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Petroleum Coke: Industry, Health, and Environmental Issues

North American crude oil and natural gas production has increased significantly over the past decade, primarily as a result of new or improved technologies (e.g., hydraulic fracturing, directional drilling, in situ injection) used on unconventional resources (e.g., shale, tight sands, coalbed methane, oil sands). The increase in production has occasioned a range of societal transformations, both economic and otherwise, including the potential for new environmental impacts.

One area of concern arises from the production and use of petroleum coke, or petcoke. Petcoke is a co-product of several processes used during petroleum refining to upgrade "residuum" into gasoline and middle distillate-range fuels. Residuum (or resid) is the substance that remains after refineries initially distill heavy crude oils. Nearly half of U.S. petroleum refineries (56 in 2015, as reported by the U.S. Energy Information Administration [EIA]) have the capacity to process heavy crude oils. Many refiners installed technologies over the past decade to take advantage of lower priced heavy crude oils from Saudi Arabia, Venezuela, and the Canadian oil sands.

In 2013, issues related to the production of petcoke in Detroit and Chicago drew national attention. In both instances, petcoke produced at local refineries was being stored in large piles prior to sale and shipment. Community stakeholders raised questions regarding the impacts of stored petcoke on air quality due to fugitive dust and water quality due to run-off; the potential for toxic and other emissions (including carbon dioxide emissions [CO_2]) from petcoke's combustion as a fuel; and whether these issues were adequately addressed by local, state, and federal regulations. As petroleum refining is a nationwide commercial industry, these questions may arise—or be revisited—in other locales.

Production and Composition

Petcoke often has economic value as both a heating fuel and as a raw material in manufacturing. Fuel-grade petcoke can substitute for coal in power plant boilers, having the advantage of a higher heating value. Conventional coal-fired boilers often blend petcoke with coal, and newer boiler designs can substitute it entirely. In manufacturing, petcoke is used in the aluminum, graphite electrode, steel, and titanium dioxide industries. In 2015, EIA reported that U.S. refineries produced in excess of 57 million metric tons (MMT) of petcoke, of which 26% was used as on-site refinery fuel, 12% was marketed domestically, and 62% was exported. Top destinations for exports in 2015 included India (4.7 MMT), Japan (4.3 MMT), and China (3.3 MMT).

Petcoke is composed primarily of carbon. The specific chemical composition of petcoke depends on the composition of the petroleum feedstock used in refining. Petcoke impurities (i.e., the non-elemental carbonaceous substances) include some residual hydrocarbons left over from processing (referred to as volatiles), as well as elemental forms of nitrogen, sulfur, nickel, vanadium, and other heavy metals. These impurities exist as a hardened residuum captured within coke's carbon matrix. **Table 1** provides an observed range of petcoke's main properties.

Table 1. Petcoke Elemental Composition

Composition	% by weight
Carbon	80.0–95.0
Volatile matter	5.0–15.0
Hydrogen	3.0–4.5
Sulfur	0.2–6.0
Ash (including heavy metals)	0.1–1.0
Nitrogen	0.1–0.5

Source: American Fuel and Petrochemical Manufacturers, *Petroleum Coke Overview.*

Health and Environmental Impacts

The recent increase in coking capacity in the United States has raised concerns over the potential impacts of petcoke on both human health and the environment. These impacts may arise during various stages of petcoke's life cycle, including its production, handling, storage, transportation, combustion, use, and disposal.

The U.S. Environmental Protection Agency (EPA) has surveyed the potential human health and environmental impacts of petcoke through its High Production Volume Challenge Program. Additionally, in 2016, the U.S. Department of Health and Human Services, Agency for Toxic Substances and Disease Registry (ATSDR), conducted an analysis on the potential impacts of particulate matter (PM) and metals exposure stemming from the Chicago petcoke storage facilities in 2013.

Most chemical analyses of petcoke, as referenced by EPA and ATSDR, find it to be highly stable and non-reactive at ambient environmental conditions. Most toxicity analyses find it has a low health hazard potential in humans, with no observed carcinogenic, reproductive, or developmental effects. Only animal case studies of repeated-dose and chronic inhalation have shown respiratory inflammation attributed to the non-specific effects of petcoke as a dust particle rather than the specific effects of petcoke's chemistry. The ASTDR analysis of petcoke's particulate effects found a potential for a "health threat to sensitive individuals and to those with pre-existing respiratory illnesses" on poor air quality days.

In regard to reactivity, petcoke is generally stable under normal conditions. However, like many organic substances, petcoke has the potential to become flammable or explosive under certain conditions. Emissions from the combustion of petcoke can release common pollutants (e.g., PM, nitrogen oxides [NO_x], and sulfur dioxides [SO_2]), hazardous substances, and CO_2. When combusted as a fuel, petcoke commonly has higher emissions of SO_2 and CO_2—per unit of energy produced—relative to other comparable hydrocarbons (see **Table 2**).

Table 2.Petcoke vs. Coal: Combustion Emissions

Fuel	HHV Btu/lb (avg.)	SO_2 lbs./ Million Btu	CO_2 lbs./ Million Btu
Petcoke	14,200	0.3–8.5	207–245
Coal			
Pittsburgh #8	13,300	3.2–3.5	202–204
Illinois #6	11,000	6.0–8.1	201–203
Wyoming PRB	8,400	0.9–1.2	211–213
Texas Lignite	7,100	1.5–4.8	205–224

Source: CRS, with data for higher heating values (HHV) in British thermal units per pound (Btu/lb) and sulfur and carbon content ranges from **Table 1** and M.I.T., *The Future of Coal,* 2007, p. 111.

Regulatory Requirements

Various aspects of the production, handling, storage, transportation, combustion, and use of petcoke have been addressed at local, state, and federal levels to protect human health and the environment. While some federal statutes address certain environmental impacts of petcoke's life cycle, most regulatory action and oversight has been undertaken at the state and local levels, generally through facility-specific permitting requirements. With few exceptions, petcoke is not regulated specifically. Rather, it is petcoke's potential contribution to more general hazards (e.g., air and water quality impacts such as haze, fugitive dust, and stormwater runoff) that is monitored and controlled through various regulatory requirements.

Waste Classifications

Federal law generally exempts petcoke from classification as either a solid or hazardous waste. The exemption stems from the scope of the statutory term "solid waste" as decided in *American Mining Congress v. U.S. EPA*. In that decision, the court held that materials recycled and reused in an ongoing manufacturing or industrial process were not considered to be "discarded" and, hence, not considered to be "solid wastes." Furthermore, in 1998, EPA identified a list of petroleum refining wastes that would be subject to federal regulations applicable to the management of hazardous waste established under the Resource Conservation and Recovery Act. In this rulemaking, EPA stated that petcoke is not a waste but rather a "co-product" of the refining process. In a separate rulemaking, EPA further supported this classification by including petcoke among its definition of "traditional fuels" (at 40 C.F.R. §241.2).

Similarly, petcoke is not subject to the federal cleanup authorities of the Comprehensive Environmental Response, Compensation, and Liability Act (often referred to as Superfund) because of the exclusion of petroleum from the statute. The act defines a hazardous substance, pollutant, or contaminant to exclude "petroleum, including crude oil *or any fraction thereof* which is not otherwise specifically listed or designated as a hazardous substance."

Industrial Stormwater Runoff

The storage of petcoke may be regulated under certain provisions of the National Pollutant Discharge Elimination System (NPDES) permit program, as authorized in Section 402 of the Clean Water Act, if it is determined that runoff from storage sites due to rain or snowmelt has the potential to transport the substance to nearby surface waters. Common NPDES permit requirements include the development of a written stormwater pollution prevention plan and the implementation of control measures. Control measures could include site-specific best management practices, maintenance plans, inspections, employee training, and reporting. NPDES permit programs are typically administered by state and local agencies.

Fugitive Dust

The handling, storage, and transportation of petcoke may create local nuisance problems due to the release of fugitive dust into the atmosphere. Regulatory oversight for this issue is commonly implemented at the state and local levels and generally takes the form of a fugitive dust control program. These programs are often a necessary component to any air permitting requirements for industrial sources, including permits to install, operate, or decommission a facility.

At the federal level, EPA has set National Ambient Air Quality Standards (NAAQS) for PM, among other pollutants, under the Clean Air Act. If fugitive dust generation is determined to be an issue at a facility that produces, handles, stores, or transports petcoke, and if the facility is situated in an area that EPA identifies as "nonattainment" for PM NAAQS, then it may be possible for state authorities to require the facility to report on and manage its fugitive dust emissions—if it is not doing so already—within the context of their NAAQS State Implementation Plan.

Petcoke Combustion in Power Generation

When petcoke is combusted at power generating or other industrial facilities, the resulting emissions would be regulated under the specific standards set on the respective facility. For example, federal regulations that may be implemented could include EPA's New Source Performance Standards for Electricity Generating Units, Mercury and Air Toxics Standards, Cross State Air Pollution Rule for NO_x and SO_2, Title V Permitting Requirements, Greenhouse Gas Reporting Requirements, and Steam Electric Effluent Guidelines.

Richard K. Lattanzio, Specialist in Environmental Policy

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