**210Po concentration in desulfurized waste water of coal-fired power plant**

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**ABSTRACT**

The concentration of 210Po in the desulfurized waste water can be affected by the operation of the wet desulfurization system in the coal fired power plant (CFP). However, this correlation is poorly studied and documented in current literature. The aim of this study was to report 210Po concentration level in desulfurized waste water from a CFP using wet desulfurization system. The average concentration of 210Po in the waste water samples from wet desulfurization system was measured 2.4 ± 0.3E-3 Bq/L, 4 times higher than the concentration of 210Po in our control samples (sea water), which is 6.1 ± 1.4 E-04 Bq/L. The annual total discharge of 210Po by the waste water of desulfurization system was estimated to be 7.03 × 10^8 Bq/GWa, which is much higher than the total release of 210Po in air from stack of a modern CFP.

**1. Introduction**

Coal is the second-largest energy source, playing a paramount role in generating electricity by contributing up to 39\% in global production (Alam & Mohamed, 2011). In China, coal plays a much bigger role in electricity generation by accounting for over 75\% of the nation’s electricity capacity (Chuangao et al., 2017). Heavy research efforts have been focused on the potential hazard on environment from fossil fuel. UNSCARE (United Nations Scientific Committee on the Effects of Atomic Radiation) concluded that 210Po has a substantial enrichment in NORM (Naturally Occurring Radioactive Materials) industries due to the low boiling points of 210Po (United Nations Scientific Committee on the Effects of Atomic Radiation, 1982). It was concluded that the 210Po from CFP could pose potential radiation risk to the environment and general public by releasing out to environment along with the residual waste from CFP. In order to take measure for responding the radiation risk from 210Po, many work have been done on studying the 210Po discharge and distribution in CFP. Majority of the work were performed on solid, particle, and gas phase environmental samples from CFP, for instance, fly ash, bottom ash, particles from stacks, and flue gases (Chuangao et al., 2017; Hedvall & Erlandsson, 1996; Mora, Robles, Corbacho, Gascó, & Gázquez, 2011; Roeck, Reavey, & Hardin, 1987; Ruirui, Chuangao, & Jingshun, 2013). However, 210Po concentration in the desulfurized wastewater from CFP, which could have significant environmental impact in liquid phase from the wet desulfurization CFP, haven’t drawn enough attention and been understood well.

One direct environmental impact from the waste water containing 210Po after wet desulfurization process is that the 210Po could be accumulated in a variety of marine organisms if the desulfurized water is directly discharged to the sea, which is a common practice for CFPs located along coastal line (Carvalho et al., 2017). The contamination of 210Po in ocean can be spread to seafood through food chain, and eventually affect human being. Lubna et al. estimated the 210Po concentration level in marine organisms from the coastal area close to a CFP and assessed its impact on seafood consumers (Alam, 2016; Alam & Mohamed, 2011, 2018). They found that the average activity observed in the dissolved phase is higher than that of other places in the same country. Baeza et al. found that the 210Po has accumulated in the effluent water from one CFP. They concluded that the waste water evacuated from CFP may have more or less significant increase of radionuclides such as U, Ra, and Po due to the water effluent that are in direct contact with the fuel, fly ash, and bottom ash (Baeza et al., 2012). Therefore, studying the 210Po concentration level in the desulfurized water could plays a constructive role in understanding the potential health hazard from CFP.

According to the statistics of China Electricity Yearbook in 2014 (Editorial Board of Electric Power Yearbook of China, 2014) and the bulletin published by the Ministry of Environmental Protection (MPE) in 2014 (Ministry of Environmental Protection of the People’s Republic of China, 2014), the total capacity of coal-fired units was 0.786 billion kW, 95.93\% of coal-fired units installed desulfurization devices, with limestone-gypsum wet desulfurization as the dominant
process (92.3%), followed by seawater desulfurization and ammonia process (7.7%). 99.49% of desulfurization devices were installed after 2000. All those wet desulfurization processes have to deal with waste or byproducts in liquid phase containing $^{210}$Po, so there is a need to study the $^{210}$Po concentration of water from wet desulfurization process. In order to finish this task, $^{210}$Po concentration of waste water after wet desulfurization process of one coastal CFP in China was studied.

2. Material and methods

2.1. Sampling process

The sampling plan was made based upon the procedures of whole plant and the sampling plan was displayed in Figure 1. The water samples were taken at the intake of the desulfurized water in the power plant, and from the final effluent from the aeration tank (shown in Figure 2) for desulfurized waste water which were directly discharged to the sea later. The desulfurized water from two CFPs with wet desulfurization system were sampled. The total volume of each water sample was 20 L.

2.2. Sample measurement

The measurement of $^{210}$Po in desulfurized waste water is mainly based on the national standard GB12376-90 (Ministry of Environmental Protection of the People’s Republic of China, 1990). The $^{209}$Po tracer was added for the measurement. The $^{210}$Po was detected using a Canberra alpha Analyst™. The measurement time was set to 1.6–1.8E+5 s. The concentration was obtained by averaging three samples and the uncertainty was the variation among three samples. The detailed analysis process was shown in Figure 3.

3. Results and discussion

Total eight samples from CFP-1 and CFP-2, and one sample of sea water from inlet were analyzed, and the results were listed in Table 1. The samples were collected at the same day.
Figure 3. A flow chart for measurement of $^{210}$Po.
The sea water from inlet was taken as a control, and the concentration of \( ^{210}\text{Po} \) was \( (6.1 \pm 1.4) \times 10^{-3} \) Bq/L. Seven samples were taken when the wet desulfurization system was in operation, and the average concentration of \( ^{210}\text{Po} \) in those samples was \( (2.4 \pm 0.3) \times 10^{-3} \) Bq/L, which is about 4 times higher than the concentration of \( ^{210}\text{Po} \) of control. It was observed that the concentrations of \( ^{210}\text{Po} \) in the desulfurized water were substantially higher than the sea water from the inlet, which indicated that part of the \( ^{210}\text{Po} \) was captured by the desulfurized water and dissolved in the water. This was in line with observations reported in (Mora et al., 2011; United Nations Scientific Committee on the Effects of Atomic Radiation, 1982). It is worth noting that the \( ^{210}\text{Po} \) concentration returns to background level when the desulfurization is not operating as the plant is ceasing operation. This indicates that the \( ^{210}\text{Po} \) is in the solution of desulfurization water.

The total discharge quantity of \( ^{210}\text{Po} \) into sea by the wet desulfurization system could be determined by

\[
A = C \times V \times t \times w
\]

where \( A \) is the total activity of \( ^{210}\text{Po} \) discharged to ocean, \( C \) is the concentration of \( ^{210}\text{Po} \) in the desulfurized waste water, \( V \) is the water consumption volume of wet desulfurization system per hour, \( t \) is the total operation time, and \( w \) working load of the unit.

CFP-1 and CFP-2 consumed same amount of water at \( 1.8 \times 10^4 \) m\(^3\)/h. The working load is 65%. Then the \( ^{210}\text{Po} \) discharged into the sea every year by CFP-1 and CFP-2 was calculated as

\[
2.4 \times 10^{-3} \text{Bq/L} \times 1.8 \times 10^7 \text{m}^3/\text{h} \times 24 \times 365 \times 65\% \times 2 = 4.92 \times 10^8 \text{Bq}.\]

Given that the electric power of for CFP-1 and CFP-2 was \( 70 \times 10^4 \) kW, the \( ^{210}\text{Po} \) discharge from both units is \( 7.03 \times 10^8 \) Bq/GWa. It was worth noting that this discharge was much higher than total \( ^{210}\text{Po} \) release from stack for a modern CFP, which is \( 9.30 \times 10^7 \) Bq/GWa (UNSCEAR, 2017). We concluded that the discharge of \( ^{210}\text{Po} \) from wet desulfurization system could not be neglected in the evaluation of radiation environmental impact from CFP using wet desulfurization.

4. Conclusion

To the best of our knowledge, this is the first piece of research to study the \( ^{210}\text{Po} \) discharge from the wet desulfurization system of CFP. In this study, we sampled and measured the concentration of \( ^{210}\text{Po} \) from the waste water from wet desulfurization system. For two units studied in this work, the results show that the concentration of \( ^{210}\text{Po} \) in the waste water from wet desulfurization system is substantially increased from background. This indicates that there are some \( ^{210}\text{Po} \) dissolved into the water used for wet desulfurization. The annual discharge of \( ^{210}\text{Po} \) by the waste water of desulfurization system is much higher than the total release of \( ^{210}\text{Po} \) in air from stack. The discharged \( ^{210}\text{Po} \) can concentrate to sea fish and result in internal exposure to human beings deriving from sea food consumption. Attention shall be paid for further evaluation of the discharge mechanism thoroughly and designing corresponding control measures. This work sheds a light on a comprehensive evaluation of the environmental impact from CFP using wet desulfurization.

Disclosure statement

No potential conflict of interest was reported by the authors.

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