



Environmental pollutants and their effects on pigeon health and flight performance

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Abstract. Urban and industrial environments expose pigeons (*Columba livia*) to a diverse array of environmental pollutants, including heavy metals, organic contaminants, and particulate matter, which accumulate in feathers and internal tissues. This mini-review synthesizes current evidence on the sources, exposure pathways, and physiological consequences of these pollutants, with a particular focus on their effects on pigeon health and flight performance. Heavy metals such as lead, cadmium, and mercury, along with organic compounds like polycyclic aromatic hydrocarbons and pesticides, are consistently detected in pigeons inhabiting polluted areas. These contaminants induce oxidative stress, disrupt metabolic processes, and alter hematological parameters, indicating systemic physiological impairment. Additionally, pollutant accumulation affects plumage characteristics and may interfere with visual signaling and thermoregulation. Experimental studies further demonstrate that sub-lethal exposure to cholinesterase-inhibiting pesticides significantly impairs flight performance, prolonging homing times and suggesting potential consequences for navigation and migration. Overall, pigeons serve as effective bioindicators of environmental pollution, providing valuable insights into the ecological and physiological impacts of anthropogenic contaminants on avian species.

Key Words: bioindicators, *Columba livia*, environmental pollution, heavy metals, oxidative stress, particulate matter, pesticides, urban ecology.

Introduction. Pigeons (*Columba livia*) are widely regarded as an important model organism in biological research, owing to their remarkable navigational capacities, phenotypic diversity, and well-documented physiology, which support integrative investigations across behavior, morphology, and metabolism (Ionescu et al 2015; Ionescu & Oroian 2015; Ionescu & Oroian 2019; Popescu et al 2026; Popescu & Cimpean 2026).

Urban and industrial environments expose pigeons to complex mixtures of heavy metals, airborne particulate matter, and pesticides. These pollutants accumulate in feathers and internal organs and are increasingly assessed with physiological biomarkers to infer health status and, more rarely, flight performance.

The aim of this mini-review is to critically evaluate the current body of literature regarding the types, sources, and biological effects of environmental pollutants on pigeons. Specifically, the study seeks to (i) identify major classes of pollutants and their primary exposure pathways, (ii) synthesize evidence on physiological, cellular, and metabolic responses to pollutant exposure, and (iii) assess the extent to which environmental contaminants influence flight performance. Furthermore, the review aims to highlight the utility of pigeons as bioindicators for monitoring urban and industrial pollution and to identify gaps in knowledge concerning the integration of health biomarkers with functional performance outcomes.

Types of Environmental Pollutants and Exposure Pathways. Heavy metals such as lead (Pb), cadmium (Cd), mercury (Hg), nickel (Ni), chromium (Cr), copper (Cu) and zinc (Zn) accumulate in pigeon feathers and multiple internal organs in highly urbanized or

industrial areas (Frantz et al 2012; Cui et al 2021; Kurhaluk et al 2021; Tkachenko et al 2021; Aljohani 2023; Tkaczenko et al 2024; Cui et al 2024; Ilyas et al 2024; Asgari et al 2024). Organic pollutants including polychlorinated biphenyls (PCBs), organochlorine and organophosphate pesticides, polybrominated diphenyl ethers (PBDEs), pyrethroids and polycyclic aromatic hydrocarbons (PAHs) are widely detectable in pigeon feathers, with PAHs showing the highest mean concentrations (González-Gómez et al 2020). Particulate matter and associated metals deposit externally on feathers and internally in lungs. Pigeons in polluted regions show higher lung metal loads and particulate retention, especially in fine winter particles (Li et al 2021; Ellis et al 2023; Cui et al 2024; Iacob et al 2024). Pollutant exposure occurs through inhalation of contaminated air, ingestion of polluted food and soil, and accumulation on plumage (Tkachenko et al 2021; Ellis et al 2023; Cui et al 2024) (Table 1).

Table 1

Key pollutants measured in pigeon feathers and tissues (summarized by Consensus 2026)

<i>Matrix / Site</i>	<i>Main pollutants and patterns</i>	<i>References</i>
Feathers – industrial / traffic sites	Elevated Pb, Cd, Zn; strong spatial differences; sex effects	Frantz et al 2012; Cui et al 2021; Tkachenko et al 2021; Aljohani 2023; Asgari et al 2024; Tkaczenko et al 2024
Feathers – organic pollutants	PAHs » OCPs, PYRs, PCBs, OPPs, PBDEs; >90% detection	González-Gómez et al 2020
Internal organs (liver, kidney, heart, muscle, bone, lung)	Cu and Pb generally highest; Cd, Ni, Cr, Co also present; often higher in more polluted cities	Aljohani 2023; Cui et al 2024; Iacob et al 2024; Ilyas et al 2024
Feather surface particulates	PM mass and optical properties differ between urban and rural pigeons	Ellis et al 2023

Note: PAHs - polycyclic aromatic hydrocarbons; OCPs - organochlorine pesticides; PYRs - pyrethroids; PCBs - polychlorinated biphenyls; OPPs - organophosphorus pesticides; PBDEs - polybrominated diphenyl ethers.

Physiological and Cellular Effects on Pigeon Health. Multiple studies show oxidative stress in pigeons from contaminated habitats, with increased lipid and protein oxidation and altered antioxidant enzymes in liver, kidney, brain, and muscle (González-Gómez et al 2020; Kurhaluk et al 2021; Tkachenko et al 2021; Tkaczenko et al 2024; Kurhaluk et al 2025). Lead exposed pigeons exhibit disturbed Krebs cycle enzymes, lactate/pyruvate balance, and reduced antioxidant defenses across organs, indicating impaired energy metabolism and oxygen dependent processes (Tkachenko et al 2021; Kurhaluk et al 2025). In polluted areas, higher superoxide dismutase activity in brain and liver and greater carbonyl derivatives in kidney and liver suggest intensified reactive oxygen species formation (Tkaczenko et al 2024). Muscle studies reveal enhanced lipid peroxidation and oxidative protein modification with decreased superoxide dismutase (SOD), catalase, and glutathione reductase activities, consistent with cardio and hepatocellular damage (Kurhaluk et al 2021). Blood and hematological changes include increased erythrocyte fragility and hemolysis in males from polluted areas (Tkaczenko et al 2024). While not in pigeons, passerine studies link elevated feather metals and particulate matter (PM) to anemia like erythrocyte profiles, altered leukocyte ratios and suppressed antioxidant capacity, supporting systemic health impacts of similar pollutants in birds (Bauerová et al 2017; Li et al 2021; Freitas et al 2024).

Urbanization, Plumage, Metabolism and Pollutant Signaling. Urban pigeons provide fine scale information on local contamination because they show limited

movement; metal concentrations in feathers vary strongly among nearby urban sites (Frantz et al 2012; Cui et al 2021; Tkachenko et al 2021; Asgari et al 2024). External PM accumulation reduces feather reflectance and alters color, potentially affecting visual signaling and insulation, and urban particulates are optically darker and less reflective than rural ones (Ellis et al 2023). Feathers reliably reflect internal loads of Cd, Pb and Hg, correlating with liver and kidney concentrations in young pigeons and marking spatial-temporal differences in atmospheric metals (Cui et al 2021; Aljohani 2023; Iacob et al 2024; Asgari et al 2024). Urban gradients and heat islands also interact with plumage melanism: darker pigeons show distinct antioxidant and mitochondrial profiles, and higher urban temperatures are associated with lower antioxidant and metabolic activity, which may modify responses to oxidative challenges from pollution (Jiménez et al 2023; Arcila et al 2025).

Pesticides and Flight Performance. Experimental dosing with cholinesterase inhibiting pesticides demonstrates direct impacts on flight ability. Single oral doses of carbofuran (0.25–1.0 mg kg⁻¹) cause a dose dependent increase in homing flight time, with birds at 0.5–1.0 mg kg⁻¹ slowing markedly and falling behind the flock, whereas diazinon at the same doses has little effect on flight time (Brasel et al 2007). Similar work with chlorpyrifos and aldicarb shows that sub lethal, environmentally relevant doses significantly prolong flight times. Peak plasma cholinesterase inhibition coincides with likely migratory flight periods, indicating potential disruption of migration performance at field realistic exposures (Moye & Pritsos 2010). These studies validate homing pigeons as models for assessing how agricultural pesticide pollution can impair avian flight performance through neurotoxic mechanisms (Brasel et al 2007; Moye & Pritsos 2010).

Conclusions. The available evidence demonstrates that environmental pollutants exert multifaceted and measurable effects on pigeon health, spanning oxidative stress, metabolic disruption, and hematological alterations. Heavy metals and organic contaminants accumulate consistently in both feathers and internal organs, validating the use of pigeons as reliable bioindicators of environmental contamination. Moreover, external particulate matter influences plumage properties, with potential ecological consequences for signaling and thermoregulation.

Importantly, experimental findings indicate that certain pesticides, even at sub-lethal and environmentally relevant concentrations, can significantly impair flight performance through neurotoxic mechanisms. This establishes a direct functional link between pollution exposure and reduced ecological fitness. Despite these advances, there remains a relative scarcity of integrative studies that simultaneously assess physiological biomarkers and behavioral or performance outcomes.

Future research should prioritize multidisciplinary approaches that connect biochemical, ecological, and functional parameters to better understand the full impact of pollution on avian species. Such efforts are essential for improving environmental monitoring strategies and for assessing the broader ecological risks posed by anthropogenic contaminants.

Acknowledgements. Consensus was used when rendering Table 1 (<https://consensus.app>. Consensus NLP, Inc).

Conflict of Interest. The authors declare that there is no conflict of interest.

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