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STUDY ON LAND QUALITY MONITORING SAMPLING IN OPENCAST COAL MINING AREA - TAKING PINGSHUO OPENCAST MINING AREA AS AN EXAMPLE

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ABSTRACT

Land quality monitoring is one of necessary means to grasp land use in mining area, which could guide land reclamation. In order to obtain the land quality changes, control the workload and improve efficiency in a certain extent, it is required to monitor land quality in mining area. This paper developed a series of principles should be followed, such as representative, controllability, randomness and variability. It selected land pollution, ground slope, effective soil thickness, soil texture, soil bulk density, pH, organic matter, nitrogen, phosphorous and potassium as quality monitoring indicators, and described the choice of monitoring plots and sampling method on profile and hybrid soil. In this paper, Pingshuo opencast coal mine on the Loess Plateau was taken as an example, and 18 plots were selected under different situations. Among the plots, soil sampling was implemented by 10cm intervals. In the end, it is collected a total of 204 copies, including profile and hybrid soil samples. The result showed that the monitoring plots selected could basically cover the land quality situation, including the original, damaged without reclamation, and reclaimed land. The quality indicators could meet the dynamic monitoring requirements of land quality, which helped accumulate experience for the full implementation of land quality monitoring and sampling in the mining area in the future.

KEYWORDS

Monitoring sampling, land quality, reclamation, Pingshuo mining area

1. INTRODUCTION

Establishing a monitoring system for land reclamation for the purpose of grasping the land damage and reclamation situation has become urgent tasks of land management in mining area. Land damage situation is the research basis of the feasibility of land reclamation and the reclamation direction, but also the compilation basis of reclamation technology and prepared funds within the reclamation scheme. The implementation of dynamic monitoring of reclaimed land quality can track changes of quality, which is a way of improving it by remedial measures timely. And the useful experience can be provided through summarizing the specific methods which had improved the quality significantly. Therefore, studying on quality monitoring sampling could lay the foundation to set up a monitoring system for land reclamation in mining area.

Currently involved in land quality monitoring sampling is mainly the soil environment survey and the precision agriculture [1-5]. The former is for geochemical and soil pollution survey, focusing on the monitoring of chemical elements and contaminants in the soil. Based on a study, the latter is aimed at farmland for agriculture production, which is more suitable for small scale land, and sampling points are generally arranged more intensive [6-8]. Study showed soil sampling methods commonly used are generally the classical sampling methods and spatial sampling methods, but these two methods both required a large number of samples and take too much manpower, material resources and time [9-11]. Land in mining area has its own particularity, which means there are 3 stages named original land, destructed land without any reclamation, and reclaimed land respectively. Therefore, how to economically feasible, and to reflect the characteristic of land use and quality changes in mining area as far as possible, is the focus of monitoring sampling study. In this paper, taking Pingshuo mining area as an example to explore the principles and indicators of land quality monitoring, and to explain the method of sampling selection and soil sampling, for the purpose of providing the basis for the investigation and monitoring of land quality in the future.

2. MONITORING SAMPLING PRINCIPLES

2.1 Representation

One of land quality monitoring sample' goals is for evaluating land quality, hence the sampling plots should be able to reflect the land characteristics in mining area. From the perspective of reclamation, it is necessary to soil survey in 3 stages of land use, such as before mining, mining and after mining. So, it need to select the representative land in the mining area and its surrounding environment, in order to reflect actual situation represented by the type of land.

2.2 Controlling

Land use in mining area is complex, and there are also a number of indicators for evaluation of land quality, which means that it is not realistic to survey and sample every land and take all the indicators as the evaluation content. Therefore, in addition to the representation, controlling is another important principle. By controlling the sample plots and evaluation indicators can meet the monitoring need of undamaged land, unreclaimed land and reclaimed land, and also save manpower and time.

2.3 Randomness

Because the sampling results of representation and controlling related to

error, while the number of sample plots depends on the study area, as well as the complexity of object and precision of research zone, sampling points should be randomly distributed in typical plots in order to control the error brought by sampling and reflect the true situation in mining area.

2.4 Variability

Changes of land quality have affected land productivity significantly. Based on a study, land in mining area itself is changeable, so it is no need to monitor if selected sample plots could not be able to reflect the variations of land quality [12].

3. MONITORING INDICATORS

Determination of land quality monitoring indicators is the premise of selecting plots and soil sampling. The selected monitoring indicators should be combined with the actual situation in mining area, which are:

3.1 Land pollution

Coal gangue and fly ash contains part of pollution elements, including Pb, Cr, Mn, Cu, Zn, Cd and other heavy metals during the process of stacking, transport or as filling material. According to a researcher, releasing of pollution elements will pollute the soil and crops, resulting in reclaimed land cannot be used due to environmental issues [13, 14]. Therefore, the first concern is soil contamination in mining area, and the content of heavy metal is listed as control indicators. Only when the environment quality of soil reaches the normal standard, then the specific land use direction could be considered.

3.2 Surface slope

Surface slope is the main factor affecting the spatial variability of fertile, which determines the redistribution of that. According to a research, the influence of surface slope is mainly manifested in soil erosion, capital farmland construction conditions, irrigation conditions, mechanical ploughing [15]. In large opencast mining area, the destructive land generally forms dump by topography remodeling, mainly composed of slope and platform. For the part of slope, it determines the land use direction. Such as in steep slope areas, it is not suitable for agricultural irrigation and mechanization, which means not used as farmland.

3.3 Effective soil thickness

Based on the study, effective soil thickness is referring to the sum of all soil layers and loose materials layers, which are the main limiting factor for plant growth and soil biological activity [16]. In mining area, the soil is reconstructed by filling other soils or rocks, and then vegetations are planted for restoring productivity. There would be barrier layer in the new reconstructed soils due to different heap sequence or other human factors, which will make the effective thickness smaller and affect the normal growth of reclaimed vegetation. Hence, soil effective thickness should be taken as an important factor for monitoring land quality in mining area.

3.4 Texture of soil profile

Soil texture refers to the combination of the state of the soil mineral particles within different size in diameter, and has closely related to nutrient content, water permeability, soil aeration, fertilizer and water conservation, etc. Many things can influence the changes of soil texture, because the dumps are mainly heaped by soil, coal gangue, fly ash and other materials, plus human's management activities and the process of leaching and deposition. So, soil texture is selected as monitoring factor, not only the surface layer, but also other different layers should be taken into account in the soil profile.

3.5 Soil bulk density (BD)

BD is the natural state of the dry soil weight per unit volume. Small BD indicates that the soil is loose, porosity is big, retention capacity of water and nutrient is good, and the maturation of soil is in high degree. The BD in dump is higher than natural soil because of the mechanical compaction during the process of heap before reclamation. When BD is too big, it will affect the condition of air, water and fertilizer in soil, and the thrust of vegetation root, which affect the land quality. Reclamation is the process of soil maturation. According to studies, the BD in longer reclaimed land is closer to that of natural soil [17-19], so it has been taken as an important indicator.

3.6 pH

Based on a research, pH can influence other soil chemical properties and restrict many physical, chemical and biological process, which affects nutrient exchange, movement and migrations [20, 21]. Coal gangue is the first major solid waste in mining area, and its treatment is usually planting vegetation directly or after covering soil. Because of the acid properties of coal gangue itself, vegetation is not suitable to be planted in the beginning of reclamation, which means that some measures should be taken to improve its acidity. Organic matter (OM) and nitrogen (N), phosphorus (P) and potassium (K): The content of OM, N, P and K in soil is an important criterion to evaluate land quality [22, 23]. OM has the ability to improve the soil structure, promote the formation of granular structure, which will help increase the soil loose, improve soil aeration and water permeability, as well as good buffer for acid, alkali and toxic substances, which has the extremely significance to environment protection and sustainable development. Content of N, P and K are the hallmark of soil fertility, which has a direct effect on the normal growth vegetation. They are related to reclamation materials and fertilization, so there is a need for dynamic monitoring to adjust reclamation measures.

It is necessary to classify the above indicators depending on land use. For example, for the reclamation of cultivated land, pollution situation should be as extremely strict controlling indicator with one vote veto, i.e. when the degree of pollution of the reclaimed land is more than permitted by the state standards, the reclamation direction is no longer considered, and to reduce the content of heavy metals in soil in the primary task. Surface slope is taken as strict controlling monitoring indicator, which determines the reclamation direction, i.e. when the slope is too large, the operation of tillage machinery, construction of water conservancy and maintenance of water and soil will be inconvenient, and the reclaimed land will be only suitable for grassland or woodland. Effective soil thickness, texture of soil profile and BD are less strict controlling monitoring indicators, because they are determined the basic site conditions of vegetation growth, among which the first two items are not easy to change. While BD would take a long time to return to the normal status by deep plowing or other measures, so longer time are required for long-term observation. pH, OM, N, P and K are general controlling indicators as assisted projects for land quality dynamic monitoring, because they can be improved by deep plowing, irrigation and fertilization in a short time. In contrast, there are some different requirements for reclaimed woodland and grassland (Table 1)

4. MONITORING SAMPLING METHOD

4.1 Selection of Monitoring Plots

1) *Land use stages*: It contains original, unreclaimed and reclaimed stages. Sampling in the original land is to obtain the background value of local land quality, which could be a reference for destroyed land. Sampling in unreclaimed land is to find out the damage situation and make some appropriate measures. Sampling in reclaimed land is to acquire the land quality after some technology has been applied in order to adjust it or be as a basis for land quality acceptance.

2) *Types of land use*: Current reclamation orientation mainly is arable land, woodland and grassland, so the plots should contain them in the three stages mentioned above. For the unreclaimed stage, dump is selected directly in opencast mining area.

3) *Ground slope*: When the land stage and use have been determined, ground slope need to be considered. For example, original landscape has its ups and downs, while reclaimed land has platform and slope through landscape reconstruction. So, the slope of original land and reclaimed land should be considered.

4) *Sampling time*: The best sampling time in original plots is in summer, and only once. Sampling in un reclaimed plots is applied before reclamation, and also only once. To master the dynamic changes of land quality, sampling can be applied every year in the beginning of reclamation, while several years a time in the middle and late time,

according to the earlier research. The reclamation time is longer, the interval time is longer, and the sampling time is suggested in summer.

4.2 Soil Sampling

Soil profile sampling and mixed sampling are applied at the same time, and some in-situ record should be made.

5) *Profile sampling*: Development of soil can be observed by digging the profile, and the effective soil thickness can be also ascertained. Stratified sampling of soil profile is helpful in getting to know the pollution, texture, BD, pH and others in each layer. Because of the differences of dump materials, heap orders, mechanical crash and reclamation orientation, taking 10 cm as the interval in the range of 0-100 cm. If soil compaction is too server, or there is rock layer mixed with dump materials, the effective soil thickness is determined by the normal dig depth or the layer above rocks.

Table 1: Monitoring indicators of reclaimed land quality.

Monitoring indicators	Unit	Monitoring methods	Monitoring way	Arable land	woodland	Grassland
pollution		AAS	quantitative	Extremely strict control	Strict control	Less strict control
Surface slope		Site investigation	quantitative	Strict control	Strict control	Less strict control
Effective soil thickness	cm	Site investigation	quantitative	Less strict control	Less strict control	Less strict control
Texture of soil profile		Hydrometer method	quantitative + qualitative	Less strict control	Less strict control	Less strict control
BD	mg/cm^3	cutting ring method	quantitative	Less strict control	General control	General control
pH		potentiometry	quantitative	General control	Normal monitoring	Normal monitoring
OM	g/kg	volumetric method	quantitative	General control	Normal monitoring	Normal monitoring
N	mg/kg	Kjeldahl method	quantitative	General control	Normal monitoring	Normal monitoring
P	mg/kg	Mo - Sb Antispetrophotography Method	quantitative	General control	Normal monitoring	Normal monitoring
K	mg/kg	flame photometry	quantitative	General control	Normal monitoring	Normal monitoring

6) *Mixed sampling*: Surface soil affects the growth of vegetation the most, so it is necessary to strengthen the study on the layer within 0-20 cm depth. In the selected plots, mixed sampling should be taken in 0-10 cm and 10-20 cm respectively. Method of mixed sampling can refer cases for investigation and soil pollution, according to the plot size and topography. Plum blossom type setting method is applicable to the field with small size and flat terrain, whose center point is arranged on the two diagonal intersections, and 5 to 10 points are designed. Chessboard sampling method is suitable for the plots with medium size, flat terrain, whose sampling points are above 10. This method is also applicable for pollution plots with more than 20 sampling points. Serpentine layout method is suitable for plots with large area, non-flat terrain, whose sampling points should be more.

7) *In-situ recording*: It is usually the general description of soil sample, which labeled with corresponding classification. Without in-situ recording will result in missing data and a waste of funds. The first thing is locating the plots with GPS positioning, because the disturbance of opencast mining activities on the ground is large, which will cause to the topographical changes a lot in different stages. Record of longitude and latitude is to ensure the continuity of land quality dynamic monitoring in the mining area. Conditions of weather, slope, land use, vegetation and so on should be recorded as well. The most important thing is to make sure the soil sample of every layer in each depth is corresponded with the record.

5. EXAMPLE

5.1 Study Area

Pingshuo mining area is located in the eastern area of loess plateau and the northern of Shanxi Province, E 112°10' 58"-113°37'20", N39°23'-39° 37' and the whole area is 375.12 km2. The landscape of mining area is gentle slope hills and the climate belongs to typical temperate semi-arid continental monsoon climate, with an average annual rainfall is 428.2-449.0 mm, temperature of 4.8-7.8 ℃, ≥ 10℃ annual accumulated temperature is 2200-2500 ℃, frost-free period is about 115-130 days. The zonal soil is chestnut soil and chestnut brown soil and zonal vegetation type is steppe.

5.2 Layout of Monitoring Plots

According to the principles mentioned above, 18 sample plots had been selected in and surrounding Pingshuo mining area in July to August 2012 (Figure 1).

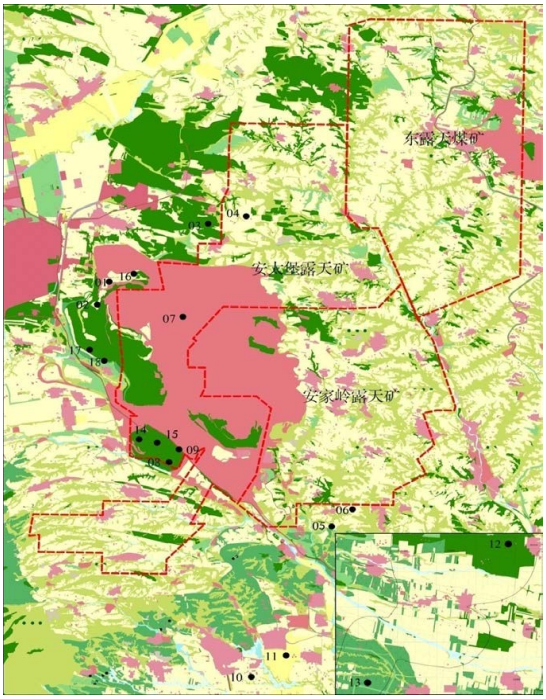

Figure 1: Layout of monitoring plots in Pingshuo mining area.

01-arable land (reclaimed since 1997). 02-grassland (reclaimed since 1994). 03-woodland (original land in hilly zone). 04-arable land (original land in hilly zone). 05-arable land (original land in hilly zone). 06-arable land (original land in hilly zone). 07-dump (unreclaimed). 08-woodland (reclaimed since 1990). 09-grassland (reclaimed since 1998 in slope). 10-arable land (original land in flat zone). 11-arable land (original land in flat zone). 12-woodland (original land in flat zone). 13-grassland (original land in flat zone). 14-woodland (reclaimed since 1994). 15-woodland (reclaimed since 1994). 16-arable land (reclaimed since 2010). 17-woodland (reclaimed since 2000). 18-arable land (reclaimed since 1994).

It can be seen that plots are mainly in the west including original land, reclaimed land and destroyed land without reclamation. As for reclaimed land, plots are selected by reclamation time respectively. For example, three plots of arable land had been selected in accordance with their reclamation time of early (16), middle (01) and late (18). Four plots of woodland had been selected in accordance with their reclamation time of middle and late (08, 14, 15 and 17). The main reason is that the longer the reclamation time, the effect of reclamation is more obvious, which means the improvement could be better reflected through the comparison of reclaimed woodland. Two plots of woodland reclaimed since 1994 had been selected because No. 14 plot was heaped all by soil, while No. 15 plot was heaped by soil and rock. It can achieve the goal of monitoring and give evidence to reclamation mode in the future through focus on the effect of different reclamation materials. Grassland reclaimed had been selected mainly by the evidence of topography, because the slope of dump was usually reclaimed as grassland. As a result, the platform (02) and slope (09) of dump had been selected as monitoring plots respectively. As for original land, topography was mainly considered, and the plots had been selected in flat zone (10-13) and hilly zone (03-06). Dump was not covered by any vegetation, and only the platform of it had been selected as plot because of safety.

Because the soil compaction is server in dump (07), it only dug into 40 cm. No. 16 plot dug into 70cm because of rock layer existing in the profile, while the rest of plots dug to 100 cm. Soil samples had been taken at 10 cm intervals in profile in all the plots. There had been total 204 samples collected in the 18 plots. Based on study, through field sampling and laboratory analysis, the land quality in the region had been assessed, and had achieved satisfactory results [24, 25].

6. CONCLUSION

It was a meaningful exploration of land quality monitoring and sampling in mining area, by filtering the necessary indicators and selecting monitoring plots. In this paper, it had taken Pingshuo mining area located in the Loess Plateau as the research object combined with land use

stages, land use types and topography, which represented monitoring plots with different temporal and spatial variation and described the sampling methods. The methods of selecting monitoring indicators and plots proposed in the research can overcome some current limitation to a certain extent, and improve sampling efficiency, and save cost. Because of the characteristics of dump process, soil samples were taken at 10 cm intervals ranged from 0-100 cm could better interpret the process of soil development during the whole reclamation and play a regulatory role on supervising the overburden thickness. Methods above all had been applied in Pingshuo mining area, but there is still some study being further improved in the future. It hopes to gain more experience in practical work in the future for bring new development in the field of land protection and use.

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