Journal of Environmental Radioactivity 171 (2017) 132–137

Contents lists available at ScienceDirect

Journal of Environmental Radioactivity

journal homepage: www.elsevier.com/locate/jenvrad

^{210}Po distribution after high temperature processes in coal-fired power plants

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ARTICLE INFO

Article history:
Received 20 July 2016
Received in revised form
22 January 2017
Accepted 19 February 2017

Keywords:
Coal-fired power plant
^{210}Po
Mass balance analysis
NORM

ABSTRACT

In this paper, the distribution of ^{210}Po after high temperature processes in six units of coal-fired power plants (CFPs) were evaluated. The coal, bottom ashes, fly ashes from electrostatic precipitators (ESP), and flue gases from stacks were sampled from four CFPs and analyzed for ^{210}Po contents. The results showed that ^{210}Po was mainly captured by the ESP, with little left in the bottom ash, and a small fraction of ^{210}Po was directly discharged into the environment through the stacks, accounting for 0.06%–0.6%, which was consistent with the reported data. It was also found that part of the ^{210}Po could not be accounted for in the mass balance analysis for the whole combustion process in CFPs, which was also in line with the reported data. The results obtained in this study provided essential basic data for environmental radiological risk analysis for CFPs.

1. Introduction

In 1982, UNSCEAR (United Nations Scientific Committee on the Effects of Atomic Radiation) pointed out that natural radioactive elements with low boiling points, such as ^{210}Po and ^{210}Pb, had a substantial enrichment in those NORM (Naturally Occurring Radioactive Materials) industries in which relatively high temperature processes were usually involved. The average activity concentrations in coal are 50 Bq/kg for ^{4} K and 20 Bq/kg for ^{238}U and ^{232}Th and their decay products, which are assumed to be radioactive equilibrium. However, in a coal-fired power plant (CFP), the average activity concentrations in escaping fly ash could reach 1700 Bq/kg for ^{210}Po and 930 Bq/kg for ^{210}Pb, compared with values of 200 Bq/kg for ^{238}U, which indicates higher enrichment for ^{210}Po and ^{210}Pb (UNSCEAR, 1982).

As for ^{210}Po, great attention has been paid on this issue, and a plethora of data have been collected, such as, 1) physical and chemical properties of ^{210}Po after high temperature processes (Mora et al., 2011); 2) the distribution of ^{210}Po in fly ash, bottom ash, and flue gases (Mora et al., 2011; Roeck et al., 1987; Smith et al., 2001; Tadmor, 1986; Vreček and Benedik, 2003); 3) the behavior and quantity of ^{210}Po discharged through stacks (Hedvall and Erlandsson, 1996; Mora et al., 2011; Nakaoka et al., 1984; Roeck et al., 1987; Smith et al., 2001; Tadmor, 1986); 4) sample methods of ^{210}Po in flue gases (Roeck et al., 1987; Vreček and Benedik, 2003); and 5) the committed dose of ^{210}Po from atmospheric release (Hedvall and Erlandsson, 1996; Smith et al., 2001; Tadmor, 1986).

In China, CFPs accounting for over 75% of the nation's electricity supply source. Hence, much attention has been paid to studying the emission pattern of ^{210}Po. In 1982, Zeng and Li analyzed the specific activity of ^{210}Po in coal, bottom ashes, fly ashes and flue gases from a CFP, and evaluated the release of ^{210}Po to atmosphere and the dose to public (Zeng and Li, 1982). In 1987, Fu and Song also evaluated the release of ^{210}Po to atmosphere and the dose to public based on CFP flue dust samples CFP(Fu and Song, 1987). In 1993, coal, bottom ashes, fly ashes and flue gases from about 20 coal-burning boilers and cooking-stoves, were sampled and analyzed for ^{210}Po contents by Pan Ziqiang (Pan,Ziqiang, 1993). Also, some years ago the current authors directly sampled flue gases from stacks to analyze the emission of ^{210}Po to the atmosphere and to estimate mass balance (Liu et al., 2013). However, the combustion systems of CFP have been updated continuously in recent years, so there is a need to study the emission pattern of ^{210}Po in those

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http://dx.doi.org/10.1016/j.jenvrad.2017.02.015

Table 1
Detailed information for the six sampled units in the four CFP studied.

CFP	CFP-A		CFP-B	CFP-C	CFP-D	
Unit	1	4	2	3	5	7
Electric power (MWe)	300	630	600	680	350	660
Load efficiency (%)	67	67	70	79	70	71
Coal consumption (t/h)	130	272	190	180	146	177
Yield of ESP ash and bottom slag(t/h)	3/31	62/6	20/30	34/4	30/5	36/6
Desulphurization system	wet flue gas desulphurization system					
Flow rate of flue gas (m^3/h)	1.21×10^6	2.21×10^6	1.6×10^6	2.23×10^6	1.33×10^6	1.98×10^6
Flue gas speed (m/s)	15	14	7.8	7.1	8	5.8
Flue gas temperature (°C)	50	50	51	86	52	80

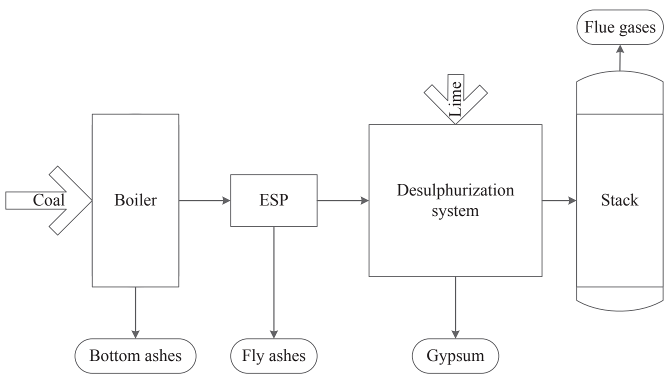

Fig. 1. Schematic of combustion system of CFPs.

updated CFPs. In order to fulfill this task, ^{210}Po distribution after high temperature processes in the combustion system of four updated CFPs in China was studied.

2. Material and methods

2.1. Information of CFPs

In this work, six units of four CFPs were studied. The basic information for each of these units is provided in Table 1.

2.2. Sample collection

As the schematic of the combustion system (Fig. 1) showed, a process-based sampling was implemented in this work. Several types of samples involved in the process were obtained, including coal, bottom ashes, fly ashes, lime, gypsum, and solid and gaseous phases of flue gases from stacks, except for CFP-A and CFP-B from which lime samples were not obtained. Particularly, for flue gases, as shown in Fig. 2, a three-level bubble trap containing 2M HCl solution was used to catch the gaseous phases after the solid phase trap. Hence, the ^{210}Po captured by the solid phase trap was defined as the part in solid phase of the flue gases, while that captured by the three-level bubble trap was defined as the part in gaseous

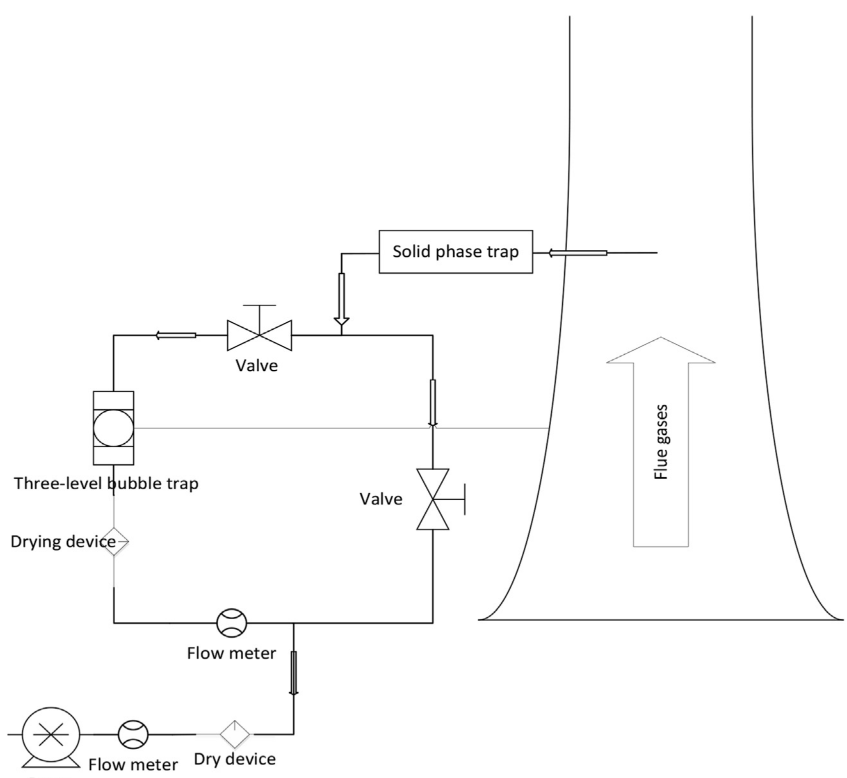

Fig. 2. Sampling of flue gases.