CHINESE GEOGRAPHICAL SCIENCE
Volume 2, Number 2, pp.126–132, 1992
Science Press, Beijing, China

A STUDY ON BUFFERING CAPACITY OF THE FOREST SOIL AGAINST ACIDIC PRECIPITATION IN SEVERAL AREAS OF CHINA

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ABSTRACT: Soil samples from several forest areas in China were analyzed by X–ray powder diffractometry after mineral separation and enrichment. The density gradient separation method with sequential extraction by acetone–methylene iodide mixtures was applied for the separation of fine sand fraction of soil samples. The clay fraction (< 2μm) was separated from silt fraction of soil samples prior to examination. Mineral components in some fine sand and clay samples were compared, and their weathering potentiality and buffering capacity against acidic precipitation were discussed.

KEY WORDS: forest soil, mineral component, acidic precipitation, buffering capacity, weathering potentiality

I. INTRODUCTION

In order to study the buffering action of forest soil against acidic precipitation, it is very important to examine the correlation between mineral component and leaching–weathering process of soil. The acid–neutralizing capacities of various soil components are different, for example, montmorillonite and illite > kaolinite > quartz[1]. Some primary minerals are easily weathered, such as olivine, pyroxene, hornblende, plagioclase, and they are important in the process of soil to buffer acidic precipitation[2]. Therefore, it is necessary to study the mineral components of soil (including primary and clay minerals).

X–ray powder diffractometry (XRPD) is one of the effective methods to examine minerals, but the normal XRPD is not very sensitive. Therefore, in order to satisfy the requirements of XRPD, it is necessary to separate and enrich minerals and to enhance the relative content of each component. The density gradient separation method[3] with sequential extraction by acetone–methylene iodide mixtures was applied for the separation of fine sand fraction of the soil samples in our work. To examine clay minerals exactly, the soil samples were strictly classified and the particle (< 2μm) was enriched.

According to the results of XRPD, we compared the mineral components of fine sand and clay fractions of soils from several forest areas in China. We also discussed the weathering potentialities and buffering capacities of these soils against acidic precipitation.

II. EXPERIMENTS AND RESULTS

1. Sampling

Soils in different horizons were sampled from five forest areas in China: Chongqing, Guiyang, Xian, Hunan, and Hebei. The five areas stand for the forest soils of various natural districts in China. The soils are yellow–red and weak acidic in Hunan, yellow and acidic in Guiyang and Chongqing, yellow and neutral in Xian, drab and neutral in Hebei. The trees grow well in Hunan, Guiyang, Xian, and Hebei, but are declining on Nanshan, Chongqing. There are serious acid rains in Guiyang and Chongqing.

2. Separating Minerals and Preparing Samples for XRPD

After scattering 200 g of soil sample by water, the sand fraction was screened step by step, and the particle–size distribution of the soil sample (% by weight) could be obtained (Table 1).

Fine sand fraction was put into an acetone–methylene iodide mixture with a special density and stirred completely, then the suspension with a lighter density and the mixture were transferred together to another bigger tube. Some acetone was added to the tube to reduce the density of the mixture. The sediment was separated, washed several times by acetone, and dried naturally. The above processes were repeated and mineral particles with densities from < 2.64 g/ cm^3 to > 3.32 g/ cm^3 could be obtained.

Silt was soaked for 24 hours in 1N HCl, then a little 2% NaOH was added. After being put in a ultrasonic cleaner for 30 minutes, the suspension was transferred to another big tube. According to Stockes formula[4], < 2μm particle in the suspension was completely extracted. Some dilute HCl was added to congeal the particle and the solution was discarded by a centrifuge. The particle (< 2μm) and the other fraction (< 2μm) of silt were dried and weighed respectively. The samples obtained from the above processes were removed organic and ferric matters, and were prepared into K^+ –saturated and Mg^{2+} –glycerine–saturated, then three kinds of oriented mounts for XRPD analysis were obtained.

3. XRPD Analysis

The obtained mineral particles with different densities were ground fully and distributed on several glass plates by using absolute alcohol. The plates as well as the three kinds of oriented mounts were analyzed respectively by a Y−2 X−ray diffractometer. The results are listed in Table 2 and Table 3.

Table 1 Particle−size distribution of the soil samples from several areas in China (% by weight)

Area	Horizon	Depth (cm)	Extremely coarse sand, 2−1 mm	Coarse sand 1−0.45 mm	Middle sand 0.45−0.2 mm	Fine sand 0.2−0.105 mm	Power sand 0.105−0.076 mm	Silt 76−2μm	Clay < 2μm
Chongqing	A	0−12	4.5	31.0	37.0	22.0	1.0	4.0	0.1
	B	12−36	3.8	10.4	47.6	23.0	1.7	10.5	2.7
	C	36−55	2.3	17.4	27.0	19.0	0.7	18.0	14.9
Guiyang	A	0−33	19.9	9.9	5.0	3.0	0.1	49.0	12.7
	B1	33−63	11.8	3.4	1.0	1.8	0.2	38.2	43.8
	B2	63−90	6.4	1.6	0.5	1.3	0.4	38.3	51.5
Hunan	A	0−17	2.2	0.5	0.9	3.3	0.4	65.1	27.6
	B1	17−76	4.7	2.3	5.1	4.0	0.3	68.5	15.0
	B2	76−120	6.6	0.8	1.7	1.2	0.8	76.4	12.5
Xian	A	0−5	3.1	1.0	2.4	2.8	0.3	84.6	5.8
	B	5−60	0.1	0.1	0.3	2.7	0.3	52.1	44.5
	C	> 60	0.5	0.4	1.0	0.7	0.1	67.3	30.0

The contents of various minerals in fine sand fraction were based on the actual weight of fine sand after separation of the soil sample. The contents of various minerals in clay fraction were based on the relative dA° of X−ray diffraction pattern[4].

III. DISCUSSION

The mineral components of soil samples show that there are significant differences among soil profiles of various areas. In tne soil sample from Nanshan, Chongqing, weatherproof minerals are the major part and the percentage of quartz plus zircon and rutite varies with the depth of soil profile, up to 46%−62%. In Xian, the major minerals in soil are mica and chlorite. Calcite in horizon A and B had been weathered, but plagioclase content increases with the depth of soil profile. In the soil profile of Hebei, weathered−able minerals (plagioclase and hornblende) increase and weatherproof mineral (quartz) decreases with the depth.

In Hunan and Guiyang, the soils had been weathered to different degrees, and the

Table 2 Results detected by XRPD in the fine sand fraction of soil samples from several areas (% by weight)

Area	Depth (cm)	Ortho-clase	Plagio-clase	Quartz	Mica, chlorite	Calcite	Horn-blende	Zircon	Rutite, anatase, brookite	Magnetite	Weathered mica and chlorite	Weathered-able mineral
Chongq-ing	0–12	18.3	0.0	57.7	12.2	0.0	0.0	0.9	0.6	0.0	10.0	30.5
	12–36	22.5	0.0	61.2	9.2	0.0	0.0	0.6	0.6	0.0	5.9	31.7
	36–55	25.3	0.0	43.4	19.4	0.0	0.0	1.1	1.1	0.0	9.7	44.7
Guiyang	0–33	6.6	0.0	24.9	5.1	0.0	0.0	0.0	0.0	0.0	63.4	11.7
	33–63	10.0	0.0	30.0	10.0	0.0	0.0	0.0	0.0	0.0	50.0	20.0
	63–90	0.0	0.0	19.7	19.3	0.0	0.0	0.0	0.0	0.0	61.0	19.3
Xian	0–5	0.0	5.1	5.7	48.7	0.0	0.0	0.0	0.0	0.0	40.4	53.8
	5–60	0.0	8.3	8.1	48.0	0.0	0.0	0.0	0.0	0.0	35.5	56.3
	> 60	1.7	11.0	10.0	50.0	8.1	0.0	0.0	0.0	0.0	19.1	70.8
Hebei	0–37	0.0	20.4	17.0	25.7	0.0	6.3	0.0	0.0	7.0	23.5	52.4
	37–68	0.0	37.6	19.8	12.0	0.0	3.8	0.0	0.0	16.1	10.7	53.4
	> 68	4.1	33.9	11.9	22.0	0.0	9.1	0.0	0.0	11.0	7.9	69.1
Hunan	0–17	0.0	1.0	29.6	4.5	0.0	0.0	0.0	0.0	0.0	65.0	5.5
	17–76	0.0	4.9	24.1	17.6	0.0	0.0	0.0	0.0	0.0	53.3	22.5

Table 3 Results detected by XRPD in the clay fraction of soil samples from several areas (% by weight)

Area	Depth (cm)	Illite	Kaolinite	Chlorite	Vermiculite	Montmor-illonite
Chongqing	0–12	63.0	37.0	0.0	0.0	0.0
	12–36	46.0	30.0	10.0	14.0	0.0
	36–55	43.0	36.0	11.0	10.0	0.0
Guiyang	0–33	0.0	40.0	36.0	0.0	24.0
	33–63	0.0	42.0	35.0	0.0	23.0
	63–90	0.0	54.0	0.0	46.0	0.0
Xian	0–5	74.0	7.0	8.0	0.0	11.0
	5–60	77.0	10.0	3.0	10.0	0.0
	> 60	71.0	11.0	8.0	10.0	0.0
Hebei	0–37	60.0	16.0	24.0	0.0	0.0
	37–68	61.0	16.0	23.0	0.0	0.0
	> 68	61.0	13.0	16.0	10.0	0.0
Hunan	0–17	39.0	61.0	0.0	0.0	0.0
	17–76	69.0	31.0	0.0	0.0	0.0
	76–120	57.0	35.0	8.0	0.0	0.0

greater part of minerals is round grain aggregate like soil particle. In X-ray diffraction patterns, the intensity of quartz peak is very strong, but the peaks of other minerals, such as orthoclase, plagioclase, mica, chlorite, etc., are very weak.

The mineral component of soil from Nanshan, Chongqing, shows that weatherproof mineral (quartz) is dominant and weathering reactions are difficult to occur in the soil. In Hebei, in contrast to Chongqing, weathered-able minerals are dominant in the soil (up to 52.4% in horizon A and 69.1% in horizon B) (Table 2), which means that the soil from Hebei is very young and has a powerful potentiality to occur weathering reactions. From Table 2, we also know, weathered-able minerals in the soil from Xian significantly increase with the depth, from 53.8% in horizon A to 70.8% in horizon C, which means that the soil also has a powerful weathering potentiality. Weathering potentiality stands for the ability of soil to occur weathering reactions under the affection of long-term leaching of acidic precipitation and reflects the capacity and endurance of soil to buffer acidic precipitation. Similar to Hunan, the layer of weathered soil in Guiyang is very thick and the soils only in horizon A, B1, and B2 were sampled. The results of XRPD show that there are a great quantity of easily weathered minerals in the two soil samples, up to 68.5% and 75.8% respectively (Table 4). The content of easily weathered minerals reflects the ability of soil to occur weathering reactions; therefore, it also reflects the buffering capacity of soil to a certain degree. It is obvious that the soils from Guiyang and Hunan consist of quantities of easily weathered minerals and have certain capacities to buffer acidic precipitation. The contents of easily weathered minerals and silt plus clay minerals of soils from several areas are compared in Table 4.

Table 4 Contents of easily weathered minerals, silt plus clay fraction in the soil samples from several areas (% by weight)

Area	Depth (cm)	Easily weathered mineral * / fine sand	(silt+clay mineral)/ soil
Chongqing	12–36	15.1	13.2
Guiyang	0–33	68.5	61.7
Xian	0–5	94.2	90.4
Hebei	0–37	75.9	57.9
Hunan	17–76	75.8	83.5

* hornblende, plagioclase, mica, chlorite, weathered mica and chlorite, etc.

The simulation of leaching experiments of acidic precipitation for several forest soils[5] showed that there are two buffering systems-primary buffering system and secondary buffering system-during the process of soil to buffer acidic precipitation. Due to the presence of secondary clay minerals and primary minerals with various amount in soil, the two buffering systems exist simultaneously. If a forest ecosystem is affected by acidic precipitation, the first reaction is the cation exchange of secondary silt and clay minerals of soil, and the second reaction is the chemical weathering of primary minerals. The two reactions consume external H^+ and release cations from minerals, and constitute the two buffering systems of soil against acidic precipitation. The content of silt plus clay minerals (stand for the primary buffering system) and easily weathered minerals (stand for the secondary buffering system) are listed in Table 4. It shows the significant differences of soil buffering capacities against acidic precipitation in several areas. The weakest buffering capacity exists in the soil from Nanshan, Chongqing, because of two kinds of the lowest mineral contents.

The results of the simulation of leaching experiments of acidic precipitation for several forest soils show that there are significant differences among the pH values of leachates. The pH values of leachates in the soils of upper horizon from several areas are compared in Table 5. The higher and more stable the leachate pH values of a certain soil with the same leaching solution, the more powerful the buffering capacity of the soil.

The order of buffering capacities of several soils is showed in Table 5: Xian, Hebei > Hunan > Guiyang > Chongqing, which depends on the contents of easily weathered minerals in the soils. The contents of easily weathered minerals in the same soils are listed in Table 4: 15.1% in Chongqing, 68.5% in Guiyang, 75.8% in Hunan, 75.9% in Hebei, and 94.2% in Xian. It is clearly that the content of easily weathered minerals of a certain soil reflects the buffering capacity of the soil against acidic precipitation.

According to the results of component of clay minerals in soils from several areas(Table 3), a great quantity of illite exists in the soils from Hebei and Xian, and the mean contents of illite in various horizons are 61% and 74% respectively, but 55% in Hunan and 50.7% in Chongqing. In Guiyang, the main minerals in horizon A and horizon B1 are montmorillonite and chlorite, but chlorite was weathered into vermiculite in horizon B2. It is obvious that the acid–neutralizing capacities of several soils are significantly different.

IV. CONCLUSION

The study of mineralogy of several forest soils in China shows that the buffering capacity of soil from Nanshan, Chongqing, against acidic precipitation is the weakest, which perhaps is one of the factors that resulted in the decline of trees in the area. The buffering capacities of soils from Hebei and Xian are the strongest due to the highest contents of weathered–able minerals, which means that the most powerful weathering potentiates exist in the two areas. The soil from Hebei is very young and the great majority of minerals has not been weathered. The soil from Guiyang is similar to that from Hunan and has a powerful buffering capacity against acidic precipitation due to the higher content of easily weathered minerals.

The analytical result of clay minerals in soils from several areas shows that the order of acid—neutralizing capacities of several soils (which stands for the cation exchange reactions) is the same as that of buffering capacities of the corresponding soils (which stands for the weathering reactions of primary minerals).

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