



Laboratory Medicine in the Era of Climate Change: From Awareness to Responsibility

İklim Değişikliği Çağında Laboratuvar Tıbbı: Farkındalıktan Sorumluluğa

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Climate change describes long-term changes in global temperatures and weather patterns. Although natural factors such as solar variability and volcanic activity can influence the climate, the rapid warming observed since the 19th century is largely the result of human activities. The burning of fossil fuels for energy, transport, and industry has increased atmospheric concentrations of greenhouse gases such as carbon dioxide and methane, which trap heat and raise global temperatures. Deforestation, agriculture, and oil and gas production further contribute to these emissions (1).

There is now broad scientific consensus that human activity has been the dominant driver of global warming over the past two centuries. The Earth's average surface temperature is approximately 1.4 °C higher than in the pre-industrial era, and the most recent decade has been the warmest on record. Importantly, climate change is not only about temperature increase. Because the climate system is interconnected, warming influences water cycles, ecosystems, and extreme weather patterns, leading to droughts, water scarcity, wildfires, sea-level rise, floods, melting ice, stronger storms, and biodiversity loss.

The scientific foundation for understanding this process was strengthened by the early atmospheric carbon dioxide measurements of Charles David Keeling, which clearly demonstrated a continuous rise in greenhouse gas concentrations. Based on such evidence, global climate governance developed under the umbrella of the United Nations through key agreements, including the 1992 United Nations Framework Convention on Climate Change, the 1997 Kyoto Protocol, and the 2015 Paris Agreement. These frameworks, supported by the Intergovernmental Panel on Climate Change Assessment Reports, provide the legal and scientific basis for international mitigation and adaptation efforts (2–4).

In addition to climate-specific agreements, the United Nations incorporated climate action into the broader 2030 Agenda for Sustainable Development. Among the 17 Sustainable Development Goals, Goal 13 directly addresses climate change, while other goals—such as clean energy, sustainable cities, responsible consumption and production, and protection of terrestrial and marine ecosystems—reinforce an integrated approach linking environmental protection, economic development, and social equity (5,6).

Sustainability itself, as defined in the 1987 Brundtland Report, refers to development that meets present needs without compromising the ability of future generations to meet their own. In practical terms, it requires a careful balance between environmental protection, social fairness, and economic viability. Growth and well-being cannot be considered sustainable if natural systems are degraded or inequalities are deepened (7).

Against this global background, it is important to recognize that the healthcare sector is not environmentally neutral. Healthcare activities are estimated to account for approximately 4–5% of global greenhouse gas emissions. Energy-intensive hospital operations, procurement of medical technologies and pharmaceuticals, transportation, and complex supply chains all contribute to this footprint. Hospitals operate continuously and depend heavily on heating, cooling, ventilation, sterilization, and diagnostic systems. Reducing the carbon footprint of healthcare therefore requires systematic improvements in energy efficiency, sustainable procurement, waste reduction, and the integration of lower-carbon technologies in both clinical and laboratory settings (8).

Research and clinical laboratories are central to patient care and scientific progress, yet their environmental impact



is often underestimated. Continuous operation, strict ventilation requirements, refrigeration systems, automation platforms, and the widespread use of single-use materials result in high electricity and water consumption, as well as substantial plastic and chemical waste. When procurement, diagnostics, pharmaceuticals, and supply chain emissions are included, the overall footprint of laboratory services becomes significant (9).

Recognizing this, professional organizations in laboratory medicine have begun to address sustainability more explicitly. In Europe, the European Federation of Clinical Chemistry and Laboratory Medicine promotes the transition toward greener laboratory practices in alignment with the European Green Deal, while maintaining quality and patient safety (10). At the global level, the International Federation of Clinical Chemistry and Laboratory Medicine works to identify high-quality scientific evidence, develop practical recommendations for laboratories in both developed and developing countries, support education, and advance human biomonitoring related to environmental exposures (11). These initiatives underline that laboratory medicine has a responsibility not only to ensure analytical excellence but also to consider its environmental consequences.

A first step toward sustainability in laboratories is understanding and measuring their carbon footprint. This includes evaluating emissions associated with electricity consumption, heating and cooling systems, equipment use, purchased goods, and waste streams. In most laboratories, energy demand is the largest contributor, particularly due to ventilation systems, refrigeration units, and continuous instrument operation. Water consumption in cooling and washing processes also represents a substantial resource burden (7).

From a chemical perspective, safer-by-design approaches aim to reduce hazardous substances at the planning stage of experiments and diagnostic procedures. In today's complex chemical environment, humans are exposed to numerous synthetic compounds throughout life—an exposure pattern often described by the concept of the exposome, which links environmental chemicals to measurable biological effects. Appropriate segregation, handling, and treatment of hazardous and liquid chemical waste are therefore essential to protect both environmental and occupational health (7).

Sustainability also involves reducing material use, limiting dependence on single-use plastics, and applying lifecycle thinking to laboratory operations. Procurement decisions that prioritize durability, energy efficiency, and lower environmental impact contribute meaningfully to long-term improvements. Industry partners and suppliers likewise play a role by improving production

standards and transparency. Ultimately, meaningful change requires institutional leadership, a culture that values environmental responsibility, and structured education that equips laboratory professionals with the knowledge and skills needed to implement sustainable practices. Emissions related to professional travel for conferences and collaborations should also be acknowledged as part of the overall environmental footprint of scientific work (9).

Even small and practical changes in daily laboratory routines can create meaningful environmental benefits when applied consistently. Simple actions such as reducing unnecessary energy use, optimizing test requests, minimizing single-use materials, or improving waste segregation may appear minor individually, yet collectively they can lead to substantial impact. Education and the development of green skills are therefore essential to embedding sustainability into routine laboratory practice. We have only one planet, and there is no alternative environment to replace it. Protecting natural resources and reducing our ecological footprint are responsibilities we carry not only for ourselves but also for future generations. Caring for our planet today is the most meaningful legacy we can leave—ensuring a healthier world for those who come after us.

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