

# Environmental Issue of Coal Ash Imported From Japan after Fukushima Nuclear Power Plant Disaster: A Case Review in South Korea

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## ABSTRACT

In South Korea, the cement companies are importing Coal Ash (CA) from Japan and recycling it as an alternative raw material for cement and an auxiliary fuel for the furnace in the cement manufacturing process. However, the issue of human and environmental risks has been raised because of the radioactive contamination that occurred from the tsunami in Japan in 2011. Therefore, in this review, the environmental issue of CA imported from Japan after the Fukushima Nuclear Power Plant Disaster (FNPPD) and the national countermeasures for solving it were discussed.

**Keywords:** Coal Ash; Transboundary Movement of Waste; Environmental Issue; Fukushima Disaster

**Abbreviations:** TMW: Transboundary Movement of Waste; BC: Basel Convention; CA: Coal Ash; CPP: Coal-Fired Power Plant

## Introduction

Since many countries were reluctant to dispose of waste with hazardous substances in their territories to protect their own country, they relied on exporting the waste to underdeveloped or developing countries in an easy way to solve this problem. However, this Transboundary Movement of Waste (TMW) caused environmental pollution in importing countries, and the necessity for international cooperation to protect the environments of underdeveloped or developing countries was recognized as a national issue [1]. As such, the Basel Convention (BC) on the control of TMW and their disposal was adopted in March 1983 and came into force in May 1992 to protect the environment from illegal TMW and support eco-friendly projects [2,3]. South Korea joined the BC in February 1994 and the TMW is controlled by the 'Transboundary Movement of Waste and Their Disposal Act' and related enforcement ordinance, which were released from the Ministry of Environment [4,5]. In this situation, the amount-scale of various wastes imported to South Korea has increased every year. Among them, the Coal Ash (CA) accounts for the largest proportion

and it corresponded to over 70% of all the imported waste. The import of CA has gradually increased since 2008 and all of it comes from Japan. The imported CA is mostly used as subsidiary fuels or alternative raw material of cement for building construction [6]. However, the issue of human and environmental risks has been raised by both the National Assembly and private organizations. Because the cement produced by using the CA imported from Japan, where the radioactive contamination occurred from the tsunami, has uncertainty about safety.

## Mini Review

CA is the inorganic waste that remains unburned in the furnace of Coal-Fired Power Plant (CPP). It is classified into two main types with fly ash (collected from electrostatic precipitators) and bottom ash (collected from the bottom of boiler units). The particle sizes are widely distributed between under 0.1  $\mu\text{m}$  and over 5 cm in diameter. The main components are silica dioxide ( $\text{SiO}_2$ ), aluminum oxide ( $\text{Al}_2\text{O}_3$ ), iron oxide ( $\text{Fe}_2\text{O}_3$ ), calcium oxide ( $\text{CaO}$ ), and magnesium oxide ( $\text{MgO}$ ) [7,8]. CA has been utilized as a recyclable material in the

industrial field and can play an important role as a new alternative resource. Indeed, many research studies were investigated, such as the utilization of cementitious resource and concrete aggregate [9,10], the investigation of physical characteristics for recycling material [11], the reuse of shotcrete and building materials [12,13], the application of nanoporous materials in the synthesis field [14], etc. For this reason, CA is one of the large-scale wastes that are traded internationally. Based on the BC, B2050 code (included in List B of BC text) applies to CA as a general-management waste which doesn't contain on hazardous substance [15]. In the case of South Korea, according to Korea Environment Corporation [6], the total amount of CA on transboundary movement was about 1.3 Million Tons (MT) in 2016. The import scale of CA increased more than three times in 8 years from about 0.4 MT in 2008, when CA began to be imported [16].

In South Korea, CA is indicated as a recyclable by-product in the 'Act on the Promotion of Saving and Recycling of Resources' released from the Ministry of Environment [17]. Besides, the specific recycling methods of CA are provided by the 'Guideline for Recycling of Steel Slag and Coal Ash Producers (Notification No. 2016-217, Ministry of Environment)' [18]. Thus, the major cement companies import the CA and recycle it as an alternative raw material for cement and an auxiliary fuel for the furnace in the cement manufacturing process; in 2016, 1.2 MT of imported CA was recycled as alternative material and 0.1 MT was an auxiliary fuel [6]. All imported CA comes from a Japanese CPP. In Japan, the large amount of CA has generated annually from the CPP and it was approximately 7.1 MT in 2000 [19]. Among them, more than 1.5 MT of CA was sent to landfill sites [20]. Landfill treatment in Japan is burdensome for CPP because it requires a lot of costs. Therefore, they choose to export to Korea, which costs less than landfill treatment. From the perspective of the importer (cement companies in South Korea), it is an attractive deal that cannot be rejected. Because importer can receive the treatment cost from Japanese CPP and generate the profits through domestic recycling.

Fukushima Nuclear Power Plant Disaster (FNPPD) was occurred by the Tohoku earthquake and tsunami in March 2011 [21]. The earthquake had generated a tsunami with 14 m high. Consequently, the tsunami swept over the plant's seawall and then hit the lower parts of the nuclear power plant reactors [22,23]. The resultant loss of reactors led to the release of radioactive contamination [24,25]. Large amounts of water contaminated with radioactive isotopes were released into the Pacific Ocean during and after the disaster [26,27]. According to a 2014 report by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) [28], there has been ongoing controversy over the health effects of the disaster. Besides, an ongoing intensive cleanup program to both decontaminate affected areas and decommission the nuclear power plant will take several decades [29,30].

After FNPPD, trace amounts of radioactivity, including iodine-131 (I-131), cesium-134 (Ce-134), and cesium-137 (Ce-137), were widely observed [31-34]. As the result, it was confirmed that the radioactive material constantly can be released from the containment vessels in the nuclear power plant for several reasons: deliberate venting to reduce gas pressure, deliberate discharge of coolant water into the sea, and uncontrolled events. Indeed, in 2015 (4 years after FNPPD), the tap water contamination was still higher in Tokyo compared to other cities in Japan [31]. Thus, concerns about the possibility of a large scale release led to a 20 kilometer exclusion zone around the power plant and recommendations that people within the surrounding 20-30 kilometer zone stay indoors. All CA imported to South Korea comes from CPP located in 15 regions including Hekinan, Hokuriku, Isogo, Kobe, Maijuru, Matsushima, Matsuura, Miike, Nanao, Noshiro, Sakata, Tachibana, Takehara, Tomakomai, and Tsuruga in Japan [6]. Looking at the distance between the local points of FNPPD and CPP, the nearest region was Tachibana (within 30 km), followed Matsushima (within 100km), Matsuura (within 100km), Hokuriku (within 200km), Isogo (within 250km), and Isogo (250 km). All areas mentioned above have potential exposure to the radioactive material. In particular, the CA generated from the CPP in Tachibana, which is a region located in Fukushima, has the potential danger directly affected by the radioactive contamination.

Most Korean has a negative impression of the CA imported from Japan because of FNPPD. In particular, the National Assembly, the environmental civic group, and the media have raised concerns about the deterioration of the environment around the cement companies (which import the CA) and the impact on the human body of residents living in the apartment built of cement produced by using imported CA. Thus, some research institutes with national support investigated the health impact of residents living around in the regions of Jecheon, Danyang, Samcheok, Gangneung, Donghae, and Jangseong where cement companies are concentrated [35,36]. As a result, only a few patients with pneumoconiosis and chronic obstructive pulmonary disease were found, but there were no cases of radiation damage. Additionally, the government tightened its safety inspection with radioactivity tests for CA imported from Japan, in an apparent attempt to counter the FNPPD.

The Wonju Local Environment Agency is in charge of the inspection institution. This agency is performing the radiation test (uSv/h) and radioactivity tests including I-131 (Bq/kg), Ce-134 (Bq/kg), and Ce-137 (Bq/kg) of the CA imported from Japan. According to the analysis data for three years (2016-2018) [37], the result of radiation was detected within the range from 0.143 uSv/h to 0.233 uSv/h, and it indicates that the data was also within the range of Environmental Radiation Dose Rate (0.05-0.3 uSv/h). In the case of radioactivity, the Ce-134 and Ce-137 were detected within the ranges from 0.180 uSv/h to 0.557 uSv/h and from 0.216

uSv/h to 0.584 uSv/h, respectively. Both results did not exceed the value of the standard of Radioactivity in Food (100 Bq/kg; the sum of Ce-134 and Ce-137). Whereas, I-131 was detected within the range from 0.211 Bq/kg to 0.563 Bq/kg and did not exceed the Radioactivity in Food (100 Bq/kg; only I-131).

To confirm the harmfulness of cement produced by using the imported CA, the National Institute of Environmental Research conducted an environmental assessment of it [38]. The heavy metal contents with Pb, Cu, As, Hg, Cd, and Cr6+ were considered to be the assessment elements for determining harmfulness. In South Korea, there is no legal standard for the safety of cement with waste. In general, the government requires the contents of six heavy metals for permitting recyclable waste. Their contents can be obtained using the Korean standard official methods of Pb (ES 06402.2), Cu (ES 06401.2), As (ES 06403.2a), Hg (ES 06404.1a), Cd (ES 06405.2), and Cr6+ (ES 06407.2) [39]. According to the analysis result for last three years, the concentrations of Pb, Cu, As, Hg, Cd, and Cr6+ were 88.38-147.90 mg/kg, 33.06-210.96 mg/kg, 8.90-18.34 mg/kg, 0.04-0.17 mg/kg, 8.40-8.91 mg/kg, and 6.11-11.15 mg/kg, respectively. Compared to the six element's contents of a typical cement product, there was little difference.

In South Korea, the waste is managed as two types of general waste and hazardous waste. When imported waste is classified as hazardous waste, its import is strictly regulated by the government. Here, the leaching toxicity with Pb (standard value of 3 mg/L), Cu (3 mg/L), As (1.5 mg/L), Hg (0.005 mg/L), Cd (0.3 mg/L), and Cr6+ (1.5 mg/L) is considered to be the standard for determining hazardous wastes [39]. The leaching toxicity test is carried out using the Korean standard official method of a sample of preparation (ES 06150) [40]. According to the results analyzed from the National Institute of Environmental Research [41], the leaching toxicity of CA imported from Japan did not exceed the standards. The values of Pb, Cu, Hg, and Cd were not detected, whereas As and Cr6+ showed the low leaching concentrations of 0.01-0.03 mg/L and 0.02-0.15 mg/L, compared with the standard of 1.5 mg/L. In 2017, the amount of domestic CA generated from the Korean CPP was up to 8 MT, of which 20% (1.6 MT) depends on landfill treatment [41]. Despite the high dependence on the landfill for domestic CA, the cement companies could not stop importing the CA from Japan due to the economic benefits. Therefore, two issues with the potential danger of radioactive contamination and the stagnant recycling situation of domestic CA can be major hurdles in achieving effective management policy on TMW in South Korea. To address the two issues, several countermeasures must be considered as follow. First, the current standard of the imported CA needs to be strengthened and to be strictly controlled like a regulated or prohibited waste, in only countries where a radioactive accident has occurred (even if the level of radioactivity in the CA does not exceed the related standard) [42].

Second, the improved government-initiated support system (e.g., exemption of road toll, support of financial loan, stabilization of recycling market, expansion of demand-route for a recycled product, etc.) can be required to promote the recycling of domestic CA [43]. Third, the producer's responsibility for recycling needs to be strengthened [44]. Namely, the recycling cost of CA can be shared by the CPP (producer) by estimating the recycling fulfillment rate. Fourth, the list of recyclable items from the use of CA, which can be approved by the government without any permission procedure, should be expanded: the existing 15 items including concrete admixture, cement, lightweight aggregate, cement secondary product, embankment, cover, road aggregate, wood adhesive, cement clinker, drainage layer, ceramic, rubber and plastic filler, paint/abrasive/insulation materials, steelmaking, and topsoil fertilizer [18]. Fifth, it is necessary to continuously discuss additional measures to reduce the import amount and increase the domestic recycling ratio by operating a public-private consultative group including the government, CPP, and cement company (importer). This review covers only the issue of CA imported from Japan after FNPPD in South Korea. Since the environmental issue on the TMW varies depending on different situations in each country, there are limits to the direct application of this case review. However, it can suggest a good reference for understanding the sensitive matter on the TMW and finding the national countermeasures to solve it in each country.

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