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Chasing the ^{55}Cs-137 in the Environment on Shrimp Export Rejection: A Marker to Slag-Concrete Fly Ash Alkali Advantage over Commercial Activators

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Abstract— *Regarding the Cs-137 exposure cases on 2 September 2025, the Environment Minister of the Republic of Indonesia declared a plan to pursue civil and criminal legal action against both PT Peter Metal Technology as the first party and the Management of Modernland region Cikande, Serang District, Banten Province, as the second party. The ministry stated that after decontamination at the first point, the radiation rate is then below the permitted threshold of 0.4 microsieverts per hour, the same as before exposure. A comprehensive health investigation will be conducted for employees and surrounding residents. Executing Cs-137 SOP waste handling and revealing that carelessness in SOP is a crime are the aims of this study. The hypothesis is that radioactive Cs-137 waste found in foods, spices, and cloves in Indonesia originated from negligent and careless handling of scrap iron exposure sewage waste steels from ex-batteries and electronic devices. The method involved hypothesis testing using parsimony, Bayesian analysis, and network analysis on Cs-137 in non-nuclear reactor pollution. The results are presented in two tables and two figures that support the understanding of waterborne, highly soluble Cs-137 in alkali-activated materials (AAM). The discussion explains why waste SOP handling should be strictly enforced globally. Cs-137 from waste could be more hazardous than Fukushima and Chernobyl disasters because the locations are not detected by people; only then leukemia prevalence is highly reported. The conclusion emphasizes that with the transformation to electric cars, Cs-137 doping in ceramic industry 4.0, and alkali-activated concrete, the hazardous nature of Cs-137 should be handled with restrictive covenants until the value and enjoyment of adjoining land and seawater shrimp are preserved.*

Keywords—Alkali-Activated Material, Cs-137, Electronic waste, Fly Ash-Slag Concrete, Geopolymer.

I. INTRODUCTION

Cesium-137 contamination in shrimp, spice, and clove was reported in Cikande [1]. The airborne Cs-137 and the location of the radioactive Cs-137 exposure area, along with the source of contamination, became a national topic of concern. The Environment Minister of the Republic of Indonesia, Hanif Faisol Nurofiq (HFN), declared a plan to pursue both civil and criminal legal action against both parties in Cikande, Serang District, Banten Province [2]. The two parties are: first party PT PMT Peter Metal Technology, and the second party is the management of Modernland region Cikande (PT Modern Industrial Estate). HFN stated to journalists in Serang on Tuesday, September 30th, 2025, that environmental pollution cases cannot be resolved through out-of-court mediation and must be brought to justice. The scrap iron/steel mills industry case in civil court-crime court is intended to have a deterrent effect so that metal mills industries cannot be negligent in their business operations, where environmental pollution falls under section 98 verse 1. PT PMT is suspected of milling scrap metal containing Cs-137 without knowing the level of hazardous content (Fig. 1). Nuclear pollutant Cs-137 in Serang is estimated to have come from water exposure or overseas sources. Ignorance or carelessness does not erase the responsibility of the milling company and parties that break the law.

Meanwhile, the task force handling Cs-137—comprising the Environmental Ministry, Police, National Research and Innovation Agency (BRIN), and the Nuclear Energy Regulatory Agency of Indonesia (BAPETEN)—continues decontamination at 10 points of Cs-137 exposure. Environmental remediation of the areas is also being conducted. Following the Cs-137 exposure case on 2 September 2025, on September 23rd, 2025, HFN stated that 6 points exist, one is already decontaminated, and there are 5 points more. Decontamination is being used on commodities at the Modern Cikande Industrial region (7 quintals of goods in the form of iron plating and other contaminated material) and is being moved by officials using Personal Protective Equipment (PPE) (see Fig. 1). PT PMT, which was the temporary storage site for contaminated materials, has been relocated to a location prepared by the government. The Cikande recovery from Cs-137 radiation exposure could take months, and PMT is 8 minutes from here, said HFN. According to HFN, at the first point, the radiation rate is now below the permitted threshold of 0.4 microsieverts per hour, similar to the condition before exposure. A comprehensive health investigation will be conducted for employees and surrounding residents. The aims are to prosecute Cs-137 waste SOP violations and other potential radioactive metals globally, and to reveal that carelessness in SOP is a crime.

Hypothesis: The radioactive Cs-137 waste found in foods, spices, and cloves in Indonesia in September 2025 was caused by negligent and careless handling of waste hazardous immobilized steel from ex-battery rubbish and electronic devices.

Radioactive exposure in Cikande is considered caused by SOP carelessness according to Geopolitician International Relations Analyst, Dian Wirengjurit. Most inhabitants have been relocated [3].

II. METHODS

This review was conducted with a hypothesis test on human case reports and electronics case industries waste production and handling, using Cs-137 as a keyword. Hypothesis testing was performed with parsimony, Bayesian analysis, and network analysis on Cs-137 in non-nuclear reactor pollution. This review used Science Direct and other search engines based on PubMed criteria.

III. RESULTS

Two figures and two tables support the understanding of why waste SOP handling should be strictly enforced globally. The figures show moving junk/waste scrap iron (Fig. 1) and recycling concrete panels for buildings (Fig. 2a) and ceramics (Fig. 2b). Two tables present supporting references on Cs-137 waste (Table 1) and the difference between natural Cs-133 and radioactive Cs-137 isotopes (Table 2).

FIGURE 1: Moving the radioactive Cs-137 waste found in Cikande, 2025
Source: Antara News [4]

Cs-137 was found in waste furnace byproducts from steel production industry.

2a **2b**

FIGURE 2a. Waste recycling concrete panel for buildings. 2b. Wash basin Ceramic from Coffee

Antara, Indonesia's first news agency, chased the source of the liquid radioactive waste [4]. The quantity of liquid radioactive waste is now a significant global challenge, requiring successful action plans for safe management. Immobilization of Cs-137 radionuclides, a significant component of liquid radioactive waste in ceramic matrices based on Cs-137-saturated NaY Faujasite zeolite, has been revealed [5]. Various thermal methods were employed, including: 1) cold pressing and sintering, 2) cold pressing and sintering with microwave assistance, 3) hot pressing, and 4) spark plasma sintering immobilization capabilities. Cold sintering is similar to the geological formation of rocks where a ceramic powder is successfully processed with the aid of a liquid phase under intense external pressure and limited heating conditions (below 350°C), usually 400-1000°C. Zeolite powder was saturated with Cs-137 radionuclides using an adsorption technique with low-activity model liquid radioactive waste. Thermal behavior through NaY Faujasite annealing shows a high gap due to heat loss from the outer superficial layer, so it is better to combine microwave sintering with pressing. Spark plasma sintering demonstrated the highest effectiveness for immobilizing Cs-137 radionuclides in NaY Faujasite matrices, as reported in Solid State Sciences [5].

TABLE 1
37 SUPPORTING REFERENCES ON ^{55}CS-137 HUMAN CASES AND INDUSTRIES 4.0

Author, year	Topic/Aims Variables of Interest	Adjustment for other variables	Comparative risk measures for Cs-137	Information
Kausar A, 2021 [6}	Cesium doping (Alkali Metal doping)	Perovskite solar cells (PSCs)	Lead (II) acetate-based PSCs	Any category related minerals and ceramics
Mollaamin, 2025 [7]	Cesium doping	(Li/Na/K) batteries	Eco-friendly energy storage	In $Ge_5Si_5O_{20}$ 2D layered materials too
Mollaamin, 2025 [8]	Cesium doping (-p) pm Li, K, Na -ion batteries	As electrolyte additive	Upgrade Performance and Stability	Improved Battery Capacity
Mollaamin, 2025 [9]	Alkali Metal Doping	Copy Hydrogen-Capture/adsorption	With SnO_2-SiO_2 core materials	Alkali metal-ion battery
Ma M, 2024 [10]	Interlayer Cs-N grow photocatalytic output	Excellence of easy to utilize	Vis-light-driven photocatalyst	g-C_3N_4 on earth plentifully
Kulkarni GK, 2025 [11]	Cs doping and f-CNTs Solar energy	$Cs_xFA_{1-x}PbI_3$ SCAPS-1D	Perovskite Solar Cells structure effectiveness	The impact of thickness, trap density,
Izrael'yants 2017 [12]	Cs deposition lessen to φ~ 3.1 eV and to φ~2.9 eV with potassium doping	A highest emission current	At an optimal thickness of coating	MWCNTs-electrical arc photovoltaic

Kumanek B, 2022 [13]	Doping engineering of SWCNT by ^{7}N-14	Changing the type and concentration	Superficial strategies	To recover and reuse thermal energy
Bahmanrokh G, 2025 [14]	Pollucite Ceramics and Glass-Ceramics	As progress waste form	For the immobilization of Cs-loaded IONSIV Wastes	Environmental case
Meyer A, v2017 verified 2022 [15]	Procedure for determining the activity level of Cs-137 in seawater	Per cubic meters of seawater	Cs-134 should be excluded	20-45 L sample amount Cs-137 is precipitated after various purification steps
Zheng Z, 2023 [16]	Zeolite-Rich can effectively immobilize radioactive nuclides	Geopolymer from the Hydrothermal Synthesis	From Fly Ash A large amount of low- and intermediate-level radioactive waste liquid	Stimulated Cs+ Operation of nuclear power plants produces
Proust V, 2024 [17]	Cs-137 nuclear waste	Significant threats to the environment	Cs entrapment	adsorption efficiency tied to microstructure
Milyutin V, 2023 [18]	Removal of Cs-137	From Liquid Alkaline High-Level Radioactive waste	Imitated Solution	By Sorbents of Various Classes
Pang M, 2025 [19]	Cs-137 extraction in radioactive salt lakes and wastewater	with Zn-doped Mn hexacyanoferrate electrode	Cs+/Na+ molar ratio of 1:40	Outstanding Cs-electrosorption capacity and stability
He P, 2019 [20]	Safe trapping of radioactive nuclear waste such as Cs-137	Nuclear waste good chemical and thermal stability	pollucite structure	By geopolymer precursor technique
Wu Y, 2024 [21]	AAM prepared entirely from waste materials	Source of alkaline waste vs. Portland cement	Relate to by utilizing low-carbon industrial waste	AAM are crafted without commercial activators
Qin Y, 2022 [22]	Alkali-activated material (AAM)	Geopolymer to limit CO2 emissions	industrial by-products/precursor	Vs. ordinary Portland Cement (OPC)
Franca S, 2023 [23]	Alkali-activated material (AAM)	dissolution process	polycondensation of precursors	of precursors in high S, 2023 solution
Ge K, 2025 [24]	Preparation of low-carbon cementitious materials based on fly ash	By alkali-salt solid waste synergistic effect from biomass power plant	Activator ratio optimization, hydration process and sustainability opinion	Process Safety and Environmental Protection
Rossi L, 2022 [25]	AAM from existing standards to structural industry	future perspectives	cement and concrete production	contribute significantly to global greenhouse gas emissions
Marvila MT, 2021 [26]	AAM has superior properties	compared to Ordinary Portland cement (OPC).	AAM/geopolymers also lessen environmental risks	The precursor (solid or powder) and the activator (pH)
Kriven WM 2024 [27]	Geopolymers & AAM positioning as climate change mitigation	In mitigating climate change and market challenges	To harness the benefits of these materials as extremely important for sustainable construction	prioritizing low-cost alternatives and local waste materials
Alhassan, 2023 [28]	Cesium in geopolymer	Immobilization mechanism radioactive wastes	Effects of alkaline activators as crucial for sustainable construction	High temperature and acid resistance
Zhang C, 2025 [29]	Activated Fly Ash (AFA) enhanced adsorption capacity	reduced dispersion coefficient, pore density decreasing	Potential suitability as landfill barriers	To landfill its old computer
Tian Y, 2022 [30]	Silver niobate perovskites (AgNbO3) high-power energy storage/ conversion,	Peculiar anti-ferroelectricity and Narrow bandgap semi-conductivity	Lead to different types of external stimuli, incl. electric fields, light and mechanical forces.	Apps incl. dielectric, piezoelectric, photocatalytic and photo voltaic devices

Abhishek, 2022 [31]	Alkali Activated Fly Ash-Slag Concrete	Fresh Mechanical	Durability Properties	Innovative Infrastructure Solution
Palomo A, 1999 [32]	Alkali-activated fly ashes (AAFA) is highly alkaline mix	Waste materials from industrial mining functioning	Has become a significant area of cement for the future	Fly ash (no other solid material was used)
Puertas F, 2000 [33]	AAFA	Slag cement	Strength behavior and hydration product	Cement and concrete research
Skvara F, 2007 [34]	Alkali Activated Fly Ash Geopolymer Materials	is exploited as an additive to cement and concrete	But the majority is throwing away on dumps (for instance)	In a mixture with waste
Iyer RK, 2022 [35]	Ni, Cu, Ti, Rare-Earth Elements. Cu, Ni are used in wiring and batteries trades	Sulfide ores (mix of S and one or more other elements like Cu, Ni, Zn, Pb, etc.)	ore grade effects energy and material	needs only for the mining and do good to stages
Jose SA, 2025 [36]	Solid-State Li Batteries	Advances, Challenges, Future Perspective	Increased safety, higher energy density, longer life cycles	The electrolyte
Zhou J, 2025 [37]	Cs doping master plan boost Perovskite	toward efficient and lasting rechargeable zinc-air batteries	Reduce oxygen vacancies formation	bifunctional oxygen electrocatalytic action
Yubonmhat K, 2024 [38]	Ordinary Portland Cement (OPC)	Solidification of Cs-137 polluted	Electric arc furnace dust (EAFD)	Several mixing recipes
Chen ZH, 2025 [39]	^{38}Sr-90 green and sustainable uptake	Crucial needed for radionuclides heal using electroactive ion exchange stuff between Sr^{2+} vs. ($Na_2La_2Ti_3O_{10}$)	Electrochemically switched ion exchange (ESIX) method, ready as working electrode Sr^{2+} adsorption	A titanate perovskite ($Na_2La_2Ti_3O_{10}$) with outstanding acid, irradiation resistance, thermal stability, effectively capture Sr^{2+}
Wei C, 2025 [40]	Cs-137 and Sr-90 from radioactive waste liquid	The efficient Cs^+/Sr^{2+} capture by coating thioniobates and thiotantalate	Dismissal mechanism	Metal sulfide and ion exchange
Rao GS, 2021 [41]	Capacitive Sensor (CS) with Wireless Readout (WR)	CS are most often used for the amount of liquid level in the	Design and growth of Level Transmitter using CS with WR	International J Electrical Engineering and Informatics
Han, 2021 [42]	Cesium Doping	for act expansion of Pb(Ac)2 form PSCs	A successful method	PSCs (Perovskite Solar Cells)
Zhang X, 2017 [43]	2-D PSCs via cesium doping	Stable high capability	Cs^+ doped 2D $(BA)_2(MA)_3Pb_4I_{13}$ PSCs	PSCs
Machin, 2025 [44]	Solid-State Lithium Batteries	Dendrite repression strategies	From Interface Engineering	Material Innovations Batteries
Nakamura, 2011 [45]	Magnetic Resonance Images	Lanthanum Carbonate	Signal Intensity	Japanese J Rad
[46]Zhu Y, 2022 [46]	Toward High-Strength CNT Fibers	SWCNT, DWCNT	Controllable arrangements & strengthening strategies	Cylinders rolled from a single layer graphene sheet. Nanomaterials
Abubakre OK, 2023 [47]	CNT-reinforced polymer nanocomposites	For sustainable biomedical apps	The existence prosthetic industry due to their unparalleled strength-to-weight characteristics	Advanced Materials and Devices
Kandy SB, 2019 [48]	Raise the effective unbundling and particular dispersion	in Highly Concentrated Emulsions	Effect of Organic Alteration on MWCNT	The noncovalent modification

Freitas B, 2021 [49]	Strong, flexible, freestanding and high surface area activated carbon	MWCNTs and an activated carbon (AC) composite material	as an electrode electrical double-layer capacitor (EDLCs)	Excellent electrode properties for aqueous-based supercapacitor
Pandey PC, 2023 [50]	Prussian blue NPs-mediated sensing and dismissal of Cs-137	PBNPs display superparamagnetic behavior	Magnetic properties are linearly conditional on the Cs ion level	Toxicology, Pollution and the Environment
Liu H, 2023 [51]	The removal of Cs from radioactive wastewater	The latest research direction	1580 articles connected aqueous Cs treatment 2012-2022	Prussian blue, graphene oxide, hydrogel, nanocomposites in high capacity
Yang C, 2021 [52]	Solid-State batteries	Commitment both high energy density and safety	Inorganic ion conductors pemit fast ion transport, but to rigid	Copper-coordinated cellulose ion conductors
Wan H, 2023 [53]	Progress in Solid Electrolytes	And Solid-State Li Batteries (SSLBs)	Interface pattern for all SSLBs to suppress the Li dendrite growth	High energy and fast charging capability
Zhang H, 2023 [54]	SSE for Li anode based All-SSBs	For Li-anode	Li_2ZrCl_6 Li_6PS_5Cl for ASSLBs	Halide/Sulfide composite

From Table 1, it is revealed that Cesium and Cs-137 are used in Perovskite Solar Cells (PSCs), batteries, CNTs, immobilization of Cs-137 [28], and as a hazardous pollutant. Prioritizing low-cost alternatives and local waste materials [27] positions these materials as essential for sustainable construction and climate change mitigation [24,25,26,27]. Cs doping (alkali metal doping) in PSCs is also done similarly as in cement and ceramics for the present and future [6]. It is only made from fly ash, water, and cellulose with a highly alkaline solution, contributing to cement and concrete in sustainable construction production [20,21,22,23,24,25,26,27,28].

Alkali-Activated Fly Ash-Slag Concrete has fresh mechanical durability properties and innovative infrastructure solutions [31,32,33,34]. Advances in solid electrolytes and Solid-State Batteries (SSLBs) are revealed [36,53,54]. Interface design for all-solid-state-lithium batteries [53] and halide/sulfide composite solid-state electrolyte for Li-anode based all-solid-state batteries have been reported [54]. Li_2ZrCl_6 (LZC), a composite solid-state electrolyte (SSE) combining LZC and argyrodite buffer layer (Li_6PS_5Cl, LPSC), prevents the unfavorable interaction between LZC and Li metal. LZC for SSEs has been recognized as a candidate halide SSE for All-Solid-State Li Batteries (ASSLBs) with high energy density and safety due to its compatibility with 4V-class cathodes and low bill-of-material (BOM) cost. The development of halide-based high-performance ASSLBs is reported. Solid-State Lithium Batteries: Advances, Challenges, and Future Perspectives [36].

Artificial Soft-Rigid Protective Layer for Dendrite-Free Lithium Metal Anode has been reported [55]. Ex situ coatings, composed of polymer, inorganic ceramics, and their hybrids, offer controllable mechanical strength, thus overcoming the fragility issue that in situ Solid Electrolyte Interphase (SEI) essentially meets [55]. Heterogenous doping via nanoscale coating impacts the mechanics of Li intrusion in brittle solid electrolytes [56]. This complements present bulk design rules to minimize mechanical failure in solid-state batteries, solid electrolytes [36,53,54,56], interface engineering [13,44,53], interlayers Cs-N [10], Cs doping-photocatalysis [10,30], Cs doping-coatings MWCNTs [12], and MWCNTs-electrical arc photovoltaic [12] are reported. Ex situ coating [56], nanoscale coating [56], known as composite polymer electrolytes a.k.a. nanocomposite [47,49,54,63,64], parallel with the basic Cs-137 generator [57]. Capacitive Deionization Using an Ion-Exchange Layer Coated on a Carbon Electrode [58] and electrochemical removal of cesium ions already exist [14,16,18,19,40,50,51,58].

Cesium doping (alkali metal doping) in PSCs is associated with minerals and ceramics [6]. Cesium doping for performance improvement of lead(II)-acetate-based PSCs [42] and stable high efficiency two-dimensional PSCs via cesium doping [43] have been reported in Energy and Environment.

The electrolyte types could be sulfide, oxide, or polymer. Sulfide electrolytes contain sulfur plus one or more other elements. Oxide electrolytes contain oxygen plus one or more other elements. Polymer electrolytes contain polymer plus one or more other elements. Sulfide ores (compounds of sulfur and one or more other elements like Cu, Ni, Zn, Pb, etc.) are used. Halide is a binary compound of a halogen (F, Cl, Br, I, At, Ts), group 17/VIIA, with another element or group. Zhu C, 2015, revealed electrochemical sensors and biosensors with nanomaterials and nanostructures [59]. Zhu Y, 2022, reported controllable preparation and strengthening strategies towards high-strength carbon nanotube fibers with nanomaterials [46].

All these electronic appliances, medical devices, and computers contain Cs-137, including devices for calibrating radiation detectors (Geiger counters), resistors, transistors, sensors, and capacitor components. Heterogenous doping via nanoscale coating impacts the mechanics of Li intrusion in brittle solid electrolytes [56]. Cs-137 capacitors (alkali metal doping) use ceramic/metal components as part of capacitors in every electronic device. Spintronics use spin (intrinsic electron) to produce more efficient electronic appliances, such as very sensitive magnetic sensors and high-capacity memory. Applications and benefits include data storage, magnetic sensors, and increased capacity in hard-disc drive storage significantly. Spintronics and device applications have been recorded [60,61], and as a challenge for materials science and solid-state chemistry [62]. Intrinsic isolated barrier wire transmitter signal condition technology for hazardous areas [61] supports the advancement of higher inductance, higher conductivity, higher energy density, and safety.

Electronic product competition continually increases, such as high-strength CNTs fibers [46], CNT-reinforced polymer nanocomposites for sustainable biomedical applications [47], which increase MWCNT performance [48,49]. Nowadays, solid-state batteries (SSB), and in the future, all use Cs-137 to increase performance such as larger storage, sustainability, and recycling [52,53,54,55] should be transparent. Also, since SS chemistry-spintronic technologies [62] and the development principle of device applications [60,61] all become broadly known.

Cs-137 is used in small scale for calibration of radiation detectors (Geiger counters), and in large scale for medical radiation therapy for cancer [57]. Cs-137 is also used in industry to measure thickness or flow. Mishandling Cs-137 at high levels could destroy nucleic acid DNA, inducing cancer and acute radiation diseases. Other reports on Carbon Nanotubes (CNTs) [46,47,48,49], Cs-137 nanoparticles [50], removal of Cs-137 radioactive [50,51], on SSB [52,53,54,55], on LRC [56,58,59,60,62], on structural nanotubes, nanocomposites and perovskite phase [63,64,65,66], on LED, OLED, optical materials [67,68,69,70,71,72,73], and on ceramics coated on porous graphene electrodes [76] have been recorded. MWCNTs are used to make porcelain and ceramics, leveraging low thermal conductivity for insulation and durability.

IV. DISCUSSION

The association of Cs-137 doping for Perovskite Solar Cells (PSCs) and related minerals and ceramics, extraction of Cs-137, nanotubes, nanocomposites, nanocrystals, and their applications that enhance efficiency and stability have been recorded [6,63,64,65,66,67,68,69]. The removal of Cs-137 from wastewater and liquid alkaline wastewater has been reported [18,40,50,51]. The high solubility of Cs-137 should be widely known, as Cs-137 is more soluble than Na, K, and Rb [74], supporting the advancement of using alkali metals for doping. The argumentation of Cs-137 and their hazardous environment globally are as follows.

4.1 ^{55}Cs-133 Non-Radioactive (Natural) vs. ^{55}Cs-137 Radioactive (Synthetic)

^{55}Cs-117 to 146 have atomic weights with abundant isotopes or half-lives ranging from 0 seconds to years (30.1 years). Different decay modes include β^- and β^+; Δ(MeV) -86.560, Jπ: 7/2+; σ_n(b): compared to ^{92}U-238 and ^{92}U-235. Abundant energy is caused by an unbalanced neutron-to-proton ratio. Main nuclides that are unstable release alpha, beta, or gamma rays.

TABLE 2
NON-RADIOACTIVE VS. RADIOACTIVE OF ^{55}CS AND ^{92}U PHYSICAL CHARACTERISTICS

Z	Nuclide	A	Abundance or $t_{1/2}$	Decay Mode	N = A-Z	Δ (MeV)	Jπ/Spin	σ_n (b)
55	Cs Cesium	133	100%	None	78	-88.089	7/2+	27g 2.5m
55	Cs Cesium	137	30.17y	β^-	82	-86.56	7/2+	0.11rs
92	U Uranium	238	99.275% 4.468×10^9y	α	46	47.307	0+	2.7
92	U Uranium	235	0.720% 7.038×10^8y	α	43	40.916	7/2	580r

Nuclide refers to a specific nucleus specified by A and Z. General notation for a nuclide X is written as ^{A}_Z X

N = Total neutrons in core X = A – Z

Z = Atomic Number

A = Atomic Weight

IT = Isomeric Transition (γ emission and electron decay conversion)

α = Alpha decay

SF = Spontaneous fission (only if branches with this mode is >1%)

β^- = Beta decay negative

Δ(MeV) = Mass excess

Jπ = Spin J and Parity

σ_n(b) = Neutron capture cross section in barns (b = 10^{-24} cm²)

g, m = ground state, m isomeric state

rs, r = rapid-process, slow process (thermal)

Cs-137 is an alkali metal element (Group I metals), which are powerful reductants in aqueous solution. Their high solubility in water gives them strong fluidity. Their common name "alkali metals" comes from their ability to reduce water to form alkalis (soluble bases) and hydrogen gas. The reaction of Group I elements with water increases in vigor with increasing atomic number (AN; Z) [74]. Lithium (AN:3) reacts steadily with water in an unspectacular manner. Cesium (AN 55) reacts explosively, shattering its glass container. A base that is soluble in water is called an alkali. Dissolving an alkali in water gives an alkaline solution, which has a pH greater than 7 [74].

Alkaline, sometimes called alkali-activated materials (AAM) or geopolymers [16,20,27], have superior properties compared to Portland cement in mechanical strength, acid/salt resistance, and thermal stability; they are conducive to the solidification of hazardous wastes [38]. Furthermore, a large amount of fly ash is produced every year worldwide, and geopolymers prepared from fly ash do not need to emit CO_2, which alleviates some of the greenhouse effect [22]. Thus, the utilization of fly ash is recycling Cs-137 to decrease carbon emissions based on fly ash safety and environmental protection [24].

Goodbye to cement: nowadays, a new building material using just fly ash (Alkali Activated Material AAM/Geopolymer, aka Precursor), water, and cellulose is eliminating the need for cement entirely. Intended for low-rise structures, the material is strong, widely accessible, and dramatically cleaner than traditional concrete. Cement is responsible for global CO_2 emissions, while geopolymer has adsorbed CO_2 emissions. Soil with recycled cardboard tubes forms a simple yet durable wall system. It produces carbon emissions only one-quarter of concrete at less than one-third of the production cost. This also maintains structural integrity without using any cement, prevents cracking, supports vertical loads, and eliminates the need for emission-heavy industrial materials. Even more, the system is fully recyclable, meaning construction waste can be drastically reduced. Waste toward Alkali Activated Fly Ash-Slag Concrete construction could deliver notable environmental and economic advantages [27].

In Table 1, it is recorded that slag concrete from AAM/geopolymer made from fly ash adsorbs Cs-137; this system also hides the waste radionuclides Cs-137 and Sr-90, which are adsorbed very well by the concrete. Even more, the concrete acts similarly to a lead (Pb) wall in a gamma-ray room for Cs-137. Exporting geopolymer with low carbon emission and importing cardboard cellulose are trendy, but waste products containing Cs-137 must be handled with an ethical spirit not to harm tropical rainforest peoples. However, recycling Cs-137 without strict SOP makes fly ash airborne and highly soluble in soil and water, producing high Cs-137 concentrations above 10 kGy or less standard. Shrimp, clove, and spice samples with more than 10 kGy are judged to be contaminated. On the contrary, the high concentration of Cs-137 in shrimp, clove, and spice could reveal nucleotide contamination. It should be decontaminated, similar to the Chernobyl and Fukushima hazard environments.

4.2 How and What For is ^{55}Cs-133 (Natural) Enriched to be ^{55}Cs-137?

The origin of Cs-137 is from isotopic radioactive synthesis produced from nuclear fission, as happens in nuclear reactors or from nuclear weapon tests/trials. Cs-137 cannot be produced from Cs-133, as they are different isotopes. The long half-life of Cs-137 allows it to last long in the environment and easily expose soil, water, and the food chain. If it enters the body, Cs-137 can accumulate in muscles, increasing cancer risk, including leukemia.

Cs-137 particles also originate from spontaneous fission of U-238. Cs-137 is more often found from U-235. With a relatively low boiling point of 671°C, it is easily evaporated, and when released unexpectedly at high temperatures, such as in the Chernobyl nuclear hazard or atomic explosion, it can travel extremely long distances airborne. After becoming sediment in the soil, this radioactive fission product moves and spreads easily in the environment due to its high solubility and common chemical compound being salt. Investigation of industrial salt import of Cs-137 is needed, apart from awareness of imported concrete. Imported industrial salt containing Cs-137 is used in the production of products like glass, ceramics, and every concrete for building walls and floors (Fig. 2a, 2b).

In the past, electronic waste should have been disposed of in deep geological repositories, but now it is found in everyday polymers in walls and road construction [Borges MHB. Petroleoegas 08/01/2026:23:25] and solid-state batteries with a half-life of 30 years. In the past, Cs-137 was produced from nuclear fission of plutonium and uranium and decayed to barium-137, its isobar, used in medical applications [57]. For cancer therapy, Cs-137 is used in medical devices for cancer treatment. The Cs-137 is held in a specialized chromatography column. Germany and Denmark's 73,000-ton floating concrete project has taken Europe by storm: how a massive block of concrete is crossing the Baltic Sea to connect two countries, transforming underwater engineering and revolutionizing the future of global infrastructure [Borges MHB. Petroleoegas 08/01/2026:23:25].

Almost all cases are found from waste iron steel, or apartment concrete walls mixed with gravel, or smelters of gamma-ray generators [57]. There is no report of Cs-137 from sensors, actuators, storage information, spintronics manufacture, or microelectronic devices factories. But it is found in ceramics [6,14]. On 5 October 2025, Antara reported that the Environment Ministry defeated 73 containers of illegal electronic waste from the state, in which Cs-137 was used for doping [4].

In beta decay of Cs-137, the decay process that Cs-137 undergoes beta-minus decay, where a neutron in the nucleus transforms into a proton, releasing an electron (beta particle) and an electron antineutrino. In this beta decay, ^{55}Cs-137 changes into ^{56}Ba-137m (Group IIa). The atomic number increases by one due to the conversion of a neutron into a proton. Gamma emission occurs when the excited Ba-137 nucleus then quickly transitions to its ground state by emitting a high-energy gamma ray (662 keV). Gamma rays are highly penetrating and dangerous to humans because they cause cellular damage.

4.3 Alkali Metal Cs-137 Improving PSC Performance and Stability

Alkali metals are silvery, soft metals that are highly reactive, with reactivity increasing down the group. So, Cs-137 in period 6 is highly reactive. Their valence electron is one, so like Na^+ and K^+, it is soluble in water. They have low melting points, low boiling points, low densities, and are excellent conductors of heat and electricity. Due to their high reactivity, Cs-137 is not found freely in nature and is stored under mineral oil solution to prevent reaction with air and water, which can be explosive. Food irradiation at doses of 10 kGy or less have been found by international expert committees to be wholesome and safe for human consumption. Cs-137 can be used as a means of enhancing particular properties of various food commodities by means of sterilization, insect disinfestation, delayed senescence, ripening, and sprout inhibition. Future plans relating to both sewage sludge and food irradiation make Cs-137 marketable. In Perovskite Industry 4.0, PSCs (Perovskite Solar Cells) are a type of solar cell that uses perovskite material as the active surface. Perovskite materials have a unique crystal structure and can adsorb light and emit heat, making them promising candidates for solar cell applications. PSCs achieve high efficiency in a short time at low cost and can be made with high flexibility [6,42,43]. The increasing stability and decreasing ion migration in PSCs can be achieved by new doping and materials such as cesium [6,42,43]. In CNTs Industry 4.0, doping is also determined by cesium [11,12,13], and the challenge of new ideas in the making of supercapacitors in MWCNT [49].

Activated Alkali Materials (AAM), Alkali Activated Fly Ash (AAFA), and immobilized Cs-137 in concretes are low-cost sources for electronic and ceramic industries. Alkali metals are good for doping. Alkali metal doping (using elements like Cs^+, Rb^+, K^+, Na^+, Li^+) yields a roadmap for increasing perovskite solar cell (PSC) performance and stability by regulating perovskite crystal structure, passivating defects, and suppressing ion migration. Doping with these cations offers benefits such as enhanced crystallinity, improved charge transport, and suppressed recombination, leading to higher power conversion efficiencies and extended operational lifetimes, though understanding the precise effects and location of the doped ions remains an area of active research.

Alkali-activated material (AAM)—also known as geopolymers [16,20,27]—is created from a range of materials (usually industrial by-products), known as precursors [20,22,23,26]. AAM are recognized as potential alternatives to Ordinary Portland cement (OPC) to limit CO_2 emissions and beneficiate several wastes into useful products [22]. The limit carbon emissions by using industrial by-products like fly ash and slag as substitutes for OPC. AAM need less energy and can use waste streams, thus producing lower carbon emissions than traditional cement production. AAMs can reduce carbon emissions by a significant percentage, sometimes up to 44.75% lower than cement concrete, and offer other benefits like alkali metal doping and cesium doping-enhanced durability and corrosion resistance [8,13,14,70]. AAMs production can be done at lower-temperature production [22]. AAMs help manage waste while creating a new, low-carbon construction material. AAMs also lower greenhouse gas emissions [22,24] reduced by 31% compared to OPC. The use of waste materials in AAMs promotes a circular economy by repurposing waste and protecting natural resources [23].

AAM results from the dissolution process and polycondensation of precursors in high pH solution [23]. AAM/geopolymer concrete has superior properties compared to Ordinary Portland cement (OPC) [24]. Marvila, 2021 [26], recorded that AAM focused on the reaction mechanisms of AAM, how these materials are formed and the chemical processes that cause them to harden, providing an important reference for understanding this type of sustainable cementitious binder. AAMs/Geopolymers are created from two main components: the precursor (solid or powdered such as metakaolin, fly ash, or blast furnace slag) and the activator (an alkaline solution, such as sodium or potassium hydroxide and/or silicates, which initiates the hardening process (high pH environment). AAM have durability and mechanical properties, resistance to chemical attack and high temperature, and standardization and practical application [26]. High pH solution (high pH environment) initiates the hardening process [23,26]. Why geopolymers and alkali-activated materials are key components of a sustainable world: a perspective contribution, is reported [27].

Ge, 2025, revealed that promoting the implementation of biomass power plant fly ash (BPP-FA) in low-carbon-cement-based systems, rather than landfill disposal, is a significant approach to accomplish energy conservation, emission reduction, and resource recycling in the construction industry, now beneficial to the green and sustainable development of building materials [24]. Low carbon cementitious material based on fly ash safety and environmental protection has been a landmark to the aims of climate crisis and environmental crisis [24].

A review of the use of recycled solid waste materials in asphalt pavements has been reported [80]. It is to replace natural aggregates, enhancing sustainability and reducing environmental impact. Fly ash offers high mechanical strength and durability for subgrade and surface layers when properly processed.

4.4 Parsimony on Three Cases This Week

A very senior doctor diagnosed typhoid fever without a Widal test based on a young student in the Faculty of Medicine, University of Airlangga, Surabaya, East Java. The patient, a neighbor in Semarang, Central Java, held his mother's hand, was apathetic, with complaint of 7 days fever, constipation, and came from an endemic typhoid area. Another two senior doctors in the north seashore of Banten, Java, diagnosed typhus 'almost labor' with only first Widal positive, at the early and end of the rainy season.

A distinctly senior doctor diagnosed Cs-137 exposure from electronic waste in Cikande and everywhere globally from the experience of lecturing LRC circuit in the Medical Faculty/National Top Referral General Hospital, and revealed that groundwater from electronic and 'concrete' waste sources of fly ash in junk/wreck scrap iron and waste recycling concrete panels for buildings, ceramics, and batteries are the source of Cikande Cs-137 exposure.

Thinking parsimoniously is about simplicity and efficiency. Not overcomplicating means choosing models that are straightforward and easy to understand without sacrificing accuracy. Parsimony is a mindset that values clarity and practicality. Each person globally should be parsimonious in fighting groundwater Cs-137 exposure. Zeolite is indeed being used to help mitigate radioactive contamination in the Chernobyl disaster area. Zeolite has been used to absorb Cs and Sr isotopes, which are some of the most problematic radioactive contaminants. It is also used in Fukushima to mitigate radioactive contamination from contaminated groundwater (clinoptilolite, a type of natural zeolite) [5,16].

4.5 Ferroelectric [75,76,77], Ferromagnetic [75], Semiconductor [7,54,72], Optical Material [73], OLED [69,71]

Alkali Activated Binder immobilization mechanism for hazardous and radioactive wastes using Cs-137 in geopolymer [14,28,38]. Immobilization of cesium in geopolymer and stabilization/solidification of pollutants are reported [29,38], using fly ash and the structure properties and multifunctional silver niobate perovskites also [30]. Alkali Activated Fly Ash-Slag Concrete is reported [31,32,33]. Cesium doping boosts Perovskite durable rechargeable [37], and Ordinary-Portland-Cement (OPC) solidification of Cs-137 contaminated electric arc furnace dust from steel production industry in Thailand [38].

Increasing performance also exists in Solid State Lithium Batteries and Carbon Nanotubes (CNTs) [46,47,48,49]. Freitas B, 2021, reported activated carbon and MWCNT supercapacitor [49]. Removal of Cs from radioactive wastewater was also reported [50,51]. Stable high efficiency two-dimensional PSCs via cesium doping were reported [43]. The effort in improving solid-state batteries was recorded [52,53,54,55]. Meanwhile, in the market, Capacitor Cs-137 was broadly known and MWCNT [12,69] is used to make supercapacitors [49]. Electrochemical sensors and biosensors with nanomaterials and nanostructures are recorded [59].

Another electronic component, SSE (Solid State Electrolyte) for Li anode in solid-state Li batteries [54]. A thin layer which forms on the surface of the Li anode functions to protect the anode from side-reaction with electrolyte, important to stabilize Li-ion batteries. Li itself is more used as ion (Li^+) that moves between anode and cathode, not as anode directly [72].

Phase transition, dielectric, ferroelectric and ferromagnetic properties of La-doped $BiFeO_3$-$BaTiO_3$ multiferroic ceramics [75]. Multiferroic properties of $BiFeO_3$/$BaTiO_3$ multilayered thin film [76]. Ivanov M, 2012, reported in Ferroelectrics vol. 433 of Enhanced Magnetization and Ferroelectric Switching in Multiferroic BST/BNFO Superstructures [77]. MWCNT could be used as Li-ion anode material increasing conductivity and capacity of Li storage. Co-sublimation of two or more materials concurrently is for making thin layers, which can be used to deposit organic or inorganic materials. Cesium-carbonate doping is often used to increase essential electronic material quality, mainly for OLED applications or solar cells. This optoelectronic material, Cs-carbonate doping in blue OLED, increases brightness and makes it more effective [69]. Through lowering the electron injection barrier, Li-ion battery technology continues to grow with demand for Electric Vehicles (EVs), New Renewable Energy Storage such as solar panels and wind turbines, electronic components in smartphones and laptops for high density and longer life, medical instruments such as pacemakers and patient monitoring, robotics and automation reliability and cost effectiveness. Solid-state batteries, zinc-air batteries [37], Li-air batteries, and Li-sulphur batteries each have their quality properties on solid electrolyte, O_2 air as cathode reactant, using sulfur as cathode, for safety, increasing capacity, and reducing cost.

4.6 Three Far-Different Locations but One Cause: ^{55}Cs-137 Rejected Export Samples in Shrimp, Spices, and Cloves are Chased by the Government

Promotion and prevention by water treatment, monitoring and decontamination of Cs-137 have long been reported [15,17,18,19,20]. The history of Prussian Blue similar to therapy Prussian Blue in Primary Health Centres; antibacterial, type of exposure, and antibiotic/MDR scanning, chemical toxic like aflatoxin, color waste catalyst, and this radioactive Cs-137 decontamination [50] should be done and detected everywhere. Batteries and Cs-137, waste batteries vs. many locations in Indonesia and everywhere globally from scrap iron/metal/concrete were detected. Zeolite-Rich can effectively immobilize radioactive nuclides [5,16], and become zeolite concrete and ceramic. Although Cs-137 is a main product of nuclear fission and is commonly found in nuclear waste and accidents, it is also found in waste batteries [5] and concrete [28,38].

The sequence of events: firstly, the government determined Cikande as an exposure area of radioactive Cs-137 by the Ministry of Food Sector Coordinator on 30 September 2025: ZH, state special incident radiation of Cs-137 radionuclide radiation. Coordination meeting in Graha Mandiri was held on Tuesday 30 September 2025. The government closed the source of Cs-137 exposure near the shrimp cold storage factory in Cikande. Followed by the decision of Cikande as a contaminated area, there were also prevention measures for the entering of contaminated containers in Tanjung Priok harbor, and removal of the radiation source. National Research and Innovation Body (BRIN) revealed that the Cikande area was exposed to radioactive material, and BRIN researchers compared Fukushima Daiichi and Chernobyl with the finding on spices which come from Indonesia, and cloves which are centuries known from North Molucca Islands.

Other than PTPMT in Cikande as Cs-137 contaminated, 15 owners of scrap metal stalls around were found and inspected. The task force investigated the management of PTPMT which comes from abroad and the advancement of the interrogation. Nuclear Cs-137 exposure in Serang is suspected to have come from abroad. Based on expert explanation, the material is only produced by nuclear reactors, which do not exist in Indonesia, so it is supposed that the exposure came from other countries, which then came in without control," said HFN in Serang, Tuesday 23 September 2025 reported by Kompas, Bandung [3]. Before, it was revealed by BAPETEN that some new points of exposure by radioactive material were found in Serang district area, Banten Province. Then, on 11 September 2025, BAPETEN and customs in Tanjung Priok Harbor Jakarta prevented imported products contaminated by radioactive Cs-137 from entering Indonesia. After receiving a report on 10 September 2025 about the existence of 9 containers from 14, which triggered alarm warnings at the Radiation Portal Monitor (RPM) because they exceeded the established threshold limit. The imported waste product mentioned came from the state, then said from the Philippines. The Philippines said to convey that there is a command to discard those concretes to Indonesia. On 5 December 2025, the task force said of Cikande Cs-137 hazard that it is not from the Philippines, but purely from PMT. The law of intentionally harming the environment (law article 598 to be sentenced up to 10 years prison or Rp. 10 billion fine), not just a negligent one (law article 599 to be sentenced up to 5 years prison or Rp. 5 billion fine) on environmental crimes in Indonesia is regulated in the new Penal Code (KUHP), Law No. 1/2023.

Diplomatically ambiguous: First said 'from the Philippines', became 'not from the Philippines' allegedly ordered by big brother, but the essence is that the waste byproduct contaminated Cs-137 is in Indonesia. So, it is counted as economic war or crime war because by Indonesian people, those concretes are recycled to be fly ashes again. There should be a law that all concrete which contains hidden Cs-137 and other radioactive nucleotides should not be scrapped before 30 years. It is wise to throw waste electronic in their own land or deep big hole. Concrete/ceramic used to immobilize Cs-137 for 30 years could be everywhere, not only Indonesia. This technology could also be a new Industry 4.0 to one who knows, but the scrap concrete/ceramic should be strictly controlled because Cs-137 is very soluble in groundwater and seawater, but not in fish pond water. So, Cs-137 is more waterborne than airborne to this plant, shrimp, clove, etc. contaminated.

4.7 Lanthanum Doping vs. Laterite Usually as Lanthanum Nickel Oxide/Alloy

Lanthanum doping is an activity where lanthanum, a rare-earth metal, is introduced into a material to boost its quality. This technique has been applied in various fields, including energy storage and photocatalysis. Requirements of lanthanum doping include: supercapacitors e.g., to silver niobate nanoparticles (La-$AgNbO_3$), a potential game-changer for future energy storage systems; for Lithium-ion batteries, lanthanum doping can improve the long-cycle performance of lithium-rich layered oxides, increasing discharge capacity and stability; for enhancing photocatalytic and antibacterial capacities, making them worthy for environmental demand. Lanthanum-doped nanoparticles such as $Mg_{0.33}Ni_{0.33}Co_{0.33}Fe_2O_4$; improved optical properties: lanthanum aluminate perovskite doped with Nb^{5+} has displayed better reflectivity, reaching up to 99.7% in the near-infrared light band; improved surface area of materials, leading to better energy storage and photocatalytic performance; enhanced electrical conductivity, enabling faster charge/discharge cycles; stability and durability: lanthanum doping can stabilize crystal structures, reducing degradation and upgrading material lifespan. Lanthanum is extracted from laterite sand or stone, usually as lanthanum nickel oxide. Sulfide ores (compounds of S and one or more other elements like Cu, Ni, Zn, Pb, etc.) than the Nickel, Copper, Titanium, and Rare-Earth elements esp. Lanthanum become life-cycle inventory of critical materials [35]. This means that for sulfide ores, ore grade influences energy and material need only for the mining and beneficiation stages. In contrast, for laterite ore rich in lanthanum as Rare-Earth Elements (REE), it makes it a thermally stable material used in optical glass, fibers, ceramics, and catalysts in recent and future modern electronics such as perovskites and concretes/crystals/ceramics nanoparticles up to concrete for buildings. Perovskite Solar Cells have been reported, simultaneous with Solid State Battery in modern Industry 4.0. Cs doping improves structural stability by preventing the transition to non-perovskite phase of PSCs [6].

High-performance humidity sensors based on $SnO_2/Ti_3C_2T_x$ nanocomposites coated on porous graphene electrodes has been reported by Tseng SF in Ceramics International 2024 [78]. The Cs-137 which is unstable releases alpha, beta, or gamma rays. The gamma rays are highly penetrating and dangerous to humans because they cause cellular damage. Adams S in Advanced Physics also reported the everyday use of gamma rays to induce mutations in genetic experiments, and can be used to sterilize medical equipment and foods [79]. A review of the use of recycled solid waste materials in asphalt pavements is published in Resources, Conservation and Recycling in 2007 [80].

LIMITATIONS

Multiferroic materials are very unique due to the coexistence of both ferroelectricity and ferromagnetism, and are being extensively investigated by researchers worldwide due to their potential applications in novel devices such as sensors, actuators, storage information, spintronics, and microelectronic devices [60,62,63,64,65]. Imported Cs-137 pathways for Lithium battery manufactures and waste channel paths of rubbish batteries in general use Fly Ash in the making of AAM/AAC [9]. However, alkali-activated material (AAM) utilization is limited presently by the lack of normative and construction guidelines. The limitations and challenges still hinder their standardization and wider application in the AAM/alkali-activated concrete/ceramic (AAC) construction field using significant numbers of industrial by-products and wastes into concretes [25]. Moreover, references on Cs-137 doping should be found using weighted Bayesian, hindered by alkali metal doping [6], alkali-activated material, geopolymer, precursor [20,26], and only Cs without -137 [10,11,12,13,14,42,43]. Cs-137 entrapment is more associated with green activities and climate change mitigation than related to batteries advancements [27] and also PSCs.

V. CONCLUSIONS

Battery raw materials, metal scrap, concrete scrap, imports, and exports from groundwater or aquifers—not headwater to lower sections of rivers—should be managed with proper training. The end reservoir collection and storage should be transparent, accountable, and have clear instructions. No ignorance, no carelessness globally about these cases is permitted. Cs-137 in many locations—from shrimp to spices and cloves—will be a good indicator to detect careless executive, judiciary, and legislative actions. No compromise on this. Cs-137 waste could be more hazardous than Fukushima and Chernobyl disasters because not every location is detected. Moreover, with the widespread transformation to electric cars and Cs-137 doping in concrete and ceramic Industry 4.0, the hazardous nature of Cs-137 should be handled with restrictive covenants until the value and enjoyment of adjoining land and seawater shrimp are preserved.

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CONFLICT OF INTEREST

The author declares no conflict of interest, but has a strong one-earth sense of belonging

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