Effects of Magnetic Treatment on Leaching Releasing of Heavy Metals Element in Fly Ash from CFB

LIU Xin-Zhong,^{1,2,3} WENG Ren-Gui,¹ XU Sheng,¹ XIA Xue-Fen,¹ WU Xiao-Hang,¹ LIN Xiao-Ying¹

¹Fujian University of Technology, Fuzhou, Fujian 350007, P. R. China,

²Shandong University of Technology, Zibo, Shandong 255049, P. R. China

³Author for correspondence (tel.:+86059188100989; fax:+86059188100989; e-mail: liuxinzhong@fjut.edu.cn)

Abstract: The effect of the intensity of magnetic field on the chemical activity and characteristics of heavy metals Pb and Cr in power plant fly ash from Circulating Fluidized Bed Boiler (CFBFA) was studied through the project of Tessier's successive chemical extraction and successive leaching, according to the general regulation of the influence of magnetic treatment on water and minerals. The results show that the intensity of magnetic field has a distinct impact on the releasing amount of heavy metals in power fly ash. With the same leaching medium, the amount of releasing under the magnetic field with the intensity of 0.1T is more than that with the intensity of 0T and 0.25T. Meanwhile, the property and chemical activity of released heavy metals Pb and Cr are studied with the different pH value of leaching medium. The analysis of particles size distribution of power fly ash shows that the particles with smaller size are the majority of total particles, so the trace elements tend to enriching in smaller particles of power fly ash. The degree of enrichment of trace element is closely related to the average particle size of CFBFA.

Keywords: fly ash from CFB; leaching medium; successive leaching; heavy metal; magnetic treatment

I. INTRODUCTION

The main energy source in China is coal, which results in large quantities of fly ash from Circulating Fluidized Bed Boiler (CFBFA). Recently, China gains *number-one world ranking* for 160 million ton of fly ash produced by coal every year. CFBFA is partially used in industry and agriculture, such as road building, cement making, concrete mixing, magnetized fertilizer mixing and so on. However, most of it is piled up but not in beneficial use. The fine particles (<20um) of the power fly ash are easy to enter the air, the water and the earth when people move and store the ash, which gives a bad effect on environment and zoology^[2-3].

Besides the elements of Si, Al and Ca, there are some trace elements in the power fly ash, including some noxious and radioactive heavy elements, such as Cd, Pb, Cr, As, Zn, Cu and Ni, which will cause the potential environmental pollution with increasing power fly ash production and stack, and it attracted close attention extensively by Environmental Chemists and Geochemists^[3-5].

The basic approaches to the disposal of fly ash are landfill and ash, while they both have their disadvantages^[6-8].

The power fly ash also has a bad effect on the terrestrial ecosystem due to leaching of potential toxic substances into soil and ground water which is not conducive to growth of the

vegetation, changes components of the plants growing on it and increases the potential toxic substances which can be recycled and cumulated through food chains.

The significant impact on aquatic ecosystems can be described as follows: the polluting elements in the CFBFA can be soaked out continually by rains or leaching water into the surface and ground water; most items of the elute (such as pH value, rigidity, the content of oxide, sulfide, heavy metal, suspend substances etc) go beyond the Chinese standard of drinking water (GB5749—85)^[8-14] greatly.

Experiments of eluviation show that concentrations of heavy metals in the eluting out of power fly ash are 10 to 100 times as many as water quality standard (GH2B—1999 (IV、V) in China)^[24-27]. it's reported that there are about billion tons of leaching water either running into surface water or used for agriculture in China every year.

Research is presented as follows: the chemical activity and its variational rules of heavy metals under magnetic field with different intensity ; the impacts of magnetic field on leaching character of the heavy metals of fly ash under the natural condition.

II. MATERIALS AND METHODS

2.1 Samples and analysis

2.1.1 The composition of power fly ash

The experimental samples are provided by Baiyanghe Electric Power Industry Company, Shandon, the major composition is listed in table 1 and the contents of trace elements in table 2.

The main composes of the power fly ash are SiO₂, Fe₂O₃, Al₂O₃ and CaO, which make up 81.77% in total.

Table 1. Compositions of elements in the particles of power fly ash

Chemical component	SiO ₂	Fe ₂ O ₃	Al ₂ O ₃	TiO ₂	CaO	MgO	K ₂ O	Na ₂ O	SO ₃	P ₂ O ₅	Burning lost
Content (%)	43.87	6.42	24.05	0.99	7.43	1.21	0.93	0.47	8.43	0.21	10.73

Table 2. Contents of trace elements in power fly ash

Trace Element	Pb	Cr	Co	Ni	Cu	Zn
Content (10 ⁻³ mg/g)	36.1	87.1	28.4	40.1	170	123

2.1.2 The phases in the power fly ash

The X-ray examination shows that the fly ash in the experiment adopts main phase SiO_2 , hypo-phase CaSO_4 and some FeS_2 .

2.1.3 Granularity distributing character

The grain sizes are listed in table 3. It shows that the average size of the ash is $27.52\mu\text{m}$, 93.27% ash particle within $80\mu\text{m}$ cumulation size, and 61.69% within $30\mu\text{m}$.

Table 3. Size distribution of power fly ash
Time of ultrasonic treating: 120s

No.	ash size (μm)	Cumula- tion (%)	No.	ash size (μm)	Cumula- tion (%)	No.	ash size (μm)	Cumula- tion (%)
1	0.10-0.12	0.00	15	1.51-1.83	6.94	29	22.76-27.63	59.63
2	0.12-0.15	0.00	16	1.83-2.22	11.38	30	27.63-33.54	64.77
3	0.15-0.18	0.00	17	2.22-2.70	16.08	31	33.54-40.72	71.72
4	0.18-0.22	0.00	18	2.70-3.28	20.22	32	40.72-49.43	79.23
5	0.22-0.26	0.00	19	3.28-3.98	23.66	33	49.43-60.00	85.92
6	0.26-0.32	0.00	20	3.98-4.83	27.13	34	60.00-72.84	91.34
7	0.32-0.39	0.00	21	4.83-5.86	30.93	35	72.84-88.42	95.54
8	0.39-0.47	0.00	22	5.86-7.11	35.37	36	88.42-107.33	98.40
9	0.47-0.57	0.00	23	7.11-8.64	39.75	37	107.33-130.29	100.00
10	0.57-0.69	0.00	24	8.64-10.8	43.64	38	130.29-158.17	100.00
11	0.69-0.84	0.21	25	10.48-12.73	46.89	39	158.17-192.00	100.00
12	0.84-1.02	0.75	26	12.73-15.45	50.09	40	192.00-233.07	100.00
13	1.02-1.24	1.85	27	15.45-18.75	53.23	41	233.07-282.93	100.00
14	1.24-1.51	3.70	28	18.75-22.76	56.22	42	282.93-300.00	100.00

D10=2.10 μm D50=15.37 μm D90=69.67 μm D25=4.31 μm D75=44.52 μm
<30 μm cumulation=69.69% <80 μm cumulation=93.27% Dav=27.52 μm
S/V=9933.59 cm^2/cm^3

Disperse medium: distilled water

Concentration of sample: 1.4

Instrument: laser granularity analyzer (Winner2000)

2.2 Selection of leaching medium

The mixture of hydrochloric acid and nitric acid was selected by considering the acid rain and ash water treatment. The mixture acid solution was adjusted by diluted to a given pH value (at 6.00, 4.00, 2.00 respectively).

2.3 The setting of leaching experiment

The device of leaching experiment was shown as figure 1.

Figure 1. The sketch map of the leaching device

2.4 Process of leaching experiment

2.4.1 The biacid impregnant preparative

The biacid leaching medium made up of hydrochloric acid and nitric acid (3:1, volume ratio) is diluted to 1000ml with different pH value (6.00, 4.00 and 2.00) respectively, and kept in flasks.

2.4.2 The leaching device

Three sets of leaching device were assembled and each leaching device works under the four different magnetic fields with intensity 0 T (a), 0.1 T (b), 0.25 T (c), 0.35 T (d) respectively.

2.4.3 Power fly ash sample preparative

The four leaching columns (sign a, b, c and d) were loaded with 10g power fly ash (weighed up by analytical balance) respectively.

2.4.4 Experiment process

The ratio of ash and biacid leaching medium is 1:20 (W/W) and 10g power fly ash matches 200g leaching medium. 10mL leaching medium is added extrally in the first leaching process in order to make the elute around 200mL. The successive leaching method is adopted at the rate of $0.14\text{ mL}\cdot\text{min}^{-1}$ and the leaching time is about 60h in all.

At first, the 200mL leaching medium with pH=6.00 was introduced and the leaching time was 60h. Secondly, the elute was kept in a flask for analysis. Then the same amount of medium with pH=4.00 was added. Finally, the same quantity of medium with pH=2.00 was introduced. The processing of last two medium were similar to the process of the first one. All the experiments are carried out under a, b, c and d conditions respectively.

III. RESULTS AND DISCUSSION

3.1 Results

The contents of Pb and Cr elements in the leaching solution of power fly ash show in table 4, which were determined by ICP plasma emission spectrophotometry.

Table 4. The contents of Pb and Cr elements (ng/ml) in the leaching solution under different intensity of magnetic fields

Intensity of magnetic fields (T)	Contents of Pb and Cr elements (ng/ml)					
	pH= 6.00		pH=4.00		pH=2.00	
	Pb	Cr	Pb	Cr	Pb	Cr
0	0.04	6.0	<0.02	4.1	<0.02	7.8
0.10	0.39	5.2	1.4	6.5	<0.02	8.4
0.25	<0.02	5.8	<0.02	6.1	<0.02	7.1
0.35	<0.02	5.5	<0.02	5.8	<0.02	6.5

3.2 Discussion

3.2.1 Leaching release properties of heavy metals under the different intensity of magnetic fields

3.2.1.1 Effect on Pb element leaching release under the different intensity of magnetic fields

Figure 2. Leaching release of Pb under the different intensity of magnetic fields

As shown in Fig. 2, the content of Pb decreases with the increase of magnetic fields intensity by 60 hours leaching with 200ml leaching medium at pH=6.0. At H=0, the content of Pb is 0.04ng/ml, at H=0.1T, the content of Pb is ten times as many as it at H=0, and at H=0.25T, the content of Pb is unexpectedly under 0.02 ng/ml.

When the following leaching is at pH=4.0, the Pb content of the elute varies with the increase of magnetic fields intensity at H=0.1T and the leaching reaches the maximal (1.4ng/ml). It can be concluded that the magnetic fields intensity takes important part in the leaching release of Pb, and the maximal leaching release may be under magnetic fields intensity 0.1T.

When the last leaching underwent with 200mL leaching medium at pH=2.0, the Pb cannot be tested out, even at H=0.1T. Due to the successive leaching, the power fly ash has been undergone the leaching medium at pH=6.0 and pH=4.0 respectively, and the Pb content is rather few.

3.2.1.2 The effect on Cr element leaching release under the different intensity of magnetic fields

Figure 3. The leaching release of Cr under the different intensity of magnetic fields with different pH value

As shown in Fig 3, the intensity of magnetic field seems to put effect on the amount of Cr element leaching release slightly when leaching medium is adjusted to pH = 6.0, even at H(T) = 0, the leaching release is distinct. It means that the Cr element can cause pollution on the environment as long as the ash is washed by rain.

The ash was leached next by 200mL leaching medium with pH = 4.0 (the red line in Fig 3). The experiment showed that the Cr concentration increased with the growth of intensity of magnet field at H < 0.1T and decreased with it at H > 0.1T. The maximal concentration of Cr in elute was at H = 0.1T and had a similar regular to the Pb leaching at pH = 6.0, that is, at pH = 4 and H = 0.1T, the leaching concentration of Cr reached the maximal.

The blue line in fig.3 show the concentration of Cr in elute at pH = 2.0, which also has a maximal concentration at H = 0.1T.

The Cr concentration of leaching filtrate is much larger than Pb concentration, and it can be attribute to the stronger combination state of Pb element in the ash.

3.2.2 Leaching release properties of heavy metal elements in power fly ash in different pH value mediums

3.2.2.1 The leaching release properties of Pb at different pH value

Figure 4. The leaching release concentration of Pb at different pH value

As shown in fig 4, when the H = 0, the maximal concentration of Pb is at pH=6.0 With the rising of the acidity, the release of Pb reduced. It is said that the Pb element can be lixiviated out at pH=6 with no extra magnetic field. And it can be concluded that the power fly ash will give a bad effect on the soil if it is piled up for a long time without any cover from rain in nature.

On the contrary, when the ash expose under strong magnetic field (H= 0.25T), the release of Pb is limited, and can not be tested out.

At magnetic field H=0.1T, the release concentration varied great. The leaching medium with pH=4 gave the maximal release concentration (the blue line in Fig. 3), at the same pH value, the Pb can not be tested out under H=0T or 0.25T. As to leaching medium with pH=6, the release concentration of Pb is about ten time as many as that under H=0T.

The experiment reveals that the magnetic intensity plays an important part on the leaching process and on Pb leaching properties.

3.2.2.2 The leaching release properties of Cr at different pH value

Figure 5. The leaching release concentration of Cr at different pH value

When $H=0$, the leaching release concentration of Cr varied with the change of pH value. At $pH=4$, the leaching release is much less than it at $pH=2$ or 6 . At $pH=2$, the concentration is the largest. At $H=0.1T$ and $0.25T$, the concentration of Cr increased with the decrease of pH, in other word, the leaching release increased with growth of the acidity. It can be concluded that Cr(III) solutes out of the ash increasingly while the acidity increases.

3.2.2.3 Analysis on the total Cr and Pb of leaching release

Table 5. The total Pb, Cr in 200ml leaching filtrate

Magnetic intensity (T)	0	0.1	0.25
Pb ($\times 10^{-2}$ %)	0.222	9.700	0.000
Cr (%)	0.411	0.462	0.436

Table 6. The leaching ratio of Pb and Cr out of power fly ash

Magnetic intensity (T)	0	0.1	0.25
Pb (ug)	0.0080	0.0358	0.000
Cr (ug)	3.58	4.02	3.80

The tables show that there is no linear relationship between the leaching amount of Cr and Pb and the magnetic intensity. And it is showed that the maximal leaching locates within a range of magnetic intensity, or in a given intensity. Although the leaching amount varies greatly, the total leaching heavy elements is very few. The characteristic of leaching of heavy metals is effected by many factors such as medium solution, ratio of ash and leaching liquid, leaching time, leaching temperature, stir intensity etc.

IV. CONCLUSION

4.1 The phases of the power fly ash from Circulation Fluidized Bed Boiler are mainly quartz, anhydrite and iron pyrites, whose main composings accounted for 81.77% are SiO_2 , Fe_2O_3 , Al_2O_3 , and CaO .

4.2 The ash has a small mean granularity, only 27.52 μm , and 56.22% of it around 22.72 μm , only 30.93% less than 5.86 μm .

4.3 The amount of Pb and Cr elements leaching is quite a few according to the analysis of the leaching ratio, and it will be less when leaching in the rain under the nature environment, so the heavy elements (Pb and Cr) can not make obvious pollution to the soil.

4.4 The successive leaching experiments show that concentrations of Cr and Pb do not have the linear relation with the magnetic intensity. The control experiment shows that the maximal leaching release of Pb element occurs at $H=0.1T$ with medium $pH=4.0$, and that of Cr element occurs at $H=0.1T$ with medium $pH=2.0$.

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