Environmental Sustainability in the Clinical Laboratory

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Climate change poses a major threat to global health. We are already witnessing the spreading of vector-borne diseases and an increase in heat and air pollution-related illness and death, all whilst the very essentials of good health - clean air, safe drinking water, nutritious food supply and secure shelter – face unparalleled threat. This crisis disproportionately impacts vulnerable populations, amplifying existing global health inequities [1, 2].

Ironically, healthcare systems themselves contribute to environmental degradation, with 4-8% of global carbon emissions being apportioned to health sector activities (3, 4); an amount that is comparable to the emissions of entire countries the size of Germany or Japan. Healthcare activities also generate substantial amounts of waste, including biological, chemical, and solid waste, with plastic waste alone estimated to constitute up to 25% of a hospital's total waste output (5). In fact, during the COVID-19 pandemic, the demand for disposable medical supplies was so high that it not only generated millions of tonnes of plastic waste, but it also revealed the vulnerabilities of the global plastics supply chain (6).

Addressing the environmental footprint of healthcare is therefore critical to ensuring that efforts to protect health do not inadvertently harm the planet. Failing to address the sector's significant carbon footprint and waste production not only undermines public health but also contradicts the very mission of healthcare - to do no harm by contributing to the very environmental conditions that exacerbate health risks.

Environmental impact of clinical laboratory testing

Given the urgent need for healthcare systems to reduce their environmental footprint, it is essential for the medical laboratory to understand its contribution to this challenge. Pathology testing is integral to modern healthcare with it being reported that 95% of all clinical pathways rely on these services [7]. With around 14 billion tests performed annually in the US, 1.2 billion in the UK, 113 million in Australia [7, 8], and proportionate figures reported across Europe, it is likely that the worldwide total stands in the tens of billions of pathology tests every year. Furthermore, these estimates do not even take into consideration the additional testing undertaken using home testing kits, which are typically one-time use plastic devices. Therefore, with predicted continued growth in the diagnostic sector it is easy to imagine the scale and impact diagnostic testing has, and will continue to have on the environment if things do not change.

Laboratories themselves are understood to be energy intensive environments, consuming approximately 3 to 6 times more energy than that of similar-sized office spaces [9].

This high energy usage is due to the extensive use of equipment with significant power requirements, such as ultra-low temperature (ULT) freezers, freezers, refrigerators, centrifuges, analysers, incubators, and fume hoods, as well as climate control systems [8, 10]. Further to their high energy requirements, laboratories also consume large amounts of water and generate vast quantities of waste, including biological, chemical, and plastic waste, often requiring specialist management such as incineration, or specialist disposal. Incineration of typically plastic biological waste can release toxic emissions, including dioxins and furans, and there is potential harm from hazardous chemicals either entering wastewater or contaminating land if improperly managed [11, 12].

Through several recently published life cycle assessment (LCA) studies on commonly requested pathology tests we have gained an understanding of the environmental impact of pathology testing, particularly regarding the most carbon intensive components of the testing process. The calculated CO2e emissions for individual CRP, INR, full blood count, urea and electrolytes tests is in the order of 74-274 g/test, with the dominant source of emissions being from the pre-analytical phase, specifically the production and transport of plastics used for sample collection. In contrast, for urinalysis, the greatest proportion of emissions came from the laboratory testing process, and the overall emissions were also determined to be significantly higher at 538 g CO2e (13, 14). The emissions from processing histopathology biopsies was demonstrated to be even greater still, with one study estimating emissions in the range 280-790 g CO2e, and citing the production of supplies and reagents as the largest contributing elements (15). Given the tens of billions of tests conducted globally each year, and the continuing growth of the diagnostic sector, it is easy to appreciate that the cumulative carbon footprint is likely to be staggering.

Organisational action, drivers for change, and environmental management systems

Prior to the 2000s, there was limited awareness of the environmental impact of clinical laboratories, and sustainability was not a primary concern. It is only within the past few years that sustainability has gained some traction in the sector. This gradual shift reflects changing attitudes towards integrating sustainability into healthcare as a whole, with healthcare organisations worldwide only recently beginning to legislate carbon reduction initiatives; notable examples including the NHS's Net Zero strategy launched in 2020 and the subsequent Health and Care Act in 2022, New Zealand's healthcare system commitment in 2021, and the Global Green and Healthy Hospitals initiative. Several key areas have been identified for reducing carbon emissions, such as replacing fossil fuel energy sources with renewables and developing a more sustainable supply chain, since the use of raw materials for manufacturing and distributing healthcare products is the largest contributor to its carbon footprint. For instance, in the UK, the NHS Suppliers Roadmap mandates that all suppliers develop a carbon reduction plan, whilst procurements over a certain value must incorporate a 10% social value weighting. The addition of social value in procurement contracts ensures that purchasing decisions not only address sustainability, but also promotes social equity and community well-being – all of which are linked in the overall health of communities.

Whilst the reduction of carbon emissions is the primary focus for healthcare, aligning with global objectives in tackling climate change, there are efforts driving the responsible use of chemicals.

In this area there are over 100 directives and regulations that have been established. Notable examples include the Stockholm Convention (2001), which targets the elimination of persistent organic pollutants, and the EU Registration, Evaluation, Authorisation and Restriction of Chemicals (REACH) (2006), which regulates the use of substances of high concern. More recently, the EU Chemicals Strategy for Sustainability (2020) has set ambitious goals to phase out chemicals that pose risks to human health or the environment. These regulations are already beginning to influence the use of potentially harmful chemicals in clinical laboratories, encouraging their phasing out or safer disposal – an important step towards reducing the harm from our chemical use.

Systems and frameworks have existed since the late 1980s that have been designed to facilitate the development of sustainable environmental practices within organisations. The most internationally recognised of which is ISO 14001, a voluntary standard that provides a framework for the development of an environmental management system, with a focus on continual improvement. Whilst this standard has been broadly adopted throughout industry, it has been less widely implemented within healthcare, and only a few reports indicating its acceptance into clinical laboratories [9, 16]. The reasons for this are unclear, but since clinical laboratories, their commissioners and users all have an emphasis on clinical quality outcomes and adherence to standards such as ISO 15189, it seems probable that it has simply not been within the scope and vision of usual laboratory business.

Emerging sustainability in the clinical laboratory

In the past few years there has been encouraging progress within the field of laboratory medicine and the broader in vitro diagnostic industry regarding sustainability. Various professional organisations have actively engaged in sustainability initiatives by developing environmental strategies, forming dedicated task forces, or appointing sustainability leads. For instance, the International Federation for Clinical Chemistry and Laboratory Medicine (IFCC), the European Federation of Clinical laboratories and Laboratory Medicine (EFLM), The British In Vitro Diagnostics Association (BIVDA), The Association for Laboratory Medicine (LabMed), the Institute of Biomedical Science (IBMS), The Royal College of Pathologists have all taken significant steps to promote sustainability. By including sustainability in conference sessions and in news agendas they are fostering awareness and encouraging sustainable practices in the clinical laboratory community.

In addition to ISO 14001, there are certification programmes specifically aimed at laboratories that provide a structured set of actions that laboratories can implement in order to achieve measurable environmental impact reductions. MyGreenLab, a non-profit organisation promoting sustainability practice in laboratories, and the Laboratory Efficiency Assessment Framework (LEAF), developed by University College London (UCL) are two such examples; albeit they are largely designed with research and industry laboratories in mind. The European Federation for Clinical Chemistry and Laboratory Medicine (EFLM) is a clinical laboratory-focused scheme that provides both a means for certification, as well as a freely available checklist. All schemes focus on the established themes of reduce, reuse, and recycle, focusing on the use of energy, waste, chemicals, and water.

Energy conservation remains a straightforward approach for reducing carbon footprints in laboratories. Modern laboratories are increasingly designed or retrofitted to meet energy-efficient building regulations, such as the U.S. LEED (Leadership in Energy and Environmental Design) certification or the European Union's Nearly Zero-Energy Buildings (NZEB) standards. These regulations promote the use of high-efficiency air condition systems, LED lighting, and smart building technologies to optimize energy usage, ultimately reducing both operational costs and carbon emissions. But for laboratories unable to do this, there are plenty of simple and effective energy reduction actions, such as switching off equipment when not in use, using more energy efficient models, moving to LED lighting, optimisation of climate control systems, and efficient use of fridges and freezers. For example, increasing the temperature of ultra-low temperature freezers by just 10°C from -80°C to -70°C can lead to energy savings of around 30% [17]. A baseline assessment conducted by one laboratory using MyGreenLab assessment criteria revealed potential annual energy reduction of 9200 kWh in energy consumption and 7.3 tonnes of CO2e emissions [18].

Switching to digital solutions for test ordering and reporting not only improves turnaround times but it removes vast amounts of paper from the process. Recycling non-contaminated waste prevents material ending up in landfill. One laboratory reported that a 14-test biochemical panel produced 1,089.2 kg of waste, of which 21.4% was recyclable, amounting to carbon savings of 265.7 kg of CO2e [19], and another laboratory revealed that through employee engagement, they were able to recycle over 60% of their total waste including a wide variety of materials such as Styrofoam, glass, and carpet [20].

Diagnostic stewardship is a well established practice that laboratories have developed in which the careful use of tests is promoted in order to not only enhance patient outcomes, prevent overdiagnosis and patient harm, but also to protect laboratory resources and reduce costs. Along with other test reduction strategies such as setting minimal retesting intervals, they can be effective at reducing waste, saving money, and have environmental benefits [21]. There are many publications on the benefits of these approaches, especially in terms of patient outcomes and cost savings, but in some of the more recent publications the environmental benefits have also been quantified.

Examples:

A Canadian study showed that 76% of patients had unnecessary bloodwork, resulting in an average of 4.4 blood vials, 16.5 tests and 18 mL of blood loss per patient, equating to 61 kg CO_2e (974 g CO_2e per person) and a cost of $5235 [22].

In another study from a single UK hospital, it was demonstrated that by eliminating group and save testing prior to elective surgeries with a low (<1%) transfusion rate, they could save 172kg CO_2e per annum [23].

In country-wide study it was determined that 76.5% of Australia's vitamin D tests provide no net health benefit at all, wasting >87 million Australian dollars and 28.6-42.0 tonnes CO_2e; equivalent to driving ~160 000– 230 000 km in a standard passenger car [24].

Integrating sustainability into laboratory medicine offers more than just environmental benefits; the cumulative cost savings can be substantial and serve as a strong incentive for its adoptionFor instance, installing solvent recycling systems in a histopathology service, not only significantly reduced in the amount hazardous waste generated (saving 87.5 gallons of formalin, 294 gallons of xylene, and 180 gallons of alcohol annually), but also cut solvent purchasing costs by approximately $42 000 per year [25].

Conclusion

By embracing sustainability, clinical laboratories are not only reducing their environmental impact, but also strengthening the resilience and responsibility of the healthcare sector as a whole. Leveraging data-driven strategies, such as optimising testing protocols, recycling, and improving energy efficiency, demonstrates the growing importance of sustainability in laboratory operations. Substantive and meaningful change, however, will come from a combination of organisational transformation, individual actions, and fostering collaboration and innovation within the IVD industry and clinical laboratory sector.

The benefits of sustainability must be quantified, communicated, and championed, highlighting that sustainability is a balance between environmental stewardship, social equity, and economic viability. Ultimately, prioritising sustainability in clinical laboratories aligns with their commitment to high quality patient care, and the imperative of environmental responsibility, reinforcing the idea that healthcare excellence and sustainability go hand in hand.

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