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Thank you for the opportunity to share with this Committee my experience and opinions regarding coal combustion products (CCPs), and their beneficial use in sustainable construction. My name is Dr. Craig H. Benson, PhD, PE, DGE and I am a Professor of Geological Engineering and Civil & Environmental Engineering at the University of Wisconsin-Madison. I am also Director of the Recycled Materials Resource Center at the University of Wisconsin-Madison and Chair of Geological Engineering. I teach courses that pertain to sustainable construction and management of byproducts, amongst other topics. I also conduct research and development on the safe and wise use of industrial byproducts in sustainable construction as well as the environmentally sound management of wastes. I have been involved in scientific research and engineering practice for more than 25 years.

For 20 years, I have been conducting research on sustainable construction with industrial byproducts, including CCPs such as fly ash, bottom ash, and flue-gas desulphurization (FGD) residuals. Over the last decade, CCPs have become a large part of my research program because of the many ways in which they can be used safely, wisely, and economically in sustainable construction. This research has been supported by a broad distribution of stakeholders, including the US government, state governments, local governments, and industry. I strongly believe that using CCPs for infrastructure construction is advantageous for the nation. The most important advantages include creation of infrastructure that is more resilient and has longer service life while simultaneously reducing the energy consumed, water used, and greenhouse gases emitted for infrastructure construction. The US infrastructure is enormous and constitutes a major portion of our nation's capital investment and energy usage each year. Consequently, changes in regulations that may affect use of CCPs in infrastructure construction should be undertaken with great caution and care.

What are coal combustion products (CCPs)?

Coal combustion products (CCPs) generally consist of fly ash, bottom ash, boiler slag, and flue-gas desulphurization (FGD) residuals. Each is described in the following.

Fly ash. Fly ash is a fine-textured particulate collected from the off gas at coal-fired power plants to control air pollution. Although fly ash is a byproduct of controlling air pollution, scientific research and engineering practice have shown that fly ash has many useful characteristics as a construction material. Many fly ashes are cementitous, meaning that they can be used to bind particles together in a manner analogous to a conventional cement (e.g., Portland cement used in concrete). Fly ashes also are rich in calcium, silicon, and aluminum, and thus can be a good source of these elements in industrial processes such as Portland cement production. Thus, while fly ash may be considered a waste or byproduct from one industrial operation, fly ash is also a useful resource for other industrial operations (e.g., concrete production) that can be used in lieu of conventional materials that need to be mined and processed. By using fly ash in place of these conventional materials, energy and water are saved and greenhouse gas emissions are reduced. Improved engineering characteristics (e.g., durability, strength, etc.) can also be achieved.

Bottom ash and boiler slag. Bottom ash is a coarse-textured particulate residual of coal combustion that is collected from the bottom of a boiler. Boiler slag is a solid residual that collects on the boiler during combustion that is generally found as a coarse particulate. Bottom ash and boiler slag are generated in much smaller volumes than fly ash. Most bottom ash looks like sand largely because bottom ash is similar chemically to sand. Bottom ash is used in construction in the same manner as sand, i.e., as a foundation material, a backfill material, and as drainage material. Using bottom ash or boiler slag in lieu of sand or other natural aggregates precludes the need to mine sand from the earth and process the sand so that it has suitable engineering characteristics. Consequently, when bottom ash or boiler slag is used in lieu of sand or other coarse aggregate, the energy use and greenhouse gas emissions associated with mining and processing sand are avoided. Additionally, fewer quarries for sand and gravel are needed, which improves land and resource stewardship.

FGD residuals. FGD residuals are created as a byproduct of waters containing lime or limestone that are used to remove sulfur compounds from off gases to reduce air pollution (e.g., reduce 'acid rain' by removing SOx compounds). FGD residuals consist of gypsum (hydrated calcium sulfate) created when the calcium binds with the sulfur compounds in the presence of water. FGD residuals also contain small amounts of impurities. Because FGD residuals consist almost exclusively of gypsum, they are used in lieu of natural gypsum in industrial processes. The most common use is for manufacturing wallboard for building construction. Using FGD residuals in lieu of mined gypsum reduces energy use, water use, and greenhouse gas emissions. Additionally, fewer gypsum mines are required, which improves land and resource stewardship.

Have the risks changed since CCPs were designated as non-hazardous materials?

The chemical make up of fly ash depends on the coal used for combustion, the method used for combustion, the method used for collection, and ancillary processes that are employed for air pollution control (e.g., carbon injection). These factors change over time with technological innovation. However, the general characteristics of fly ashes have not changed dramatically since CCPs were originally designated non hazardous by Congress. Consequently, the risk of using fly ash in construction today is no different than it was decades ago. Similar statements can be made regarding bottom ash, boiler slag, and FGD residuals.

Fly ashes contain a variety of elements (e.g., calcium, aluminum, selenium, chromium) as do conventional earthen materials used in construction. Some of these elements are present in larger amounts in fly ash than in conventional earthen materials; others are lower. However, none of the amounts typically are high enough (or sufficiently mobile) for fly ash to be deemed "hazardous" as defined in the Resource Conservation and Recovery Act (RCRA). Thus, there is no scientific reason to manage CCPs as hazardous wastes.

Although CCPs have been designated as non-hazardous, and generally would not be considered hazardous when evaluated by the metrics in RCRA, they are not inert materials (i.e., non-hazardous does not imply inert). For example, cement reactions are initiated when many fly ashes are contacted with water in the same manner that cement reactions occur when Portland cement is mixed with water. These reactions create heat and alkalinity as the cements are formed. In addition, contacting CCPs with water can transfer elements in the CCP solid to the water, where they can be more mobile. Thus, like all construction materials, CCPs should be deployed in properly engineered applications using appropriate safety precautions that result in no adverse impact to the environment. Applications where CCPs are used in a dry environment (wallboard) or in a cemented monolithic environment (e.g., concrete) tend to have very low release and pose virtually no risk to the environment. In most cases, these applications have virtually no measure release.

Even in applications where releases may occur (e.g., stabilized base course in a roadway), the release needs to be considered relative to releases from conventional construction materials and to environmental standards. Because all construction materials are comprised of elements derived from the earth, they have the potential to release elements to the environment when contacted by water. Thus, a CCP may adversely affect the environment relative to a conventional construction material only if the CCP releases elements in a greater amount. Research has shown that some elements are released from CCPs in lesser amounts than from conventional construction materials, which means that CCPs may have *less* impact on the environment than conventional construction materials. In other cases, CCPs can release elements in greater amounts than a conventional construction material. In such cases, an adverse impact to the environment occurs only if elements are released at levels above environmental standards. Research that I have conducted, and the research of others, have shown that CCPs used in properly engineered applications generally do not release elements to the environment in amounts that exceed environmental standards.

Will the “hazardous waste” stigma affect beneficial use?

When we use CCPs as a resource, we realize significant advantages, notably reduced consumption of energy and water and lower greenhouse gas emissions. In some cases we obtain a superior product when fly ash is used in lieu of conventional construction materials. For example, roadway systems constructed with fly ash tend to be more durable and have longer service life.

Despite these advantages, not all industrial byproducts are beneficially used. There are many factors that affect whether an industrial byproduct will be selected in place of a conventional material. One of the most important factors is concern regarding potential environmental impacts and long-term liability. Major inroads have been made to address this concern over the last two decades using scientific principles and engineering methods. Test procedures have been developed, evaluation procedures have been formulated, and computer models have been created to evaluate risks and to alleviate concerns regarding environmental impacts and liabilities. However, none of these science-based principles and tools will overcome the psychological impact of CCPs being deemed a hazardous waste. An exemption for beneficial use will have virtually no effect on this psychological impact. The “hazardous” designation will scare users and incite liability, and thereby decimate beneficial use of CCPs.

Some have proffered that a hazardous designation coupled with a beneficial use exemption will increase the amount of CCPs that are beneficially used in a manner analogous to the reduction hazardous waste volume that occurred when RCRA hazardous waste rules were originally developed. My experience suggests that this outcome is unrealistic. Beneficial use is contingent on infrastructure owners accepting CCPs in their infrastructure, which is influenced strongly by owners’ perceptions of risks. The beneficial use community has struggled for years to overcome owners’ concerns regarding liability for industrial byproducts that are not designated hazardous. This struggle can only become much more difficult if a hazardous designation is instituted, even with a beneficial use exemption. There is no basis to believe that infrastructure owners will accept that the risks of using CCPs in infrastructure are minimal when essentially the same material is deemed a hazardous waste in a different setting. Indeed, evidence in this regard has already been realized as public works agencies in California and Maryland have banned use of CCPs in their infrastructure projects. Manufacturers of competing products and materials that do not include CCPs have also taken advantage of the hazardous waste stigma by advertising that their products and materials do not include hazardous waste.

I surmise that beneficial use of all industrial byproducts will diminish if CCPs are deemed hazardous waste. The logical inference from the perspective of a potential user is "Will the industrial byproduct I am using today be designated as a hazardous waste tomorrow? How will this affect my long-term liability?" The logical decision from the perspective of the user is to avoid beneficial use of industrial byproducts altogether. The impact on the nation will be greater energy and water consumption, greater greenhouse gas emissions, and poorer resource stewardship.

What effect will diminished beneficial reuse have on energy, water use, and greenhouse gas emissions?

My research group has been conducting a study to assess how cessation of beneficial use of CCPs will affect energy consumption, water usage, and greenhouse gas emissions. Although our study is not yet final, the findings are startling. Using CCPs in sustainable construction results in:

- saving 159 trillion Btu of energy annually,
- reducing water use by 32 billion gallons annually, and
- reducing greenhouse gas emissions by 11 million tons of CO_2 each year.

In more tangible terms, using CCPs in sustainable construction results in:

- saving the energy equivalent of 1.7 million US households annually,
- reducing water use in an amount equivalent to 31% of California's annual water use, and
- reducing greenhouse gas emissions equivalent to 1.9 million passenger cars each year.

Others recognize these savings. For example, the Kyoto Protocol accepts the reduction in greenhouse gas emissions from beneficial use of CCPs.

The stigma of a hazardous designation, even with a beneficial use exemption, will substantially reduce these benefits achieved by using CCPs in sustainable construction. A financial impact will also be realized. My research group estimates that using CCPs in sustainable construction results in a cost savings between $5 billion and $10 billion annually.

Are regulations for CCPs needed?

Regulations are needed to ensure that CCPs are managed and used in an environmentally sound manner. A means to ensure that these regulations are enforced uniformly is also needed. However, this does not imply that CCPs should be managed as hazardous waste in accordance with Subtitle C of RCRA. The containment technologies stipulated in Subtitle D of RCRA (e.g., single composite liners, leachate collection systems, monitoring, etc.) are sufficient to ensure that CCPs that are not beneficially used are managed in an environmentally sound manner. Amending RCRA to permit federal control over CCP disposal using RCRA Subtitle D technologies is a logical solution that would ensure uniform application of regulations, protect the environment, and preclude the demise of beneficial use.