Macedonian Pharmaceutical Bulletin, 72 (Suppl 1) 329 - 330 (2026)
Online ISSN: 1857-8969
DOI: 10.33320/maced.pharm.bull.2026.72.03.159
Short communication

Digitalized reagent management in pharmaceutical quality control laboratories: an AI-assisted consumption and procurement analysis

Marija Zafirova Gjorgjievska*, Evgenija Dobreska, Hrisanta Godzo, Mihaela Dovichinska, Blagoj Achevski, Liljana Anastasova

Faculty of Pharmacy, Ss. Cyril and Methodius University in Skopje, Mother Tereza 47, 1000 Skopje, North Macedonia

Introduction

Reagent management is a critical support process in pharmaceutical quality control (QC) laboratories, directly affecting the accuracy, reproducibility and regulatory acceptability of analytical results. In many laboratories it is still performed through partly manual, non-integrated records that limit traceability and quantitative oversight (Charoo et al., 2023; Hole et al., 2021). Digitalization and, increasingly, artificial intelligence (AI) offer the opportunity to convert such records into actionable forecasts for procurement planning (Yuen et al., 2025) within the broader Pharma 4.0 framework (Khaliq et al., 2025; Phiri et al., 2025; Niazi, 2025). This work demonstrates, using real consumption data from a medicines QC laboratory, how AI-assisted analysis can predict reagent reorder timing and quantity and support expiry-aware procurement decisions.

Materials and methods

Reagent usage records from the CDQC laboratory at the Faculty of Pharmacy, Ss. Cyril and Methodius University in Skopje, were compiled for a representative subset of 20 reagents (10 liquid, 10 solid) comprising 49 containers logged between 2019 and 2026, selected to demonstrate the method rather than to provide a complete inventory; high-turnover reagents such as acetonitrile and methanol are in practice held at several shelf positions with a substantially higher combined consumption. For each container, the opening date and sequential usage dates were recorded; the final date marks full consumption, unless the unit was withdrawn because of expiry (an expiry-driven loss). As grammage or volume per use is not recorded, consumption was quantified through container turnover: the in-use lifespan (opening to last use), the interval between successive openings (reorder interval) and the annualized container count (containers divided by observation span). From these, the expected annual demand (annualized count times unit size) and reorder timing were derived per shelf position, and reagents whose reorder interval exceeded shelf life or that showed expiry losses were flagged for reduced purchase quantities. Three implausible manual entries were identified and excluded. The dataset was structured, analyzed and modeled with the assistance of an AI system (Claude, Anthropic) under human expert review, consistent with a human-in-the-loop approach (Romero-Obón et al., 2025).

*marijazafirova@ff.ukim.edu.mk

Results

A forecast could be derived for all 20 reagents. Liquid reagents turned over roughly three times faster than solids, with a median in-use lifespan of 123 versus 281 days and a median reorder interval of 280 versus 788 days; all expiry-driven losses (5 units across 4 reagents) occurred among solids, while no liquid reagent was lost to expiry. For fast-moving solvents, consumption was highly regular: within a single shelf position, acetonitrile and methanol were reordered at consistent intervals of roughly 150–210 days (about 2.4–2.7 units of 2.5 L per year for that position, corresponding to a forecast of some 6–7 L per year per position). The value of the forecast lies in this predictability of turnover, which allows reorder timing and quantity to be anticipated per position and aggregated across all positions of a reagent, supporting just-in-time procurement in economical bulk volumes. For slow-moving solids, the modeled reorder interval consistently exceeded the material shelf life: caffeine (2.0 years, 2 units lost), octane-1-sulfonic acid sodium salt (2.1 years, 1 unit lost), silver nitrate (4.5 years, 1 unit lost) and ammonium dihydrogen phosphate (5.7 years, 1 unit lost) were all correctly identified as expiry-prone, generating a recommendation to purchase smaller unit sizes or to procure on demand rather than in bulk. The AI-assisted model thus produced per-reagent procurement recommendations, in both quantity and timing, directly from historical usage dynamics, distinguishing reagents suited to bulk purchasing from those requiring minimal, on-demand ordering.

Conclusion

Applied to real QC-laboratory records, AI-assisted analysis of reagent consumption converts fragmented usage logs into actionable procurement forecasts, predicting reorder timing and quantity for fast-moving reagents and flagging slow-moving, expiry-prone reagents for reduced purchasing. Embedded within a validated, LIMS-based quality system and retained under human expert oversight, this approach can reduce expiry-driven waste and improve inventory efficiency while maintaining data integrity and regulatory compliance.

References

Charoo N.A. et al., 2023. Data integrity issues in pharmaceutical industry: common observations, challenges and mitigation strategies. Int. J. Pharm. 631, 122503. https://doi.org/10.1016/j.ijpharm.2022.122503

Hole G. et al., 2021. Digitalization in pharmaceutical industry: what to focus on under the digital implementation process? Int. J. Pharm. X 3, 100095. https://doi.org/10.1016/j.ijpx.2021.100095

Khaliq S.A. et al., 2025. A narrative review on automation and digitalization in quality control laboratories of pharmaceuticals. Int. J. Pharm. Integr. Health Sci. 6(2), 89–98. https://doi.org/10.56536/ijpihs.v6i2.262

Niazi S.K., 2025. Regulatory perspectives for AI/ML implementation in pharmaceutical GMP environments. Pharmaceuticals 18, 901. https://doi.org/10.3390/ph18060901

Phiri V.J. et al., 2025. Towards enterprise-wide Pharma 4.0 adoption: the challenges and up-scaling opportunities. Sci. Afr. 28, e02771. https://doi.org/10.1016/j.sciaf.2025.e02771

Romero-Obón M. et al., 2025. Human-in-the-loop AI use in ongoing process verification in the pharmaceutical industry. Information 16, 1082. https://doi.org/10.3390/info16121082

Yuen N.H.Y. et al., 2025. Laboratory Information Management System (LIMS) 4.0: a model to solve the current pain points for commercial electrical and electronic laboratories. J. Lab. Autom. https://doi.org/10.1177/18479790251385743