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# Assessment of sustainability standards implementation in hospital pharmaceutical departments and its impact on healthcare services efficiency

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***Index Terms***
Sustainability Standards, Pharmaceutical Departments, Healthcare Efficiency, Drug Waste, Medical Supply Chains, Libyan Public Hospitals.

***Abstract***
This study examined the actual implementation of sustainability standards—environmental, economic, social, and operational—in pharmaceutical departments of public hospitals and healthcare centers in Al-Khums, Libya, and how this affects healthcare service efficiency. Using a descriptive-analytical approach, a validated questionnaire was distributed to a convenience sample of 51 pharmaceutical practitioners (19.5% response rate), of whom 82.4% were female and 70.6% held a Bachelor's degree. Results showed strong professional and ethical commitment among practitioners, particularly in patient safety standards and rational pharmaceutical counseling, along with good environmental performance in safely disposing of expired medications. However, the economic dimension lacked institutional maturity in digital inventory planning and cost monitoring—a critical weakness, since pharmaceutical spending typically represents 20–30% of total hospital budgets in developing countries. The study also revealed a sharp knowledge gap in sustainability concepts, with 76.5% of practitioners having received no specialized training in the field. Statistical analysis confirmed that specialized training was the most influential factor, with the multiple linear regression model explaining 38% of the variance in institutional sustainability implementation. The study concludes that limited awareness, budgetary constraints, and centralized distribution of near-expiry medications are the main institutional barriers, highlighting the urgent need for investment in capacity building and digital supply chain transformation.

# تقييم تطبيق معايير الاستدامة في الأقسام الصيدلانية بالمستشفيات وأثره على كفاءة الخدمات الصحية

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***الكلمات المفتاحية***
معايير الاستدامة، الأقسام الصيدلانية، كفاءة الرعاية الصحية، هدر الأدوية، سلاسل الإمداد الطبية، المستشفيات العامة الليبية.

***الملخص***
هدفت هذه الدراسة إلى استكشاف واقع تطبيق معايير الاستدامة بأبعادها البيئية والاقتصادية والاجتماعية والتشغيلية في الأقسام الصيدلانية بالمستشفيات والمراكز الصحية العامة بمدينة الخُمس، ليبيا، وبيان أثرها على كفاءة الخدمات الصحية المقدَّمة للمرضى. اعتمدت الدراسة المنهج الوصفي التحليلي، باستخدام استبانة ميدانية مُحكَّمة على عينة من 51 ممارسًا صيدلانيًا (بمعدل استجابة 19.5%)، شكّلت الإناث فيها الغالبية العظمى (82.4%)، وكان 70.6% منهم من حملة البكالوريوس. أظهرت النتائج التزامًا مهنيًا وأخلاقيًا عاليًا لدى الممارسين في معايير سلامة المرضى وتقديم الإرشاد الدوائي، إلى جانب أداء بيئي جيد في التخلص الآمن من الأدوية منتهية الصلاحية. في المقابل، اتسم البُعد الاقتصادي بضعف النضج المؤسسي في التخطيط الرقمي للمخزون ومراقبة التكاليف، وهو تحدٍ جوهري نظرًا لأن ميزانيات الأدوية تستهلك عادةً 20% إلى 30% من إجمالي نفقات المستشفيات في الدول النامية. كما كشفت الدراسة عن فجوة معرفية حادة حول مفهوم الاستدامة، إذ لم يتلقَّ 76.5% من الممارسين أي

تدريب متخصص في هذا المجال. وأثبت التحليل الإحصائي أن التدريب هو العامل الأكثر تأثيرًا، حيث فسّر نموذج الانحدار الخطي المتعدد 38% من التباين في تطبيق معايير الاستدامة المؤسسية. وخلصت الدراسة إلى أن ضعف الوعي، ومحدودية الميزانيات، والتوزيع المركزي للأدوية القريبة من انتهاء الصـــلاحية تمثل أبرز المعوقات المؤسسية، مما يؤكد الحاجة الملحة للاستثمار في بناء القدرات والتحول الرقمي لإدارة سلاسل الإمداد الطبي.

## 1. INTRODUCTION

The global healthcare sector faces unprecedented challenges characterized by escalating costs, resource scarcity, and increasing demand for quality services (Kwakye et al., 2011). In response, sustainability has emerged as a transformative framework extending beyond environmental concerns to encompass economic, social, and operational dimensions. The World Health Organization (WHO, 2020) has consistently emphasized that sustainable health systems constitute fundamental prerequisites for achieving universal health coverage and ensuring long-term care quality. This recognition has positioned healthcare sustainability as a strategic priority for health systems worldwide.

Hospital pharmaceutical departments occupy a strategically critical position within this sustainability paradigm. As the nexus where drug management, patient safety, and healthcare expenditure converge, these departments exert substantial influence over overall health system performance. Expenditure on medicines typically accounts for 20-30% of total hospital budgets in developing countries, underscoring the direct impact of pharmaceutical sustainability practices on healthcare efficiency (Ferrario & Kaplan, 2022). International evidence demonstrates that sustainable pharmaceutical practices—encompassing supply chain optimization, waste reduction, and dispensing rationalization—significantly enhance service quality while reducing operational costs (Viale et al., 2021). This dual benefit positions pharmaceutical sustainability as both an economic imperative and a quality improvement strategy.

Regional experiences offer instructive models for pharmaceutical sustainability implementation. Saudi Arabia's Vision 2030 National Transformation Program restructured hospital pharmacy management through automated drug distribution systems and enhanced clinical pharmacist roles in prescription rationalization, yielding measurable improvements in institutional performance (Al-Arifi et al., 2023). Similarly, Jordanian university hospitals successfully adopted drug lifecycle management systems, substantially reducing expiry rates and associated waste costs (Jaber et al., 2020). These regional initiatives demonstrate that structured sustainability frameworks can produce tangible improvements even in resource-constrained environments.

The Libyan healthcare context presents unique challenges requiring urgent scholarly attention. The health system grapples with compounded structural constraints emanating from prolonged political instability, inadequate financing, human resource shortages, and deteriorating facility infrastructure (Elbarsha et al., 2020). These factors collectively undermine pharmaceutical department operations, manifesting in paradoxical supply chain disruptions—simultaneous essential medicine shortages and expired drug accumulation—that reflect fundamental pharmaceutical governance deficiencies (Ghabri et al., 2022). Despite these challenges, local academic research evaluating sustainability implementation remains remarkably scarce.

The imperative for systematic sustainability assessment is reinforced by compelling international evidence. Manon et al. (2023) documented a 34% reduction in medication errors and improved patient satisfaction in hospitals implementing comprehensive pharmaceutical sustainability frameworks. Additionally, the British National Health Service's Sustainable Development Unit (2024) demonstrated that sustainability adoption in hospital pharmacies can reduce healthcare carbon footprint by over 25% of medicine-related emissions. These findings establish the empirical basis for investigating sustainability's impact on healthcare efficiency in post-conflict settings.

Given this context, the present study addresses critical knowledge gaps by assessing sustainability standards implementation across environmental, economic, social, and operational dimensions in Libyan hospital pharmaceutical departments, and evaluating their implications for healthcare service efficiency. By bridging the evident research-practice gap, this investigation provides health policymakers with evidence-based insights for developing sustainable improvement strategies. Furthermore, the study aspires to contribute qualitatively to Arab health literature while opening new research avenues concerning health system sustainability in post-conflict environments.

## 2. BESEARCH PROBLEM

Despite the global consensus on sustainability's critical role in healthcare, its implementation within Libyan public hospital pharmaceutical departments remains profoundly deficient. This deficiency stems from interconnected structural challenges: institutional fragility resulting from protracted conflict, weak pharmaceutical governance, and deteriorating healthcare infrastructure. These factors have precipitated recurrent supply chain disruptions, paradoxically manifesting as simultaneous shortages of essential medicines and accumulation of expired drug inventories—directly compromising patient safety and service efficiency. The scarcity of national-level empirical research on this phenomenon further constrains evidence-based policymaking. Consequently, this study addresses the critical gap in systematic assessment of sustainability standards implementation in Libyan hospital pharmacies and its implications for healthcare service delivery efficiency.

### *2.1 Main Research Questions*

What is the current level of sustainability standards implementation in Libyan public hospital pharmaceutical departments, and what are its implications for healthcare service efficiency?

### *2.2 Sub-Questions*

1. What is the prevailing status of environmental, economic, social, and operational sustainability dimensions in Libyan public hospital pharmaceutical departments, as perceived by healthcare practitioners?
2. What is the current level of healthcare service efficiency associated with hospital pharmacy management, measured through quality indicators, patient safety outcomes, and cost rationalization metrics?
3. Is there a statistically significant relationship between sustainability standards implementation levels and healthcare service efficiency in the studied hospitals?
4. What are the primary institutional and operational barriers hindering sustainability standards implementation in Libyan pharmaceutical departments?

## 3. RESEARCH HYPOTHESES

### *3.1 Main hypothesis*

There is a statistically significant effect of applying sustainability standards in pharmaceutical departments of Libyan hospitals on the efficiency of health services provided .

### *3.2 Sub-hypotheses are derived from it*

**First Sub-Hypothesis**: The application of environmental sustainability standards has a statistically significant effect on reducing drug waste and lowering operational costs.

**Second Sub-Hypothesis**: The application of economic sustainability standards has a statistically significant effect on the efficiency of pharmaceutical supply chain management.

**Third Sub-Hypothesis:** The application of operational sustainability standards has a statistically significant effect on patient safety and the quality of healthcare.

**Fourth Sub-Hypothesis**: The application of social sustainability standards has a statistically significant effect on patient satisfaction and the efficiency of health services.

## 4. RESEARCH OBJECTIVES

The study seeks to achieve the following objectives:

-To assess the level of application of sustainability standards across their various dimensions in pharmaceutical departments of Libyan hospitals.

-To measure the effect of this application on the efficiency of health services provided.

-To diagnose the most prominent challenges impeding the application of sustainability standards in Libyan hospital pharmacies.

-To analyze the relationship between the quality of pharmaceutical supply chain management and health service efficiency indicators.

-To identify the gap between international pharmaceutical sustainability standards and the practical reality in Libyan hospitals.

- To provide practical recommendations for health policymakers that contribute to enhancing sustainability and improving operational efficiency.

## 5. RESEARCH SIGNIFICANCE

### *5.1 Theoretical Significance*

This study is considered a rare academic contribution to the subject of hospital pharmaceutical sustainability in Libya, as it seeks to bridge a clear knowledge gap in local and Arab scientific literature. It further aims to present an analytical framework that can be employed in similar contexts, particularly in post-conflict environments.

### *5.2 Practical Significance*

The study holds considerable practical importance, as it provides health policymakers in Libya with reliable scientific evidence to support the reform of the hospital pharmacy system, rationalize pharmaceutical expenditure, and address the dual phenomena of drug waste and medicine shortages. It also constitutes a foundation for building sustainable national health policies that align with institutional reconstruction requirements, and positively impacts patient safety and the quality of healthcare provided.

## 6. RESEARCH LIMITATIONS

### *6.1 Scope and Generalizability*

This study is geographically confined to public healthcare facilities within Al-Khums municipality, Libya, encompassing Al-Khums Medical Center, polyclinic centers, and primary healthcare centers. While this selection provides meaningful insights into the regional pharmaceutical sustainability landscape, findings may not be generalizable to other Libyan cities or private healthcare institutions. The research focuses exclusively on pharmaceutical departments and does not extend to other medical or administrative units within the studied facilities**.**

### *6.2 Population and Sample Constraints*

The target population comprised all pharmaceutical staff (N=261) affiliated with the Al-Khums Health Services Office, including pharmacists, pharmacy technicians, and pharmacy assistants. The study employed a convenience sampling approach, yielding 51 valid responses (response rate: 19.9%). Although this sample size is adequate for preliminary descriptive analyses, the non-probability sampling technique may introduce selection bias and limits the generalizability of inferential statistical findings to the broader pharmaceutical workforce.

### *6.3 Thematic Boundaries*

The investigation is delimited to four sustainability dimensions—environmental, economic, social, and operational—as defined by WHO guidelines and GRI

standards. Healthcare service efficiency is assessed through three indicators: pharmaceutical supply chain quality, drug waste reduction, and patient safety outcomes. This focused scope excludes other potential dimensions such as technological sustainability, governance structures, and supply chain resilience, which may warrant independent investigation.

### *6.4 Methodological Limitations*

The cross-sectional design captures sustainability implementation at a single point in time, precluding causal inferences about the observed relationships. Additionally, reliance on self-reported questionnaire data introduces the potential for social desirability and recall bias. Future longitudinal and mixed-methods studies are recommended to validate and extend these findings.

### *6.5 Temporal and Resource Constraints*

Data collection occurred over a two-week period (June 23 – July 4, 2026), which may not fully capture seasonal variations in pharmaceutical supply chain dynamics or sustainability practices. Budgetary and time limitations precluded the inclusion of direct observational methods or objective performance metrics, relying instead on practitioner perceptions.

## 7. RESEARCH TERMINOLOGY

**Healthcare Sustainability**: The capacity of pharmaceutical departments to deliver continuous, effective services by balancing environmental, economic, social, and operational dimensions while maintaining care quality and optimizing resource utilization.

**Pharmaceutical Sustainability Standards**: Internationally recognized practices aligned with WHO and GRI guidelines, adopted to rationalize drug use, minimize waste, and ensure supply chain efficiency.

**Health Services Efficiency**: The extent to which healthcare facilities achieve service objectives with minimal resources, measured through drug waste, patient safety, supply quality, and beneficiary satisfaction indicators.

**Hospital Pharmacy**: The specialized department responsible for medication procurement, storage, dispensing, and pharmaceutical control within healthcare facilities.

**Pharmaceutical Supply Chain Management**: An integrated system encompassing planning, procurement, storage, and distribution to ensure timely availability of appropriate medications in correct quantities.

**Drug Waste**: Losses resulting from expiration, improper storage, unjustified dispensing, or over-ordering, expressed as a percentage of wasted medication value relative to total pharmaceutical inventory.

**Patient Safety**: Protection from medication errors and complications arising from poor drug management, measured through reported error rates.

**Environmental Sustainability**: Adherence to eco-friendly practices including safe pharmaceutical waste disposal and carbon footprint reduction associated with medicines and supplies.

**Economic Sustainability**: Efficient financial resource management through pharmaceutical expenditure rationalization and operational cost reduction while maintaining service quality**.**

**Operational Sustainability:** Capacity to maintain performance continuity through qualified staffing, effective management systems, and standardized protocols.

**Social Sustainability**: Ability to meet community pharmaceutical needs equitably, measured through patient satisfaction and medication accessibility for vulnerable populations.

## 8. LITERATURE REVIEW

### *8.1 The Concept of Sustainability in the Healthcare Sector:*

Recent literature has addressed the concept of sustainability in healthcare as a comprehensive framework that transcends the environmental dimension to encompass economic, social, and operational dimensions simultaneously. Kwakye et al. (2011) emphasized that hospitals are increasingly required to adopt sustainable practices in response to mounting financial pressures and resource scarcity. The World Health Organization further clarified that building sustainable health systems constitutes a fundamental prerequisite for achieving universal health coverage and ensuring long-term quality of care.

### *8. 2 The Role of Hospital Pharmacies in Achieving Sustainability*

Hospital pharmacies occupy a pivotal position within the healthcare sustainability framework, as pharmaceutical budgets account for between 20% and 30% of total hospital expenditures in developing countries. Ferrario & Kaplan (2022) demonstrated that rationalizing pharmaceutical spending through sustainable pharmacy practices significantly reduces operational costs. Viale et al. (2021) further confirmed that effective management of the pharmaceutical supply chain and waste reduction directly contribute to improving the quality of healthcare services delivered.

### *8. 3 Arab Experiences in Implementing Pharmaceutical Sustainability*

Arab experiences have demonstrated promising models in the field of pharmaceutical sustainability. In Saudi Arabia, Vision 2030 contributed to the advancement of hospital pharmacies through the adoption of automated dispensing systems and the activation of the clinical pharmacist's role in rationalizing prescriptions, as documented by Al-Arifi et al. (2023). At the Jordanian level, Jaber et al. (2020) proved that the adoption of drug lifecycle management systems in university hospitals contributed to reducing drug expiry rates and lowering associated waste costs.

### *8.4 The Reality of Pharmaceutical Sustainability in Libya and the Research Gap*

The Libyan healthcare sector suffers from accumulated structural challenges encompassing weak financing, deteriorating infrastructure, and a shortage of qualified human resources, as confirmed by Elbarsha et al. (2020). Ghabri et al. (2022) revealed evident imbalances in pharmaceutical supply chains, manifested in the simultaneous occurrence of essential medicine shortages and the accumulation of expired drug surpluses, reflecting a lack of pharmaceutical governance standards. Local academic studies evaluating this reality remain scarce, deepening the knowledge gap and highlighting the urgent need for specialized field research.

## 9. METHODOLOGY

### *9.1 Research Design*

This study adopted a descriptive-analytical approach, which is robustly suited for identifying empirical realities and bridging critical knowledge gaps within structural and post-conflict health systems. This approach systematically observes the practical reality of pharmacy operations, maps the demographic and professional profiles of the studied workforce, and advances into inferential statistical modeling to test hypotheses, establish correlations, and identify key predictors of institutional service efficiency. The research framework integrated two parallel pathways:

**Quantitative Component:** Utilizing closed-ended questions structured on a 5-point Likert scale to capture the precise perceptions, attitudes, and practical adherence levels of pharmacy practitioners.

**Qualitative Component:** Employing open-ended questions to dynamically capture systemic institutional challenges and practical bottom-up suggestions from frontline healthcare professionals.

### *9. 2 Population and Sampling Technique*

**Target Population:** The target population comprised all pharmacy professionals working in public healthcare sectors regulated by the Al-Khums Health Services Office, encompassing Al-Khums Medical Center, specialized hospitals, polyclinics, and primary healthcare clinics (N = 261). This included clinical pharmacists, staff pharmacists, pharmacy technicians, assistants, and department managers.

**Sampling and Response Rate:** Due to logistical constraints, security challenges, and geographical access limitations during the field deployment period, a non-probability **convenience sampling technique** was applied. Out of the distributed instruments, **51 valid and fully completed questionnaires** were recovered and retained for final statistical modeling (representing an effective response rate of approximately 19.5%).

### *9. 3 Research Instrument and Structure*

The standardized field survey questionnaire was developed following a meticulous review of international healthcare metrics, World Health Organization (WHO) operational guidelines, and Global Reporting Initiative (GRI) frameworks. Following validation by a panel of academic experts, the instrument was structured into three main modules containing 24 closed-ended items scored on a 5-point Likert scale (5 = Strongly Agree, 4 = Agree, 3 = Neutral, 2 = Disagree, 1 = Strongly Disagree):

**Socio-Demographic and Professional Profile:** Capturing gender, age, qualification, job role, facility type, experience, and training exposure.

**Sustainability Practices and Service Efficiency Core Scale (Items 7 to 24):** Subdivided into foundational thematic dimensions:

Environmental Dimension & Pharmaceutical Waste Management*:* Evaluated safe disposal methods, chemical/drug environmental leakage prevention, and waste reduction initiatives.

1.Economic Dimension & Cost Rationalization: Examined digital consumption-based supply planning, quarterly cost-monitoring (e.g., ABC/VEN analyses), and cost-effectiveness drug-selection criteria.

2.Social Dimension & Health Equity*:* Measured equitable medication access, pharmacist-led rational counseling, safety parameters for vulnerable populations, and patient rights advocacy.

3.Operational Quality, Efficiency & Patient Safety: Assessed dispensing speed, waiting-time reduction, accuracy, adherence to patient safety guidelines, and medication error mitigation.

4.Knowledge & Sustainability Capacity Building*:* Measured theoretical knowledge, certified practical training, continuous professional development (CPD) integration, and involvement in protocol design.

5.Qualitative Open-Ended Modules: Item 25 captured perceived institutional and operational barriers, while Item 26 generated actionable, field-level recommendations for optimization.

### *9. 4 Validity and Reliability*

**Internal Consistency Analysis:** Cronbach's alpha (\alpha) was calculated across all primary sustainability scale indicators (Items Q7 through Q24). The analysis yielded an overall **Cronbach's alpha of \alpha = 0.87**. This coefficient demonstrates an **excellent level of internal consistency** and significantly exceeds the standard academic threshold of 0.70, confirming the instrument's high reliability and establishing a green light for advanced inferential modeling.

### *9. 5. Statistical Data Analysis*

Quantitative and qualitative raw data extracted from the field survey were parsed, processed, and mathematically modeled using the **Statistical Package for the Social Sciences (SPSS v.26)**, adhering to the following computational procedures:

#### *9.5.1 Descriptive Statistical Analysis*

**Frequencies and Percentages:** Computed to map out, summarize, and tabulate the socio-demographic and institutional landscape of the participants.

**Mean (M) and Standard Deviation (SD):** Calculated for each individual item and overarching dimension to define the exact level of practice adherence and rank

operational indicators from highest to lowest, pointing out strengths and gaps.

TABLE I. FREQUENCY DISTRIBUTIONS

| Variable | Category | Frequency | Percentage |
|---|---|---|---|
| Gender | Female | 42 | 82.4% |
| | Male | 9 | 17.6% |
| Age | < 30 | 12 | 23.5% |
| | 30-40 | 29 | 56.9% |
| | 40-50 | 9 | 17.6% |
| Qualification | Bachelor's | 36 | 70.6% |
| | Diploma | 6 | 11.8% |
| | Master's | 6 | 11.8% |
| Experience | 10 years | 22 | 43.1% |
| | 3years | 17 | 33.3% |
| | 15 years | 5 | 59.8% |
| Sustainability Training | Yes | 12 | 23.5% |
| | no | 39 | 76.5% |

### *9.5.2 Inferential Statistical Analysis (Hypothesis Testing)*

To examine the proposed research hypotheses, parametric tests were executed following confirmation of normal data distribution assumptions:

1. **Independent Samples T-Test:** Utilized to determine statistically significant differences in the mean scores of sustainability knowledge and practice application (Items 21–24) between practitioners who attended specialized training programs and those who did not.
2. **One-Way Analysis of Variance (ANOVA):** Deployed to evaluate variations in patient safety and service accuracy standards based on the organizational structure of the healthcare facility (primary clinic, polyclinic, medical center, vs. specialized hospital).
3. **Chi-Square Test of Independence (\chi^2):** Used to investigate the potential nominal association between a practitioner's specific job role/title and their access to or attendance of training programs.
4. **Pearson's Correlation Coefficient (r):** Used to measure the direction, strength, and significance of relationships between continuous variables (e.g., years of experience vs. mean sustainability adherence, and age vs. theoretical knowledge).
5. **Multiple Linear Regression Analysis:** Implemented as the primary modeling mechanism to test the overarching research hypothesis. The overall mean score of sustainability practices (Items 7–24) was defined as the Dependent Variable, while socio-demographic and professional characteristics (Gender, Age, Qualification, Experience, Training, Facility Type) were entered as Independent Variables. This calculated the model's overall explanatory capacity (R^2), F-significance, and the unique relative contribution of each structural predictor via unstandardized coefficients (B) and p-values.

### *9.5.3 Qualitative Thematic Analysis*

For the textual data retrieved via open-ended items (Q25 & Q26), a systematic **thematic content analysis** was applied. The open responses were manually coded and categorized into major themes representing barriers and proposals. These qualitative codes were subsequently converted into discrete frequencies within SPSS to triangulate, validate, and contextualize the quantitative inferential findings.

## *9. 6 Result*

### *9. 6. 1 Descriptive Statistics*

TABLE II. MEAN SCORES FOR KEY ITEMS (SUSTAINABILITY & QUALITY PRACTICES)

| Item | Mean | Std.Deviation |
|---|---|---|
| Safe disposal of expired medications | 4.35 | 0.92 |
| Mechanisms to prevent drug/chemical leakage into the environment | 4.12 | 1.15 |
| Participation in pharmaceutical waste reduction initiatives | 4.08 | 1.04 |
| Periodic training of staff on low-impact waste management | 3.95 | 1.22 |
| Systematic planning of drug quantities using integrated electronic systems | 3.80 | 1.30 |
| Use of cost-monitoring tools (ABC/VEN analysis) quarterly | 3.75 | 1.35 |
| Cost-effectiveness considered in drug selection | 3.90 | 1.25 |
| Ensuring equitable access to essential medicines for all patients | 4.25 | 0.98 |
| Pharmacists provide counseling to promote safe and rational drug use | 4.40 | 0.85 |
| Speed and efficiency of pharmaceutical services | 4.20 | 0.95 |
| Adherence to patient safety standards in prescription review and dispensing | 4.50 | 0.75 |
| Sufficient theoretical knowledge of sustainability among pharmacists | 3.60 | 1.45 |
| Most pharmacy staff received certified practical training in sustainability | 3.40 | ) 1.55 |
| Sustainability culture promoted through continuous professional development | 3.50 | 1.50 |

| | | |
|---|---|---|
| Pharmacists actively participate in designing sustainability protocols | 3.30 | 1.60 |

### *9. 6. 2 Hypothesis Testing*

**A. Independent Samples T-Test**:
Comparison Between those who attended sustainability training (Yes/No) and the mean score of sustainability practices (items 21–24).
Result:
T-value = 2.45, df = 49, p = 0.018 (< 0.05)
Conclusion: There is a statistically significant difference in favor of those who received training in knowledge and practical application of sustainability.

**B. One-Way ANOVA:**
Comparison Between type of healthcare facility (clinic, polyclinic, medical center, specialized hospital) and mean adherence to safety and accuracy standards.
Result:
F-value = 3.89, p = 0.014 (< 0.05)
Conclusion: Statistically significant differences exist; specialized hospitals had the highest mean (4.6), followed by medical centers (4.3), then polyclinics and clinics (4.0 and 3.9, respectively).

**C. Chi-Square Test**:
Relationship Between training attendance and job role (manager/clinical pharmacist/staff).
Result:
Chi-Square = 6.12, p = 0.106 (> 0.05)
Conclusion: No statistically significant relationship was found between job role and training attendance.

### *9. 6. 3 Correlation Analysis (Pearson's r)*

Variables Correlation (r) P-value Interpretation
Years of experience & mean sustainability adherence 0.42 0.002 Moderate positive correlation, statistically significant
Age & theoretical sustainability knowledge (Q21) 0.31 0.028 Weak positive correlation, statistically significant
Training (Yes/No) & sustainability culture (Q23) 0.48 0.001 Moderate positive correlation, statistically significant

### *9. 6. 4. Multiple Linear Regression Dependent Variable:*

Mean sustainability practices (items 7–24)
·**Independent Variables: Gender**, Age, Qualification, Years of Experience, Training, Facility Type
Results:

| Variable | Coefficient (B) | T-value | P-value |
|---|---|---|---|
| Constant | 2.10 | 4.50 | 0.000 |
| Training (Yes=1) | 0.65 | 3.20 | 0.002 |
| Years of experience | 0.18 | 2.90 | 0.005 |
| Facility type (Specialized hospital = reference) | 0.30 | 2.10 | 0.040 |
| Age | 0.12 | 1.80 | 0.078 |
| Qualification (Master's = reference) | 0.20 | 1.50 | 0.140 |

$R^2 = 0.38$ (the model explains 38% of the variance).
Most influential factors: Training, years of experience, and facility type.

### *9. 6. 5 Qualitative Content Analysis (Open-ended Questions Q25 & Q26)*

Responses were categorized into themes with frequencies:
Challenges (Q25):

| Challenge | Frequency |
|---|---|
| Lack of awareness and training | 22 |
| Limited budget | 18 |
| Absence of clear policies/protocols | 15 |
| Poor inventory management and near-expiry drugs | 12 |
| Weak infrastructure for waste management | 10 |
| Few specialized conferences/workshops | 9 |
| Resistance to change and weak leadership | 7 |
| Inconsistent availability of essential medicines | 6 |

Challenges (Q26)

| Suggestion | Frequency |
|---|---|
| Intensive training programs and workshops for pharmacists | 24 |
| Implement integrated electronic systems for inventory and dispensing | 20 |
| Establish clear policies for safe pharmaceutical waste disposal | 18 |
| Activate electronic prescriptions to reduce paper and waste | 15 |
| Strengthen monitoring and performance indicators for sustainability | 13 |
| Improve coordination between departments and administration | 11 |
| Increase budget for medicines and supplies | 10 |
| Adopt recycling practices and rationalize energy consumption | 8 |

### *9. 6. 6 Reliability Analysis (Cronbach's Alpha)*

Cronbach's Alpha was calculated for all sustainability-related items (Q7–Q24):
$\alpha = 0.87$ (Excellent internal consistency)

TABLE III. SUMMARY of Key SPSS Findings

| Indicator | Result |
|---|---|
| Highest-rated practice | Adherence to patient safety standards (Mean = 4.50) |
| Lowest-rated practice | Participation in developing sustainability protocols (Mean = 3.30) |
| Reliability coefficient | 0.87 (Excellent) |
| Strongest predictor in regression | Training (B = 0.65, p = 0.002) |

## 10. DISCUSSION

This section interprets the empirical findings derived from the SPSS quantitative and qualitative thematic analyses, critical contextualization within the Libyan post-conflict healthcare environment, and rigorous benchmarking against regional and international literature.

### *10. 1 Socio-Demographic Dynamics and the Training Paradox*

The demographic composition of the sample (N = 51) reveals that female practitioners constitute the vast majority (82.4\%), aligning with contemporary Arab healthcare workforce trends where pharmacy roles are predominantly occupied by women (Al-Arifi et al., 2023). Although the sample exhibits high human capital readiness—with 70.6\% holding a Bachelor's degree and 43.1\% possessing over 10 years of professional experience—a critical structural paradox emerges: **76.5\% of the respondents have never received specialized training in sustainability metrics or quality management**.

This systemic training deficit directly accounts for the suppressed mean scores observed in continuous professional development (M = 3.50) and collaborative sustainability protocol design (M = 3.30). These findings corroborate the assertions of Elbarsha et al. (2020) regarding the stagnation of continuous professional evaluation in transitional health systems. Crucially, the Pearson correlation analysis reveals that while years of experience moderately correlates with practical adherence (r = 0.42, p = 0.002), it fails to inherently elevate advanced theoretical knowledge without targeted intervention (r = 0.31, p = 0.028 for age). This empirically validates the World Health Organization's (WHO, 2020) paradigm that long-term sustainability cannot rely on passive experiential accumulation but requires explicit, structured capacity building.

### *10.2 Hypotheses Verification and Sustainability Dimensions*

First: Social and Operational Service Efficiency (Sub-Hypotheses 3 & 4)

The empirical data indicates outstanding operational performance in localized micro-level tasks:

- Adherence to patient safety standards in prescription review scored the highest mean (M = 4.50).
- Pharmacist-led patient counseling achieved strong validation (M = 4.40).

These metrics strongly support the **Third and Fourth Sub-Hypotheses**, demonstrating that front-line practitioners maintain exceptional professional ethics and safety vigilance despite structural volatility. This mirrors the clinical outcomes documented by Manon et al. (2023), where standardized pharmaceutical oversight dramatically mitigated medication error margins. However, the regression model indicates that this high localized efficiency is highly vulnerable to systemic decay without macro-level institutionalization.

Second: Environmental Sustainability and Waste Management (Sub-Hypothesis 1)

Adherence to safe medication disposal protocols registered a robust mean (M = 4.35), and contamination prevention metrics reached M = 4.12, validating the **First Sub-Hypothesis**. Nevertheless, qualitative triangulation via thematic content analysis revealed an exogenous systemic barrier: the frequent central distribution of near-expiry pharmaceuticals (Frequency = 12). This supply chain failure undermines environmental performance by shifting the burden of bulk chemical waste disposal onto localized hospital pharmacies, a distinct structural vulnerability missing in more stable regional supply networks, such as Jordan's lifecycle models (Jaber et al., 2020).

Third: Economic Sustainability and Cost Rationalization (Sub-Hypothesis 2)

Economic dimensions registered moderate, yet inconsistent adherence. While consideration of cost-effectiveness in drug selection scored M = 3.90, the integration of modern inventory forecasting software (M = 3.80) and quarterly ABC/VEN econometric profiling (M = 3.75) remained low. Consequently, the **Second Sub-Hypothesis** is only partially supported. The lack of advanced fiscal auditing tools forces relying on rigid, centralized macro-procurement, inducing financial waste estimated in literature to consume 20–30% of developing nations' healthcare budgets (Ferrario & Kaplan, 2022). This is directly mirrored in the qualitative findings, where budgetary constraints represented a primary operational bottleneck (Frequency = 18).

### *10.3 Institutional Variations and Predictor Modeling*

The One-Way ANOVA test established statistically significant variations in safety and efficiency adherence based on organizational hierarchy (F = 3.89, p = 0.014). Specialized hospitals demonstrated the highest compliance (M = 4.6), whereas primary clinics exhibited the lowest (M = 3.9). This imbalance highlights an inequitable distribution of technical infrastructure, prioritizing tertiary centers over frontline preventive clinics.

Ultimately, the Multiple Linear Regression model (R^2 = 0.38, p < 0.05) identifies specialized training as the single most powerful institutional predictor of overall sustainability implementation (\beta = 0.65, p = 0.002), far exceeding the impacts of professional experience (\beta =

0.18) or institutional type (\beta = 0.30). This provides empirical justification for shifting healthcare policy focus from infrastructure procurement to targeted workforce education.

## 11. CONCLUSIONS

1. **The Systemic Execution Gap:** Libyan hospital pharmacies possess highly competent, ethically driven human capital capable of achieving superior clinical and patient safety outcomes (M = 4.50). However, this individual performance is disconnected from modern administrative architectures, suffering from severe deficits in digitization, institutionalized economic profiling, and formal training frameworks.
2. **The Training Dependency:** The Multiple Linear Regression model confirms that specialized training is the primary driver of pharmaceutical sustainability (\beta = 0.65, p = 0.002). The current 76.5\% training deficit acts as the foundational barrier hindering the activation of advanced economic and environmental protocols across Al-Khums municipality.
3. **Exogenous Supply Chain Disruptions:** Localized environmental and economic inefficiencies are largely driven by macro-level governance deficits, specifically the accumulation of expired stock resulting from the centralized distribution of near-expiry medications.
4. **Institutional Inequity:** Significant variations across facility types (F = 3.89, p = 0.014) reveal an operational imbalance. Primary and polyclinic infrastructures are excluded from quality and waste-management integration, severely undermining regional universal healthcare objectives.

## 12. RECOMMENDATIONS

### *12.1. Strategic Policy and Institutional Governance*

- **Establish a National Charter for Pharmaceutical Sustainability:** The Ministry of Health, in coordination with the Libyan Center for Sustainable Development Research, must enact a binding ***regulatory*** framework detailing mandatory Key Performance Indicators (KPIs) for hospital pharmacies.
- **Decentralize and Restructure Procurement Lifecycles:** Formulate strict compliance mandates for central warehouses ensuring all distributed medications possess a minimum shelf-life of 12 months upon delivery, eliminating the structural accumulation of near-expiry waste.
- **Equitable Capital Allocation:** Guarantee dedicated funding lines within the national healthcare budget to upgrade the technological and chemical waste infrastructures of primary health clinics and polyclinics, correcting the imbalances proven by the ANOVA analysis.

### 12.2. Human Capital Optimization and Training

- **Deploy Mandatory Training Programs:** Design and implement mandatory, quarterly professional certification tracks focusing on green pharmacy concepts, safe chemical disposal, and pharmacoeconomics, leveraging the regression model's insights (\beta = 0.65).
- **Leverage Advanced Academic Competencies:** Utilize internal personnel holding postgraduate degrees (Master's/Ph.D.) as structural peer-trainers and lead quality auditors to optimize internal resource allocation.
- **Academic Integration:** Collaborate with Libyan higher education institutions to integrate sustainable pharmaceutical development metrics directly into undergraduate pharmacy curricula.

### *12.3. Digital and Operational Transformation*

- **Mandate Digital Inventory and Forecasting Architectures:** Transition from traditional procurement methods to cloud-based inventory frameworks utilizing real-time, consumption-driven software and automated early-warning mechanisms for approaching expiration dates.
- **Enforce Quantitative Micro-Evaluation Tools:** Institutionalize mandatory quarterly ABC/VEN matrix analyses across all administrative levels to optimize expenditure, reduce cost overruns, and mitigate resource wastage.
- **Implement Comprehensive E-Prescribing Platforms:** Accelerate digital healthcare transformation by deploying electronic prescription networks to eradicate transcription errors, minimize paper waste, and monitor medication rationalization.

### *12.4. Directions for Future Research*

- **Geographical Expansion:** Commission multi-center comparative studies across diverse Libyan regions to construct an empirical national baseline for pharmaceutical sustainability.
- **Longitudinal Structural Assessments:** Shift from cross-sectional designs to longitudinal frameworks to track the long-term impacts of sustainability compliance on clinical outcomes and cost-containment over multi-year intervals.
- **Objective Carbon Mapping:** Conduct rigorous environmental audits measuring the precise carbon footprint and chemical leakage metrics of healthcare institutions in post-conflict environments.

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## BIOGRAPHIES

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