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The Invisible Poison: How PAHs in Power Plants and Refineries Find their Way into Our Food

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In today's industrialized society, many modern comforts carry unseen environmental consequences. One such concern is polycyclic aromatic hydrocarbons (PAHs), a group of persistent and toxic organic pollutants that have emerged as a worldwide food safety issue. Released largely from power plants and petroleum refineries, these contaminants can persist in the environment and enter the food chain without being detected, ultimately posing serious risks to human health. This article examines how PAHs travel from industrial sources to food, the pathways through which contamination occurs, their potential health effects, and the measures that can be taken to reduce exposure.

"There is little concern about the relatively unpopular substance 'PAH,' yet it can be more dangerous than many other pollutants."

PAHs and Why Are They a Concern

Polycyclic aromatic hydrocarbons (PAHs) are a group of organic chemicals made up of two or more fused aromatic rings. They are mainly generated through the incomplete combustion of organic materials such as coal, oil, and wood processes that are integral to power production and petroleum refining (Abdel-Shafy and Mansour, 2016). Although some PAHs originate from natural sources, such as forest fires, most environmental PAHs are derived from human activities, with industrial operations representing the primary contributors (Anyahara, 2021). Due to their high chemical stability and hydrophobic, lipophilic nature, PAHs can persist for long periods in the environment and readily bioaccumulate in biological systems (Liu et al., 2024). Several PAHs exhibit carcinogenic, mutagenic, and endocrine-disrupting properties, among which benzo[a]pyrene (BaP) is particularly well known for its strong carcinogenicity. Long-term exposure to PAHs has been associated with elevated risks of cancer, as well as adverse reproductive and developmental effects, immune system impairment, and cardiovascular disorders (Montano et al., 2025).

Industrial Sources: Power Plants and Refineries

Power plants and petroleum refineries are key contributors to polycyclic aromatic hydrocarbon (PAH) pollution, as the large-scale burning of fossil fuels in these facilities is often incomplete, especially under high-temperature and low-oxygen conditions, leading to the formation of complex PAH mixtures (Anyahara, 2021). In India, industrial and energy centers such as Singrauli, Talcher, Mathura, Jamnagar, Jamshedpur, and Amravati exhibit elevated PAH emissions, with soils within a 10–15 km radius showing ΣPAH concentrations ranging from 150 to 19,000 µg/kg, significantly exceeding background levels (Sankar et al., 2023; Chaudhary et al., 2012; Ekka et al., 2021; Romana et al., 2022). Comparable patterns are seen globally: soils near petroleum refineries in China contain 60–1,600 µg/kg PAHs, while water and sediment samples near oil refineries along the Tigris River in Iraq reach up to 3,750 ng/L and 12,795 ng/g, respectively, with high-molecular-weight PAHs dominating the contamination (Grmasha et al., 2023; Wang et al., 2024).

Pathways from Industry to Food

1. Atmospheric Deposition

Once emitted, polycyclic aromatic hydrocarbons (PAHs) can be transported over long distances in the atmosphere, either in the gaseous phase or bound to airborne particulate matter. Atmospheric deposition, occurring through wet processes such as rainfall and snowfall as well as dry processes involving dust and soot, represents a major pathway by which PAHs are transferred to agricultural soils, surface waters, and crops. Vegetables and fruits particularly those with broad leaf areas or waxy outer surfaces are especially prone to PAH accumulation through direct atmospheric deposition (Abdel-Shafy and Mansour, 2016).

2. Soil and Water Contamination

Once deposited from the atmosphere, polycyclic aromatic hydrocarbons (PAHs) can persist in soils and aquatic environments because of their hydrophobic properties. Crops are able to take up PAHs from contaminated soils through their root systems, while aquatic organisms can accumulate these compounds directly from polluted water and sediments (Abdel-Shafy and Mansour, 2016). Research has shown that leafy vegetables cultivated near industrial zones often contain PAH concentrations in the range of 65.7 to 458 ng/g, with the highest levels observed in fields located closest to emission sources (Jia et al., 2018). Similarly, root vegetables such as potatoes and carrots tend to exhibit increased PAH concentrations when grown in contaminated soils.

3. Bioaccumulation in the Food Chain

Polycyclic aromatic hydrocarbons (PAHs) are not only taken up by plants but also tend to bioaccumulate in animals. Livestock that graze on contaminated pastures or consume polluted water can accumulate PAHs in their tissues, which may then be passed on to humans through the consumption of meat, milk, and eggs (Montano et al., 2025). In aquatic systems, PAHs readily bind to sediments and are subsequently absorbed by fish, shellfish, and other aquatic organisms, resulting in elevated concentrations in seafood. For instance, shellfish collected from the Beibu Gulf in China have been reported to contain average PAH concentrations of about 183 ng/g, with fish and shrimp also exhibiting notable levels of contamination (Han et al., 2022).

4. Food Processing and Cooking

Industrial emissions are not the sole contributors to polycyclic aromatic hydrocarbons (PAHs) in food. High-temperature cooking techniques such as grilling, smoking, roasting, and frying can also produce PAHs, particularly when foods are exposed to open flames or combustion gases. Moreover, foods that are processed or prepared in or near industrial regions may contain even higher PAH concentrations as a result of the combined effects of environmental contamination and cooking-related PAH formation (Sampaio et al., 2021).

Evidence from Recent Studies

- **Vegetables near industrial areas:** Researches carried out in industrialized regions has repeatedly demonstrated substantial accumulation of polycyclic aromatic hydrocarbons (PAHs) in vegetables. In industrial areas of Shanghai, China, all 16 priority PAHs have been detected in commonly consumed vegetables, with concentrations ranging from 65.7 to 458.0 ng/g across different crop types, including leafy, stem, seed and pod, and rhizome vegetables. Among these, leafy vegetables showed the highest PAH levels, largely due to their broad surface area and direct exposure to atmospheric deposition. Comparable patterns have also been observed in Accra, Ghana, where vegetables grown near industrial facilities contained elevated PAH concentrations, again with leafy vegetables being the most contaminated. Overall, these observations highlight the increased risk of PAH contamination when vegetables particularly leafy varieties are cultivated in heavily polluted or industrial environments (Sampaio et al., 2021).

- **Cereal and oil contamination:** Long-term monitoring of food products indicates that processed cereals and edible oils are significant contributors to dietary exposure to polycyclic aromatic hydrocarbons (PAHs). PAHs are frequently detected in commonly consumed cereal-based foods such as bread, pasta, flour, and bran across many regions worldwide. While the concentrations in individual products are generally low, their regular and high consumption means they can substantially contribute to overall PAH intake in humans. Similarly, edible vegetable oils including frying, blended, sunflower, corn, and canola oils often contain multiple PAH compounds, sometimes at relatively high levels. In certain cases, the concentrations of carcinogenic PAHs or PAH groups approach or exceed established regulatory thresholds. Taken together, these findings show that processed cereals and vegetable oils globally contain measurable PAH levels, highlighting their importance in dietary exposure evaluations and food safety assessments (Liu et al., 2024).
- **Seafood contamination:** Marine pollution can result in increased bioaccumulation of polycyclic aromatic hydrocarbons (PAHs) in fish and shellfish. The accumulation of PAHs has been associated with a range of adverse effects on aquatic organisms, including cell damage, inflammation, impaired reproduction, and genetic mutations, largely due to their persistence and low biodegradability. Experimental and field studies have shown that combined exposure to PAHs and low-oxygen conditions can disrupt mitochondrial function in zebrafish, while chronic PAH exposure has also been linked to poor physical health and physiological stress in squarefish from the northern Gulf of Mexico (Wang et al., 2024).
- **Occupational exposure:** Workers and nearby residents of coking plants and petroleum refineries are exposed to polycyclic aromatic hydrocarbons (PAHs) through both the environment and contaminated food, including meals prepared on-site. Food monitoring in industrial areas shows that a wide range of PAHs is commonly present in diets, often at higher rates than in control or non-industrial regions. Some PAHs, including both USEPA-regulated and unregulated compounds, are detected in over 80% of samples, indicating widespread contamination and suggesting that standard assessments may underestimate dietary exposure. Overall, populations living or working near industrial facilities are more vulnerable to PAH intake through food consumption (Gao et al., 2024).

Health Implications

Dietary exposure to polycyclic aromatic hydrocarbons (PAHs) poses significant health risks. Long-term ingestion of PAHs has been associated with an elevated risk of cancer, particularly affecting the lungs, skin, bladder, and digestive organs. In addition, PAHs can interfere with endocrine function, reduce fertility, and lead to developmental and neurological impairments. Children are particularly at risk, as their consumption of contaminated foods relative to body weight is higher and their developing bodies are more susceptible to the toxic effects of these compounds (Bwala and Sabiu Imam, 2023).

Regulatory and Mitigation Strategies

Due to the widespread presence of polycyclic aromatic hydrocarbons (PAHs) in the environment and their associated health risks, many countries have established regulatory limits for PAHs in food. For example, the European Union has set maximum allowable levels for benzo[a]pyrene and the sum of four priority PAHs in various food products. Despite these regulations, research indicates that these limits are frequently exceeded, particularly in foods produced or processed near industrial areas (Liu et al., 2024).

Several strategies can help mitigate PAH contamination:

- **Reducing industrial emissions:** Stricter controls on emissions from power plants and petroleum refineries can significantly lower PAH levels in the surrounding environment.
- **Establishing buffer zones:** Avoiding the cultivation of food crops close to industrial facilities and creating buffer zones can help reduce contamination risks.

- **Improved food processing:** Utilizing safer cooking and processing methods—such as indirect heating or natural plant-based marinades can minimize PAH formation in foods.
- **Regular monitoring:** Enhanced surveillance of PAH concentrations in both food and the environment is critical for early detection and effective risk management (Sampaio et al., 2021).

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