but there are differences in the degree of restoration between the indicators, and we can not see the composite effects of soil physical and chemical properties.

Through the significant multivariate variance analysis of undisturbed area – restored area and restored area – damaged area paired data in Tongzhou quarry, it is found that:

Table 3 Significant multivariate variance analysis of paired data of soil physical and chemical properties in Yongledian quarry

	Undisturbed area-restored area	Restored area-damaged area
T^2 statistic	303 964.809 2	1 122 079.930 3
F statistic	2 512.105 9	9 273.387 9
P value	0.015 56	0.008 10

(i) As can be seen from Table 3, through the significant multivariate variance analysis of paired data of undisturbed area and restored area, it is found that $0.05 > p = 0.01556 > 0.01$, indicating that there are significant differences in the composite effects of soil physical and chemical properties between undisturbed area and restored area.

(ii) Through the significant multivariate variance analysis of paired data of damaged area and restored area, it is found that $p = 0.00810 < 0.01$, indicating that there are extremely significant differences in the composite effects of soil physical and chemical properties between damaged area and restored area.

2.3 Single factor hypothesis test of soil physical and chemical properties There are significant differences in the composite effects of soil physical and chemical properties between restored area and undisturbed area, between restored area and damaged area. The source of these differences can be found by the single factor hypothesis test of soil physical and chemical indicators.

Table 4 The mean ± standard deviation of various factors and single factor hypothesis test

Factors	Undisturbed area-restored area			Restored area-damaged area		
	Undisturbed area	Restored area	*P* value	Undisturbed area	Restored area	*P* value
Water content//g/g	0.15 ± 0.01	0.13 ± 0.01	0.1017	0.13 ± 0.01	0.09 ± 0.02	0.0052
Field water capacity//g/g	0.30 ± 0.04	0.29 ± 0.04	0.1948	0.29 ± 0.04	0.18 ± 0.01	0.0116
Density //g/cm^3	1.06 ± 0.09	1.22 ± 0.08	0.8335	1.22 ± 0.08	1.55 ± 0.05	0.0181
pH value	7.82 ± 0.05	8.37 ± 0.10	0.0001	8.37 ± 0.10	8.38 ± 0.06	0.0001
Organic matter//mg/kg	21.4 ± 1.87	12.65 ± 5.78	0.0419	12.65 ± 5.78	9.845 ± 0.39	0.0006
Alkali – hydrolyzable nitrogen//mg/kg	29.05 ± 17.66	29.54 ± 2.70	0.8009	29.54 ± 2.70	14.64 ± 3.22	0.0001
Available phosphorus//mg/kg	6.02 ± 5.38	9.62 ± 3.45	0.7035	9.62 ± 3.45	5.14 ± 2.50	0.0237
Available potassium//mg/kg	152.59 ± 31.21	69.67 ± 24.64	0.0829	69.67 ± 24.64	29.27 ± 4.09	0.0001
Total nitrogen//g/kg	0.23 ± 0.04	0.16 ± 0.07	0.0023	0.16 ± 0.07	0.17 ± 0.06	0.016
Total phosphorus//g/kg	0.58 ± 0.55	1.44 ± 0.36	0.2254	1.44 ± 0.36	1.32 ± 0.02	0.0001
Total potassium//g/kg	5.11 ± 1.18	5.35 ± 0.93	0.9215	5.35 ± 0.93	3.96 ± 0.65	0.001

(i) As can be seen from Table 4, the single factor hypothesis test of undisturbed area and restored area shows that there are no significant differences in 7 traits between undisturbed area and restored area, and $p > 0.05$ [soil water content ($p = 0.101\ 7$), soil field water capacity ($p = 0.1948$), soil density ($p = 0.833\ 5$), soil available phosphorus ($p = 0.7035$), soil available potassium ($p = 0.082\ 9$), soil total phosphorus ($p = 0.225\ 4$) and soil total potassium ($p = 0.9215$)]; there are significant differences in 1 trait between undisturbed area and restored area, and $0.05 > p > 0.01$ [soil organic matter ($p = 0.041\ 9$)]; there are extremely significant differences in 3 traits between undisturbed area and restored area, and $p < 0.01$ [soil pH value ($p = 0.000\ 1$), soil alkali – hydrolyzable nitrogen ($p = 0.000\ 9$) and soil total nitrogen ($p = 0.0023$).

(ii) The single factor hypothesis test of restored area and damaged area shows that there are significant differences in 3 traits between damaged area and restored area, and $0.05 > p > 0.01$ [soil field water capacity ($p = 0.0116$), soil density ($p = 0.0181$), soil available phosphorus ($p = 0.0237$), soil total nitrogen ($p = 0.0160$); there are extremely significant differences in 7 traits between restored area and damaged area, and $p < 0.01$ [soil total phosphorus ($p = 0.0001$), soil total potassium ($p = 0.0010$), soil available potassium ($p = 0.0001$), soil pH value ($p = 0.0001$), soil organic matter ($p = 0.0006$), soil alkali - hydrolyzable nitrogen ($p = 0.0001$) and soil water content ($p = 0.0052$)].

3 Conclusions

(i) There are still significant differences in the composite effects of soil physical and chemical properties between restored area and undisturbed area in Yongledian quarry, and it is necessary to continue to improve.

The traits of soil water content, soil field water capacity, soil density, soil available phosphorus, soil available potassium, soil total phosphorus and soil total potassium are greatly improved; there are still significant differences in soil pH value, soil organic matter, soil alkali - hydrolyzable nitrogen and soil total nitrogen content, and it is also necessary to continue to improve.

(ii) There are significant differences in the composite effects of soil physical and chemical properties between restored area and damaged area in Yongledian quarry, indicating that the engineering restoration means is very effective.

Soil water content, field water capacity, density, pH value, organic matter, alkali - hydrolyzable nitrogen, available phosphorus, available potassium, total nitrogen, total phosphorus and total potassium content are significantly improved.

4 Recommendations

Through the analysis of soil physical and chemical properties, we put forth the following recommendations for the future restoration work in Yongledian quarry:

(i) It is necessary to apply organic fertilizer to enhance soil fertility and improve soil structure. The organic fertilizer contains a lot of organic matter, and it is converted into humus.

The organic matter can improve soil structure and improve the soil texture, soil pore condition and absorbing performance, thereby improving soil fertility while providing the nutrients.

(ii) It is necessary to mix the soil with clay to improve soil structure. The sand grain and particle content is high in the existing soil but the clay is inadequate, so there is a need to add the clay to improve the soil structure.

(iii) It is necessary to plant trees and grass and improve soil fertility. Planting the shrubs and herbaceous plants can help to improve texture and increase fertility of the soil.

Especially the green manure leguminous plants with huge roots, coupled with the humus, can help to improve the soil structure and the ability to retain water and nutrients.

(iv) It is necessary to strengthen the closing work in the quarry to ensure that it is no longer subject to strong human damage and With the increasing ground vegetation and plant communities, eventually the ecological restoration in this region will be closer to that of undisturbed area.

References

[1] Beijing Municipal Bureau of Land and Resources. Suggestions about enhancing management of mineral resources, Jinguotu Mine[2005] 172. (in Chinese).

[2] General Office of Beijing Municipal People's Government. General Office of Beijing Municipal People's Government transpond the notification of impelling comprehensive treatment of mountainous watershed and ecological rehabilitation about closing disused mine spoils[J]. Beijing People's Government Bulletin, 2006(23): 97 - 99. (in Chinese).

[3] GAN J. Status quo and ecological rehabilitation countermeasures of the closed and disused mine spoils in Beijing Mountainous Area[M]. Beijing: China Agriculture Press, 2007: 68 - 74. (in Chinese).

[4] LI JH, ZHANG GZ. Status quo and typical ecological rehabilitation modes of the closed and disused mine spoils in Beijing Mountainous Area[M]. The National Conference on Ecological Restoration of Soil and Water Conservation, 2009: 89 - 100. (in Chinese).

[5] Beijing Municipal Bureau of Forestry and Parks. Planning for revegetation of the closed and disused mine spoils in Beijing (2007 - 2010), 2007.3. (in Chinese).

[6] LIN DY. Edaphology[M]. Beijing: China Forestry Publishing House, 2002: 123 - 128. (in Chinese).

[7] SUN XY. Edaphology[M]. Beijing: China Forestry Publishing House, 2005: 1154 - 157. (in Chinese).

[8] LIU KF. Edaphology[M]. Beijing: China Meteorological Press, 2006: 1154 - 157. (in Chinese).

(From page 88)

[13] Administration of Ocean and Fisheries of Guangdong Province. Guangdong marine environment bulletin, 2012[R]. Guangzhou, 2012. (in Chinese).

[14] CAI ZZ, WANG X, ZHENG SH. Seasonal variation and assessment of water quality in Meizhou Bay[J]. Marine Environmental Science, 2008, 27(2): 161 - 164. (in Chinese).

[15] HU CH, HUANG D, ZHOU WB, *et al*. Study on trophic status and influencing factors of typicallake fringe area in wet season——A case study of Banghu Lake[J]. Journal of Hydroecology, 2013, 34(3): 32 - 38. (in Chinese).

[16] Shindler DW. Evolution of phosphorus limitation in lakes[J]. Science, 1977, 195: 260 - 262.

[17] ZHAO YH, DENG XZ, ZHAN JY, *et al*. Study on current situation and controlling technologies of agricultural non-point source pollution in China [J]. Journal of Anhui Agricultural Sciences, 2010(5): 2548 - 2552. (in Chinese).

[18] HUANG XP, TIAN L, PENG B, *et al*. Environmental pollution in the Pearl River Estuary: A review[J]. Journal of Tropical, 2010, 29(1): 1 - 7.

[19] XIAO R, BAI JH, HUANG LB, *et al*. Distribution and pollution, toxicity and risk assessment of heavy metals in sediments from urban and rural rivers of the Pearl River Delta inSouthern China[J]. Ecotoxicology, 2013, 10.1007/s10646 - 013 - 1142 - 1.

[20] YANG WL, LAI ZN, WEI TL, *et al*. Survey of arsenic content of eight pearl river estuaries in 2006[J]. Guangdong Agricultural Sciences, 2011, 38(3): 144 - 147. (in Chinese).