Original Article

HEALTH SCIENCES
MEDICINE

DOI: 10.32322/jhsm.1342155

J Health Sci Med. 2023;6(5):993-997

Examining the influence of sample rejection rates on the carbon footprint of clinical laboratories: a retrospective analysis

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Cite this article as: Uçar KT. Examining the influence of sample rejection rates on the carbon footprint of clinical laboratories: a retrospective analysis. *J Health Sci Med.* 2023;6(5):993-997.

Received: 12.08.2023 ◆ **Accepted**: 01.09.2023 ◆ **Published**: 28.09.2023

ABSTRACT

Aims: Clinical laboratories play a vital role in healthcare, yet their operations contribute to resource consumption, waste generation, and greenhouse gas emissions. The need for sustainable practices in laboratories has led to guidelines for reducing their carbon footprint. This study aims to assess the impact of sample rejection rates (SRRs) on laboratory sustainability by calculating the carbon footprint and medical waste generated due to rejected samples.

Methods: This retrospective, single-center study obtained data from the Hospital Information Management System for two years (2021 and 2022). SRRs were calculated for different sample tube types. The carbon footprint caused by rejected samples was calculated using CO_2 emission (CO_2e) conversion factors. The weight of medical waste generated due to rejected samples was evaluated. Statistical analysis was performed using appropriate tests.

Results: In 2021 and 2022, SRRs for different sample tubes were calculated, with statistically significant differences observed. The total CO_2e value resulting from rejected samples over two years was 12.3 tons, and the medical waste generated was 3.7 tons. The highest SRR was observed in Blue top tubes, while yellow top tubes showed a significant reduction in SRR in 2022.

Conclusion: This study highlights the impact of SRRs on laboratory sustainability. The calculated CO_2e and medical waste values underscore the need to minimize sample rejections. While these values seem minor compared to global emissions, they reflect only a portion of the potential environmental impact. Reducing sample rejections not only improves patient safety and laboratory efficiency but also aligns with the larger goal of creating environmentally conscious and sustainable healthcare practices.

Keywords: Clinical laboratories, sustainability, environmental impact, waste reduction, preanalytical errors, sustainable healthcare

INTRODUCTION

Clinical laboratories play a significant role in disease management and medical decision-making.[1] However, their operations contribute to significant resource consumption, waste generation, and greenhouse gas emissions.[2] The urgency of addressing these environmental issues has led to the emergence of sustainable practices aimed at minimizing the ecological footprint of clinical laboratories. To this end, the European Federation of Clinical Chemistry and Laboratory Medicine (EFLM) has published the "Green and Sustainable Laboratories guide" on the carbon footprint of laboratories.[2] This guide outlines the potential carbon footprint sources within laboratories and provides guidance on ways to mitigate it across four key areas: Chemicals, Energy, Waste, and Water (Figure 1).

When evaluating errors associated with waste management in laboratories, it becomes evident that the most common errors occur in the preanalytical phase (prior to analysis or reaching the laboratory).[3] One likely outcome of this situation is the rejection of samples due to preanalytical errors.[4] Preanalytical errors contribute significantly to sample rejections, unnecessary testing, and subsequent waste generation.[5] Therefore, initiatives aimed at reducing errors during sample collection and transportation can lead to substantial reductions in both environmental impact and costs.

With the growing global awareness of environmental issues, a new sustainability-oriented approach has emerged, based on the concept of ISO 14001 Environmental management systems - Requirements with guidance for use.[6] According to ISO 14001 and EFLM guidelines, each product has a life cycle, which includes all stages from production to disposal. In the case of laboratories, this cycle encompasses sample collection, delivery, analysis, and result reporting.[7] Evaluating sample rejections due to preanalytical errors, the most common cause of error throughout these processes, can provide insights into process control and improvements.

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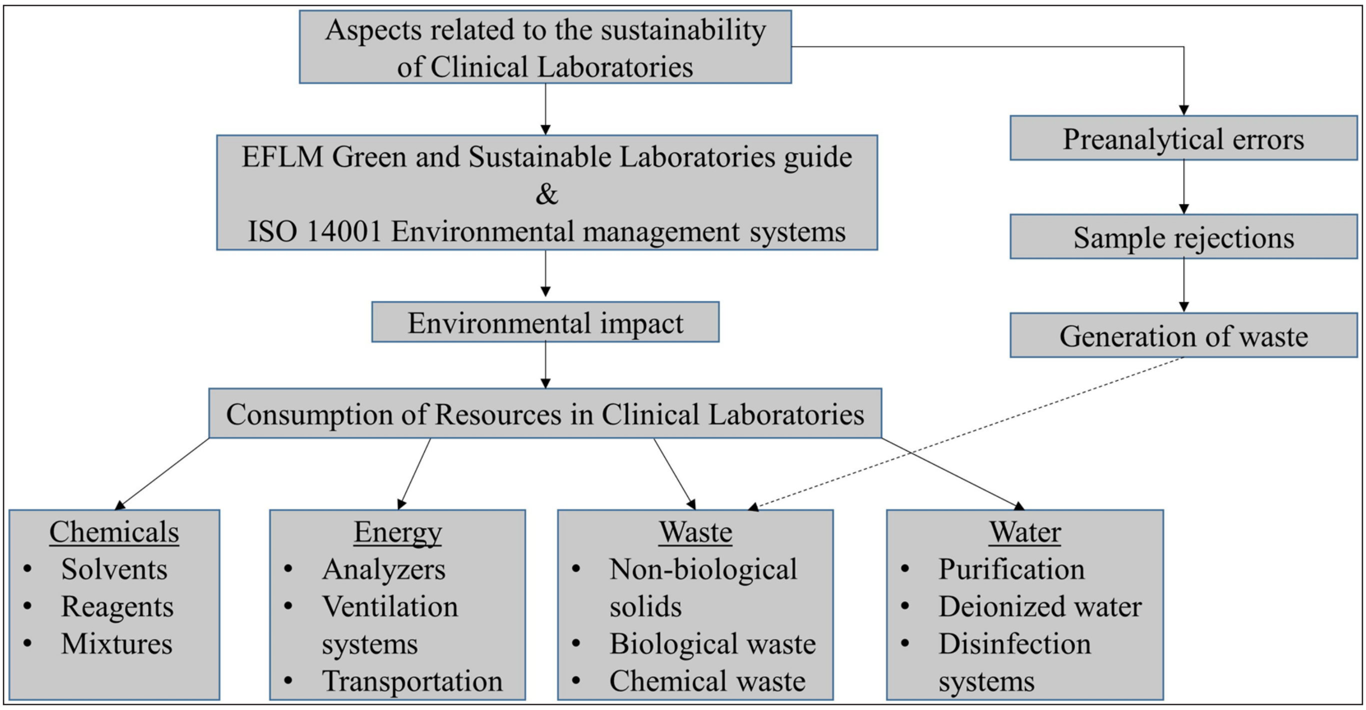

Figure 1. Potential carbon footprint sources of laboratories and their relation to sample rejections

While previous studies have explored the impact of sample rejections on patient safety[5,8,9] and even the CO_2 emission (CO_2e) levels related to the laboratories,[10,11] there appears to be a gap in directly assessing the CO_2e of rejected samples.

In this study, our aim was to calculate the sample rejection rates (SRRs) in our laboratory and to assess differences between years. Additionally, we sought to determine the potential additional CO_2e resulting from waste.

METHODS

The study was designed as a retrospective, observational, and single-center investigation. Approval was obtained from the İstanbul Başakşehir Çam and Sakura City Hospital Clinical Researches Ethics Committee (Date: 31.07.2023, Decision No: 324), and the study was conducted in accordance with the principles of the Declaration of Helsinki.

For the study, the number of sample tubes rejected by the laboratory over two years (2021 and 2022) and the total number of sample tubes received were retrieved from the Hospital Information Management System to calculate SRRs. Calculations were categorized into four groups based on the tube characteristics of the samples (yellow top/serum, blue top/coagulation, purple top/full blood count, urine container/urinalysis). The formula for calculating the SRR is as follows:

SRR (%)=(Rejected samples/Total received samples) *100

Furthermore, the carbon footprint resulting from the unnecessary usage of tubes due to sample rejections was quantified in terms of CO_2e, and the quantities of medical waste were assessed in kilograms. CO_2e conversion factors established by McAlister et al.[11] for the blood collection process, as well as the weights of materials used in blood collection such as gloves, cotton, blood collection needles, holders for vacuum tubes, blood collection tubes, and urine containers, were employed in the computation of medical waste. Calculations were conducted for each group. The formulas for calculating CO_2e and medical waste are presented below:

Gram CO_2e=Rejected samples * CO_2e conversion factors

The CO_2e conversion factors are determined as follows:

- 95 g CO_2e per serum tube with yellow top
- 79.6 g CO_2e per whole blood tube with purple top
- 84.3 g CO_2e per plasma tube with blue top
- 71.9 g CO_2e per urine container

Medical waste (kg)=Rejected samples * Weight of blood collection materials

The weight of tubes is established as follows:

- 30.84 g per serum tube with yellow top
- 23.71 g per whole blood tube with purple top
- 26.59 g per plasma tube with blue top
- 12.88 g per urine container.

To compare SRRs between the two years, SRRs were calculated separately for each year within the four groups. The Chi-square or Fisher's exact test was employed to assess differences in SRRs between the two years for these categorical groups. A p-value of less than 0.05 and a 95% Confidence Interval were considered statistically significant. Microsoft Office 365 (Microsoft Excel Software, Microsoft Corporation, US) and MedCalc® Statistical Software version 20.115 (MedCalc Software Ltd, Ostend, Belgium) were used for creating tables, generating graphs, and performing statistical analyses.

RESULTS

Out of the approximately 4 million samples accepted in 2022, approximately 77000 samples were rejected. A statistically significant reduction in the total SRRs was observed compared to 2021 (2021: 1.98%, 2022: 1.92%, p<0.001, Table 1). The SRRs of yellow top tubes significantly decreased in 2022 compared to 2021 (2021: 1.41%, 2022: 1.16%, p<0.001, Table 1). Conversely, the SRRs of purple top tubes showed a statistically significant increase in 2022 (2021: 1.41%, 2022: 1.67%, p<0.001, Table 1). The SRRs of blue top tubes did not exhibit a significant difference between 2021 and 2022 (2021: 6.59%, 2022: 6.52%, p=0.221, Table 1). The SRRs of urinalysis specimen containers significantly increased in 2022 (2021: 1.97%, 2022: 2.41%, p<0.001, Table 1). Figure 2 provides a visual representation of the SRRs.

The CO_2e value resulting from rejected samples was calculated as 12.3 tons CO_2e for the combined data of 2021 and 2022 (Table 1). The total weight of medical waste generated due to rejected samples amounted to 3.7 ton (with an average of 5.1 kg/day, Table 1). Detailed data including the total number of tubes accepted, rejected tubes, SRRs, kilogram (kg) CO_2e values, and medical waste (kg) values are presented in Table 1.

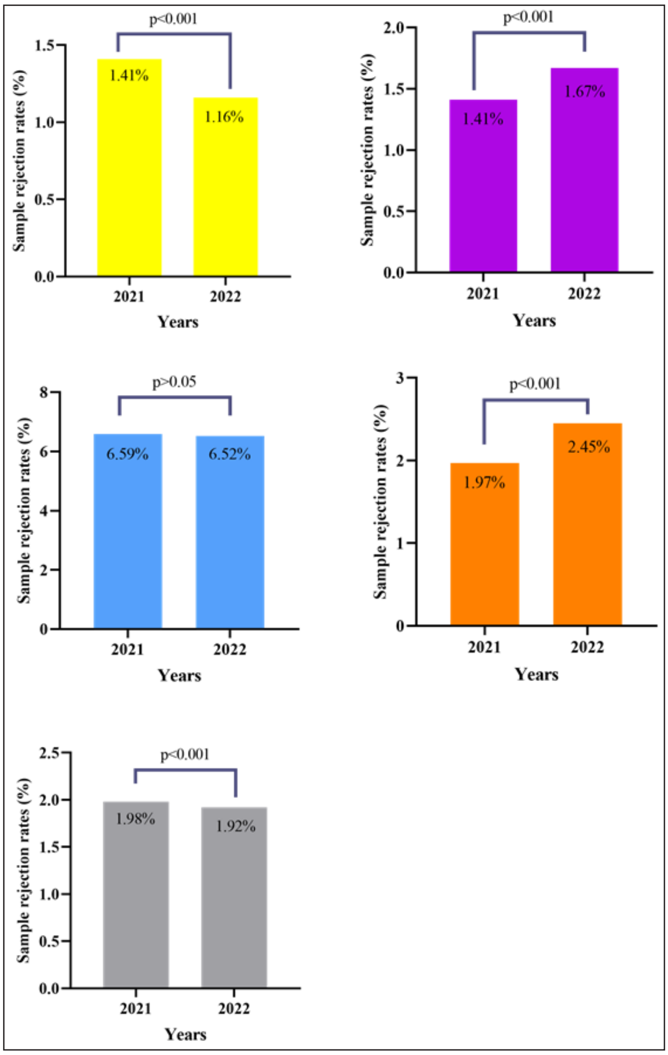

Figure 2. Sample rejection rates, categorized by year and tube types, in the study. Yellow: Yellow top tubes, Purple: Purple top tubes, Blue: Blue top tubes, Orange: Urinalysis container, Gray: Total rejection rates.

Table 1. Total number of tubes accepted by the laboratory and rejected tubes, rejection rates, CO_2e, and medical waste caused by rejected tubes, categorized by year and tube types.

Tube type	Year	Total tube number	Rejected tube number	Rejection rate	p value*	kg CO_2e**	Medical waste (kg)***
Yellow top serum tube	2021 2022	1726327 2123307	24303 24725	1.41% 1.16%	<0.001	2308 2348	750 763
Purple top CBC tube	2021 2022	1015974 1233229	14303 20635	1.41% 1.67%	<0.001	1138 1642	339 489
Blue top plasma tube	2021 2022	338358 379226	22305 24709	6.59% 6.52%	0.221	1880 2082	593 657
Urinalysis container	2021 2022	233048 290381	4592 7103	1.97% 2.45%	<0.001	330 510	59 91
Total	2021 2022 2021-2022	3313707 4026142 7339850	65503 77172 142674	1.98% 1.92% 1.94%	<0.001 NA	5657 6585 12242	1741 2000 3741

g: gram, kg: kilogram, NA: Not available. *p values were calculated by Chi-square test and statistical significance was determined as p<0.05 two-way. Statistically significant differences are indicated in bold. **According to the conversion table of McAllister et al.11 95 g CO_2e per serum tube with yellow top, 79.6 g CO_2e per whole blood tube with purple top, 84.3 g CO_2e per plasma tube with blue top and 71.9 g CO_2e per urine container were accepted. ***According to the medical waste amount tables determined by McAllister et al.11 for each tube, 30.84 g per serum tube with yellow top, 23.71 g per whole blood tube with purple top, 26.59 g per plasma tube with blue top and 12.88 g per urine container were considered to be generated.

DISCUSSION

In our study, we found SRRs of approximately 1.98% and 1.92% for 2021 and 2022, respectively, with the highest rejection rates observed in blue top tubes. The calculated total CO_2e resulting from these rejections was approximately 12.3 tons, and the medical waste amount was 3.7 tons (averaging 5.1 kg/day).

Turkey's total CO_2e value for 2021 is reported as 564.4 million tons, with a per capita CO_2e value of 6.7 tons.12 Globally, the European Commission Emissions Database for Global Atmospheric Research (EDGAR) group estimated the worldwide CO_2e value for 2021 at 37.9 gigatons.[13] While the calculated 12.3 tons from our data might appear relatively small in comparison, it is important to note that this value pertains solely to the production processes of blood collection devices. Moreover, CO_2e values related to waste disposal or extra transportation of waste were not incorporated due to the absence of calculable data. Rejected samples become wasted materials as they do not undergo desired testing, potentially leading to unfavorable outcomes. Furthermore, there exists a CO_2e value possibly generated by patients making unnecessary trips to health centers for results due to rejections.[14] Considering these factors, it is conceivable that our estimated CO_2e value might be an underestimate.

Apart from the generation of infectious waste in healthcare and laboratories, medical waste can give rise to financial and sustainability issues.[15] In their evaluation of 20 centers, Endris et al.[9] determined that laboratories generated an average of 4.9 kg/day of medical waste. Our study yielded a value of 5.1 kg/day, closely aligning with this finding. The overarching approach to mitigate laboratories' environmental impact can be summarized as "Reduce, Reuse, Recycle".[16] However, due to the risks posed by medical waste, the reuse and recycling stages for infectious materials are not feasible. Thus, reducing SRRs in laboratories is expected to help curtail medical waste and its adverse environmental effects.[17]

The impact of preanalytical errors on SRRs has been well-documented.[18] Previous research has highlighted that proper training in blood collection can significantly reduce preanalytical errors and subsequently lower SRRs.[8] Aykal et al.[19] for instance, demonstrated a reduction in SRRs from 2.35% to 1.56% following training. In our laboratory, we already implement a monthly SRR monitoring procedure and conduct blood collection training sessions. The observed decrease in SRRs during 2022, as revealed in our study, is likely attributed to the effective standardization of these rigorous monitoring and training processes.

Furthermore, our findings indicated that blue top tubes exhibited the highest SRR values in our laboratory (2021: 6.59%, 2022: 6.52%). This observation aligns with existing literature. Dikmen et al.[5] for instance, reported blue top tubes as the most frequently rejected samples in their study, with an SRR of 13.3%. Similarly, Atay et al.[8] found the highest SRR values in their laboratory to be associated with blue top tubes (SRR for blue top tubes: 2.28%). It is reasonable to attribute the proportional differences among these studies to variations in hospital and laboratory settings, as well as different working conditions.

While effective hazardous waste management is a subset of laboratories' journey toward becoming greener and more sustainable, it also encompasses chemical and solid waste. Shrank et al.[20] reported that a significant portion of the US healthcare system's expenditures (about a quarter) is allocated to waste management ($760 billion to $935 billion), a cost that notably increases when considering CO_2e equivalence. Moreover, assessments pertaining to Chemicals, Energy, and Water—factors that wield substantial impact on sustainability—are paramount for creating a "Green Lab".[2] These assessments incorporate Environmental, Social, and Economic criteria.[21] In addition to SRRs, a rational approach to test ordering can contribute to laboratory sustainability by reducing material and test chemical usage and the associated energy requirements.[22] Emphasizing the social and economic aspects of these efforts, and ensuring their persistence, can play pivotal roles in developing "Green and Sustainable Laboratories".[2,21] To achieve these aims, public awareness and support from patients, healthcare professionals, in-vitro diagnostics producers, and the general population are essential.[23] Laboratories will strengthen their standing within the healthcare sector and society as each sustainability milestone is achieved.

Our study, while providing valuable insights, does come with certain limitations. Specifically, we focused solely on calculating CO_2e values associated with the production and transportation stages of the tubes. However, as highlighted in the paper, there exists a noteworthy CO_2e related to the waste disposal phase. Unfortunately, due to the absence of relevant CO_2e values or conversion factors in the literature, we were unable to incorporate these aspects into our analysis. Furthermore, the repercussions of sample rejections extend beyond their immediate environmental impact. Such rejections can potentially lead to additional environmental harm through heightened transportation and consumption processes, be it patients returning unnecessarily for retests or the undue use of chemicals.

Another aspect to consider is that the conversion factors utilized in this study were sourced from a previously published work in the literature.[11] The author made this decision due to the obvious similarity between the blood collection devices (such as tubes, vacutainers, needles, and other consumables) employed in the referenced study and those utilized in our laboratory. Although there are valuable studies documenting and collating such data within our country, accessing these specific values from a database proved challenging. Consequently, the decision was made to directly apply the established values to our laboratory, ensuring the utilization of dependable data. This study is believed to hold significance in raising awareness regarding the potential adverse environmental impacts of laboratories. It is believed that conducting a thorough and comprehensive study into these aspects would represent another crucial step towards achieving Green and Sustainable Laboratories.

CONCLUSION

In summary, our study reveals that SRRs in our laboratory averaged around 2% annually. The CO_2e value arising from sample rejections over two years totaled 12.3 tons, accompanied by a medical waste amount of 3.7 tons. Reducing sample rejections is anticipated to yield considerable gains, enhancing patient, clinician, and laboratory safety, in addition to mitigating the carbon footprint.

ETHICAL DECLARATIONS

Ethics Committee Approval: The study was carried out with the permission of İstanbul Başakşehir Çam and Sakura City Hospital Clinical Researches Ethics Committee (Date: 31.07.2023, Decision No: 324).

Informed consent: Because the study was designed retrospectively, no written informed consent form was obtained from patients.

Referee Evaluation Process: Externally peer reviewed.

Conflict of Interest Statement: The authors have no conflicts of interest to declare.

Financial Disclosure: The authors declared that this study has received no financial support.

Author Contributions: All the authors declare that they have all participated in the design, execution, and analysis of the paper, and that they have approved the final version.

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