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Reducing Pharmaceutical and Non-Pharmaceutical Inventory Waste in Tertiary Hospital: Impact of ABC-VEN Analysis in a Zero-Waste Strategy Over 7 Years

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Aim: To evaluate the prevalence and trend of inventory waste in a tertiary hospital over the last 7 years. This included the type and average monetary value (MV) of inventory waste, as well as the outcome of using the Always-Better-Control (ABC)-Vital-Essential-Non-essential (VEN) matrix as part of a Zero-Waste Strategy.

Methods: This was a retrospective observational study conducted at King Abdulaziz Medical City (KAMC) over 7 years.

Results: The prevalence of waste was 0.21%, which equates to (SAR) 15 million out of SAR 7 billion. The pharmaceutical inventory had significantly higher waste in terms of MV and the number of items (89.8%, and 80.3%, respectively) (P<0.001). The expired pharmaceutical inventory had a significantly higher waste of MV than non-moving and obsolete inventory (79.8%, 14.3%, and 5.9%, respectively) (P<0.001). The ABC-VEN matrix categorized the inventory into Category I, which has the highest MV waste at 82.3%, followed by Category II with 16.8%, and then Category III with 0.9%. However, category II had a significantly higher number of wasted items at (58.2%), followed by Category I (24%) and Category III (17.8%) (P<0.01). The majority of MV waste consisted of a small number of pharmaceutical items that had a high clinical impact, representing 66% and 18%, respectively. After implementing a zero-waste strategy for landfills using the ABC-VEN matrix, the prevalence of waste declined from 0.9% to 0.21%. The waste sent to the landfill was zero from 2018 through 2020, saving 73.64% of the total money.

Conclusion: The use of the ABC-VEN matrix positively impacted the reduction of MV waste. The prevalence and trend rate of inventory waste were lower than the benchmarks of global companies, saving more than two-thirds of the inventory value that would have been wasted. The majority of the wasted MV consisted of a small number of pharmaceutical items that had a significant clinical impact.

Keywords: expired pharmaceutical inventory, non-moving inventory, obsolete inventory, Saudi Arabia, prevalance of inventory waste, employee engagement, rate of inventory waste

Introduction

Health expenditure has significantly increased in the recent past, particularly due to rapid population growth and the development of new technologies.[1–4] Worldwide, countries spend approximately 40% to 60% of their entire public sector health budget on purchasing pharmaceutical and medical supplies.[1] In 2019, global spending on health reached the United States (US) $8.5 trillion, constituting 9.8% of global GDP.[5]

In Saudi Arabia, the health sector consumes the largest share of health-related expenditure in the Middle East and North Africa. The government's budget allocated to the Ministry of Health increased from Saudi Arabian Riyal (SAR)

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62 billion in 2015 to SAR 79 billion in 2021, reflecting an average annual growth rate of 7.8%.[6] In 2024, per capita health expenditure in Saudi Arabia was SAR 4589.[6,7]

Mostly, the increase in expenditure results in a rise in waste. Overstocking and the accumulation of unused inventory in health facility warehouses lead to unnecessary expenditure in the healthcare sector.[8] Excessive inventory can cost an organization 20% to 40% of the total inventory value throughout the year.[9,10]

Globally, inventory wastage is a significant problem in public health facilities. It causes a substantial negative impact on the healthcare budget and environment, particularly pharmaceutical waste,[11–14] leading to billions of dollars in supply chain waste annually.[15] In 2018, hospitals in the USA wasted more than $25 billion on unnecessary supply chain items, according to a Navigant study of 2127 hospitals.[15] In 2021, the global waste management market had a worth of USD 889.58 billion.[16] Every year, Saudi Arabia generates more than 15 million tonnes of solid waste.[17]

Inventory management is crucial for effective supply chain operations, budgetary control, and reducing excess inventory.[8,18,19] The management of healthcare supply chains is more complex than that of other industries.[4,8] This complexity is due to the primary goal of healthcare supply chain management, which is to provide the necessary pharmaceutical and medical supplies to healthcare facilities in the correct quantities, at the right time, and in the appropriate locations while ensuring high quality, safety, effectiveness, and affordability.[4,8]

Recently, the concept of a "zero-waste" strategy has been adopted by a benchmarking group focused on managing and reducing waste. This group strives to elevate waste from the bottom of the hierarchy (disposal) to the top (prevention).[20,21] The zero-waste strategy involves proactive activities aimed at achieving zero-waste goals. The strategy centers on waste identification, assessment, and treatment, with a focus on prevention, avoidance or reduction, and subsequent monitoring.[22]

According to Saudi Vision 2030 and the transformation government program, the National Center for Waste Management plans to reduce the waste sent to landfills by 90% by 2040.[23]

The Zero-Waste Strategy is crucial for the sustainability, availability, and affordability of inventory for both organizations and individuals. Moreover, it has a positive impact on economic, societal, and environmental aspects. In the current study, the zero-waste strategy involves the use of the Always-Better-Control (ABC) - Vital-Essential-Non-essential (VEN) matrix to analyze waste.

The ABC-VEN matrix is a fusion of two techniques: ABC and VEN. The ABC method is one of the most frequently utilized and effective tools in material management. It is based on Pareto's Law, which posits that 80% of the total value is accounted for by 20% of the items. As such, inventory is classified into the following three categories based on their monetary value (MV): Category A, encompassing 10–20% of the items, represents 70–80% of the value. Similarly, Category B contains 10–20% of the items with a value of 15–20%, and Category C accounts for 60–80% of the items with a value of 5–10%.[24,25]

The second technique is the VEN analysis, in which the inventory is classified into three categories based on critical values and health impact. Category V represents the vital inventory required for clinical use. Category E is deemed moderately important compared to the V items. Category "N" refers to the non-essential inventory that is considered the least important and is seldom used.[26,27]

The ABC-VEN matrix categorizes inventory into three groups (I, II, and III). Category I contains all vital and expensive items (AV, AE, AN, BV, CV). Items in this category require close supervision and high levels of observation. Category II includes items that are essential and less costly than those in Category I (BE, CE, BN). Category III contains items that are non-essential and comprise the cheapest group of items (CN).[16–18,25–28]

The importance of using the ABC-VEN matrix technique in managing healthcare supply chains lies in identifying inventory with the greatest clinical and economic impact on the organization, as well as those requiring stringent control and monitoring. It also aids in the selection and purchase of inventory based on both cost and clinical aspects.[8,18,19]

The current study is the first to be conducted in Saudi Arabia, using real-world cost data to provide new insights regarding pharmaceutical and non-pharmaceutical inventory waste in terms of MV and the number of items in the government health facility warehouse.

Additionally, this is the first study to use the ABC-VEN matrix in assessing inventory waste. The findings of the study will support the efficient use of the ABC-VEN matrix in a Zero-Waste Strategy effectively reducing financial waste. These findings will also provide baseline data for future studies in the logistics field.

The purpose of this study was to assess the prevalence and trend of inventory waste in the health facilities of the MNG-HA in the Central Region of Riyadh over the past 7 years. This includes the type and average MV of waste inventory, as well as the outcome of using the ABC-VEN method in the Zero-Waste Strategy.

Material and Methods

Study Design

A retrospective observational study was conducted to review logistical data using the electronic Health Enterprise Resource Planning (ERP) system, spanning 7 years from January 2015 through December 2021.

Study Setting

The study was conducted in the Logistics and Contract Department of King Abdulaziz Medical City (KAMC). KAMC is a health facility of the MNG-HA and a Tertiary Hospital located in Riyadh, Saudi Arabia. The Logistics and Contract Department is tasked with managing the inventory supply chain and handling items such as pharmaceuticals, medical consumables, and non-medical consumable materials.

Study Sample

All waste inventory (pharmacy items, consumable medical supplies, non-consumable medical supplies) stored in Warehouse "K" during the study period were included. Warehouse "K" is a storage facility for waste inventory. Non-formulary and unplanned inventories were excluded (Figure 1).

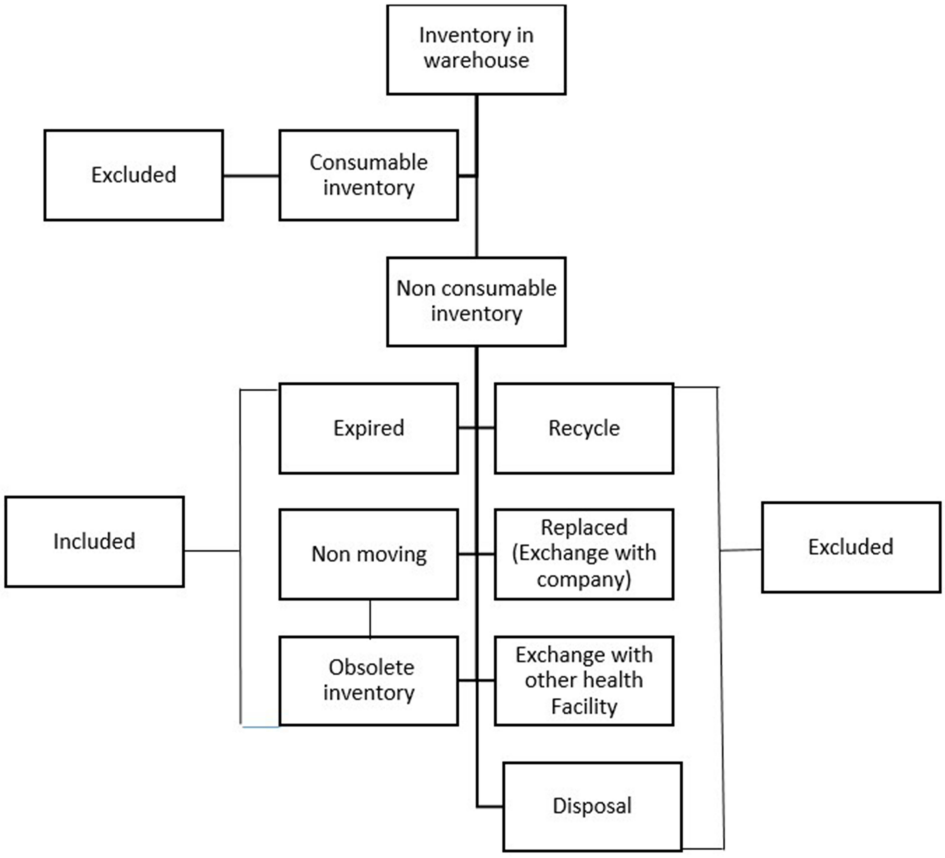

Figure 1 Inclusion and Exclusion criteria of the study.

Data Collection

Specialist planners from pharmacy and medical/non-medical planning were assigned to collect data. They gathered data for the last 7 years, starting from January 2015 to December 2021. The data was retrieved using the Inventory Management ERP system.

ERP is an Oracle Inventory Management system for managing inventory tracking and control processes, from item receipt to dispatch to the end user. Each item has a reference number, and additional information such as its location in the warehouse, name, description, quantity, price, expiration date, and vendor. The system stores all data, which can be retrieved at any time and for any duration.

In the current study, inventory waste is assessed by the MV of waste and the number of unused items in the inventory. The system calculates the wasted MV of the inventory by multiplying the quantity of each item by the unit price recorded in the system. The currency used in the study is the SAR.

The following characteristics of sample data were reviewed: (1) Type of waste inventory: The inventory was divided into two types based on the uses: pharmaceutical, and non-pharmaceutical items. Pharmaceutical inventory included drugs and Non-pharmaceutical inventory included medical and non-medical consumables; and (2) Category of waste inventory: The waste inventory was categorized into three categories based on the movement of the inventory: Non-moving, obsolete, and expired inventory.

The expired inventory is divided into Expired Pharmaceutical Inventory and Expired Medical Inventory. Expired Pharmaceutical Inventory is categorized based on therapeutic uses such as Anti-neoplastic Drugs, Anti-infective Drugs, Emergency Drugs, Endocrinology Drugs, Biological Drugs, Immunosuppressive Drugs, Respiratory Drugs, Gastrointestinal Drugs, Vitamins and Related Drugs and so on. Expired Medical Inventory is categorized based on the specialist department, such as Surgical Supplies, and Dental Supplies, Laboratory Supplies, Rehabilitation Supplies, Medical Imaging Supplies, Central Sterile Service Supplies, Vitro Fertilization Supplies, Anesthesia Supplies, to name but a few.

Tools (Techniques) Used in Zero-Waste to Landfill Strategy

There are broadly three techniques used in the Zero-Waste to Landfill strategy. These are the ABC method where ABC analysis is based on MV: A (High-value items), B (Medium-value items), and C (Low-value items); the VEN method, which is based on clinical impact; and the ABC-VEN matrix analysis, divided into three categories: category I (high clinical and cost impact), category II (moderate clinical and cost impact), and category III (low clinical and cost impact).

The Outcome of Using ABC-VEN in Zero-Waste Strategy

The study had two outcomes: the MV saved, and the MV wasted. There were three types of monetary waste: waste disposal, current waste, and real waste.

Waste disposal (sent to landfill) is defined as the MV of the waste inventory that was sent to landfill over 7 years.

Current waste refers to the MV of the waste inventory that is currently stored in a warehouse. This is the cumulative MV of the remaining waste inventory from 2015 to 2021, after implementing the Zero-Waste to Landfill strategy through various processes.

Real waste is defined as the MV of the waste inventory that was prevented or did not occur due to the implementation of a zero-waste strategy by using an ABC-VEN matrix. This is calculated by adding the total value of waste disposal, the current waste, and the value of inventory saved.

Savings or the MV saved, is defined as the MV that was saved as a result of implementing a zero-waste strategy using an ABC-VEN matrix.

Employee Engagement: The involvement of employees in attaining an organizational zero-waste strategy through proactive activities and processes, whether internal or external to the MNG-HA. Each employee was tasked with managing a group of inventory items.

Operational Definitions

The definitions in our study were based on the policies and practices of our organization concerning inventory management and the health supply chain. We defined inventory waste as any inventory that remained unused throughout the entire supply chain due to expired or unconsumed reports over a specific timeframe, with consequential negative impacts on the organization's budget.

Non-moving Inventory: Non-moving inventory refers to those items not used within a specific timeframe (three months for pharmaceutical and six months for non-pharmaceutical items), with a turnover rate of less than one.

Obsolete inventory refers to items that have remained in the warehouse with no demand for them over a prolonged period, typically at least 12 months, or products not used in the last 12 months. These items are generally more difficult to revive or move.

Expired Inventory: Expired pharmaceutical or medical items are those that have surpassed their "use-by" date.

Consumable medical inventory is defined as items used by doctors and nurses in a healthcare facility to treat patients. These consumables are disposable or semi-disposable and non-reusable, including medical devices and other supplies such as sterile needles, syringes, and swabs.

Non-medical consumables: These are items used by healthcare providers or non-healthcare providers for non-medical purposes, such as office supplies and paper.

Rate of Current Waste: The MV (SAR) of the current waste inventory divided by the expenditure for that same year, multiplied by 100 to yield a rate.

Rate of Real Waste: The MV (SAR) of the real waste inventory is divided by the expenditure of the same year, and then multiplied by 100 to obtain a rate.

Inventory Turnover: This refers to the rate of consumption, which is calculated by dividing the total cost of inventory (SAR) by the average inventory.

Zero-Waste to Landfill Strategy: The inventory is classified based on cost (ABC) and clinical impact (VEN), with the movement and consumption of items being monitored every three months according to the ABC-VEN combination.

Data Management and Analysis

Statistical analyses were performed using SPSS (version 25; SPSS Inc., New York, USA). Descriptive statistics of the categorical variables were presented in frequency and percentage, while continuous variables were conveyed as mean ± SD, or as geometric mean and median (inter-quartile range (IQR)). Charts were used to display the types of waste inventory and the most common types and classes of inventory following non-moving, expired items, and the ABC-VEN matrix. Pearson's chi-squared test was employed to assess the differences between the various types of wastage, categories, and within the same category of inventory. It was also utilized to assess the ABC, VEN, and ABC-VEN matrix among different groups. A P-value ≤ 0.05 was deemed statistically significant. The prevalence of inventory waste was determined by dividing the waste inventory, present in the warehouse, by the total inventory purchased, and then multiplying by 100.

The measures of internal consistency revealed a Cronbach's alpha for the MV and numbers, which were 0.842 and 0.801, respectively.

Results

During the study period, the total expenditure on health supply chains was SAR 7,395,962,227.74 (USD 1,972,256,594.064). The pharmaceutical supply expenditure accounted for 45.31% of the total expenditure, and non-pharmaceutical supplies accounted for 54.69% over 7 years. The turnover of pharmaceutical supplies ranged from 0.62 in 2020 to 2.22 in 2015. Meanwhile, the turnover of non-pharmaceutical supplies ranged from 3.49 in 2015 to 8.79 in 2020.

In 2021, the per capita health inventory in KAMC, which includes both pharmaceutical and non-pharmaceutical items, was SAR 2,241.51. The per capita pharmaceutical expenditure was SAR 1040 (equivalent to USD 277.33), while the per capita non-pharmaceutical expenditure was SAR 1201.5 (equivalent to USD 320.4).

Prevalence of Inventory Waste

The cumulative inventory waste's overall prevalence was 0.21% of the total health supply chain expenditure over 7 years, amounting to SAR 15,518,061.68 out of SAR 7,395,962,227.74, the mean (95% CI) of which was SAR 10,709 (SAR 8546 to SAR 12,872).

Sample Characteristics

The inventory consisted of 924 products (items), incorporating 1452 different patches or dosage forms. This totaled up to SAR 15,518,061.68 and represented 3,735,342 wasted units.

Type of Inventory

The pharmaceutical inventory significantly exceeded other areas in terms of monetary waste and the number of wasted items. In terms of MV waste, the pharmaceutical inventory accounted for 89.8% and the non-pharmaceutical inventory accounted for 10.2% of the total wasted MV. When comparing the number of wasted items, pharmaceutical inventory constituted 80.3% of the total number of wasted items, while the non-pharmaceutical inventory made up 19.7% . A significant difference was noted (P<0.001).

Figure 2 illustrates the current waste in terms of MV and the number of items. Anti-neoplastic drugs accounted for the highest waste (23.63%), followed by endocrinology drugs (9.24%), emergency drugs (6.39%), and anti-infective drugs (4.57%).

In terms of the number of items, the top item was emergency drugs, accounting for 10.26% of total items, followed by anti-infective drugs and office supplies, each with 9.23%.

Category of Waste Inventory

The MV and number of items in expired pharmaceutical inventory were significantly higher. In terms of MV, expired inventory was the highest waste (79.8%), followed by non-moving inventory (14.3%), and then obsolete inventory (5.9%). There was a significant difference (P<0.001). Refer to Table 1.

In terms of the number of wasted items, the expired pharmaceutical inventory was the most significant waste at 79.41%, followed by obsolete inventory at 15.22%, and non-moving inventory at 5.37% of the total number of wasted items. A significant difference was observed between the categories (P<0.001) (Table 1).

Expired Pharmaceutical Inventory

The prevalence of expired pharmaceutical inventory was 0.17% of the total expenditure, amounting to SAR 12,384,144.525.

In terms of MV, anti-neoplastic agents (29.7%) represented the most significant waste among expired pharmaceutical inventory, followed by endocrinology drugs (11.6%), emergency drugs (8%), and anti-infective drugs (5.7%). There was a significant difference between the drugs (P<0.001). Regarding the number of items, emergency drugs, and anti-infective drugs were the most common expired pharmaceutical items (12%), followed by anti-neoplastic agents (10%).

The pharmaceutical items that contributed to a high number of waste and low MV waste were Nasal, Ophthalmic, and Otolaryngological Drugs (7.8%, and 3.5%, respectively), Dermatology Preparations (6.67%, and 1.56%, respectively), and Over-the-Counter drugs (OTC) (5.6%, 0.7%, respectively).

Injectable medications represented 32.2% of the total number of expired pharmaceuticals, amounting to 50.6% of the total wasted MV. Oral dosage forms of medications represented 44.9% of the total number of expired pharmaceuticals, amounting to 38.38% of the total wasted MV.

Topical medications account for 22.9% of expired pharmaceuticals, representing 11.02% of the total MV wasted.

Non-Moving Pharmaceutical Inventory

The prevalence of the non-moving pharmaceutical inventory was 0.02% of the total expenditure in MV, amounting to SAR 1,553,431.16 out of SAR 7,395,962,227.74.

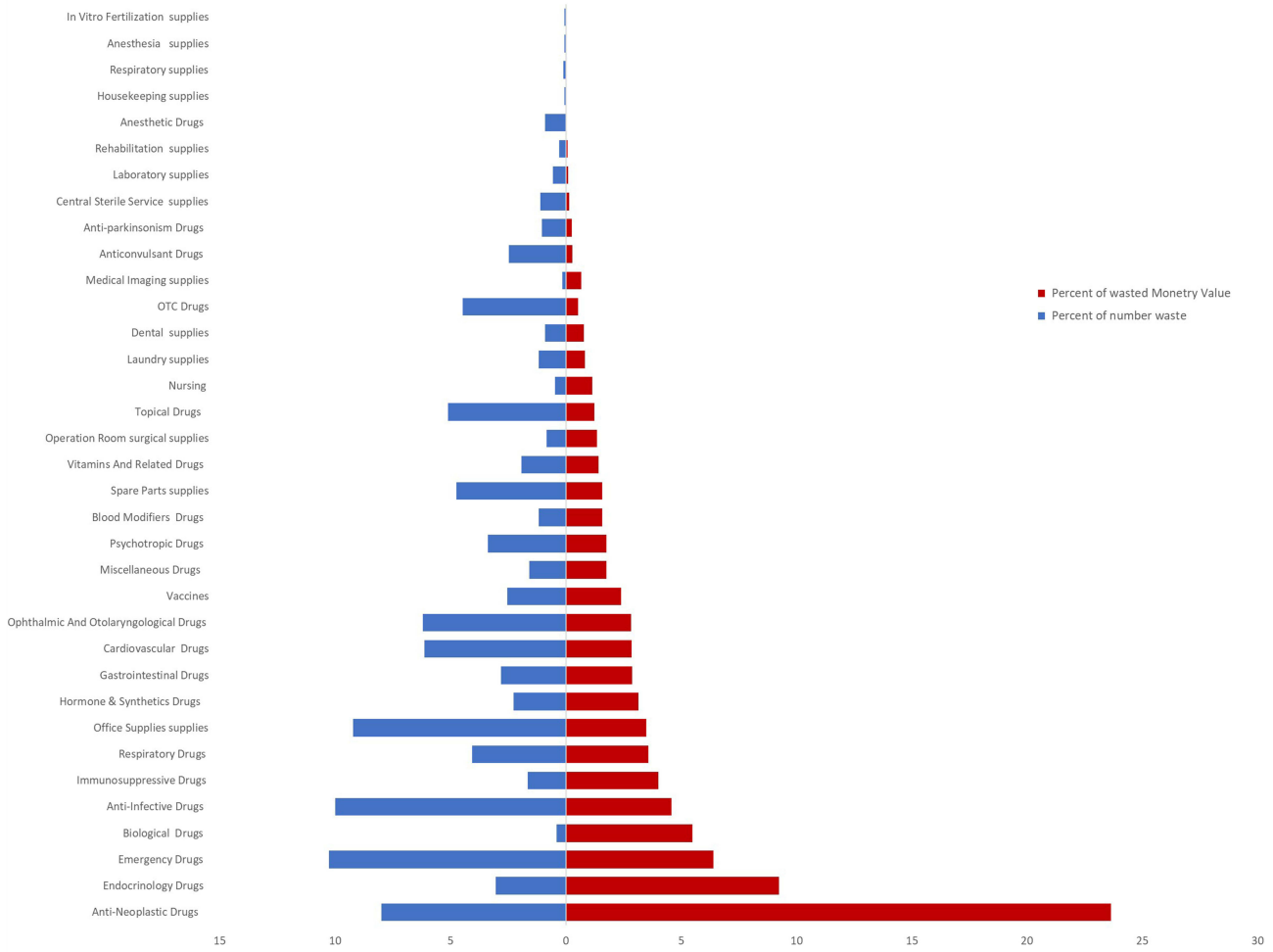

Figure 2 Type of inventory waste based on monetary value and number of items.

Non-Moving Medical Consumable Inventory (NMI)

The prevalence of waste consumable medical inventory accounted for 0.01% of the total expenditure, amounting to SAR 665,536.75 out of a total of SAR 7,395,962,227.74.

In terms of monetary waste, surgical supplies had the highest waste at 31.87%. In terms of the number of wasted items, the Central Sterile Service had the highest frequency of waste at 24.6%, but the MV was low at 3.59%.

Obsolete Inventory

The prevalence of obsolete inventory was 0.01%, equaling SAR 914,950.00 out of SAR 7,395,962,227.74. The cost and number of office supplies constituted a significantly higher proportion of obsolete inventory, accounting for 59% and 68.8%, respectively.

Techniques Used in Zero - Waste Strategy

ABC Analysis

In terms of MV waste, Class A (80%) was significantly higher than Class B (15.4%), and Class C (4.6%). The MV waste of Classes A, B, and C represented 0.15%, 0.03%, and 0.01% of total expenditure, respectively. There was a significant difference (P<0.001) (Table 2).

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Table 1 Frequency Distribution by Category and Subcategories of the Inventory Waste

Name of Category	N (%)	Mean (SAR)	Median (IR) (SAR)	Min (SAR)	Max (SAR)	Sum of Value (SAR)	% of Value*	Prevalence of Value**	P- Value
Expired Pharmaceutical									0.001
Anti-Neoplastic Drugs	116 (10.1)	5476.7	4985 (23,544.9)	37.50	287,804.4	3,674,978.61	29.7	0.05	
Endocrinology Drugs	44 (3.8)	2530.1	2429.4 (18,031.5)	46.05	538,4275	1,437,061.62	11.6	0.02	
Emergency Drugs	149 (12.9)	779.1	904.5 (4,161)	8.28	177,100	992,985.84	8	0.01	
Biological Drugs	6 (0.5)	19,930.75	36,210 (276,812.8)	300	604,215	854,756.25	6.9	0.01	
Anti-Infective Drugs	145 (12.6)	625.5	810.3 (2420.6)	2.7	149,310	713,709.38	5.7	0.01	
Immunosuppressive Drugs	24 (2.1)	2879.9	2807.2 (20,754.9)	36.4	331,800	624,447.09	5	0.01	
Respiratory Drugs	59 (5.1)	852.6	720 (3297.5)	8.9	134,442	556,318.21	4.5	0.01	
Hormone & Synthetics Drugs	33 (2.9)	1339.7	1387.44 (7445)	1.26	190,026	489,755.04	3.9	0.01	
Gastrointestinal Drugs	41 (3.6)	1005.3	1,556.1 (12,514.8)	3.15	109,175.0	445,584.48	3.6	0.01	
Cardiovascular Drugs	89 (7.7)	617.66	799.4 (4989.2)	5.04	55,275	443,645.81	3.6	0.01	
Nasal, Ophthalmic and Otolaryngological Drugs	90 (7.8)	267.8	185.56 (1125.8)	2.10	138,000	438,281.5	3.5	0.01	
Vaccines	37 (3.2)	1974.2	3713 (8490.5)	23.02	97,554.19	372,574.08	3	0.01	
Psychotropic Drugs	49 (4.2)	421.6	458.70 (1617.5)	2.80	55,666.20	272,918.64	2.2	< 0.01	
Miscellaneous Drugs	23 (2.0)	2629.6	3147.38 (15,656.3)	12.40	57,162.33	272,871.22	2.2	< 0.01	
Blood Modifiers Drugs	17 (1.5)	2430.2	6486.00 (25,814.9)	112.39	60,307.50	243,371.11	2	< 0.01	
Vitamins And Related Drugs	28 (2.4)	936.7	739.83 (3743.7)	25	64,860	219,777.50	1.8	< 0.01	
Dermatology Drugs	74 (6.4)	297.9	249.72 (1249.5)	5.40	37,540.58	193,233.09	1.6	< 0.01	
Over-The-counter Drugs	65 (5.6)	145.8	127.80 (460.6)	1.72	34,300	83,846.35	0.7	< 0.01	
Anticonvulsant Drugs	36 (3.1)	316.9	264.07 (928.9)	5.6	10,684.80	43,201.56	0.3	< 0.01	
Anti parkinsonism	15 (1.3)	690.8	651.90 (2405.4)	23.8	17,400	38,240.54	0.3	< 0.01	
Anesthetic Drugs	13 (1.1)	180.5	251.90 (472.7)	18	1580.60	4650.05	0.04	< 0.01	
Subtotal Expired Pharmaceutical	1153 (100)	804.81	750 (4671.25)	1.26	604,215	12,384,144.525	100	0.17	
Non-moving - Medical Consumable									
Surgical Supplies	12 (18.5)	3672.3	6553.5 (23,335.5)	14.00	98,175	212,128	31.9	< 0.01	
Nursing Supplies	7 (10.8)	8830.6	8572 (10,638)	1,250	133,688	179,094	26.9	< 0.01	
Dental Supplies	13 (20)	2798.8	7068 (9,152.5)	24	57,360	120,629	18.1	< 0.01	
Medical Imaging Supplies	2 (3.1)	51,000	51,000	51,000	51,000	102,000	15.3	< 0.01	
Central Sterile Service Supplies	16 (24.6)	815.5	644 (1191)	139	9434	23,860	3.6	< 0.01	
Laboratory Supplies	8 (12.3)	533.6	390 (3819)	47.00	7,480	14,793	2.2	< 0.01	
Rehabilitation Supplies	4 (6.2)	1844.9	1577 (4738.3)	769	6,750	10,673	1.6	< 0.01	
Respiratory Supplies	1 (1.5)	2272	2272	2,272	2,272	2272	0.34	< 0.01	
Fertilization Supplies	1 (1.5)	48	48	48	48	48	0.01	< 0.01	
Anesthesia Supplies	1 (1.5)	40	40	40.00	40	40	0.01	< 0.01	
Subtotal Non-moving - Medical Consumable	65	1874.1	1601 (7916.1)	14	133,688	665,537	100	0.01	

Non-moving Pharmaceutical	13 (100)		8750 (168,601.59)	6	825,000	1,553,431.16		0.02	
Obsolete inventory									
Office Supply Supplies	134 (60.6)	1130.7	1172.5 (2,982.2)	1	49,932	540,517	59.1	< 0.01	
Spare Parts Supplies	69 (31.2)	628.7	750 (2,075.5)	8	70,752	243,599	26.6	< 0.01	
Laundry Supplies	17 (7.7)	3874.6	3676 (3,203.2)	902	66,600	127,805	13.9	< 0.01	
Housekeeping Supplies	1 (0.5)	3031	3031	3,031	3,031	3031	0.3	< 0.01	
Subtotal Obsolete inventory	221 (100)	1039.5	1116 (2,958)	1	70,752	914,952	100	0.01	

Notes: Min, Minimum; Max, Maximum, ; % of Value* is the monetary value of subcategory from same category; Prevalence of Value ** is the monetary value of subcategory from total expenditure during seven years.

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In terms of the number of items wasted, Class C (67.7%) was significantly higher than Class B (18.4%) and Class A (13.9%) in total numbers. There was a significant difference (P<0.01).

Significant MV waste was observed in the pharmaceutical inventory (Class A), where 8% of wasted items represented 64% of total MV waste (P<0.001). There was also significant waste in Class C pharmaceutical inventory, where the number of wasted items was considerably higher at 57.7%, but these represented only 3.85% of the total MV.

Vital – Essential - Non-Essential (VEN) Analysis

In terms of waste items, Class E (60.2%) was significantly higher than Class N (28%) and Class V (11.6%). There was a significant difference (P<0.001) (Table 2).

In terms of MV waste, Class E (78%) was significantly higher than Class N (12.9%), and Class V (9.2%). The MV waste of Classes V, E, and N represented 0.02%, 0.14%, and 0.03% of total expenditure, respectively. There was a significant difference (P<0.001) (Table 2).

Significantly, the pharmaceutical inventory constituted a major portion of MV waste, and the number of items discarded was notably high (Class E). Specifically, 57.78% of the wasted items represented 66% of the total MV waste.

ABC-VEN Matrix Analysis

The ABC-VEN matrix was used to analyze inventory based on clinical and cost impact. Category I (inventories with both high clinical and cost impact) had the highest MV of waste, at 82.3%, followed by Category II, at 16.8%, and finally, Category III, at 0.9%. However, Category II was significantly higher in terms of the number of items wasted (58.2%), followed by Category I (24%), and then Category III (17.8%) (P<0.01).

The combined analysis of the ABC-VEN matrix revealed interesting facts about monetary waste in different categories. In pharmaceutical inventory, Category "AE" had the highest MV of waste, at 67%, representing 8.2% of items. For medical inventory, the highest MV of waste also fell in Category "AE", at 43.4%, representing 12.3% of items. In non-medical consumables, Category "AN" had the highest MV of waste, at 82.3%, representing 25% of items. All these results were statistically significant (P<0.01).

Category "CE" was significantly high in the number of items of pharmaceutical and medical inventory waste (50% and 30%, respectively). The MV represented was 3.4% and 1.7% respectively (P<0.01) (Table 2).

Figure 3 illustrates the distributed inventory waste based on the categories of the ABC –VEN Matrix. It shows that emergency drugs were significantly the highest item, categorized as Category I (56.87%), followed by anti-neoplastic agents (11.45%) (P<0.01). Office supplies constituted a significantly high percentage of Category III (25.97%).

Outcome Implementation Zero-Waste Strategy

Table 3 summarizes the inventory waste over 7 years, both before and after the implementation of the ABC-VEN matrix technique in a zero-waste strategy. It illustrates the trend of wastage throughout the study period. Additionally, the current results indicate the implementation of a zero-waste strategy.

MV Wasted

Waste Disposal

Waste disposal (sent to landfill) was zero from 2018 through 2020. However, it increased in 2016 and 2021 to 0.17% and 0.01%, respectively. The MV of inventory sent to landfills over 7 years amounted to SAR 2,230,562.23 out of a total of SAR 7,395,962,227.74. This represents a mere 0.03% of total expenditure or the equivalent of 3.3% of total real waste during these 7 years.

Current Waste

The cumulative current waste was SAR 15,518,063.375 out of SAR 7,395,962,227.74, representing 0.21% of the total expenditure. This is equivalent to 23% of the total real waste over the past 7 years.

Table 2 ABC, VEN and ABC-VEN Matrix Analysis of the Inventory Waste from 2015 Through 2021

	Expired Pharmaceutical		Medical Consumable		Non – Medical Consumable		% of Expenditure	*P - Value
	N (%)	Value (SAR) (%)	N (%)	Value (SAR) (%)	N (%)	Value (SAR) (%)		
ABC analysis								0.0001
A	124 (10.8)	9,937,361.458 (80)	20 (30.8)	594,264.13 (89.3)	56 (25.3)	752,995 (82.3)	0.15	
B	200 (17.3)	1,880,830.56 (15.1)	13 (20)	52,767.75 (7.9)	52 (23.5)	113,231 (12.4)	0.03	
C	829 (71.9)	598,015.69 (4.8)	32 (49.2)	18,504.93 (2.8)	131 (51.1)	48,725 (5.33)	0.01	
VEN analysis								0.0001
V	155 (13.4)	1,211,309.60 (9.8)	14 (21.5)	214,440.00 (32.2)			0.02	
E	830 (72.0)	10,260,022.05 (82.6)	34 (52.3)	319,795.00 (48.1)			0.14	
N	168 (14.6)	944,876.08 (7.6)	17 (26.2)	131,301.00 (19.7)	221 (100)	914,950 (100)	0.03	
ABC-VEN matrix								0.0001
Category I	262 (22.7)	10,260,629.55 (82.6)	29 (44.6)	616,693 (92.6)	56 (25)	752,995.4 (82)	0.16	
AV	17 (1.5)	888,041.53 (7.2)	5 (7.7)	192,128.00 (29)			0.01	
AE	95 (8.2)	8,377,743.58 (67.5)	8 (12.3)	288,724 (43.4)			0.13	
AN	12 (1)	671,576.37 (5.4)	7 (10.8)	112,848 (17)	56 (25.3)	752,995.4 (82.3)	0.02	
BV	27 (2.3)	226,799.37 (1.8)	4 (6.2)	197,19 (3)			<0.01	
CV	111 (9.6)	96,468.70 (0.8)	5 (7.7)	2,028 (0.3)			<0.01	
Category II	755 (65.5)	2,081,076.01 (16.8)	29 (44.6)	44,388.71 (6.7)	52 (23.5)	113,230.5 (12)	0.03	
BE	153 (13.2)	1,455,233.65 (11.7)	6 (9.2)	19,731 (3)			0.02	
BN	20 (1.7)	198,797.542 (1.6)	3 (4.6)	13,317 (2)	52 (23.5)	113,230.5 (12.4)	< 0.01	
CE	582 (50.5)	427,044.82 (3.4)	20 (30.8)	1134 (1.7)			0.01	
Category III	136 (11.8)	74,502.17 (0.6)	7 (10.8)	5,137 (0.8)	113 (51)	48,725.4 (5)	0.02	
CN	136 (11.8)	74,502.17 (0.6)	7 (10.8)	5,137 (0.8)	113 (51.1)	4,8725.4 (5.3)	0.02	

Notes: *Pearson Chi-squared test significant at $\alpha = 0.05$.

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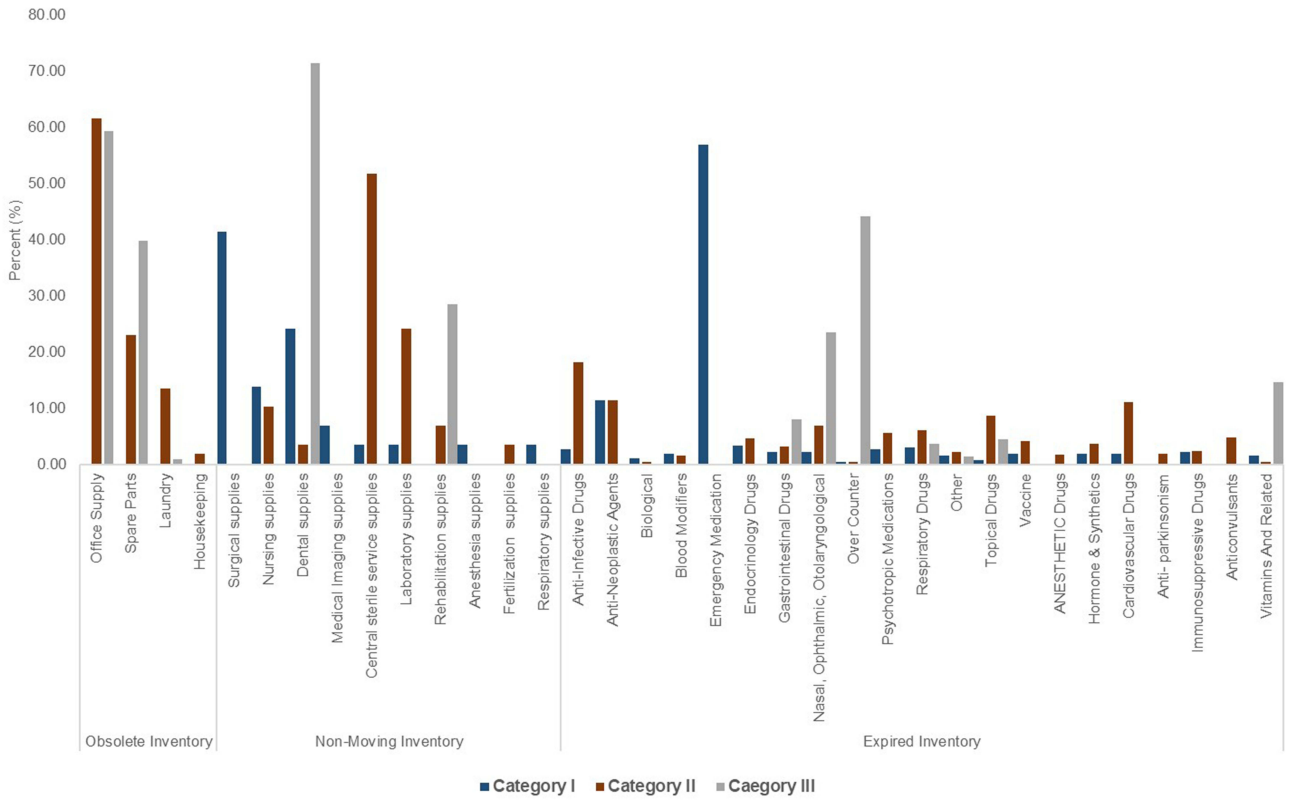

Figure 3 Generated Category I, Category II, and Category III from the ABC-VEN matrix analysis.

Real Waste

The actual wastage amounted to SAR 67,329,528.03 out of SAR 7,395,962,227.74, representing 0.91% of the total expenditure over 7 years. After implementing the zero-waste strategy, 3% of the MV of the actual waste was sent to landfill, while 23% was considered current waste. Consequently, 73.64% of the MV of the actual waste was saved.

The MV Saved

After implementing the zero-waste strategy, a total of SAR 49,580,902.425 was saved out of SAR 67,329,528.03, representing 73.64% of total real waste. The real waste declined from 0.91% to 0.21%. Figure 4 illustrates the trend of wastage compared to expenditures during the 7 years before and after the implementation of the zero-waste strategy. The current waste rate lay between 0.03% and 0.63%, while the real waste lay between 0.32% and 1.25%. Waste rates declined throughout all years overall, though the waste rate did increase in 2016 and 2021.

Employee Engagement

The average waste generated per employee each year was 0.85%, and the average monetary savings per employee each year was 2.73% (Table 3).

Discussion

In the Kingdom of Saudi Arabia, there is no data available for evaluating the rate of inventory waste in the warehouses of health facilities. This study will provide new information on the prevalence and type of wastage, the impact of implementing a zero-waste strategy, and employee engagement.

Globally, a standard rate for inventory waste does not exist. The rate of inventory waste fluctuates substantially across different countries and companies. This variation is influenced by numerous factors including geographical location, income levels, inflation rate, exchange rate, population, culture, development, and the specific type of facility.[12,21,29]

Table 3 Outcome of Zero - Waste Strategy in the Management of Inventory Waste During the Study Period

Year	2015	2016	2017	2018	2019	2020	2021	Total
Waste (SAR) (%)*								
Real waste	3,145,636.40 (0.32%)	6,362,429.53 (0.68%)	13,185,064.46 (1.22%)	10,287,193.57 (0.97%)	8,434,793.32 (0.81%)	11,300,165.73 (1.01%)	14,614,245.03 (1.25%)	67,329,528.03 (0.91%)
Current Waste	290,676.997 (0.03%)	243,536.789 (0.03%)	523,834.704 (0.05%)	1,507,186.036 (0.14%)	2,294,286.645 (0.22%)	3,317,361.822 (0.3%)	7,341,180.381 (0.63%)	15,518,063.375 (0.21%)
Waste disposal (Sent to landfill)	82,987.31 (0.01%)	1,577,802.07 (0.17%)	499,582.29 (0.05%)	0 0.00	0 0.00	0 0.00	70,190.56 (0.01%)	2,230,562.23 (0.03%)
Outcome implication of zero waste strategy**								
Monetary value Saved	(88.12%)	(71.37%)	(92.24%)	(85.35%)	(72.8%)	(70.64%)	(49.29%)	(73.64%)
Monetary value lost	(2.64%)	(24.80%)	(3.79%)	0	0	0	(0.48%)	(3.31%)
Monetary value Accumulative waste under process	9.24%	3.83%	3.97%	14.65%	27.20%	29.36%	50.23%	(23.05%)
Employee Engagement								
Waste /employee / year	0.34%	0.14%	0.15%	0.54%	1.01%	1.09%	1.86%	0.85%
Save / Employee / Year	3.26%	2.64%	3.42%	3.16%	2.70%	2.62%	1.83%	2.73%
Average turn over	2.56	2.49	2.60	2.22	2.96	2.22	2.60	

Notes: *Monetary value of wastage out of the annual expenditure at the same year, ** percentage of monetary value out of real waste during same year.

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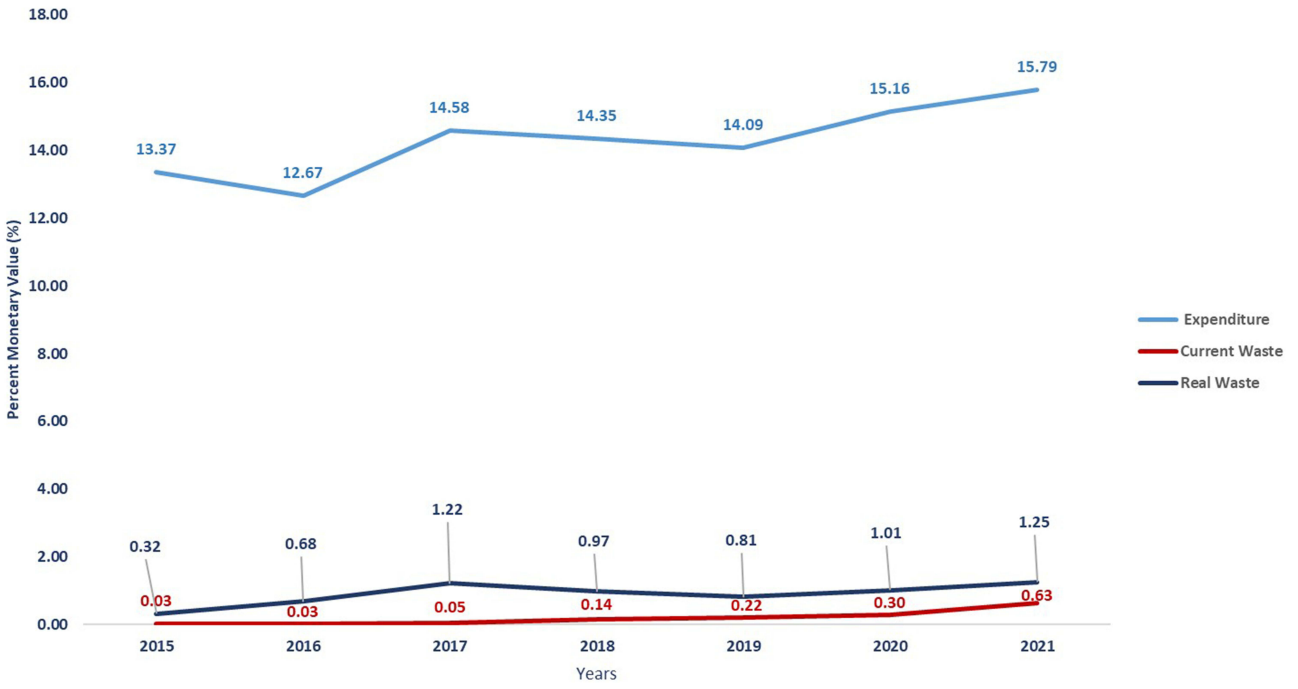

Figure 4 Trend of the current and real inventory waste compared to the expenditure during the study period (2015–2021).

Moreover, the methodology for estimating inventory wastage differs among countries. Some estimate inventory wastage based on cost (value), while others use weight (tons), making the quantification of inventory waste a challenging task.

In the current study, the overall prevalence of inventory wastage in our organization was 0.21% of the expenditure over 7 years, amounting to SAR 15,550,126.92. This prevalence of inventory waste was low, influenced by several factors such as the study's duration, the large inventory of over 5000 consumable items in the warehouses, and fluctuations in MV over time. Additionally, the Kingdom of Saudi Arabia was affected by two disease outbreaks: the Middle East Respiratory Syndrome Coronavirus (MERS-CoV) outbreak in 2015 and 2016, and COVID-19 in 2020. These health crises negatively impacted inventory movement and escalated the risk of expiry, particularly in pharmaceutical supplies. This explains the fluctuating trend of wastage observed during the study period, with an increase in 2016, 2017, and 2021 after the two pandemics.

The innovation of new pharmaceuticals, the advancement of technology, and the introduction of new systems have all increased outdated inventory. However, despite not being able to draw direct comparisons with previous studies due to differing methodologies and instruments used, the prevalance of waste in our study was lower than that of other nations. A global study conducted in 2022 involving the US, the United Kingdom (UK), France, Japan, and China found that supply chain waste stood at 4.9%, 3.7%, 3.5%, 3.5%, and 1.8% respectively.[30] Average waste was at 3.6%, translating to $163 billion in inventory, as almost 8% of the stock was discarded.[30] In another study conducted that year with 28 large pharmaceutical companies, average inventory waste was benchmarked at 4% (ranging from less than 1% to 15%), equating to a loss of $12.5 billion.[31]

In the current study, expired inventory contributed to a significantly higher waste of MV than non-moving and obsolete inventory (0.17%, 0.02%, and 0.01%, respectively). This finding is lower than the percentages of waste reported in previous studies.

Vuemed Companies reported that financial waste in a healthcare facility was estimated to constitute 5% to 10% of the total value of clinical supplies inventory at risk of expiration monthly, with 25% of the clinical supplies inventory being non-moving and 30% outdated.[29]

In developing countries, the rate of expired pharmaceutical and medical supplies has increased to 35% of the annual budget. The percentage of waste has escalated to 70% - 80% in some developing countries that receive donated

supplies.[12,27,32–35] Globally, the rate of pharmaceutical waste stands at 3% (0.5% to 9%).[22–26] In the UK, pharmaceutical loss equates to an annual loss of £300 million.[34] The rate of medical supplies waste, based on the previous study, fluctuated between 0.83% and 47%.[33] The rate of non-moving items reported in other countries was 10% by volume and 0.16% of the total annual usage value, which escalated to 25% of the inventory, at risk of non-moving in some countries.[36,37]

In the current study, the "ABC" technique was utilized to identify the most expensive inventory. It was found that the pharmaceutical inventory had the highest cost, with 10% of expired pharmaceuticals equating to 63% of the total MV wasted. The anti-neoplastic medication had the significantly highest MV wasted, representing 23% of the total monetary loss. The "VEN" technique was also used to assess critical aspects of the inventory. Dermatology medication, ophthalmic, and otolaryngological substances, as well as vitamins and related items, accounted for 6%of the MV lost and 17% of the total number of wasted pharmaceutical items, requiring more storage space.

The combination of the ABC-VEN matrix helps to identify the cost and clinical impact of wasted inventory. The waste with the highest MV was a low number of pharmaceutical inventory that had a high clinical impact.

Pharmaceutical items had a significantly higher clinical impact than other inventory, such as anti-neoplastic, emergency medication, endocrinology, and anti-infective drugs. Pharmaceuticals with high clinical and cost impacts represented 18% of total inventory and accounted for 66% of wasted MV. On the other hand, pharmaceutical items with low clinical and cost impacts represented only 9% of total inventory and accounted for a mere 0.48% of wasted MV. The wasting of essential and vital pharmaceutical items is consistent with a previous study.[38]

The availability of various types and dosage forms of therapeutic categories in our pharmaceutical inventory, especially those with high clinical impact, aligns with our organization's mission and objective to provide free health services to patients. This may explain the increased waste of pharmaceutical items.

The surgical supplies were the most wasted out of all the medical supplies, a trend consistent with waste trends in the USA. The unused surgical supplies weighed approximately two million pounds, with a value estimated at least $15 million over a single year.[39,40]

Our study found that utilizing the ABC-VEN matrix in a Zero-Waste Strategy effectively reduced the prevalence of wastage from 0.91% to 0.21%. Furthermore, zero-waste was sent to the landfill from 2018 through 2020. Although waste sent to the landfill increased to 0.17% in 2016, and to 0,01% in 2021, following two years of the COVID pandemic, these rates of waste were less than those observed in a previous study conducted in other countries. That study, which also utilized the zero-waste strategy, reported waste rates ranging between 1% and 40%.[21]

The zero-waste strategy successfully saved 73% of the value that was expected to be wasted. The use of the ABC-VEN matrix in the Zero-Waste Strategy positively impacted sustainability due to the matrix's focus on high-cost items with critical aspects. Our current Zero-Waste Strategy aligns with the Saudi Vision 2030.

In the current study, health inventory management is done proactively to prevent wastage. Employees played a vital role in achieving the zero-to-landfill objective, saving approximately 73% in MV. The range of waste per employee per year is consistent with a previous study.[21]

This research will assist decision-makers in implementing a new system aimed at improving the health supply chain and minimizing inventory waste using the ABC-VEN Matrix.

Limitations

This study has several limitations. First, the study was conducted in a single setting, specifically the Central Region of the MNG-HA. As a result, the findings may not be generalized to other healthcare facilities. Secondly, this was a retrospective study which could potentially lead to overestimations of the actual waste and MV of non-moving and expired inventory. Non-moving inventory that had accumulated was reclassified as expired, and recalled inventory was deemed non-moving.

Conclusion

The use of the ABC-VEN matrix had a positive impact in reducing waste and saving MV. The prevalence and trend rate of inventory waste in our study were lower than the global company benchmarks, saving more than two-thirds of wasted inventory value. The majority of monetary waste resulted from a low number of pharmaceutical items with high clinical

impact. These findings support the use of the ABC-VEN matrix as helpful in managing inventory and minimizing financial waste. Large-scale prospective studies are recommended to provide more accurate determinations of the quantity of wasted supplies in Saudi Arabia.

Ethical Issues

This study was approved by the IRB at King Abdullah International Medical Research Center (KAIMRC), King Saud Bin-Abdulaziz University for Health Sciences, Riyadh, Saudi Arabia (NRC22R/ 530 /11). This study followed the recommendations of the International Conference on Harmonization for Good Clinical Practice (ICH-GCP) and in compliance with the Declaration of Helsinki. Data confidentiality and privacy of information were secured by the principal investigator.

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Disclosure

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

References

1. World Health Organization. *The World Medicines Situation*. 2nd. World Health Organization. 2004. https://apps.who.int/iris/handle/10665/68735.
2. Cameron A, Ewen M, Ross-Degnan D, Ball D, Laing R. Medicine prices, availability, and affordability in 36 developing and middle-income countries: a secondary analysis. *Lancet*. 2009;373(9659):240–249. doi:10.1016/S0140-6736(08)61762-6
3. Papanicolas I, Woskie LR, Jha AK. Health care spending in the United States and other high-income countries. *JAMA*. 2018;319(10):1024–1039. doi:10.1001/jama.2018.1150
4. de Assis AG, Dos Santos AFA, Dos Santos LA, da Costa JF, Cabral MAL, de Souza RP. Classification of medicines and materials in hospital inventory management: a multi-criteria analysis. *BMC Med Inf Decis Making*. 2022;22(1):325. doi:10.1186/s12911-022-02069-0
5. World Health Organization. Global Health Expenditure Database. Geneva: World Health Organization. Available from https://apps.who.int/nha/database. Accessed Oct 21, 2024.
6. Saudi Arabia Ministry of Health. (2024). Ministry budget. Available from https://www.moh.gov.sa/en/Ministry/About/Pages/Budget.aspx. Accessed Oct 21, 2024.
7. GOV.SA National Platform. (2024). Budget: KSA's national source for government services and information. Available from https://www.my.gov.sa/wps/portal/snp/aboutksa/governmentBudget/. Accessed Oct 21, 2024.
8. Kochan CG, Nowicki DR, Sauser B, Randall WS. Impact of cloud-based information sharing on hospital supply chain performance: a system dynamics framework. *Int J Prod Econ*. 2018;195:168–185. doi:10.1016/j.ijpe.2017.10.008
9. Ganeshan R. Managing supply chain inventories: a multiple retailer, one warehouse, multiple supplier model. *Int J Prod Econ*. 1999;59(1–-3):341–354. doi:10.1016/S0925-5273(98)00115-7
10. Negi LS, Kharde Y. Identifying the root causes for inventory accumulation and prioritizing them using an MCDM-based TOPSIS approach. *Modern Supply Chain Res Appl*. 2021;3(2):145–154. doi:10.1108/MSCRA-11-2020-0031
11. Peltoniemi T, Suomi R. Eliminating medicine waste in a Finnish university hospital—a qualitative study. *J Pharmaceutical Pol Pract*. 2019;12(1):1–7. doi:10.1186/s40545-019-0188-8
12. Smale EM, Egberts TC, Heerdink ER, van den Bemt BJ, Bekker CL. Waste-minimizing measures to achieve sustainable supply and use of medication. *Sustainable Chem Pharm*. 2021;20:100400. doi:10.1016/j.scp.2021.100400
13. West LM. Medication wastage: the current situation. *J Malta College Pharm Pract*. 2015;21:25–28.
14. Chartier Y, Ed.. *Safe Management of Wastes from Health-Care Activities*. World Health Organization; 2014.
15. Reed T. *U.S. Hospitals Wasting About $25.4B on Supply Chain Every Year*. Fierce Healthcare; 2018.
16. Polaris Market Research. (2022). Waste Management Market Share, Size, Trends, Industry Analysis Report, by Type (Municipal Waste, Industrial Waste); by Services; by End-User; by Region; Segment Forecast, 2022 to 2030. https://www.polarismarketresearch.com/industry-analysis/waste-management.
17. Radwan N, Khan NA, Elmanfaloty RAG. Optimization of solid waste collection using RSM approach, and strategies delivering sustainable development goals (SDG's) in Jeddah, Saudi Arabia. *Sci Rep*. 2021;11(1):16612. doi:10.1038/s41598-021-96210-0
18. Eberle J, Allain L, Nersesian P. *Logistics of Health Care Waste Management: Information and Approaches for Developing Country Settings*. Arlington, VA: USAID; 2009.
19. Hinrichs-Krapels S, Ditewig B, Boulding H, Chalkidou A, Erskine J, Shokraneh F. Purchasing high-cost medical devices and equipment in hospitals: a systematic review. *BMJ Open*. 2022;12(9):e057516. doi:10.1136/bmjopen-2021-057516

20. Sinclair KM. *International Waste Strategy Benchmarking*. NSW Environment Protection Authority; 2012.
21. Veleva V, Bodkin G, Todorova S. The need for better measurement and employee engagement to advance a circular economy: lessons from Biogen's "zero waste" journey. *J Cleaner Prod*. 2017;154:517–529. doi:10.1016/j.jclepro.2017.03.177
22. Zaman AU. A strategic framework for working toward zero waste societies based on perceptions surveys. *Recycling*. 2017;2(1):1. doi:10.3390/recycling2010001
23. National Center for Waste Management. (MWAN). (2024). https://mwan.gov.sa/en/strategic-plan. Accessed Oct 21, 2024.
24. Nigah R, Devnani M, Gupta AK. ABC and VED analysis of the pharmacy store of a tertiary care teaching, research and referral healthcare institute of India. *J Young Pharm*. 2010;2(2):201–205. doi:10.4103/0975-1483.63170
25. Deressa MB, Beressa TB, Jemal A. Analysis of pharmaceuticals inventory management using ABC-VEN matrix analysis in selected health facilities of West Shewa Zone, Oromia Regional State, Ethiopia. *Integrat Pharm Res Pract*. 2022;11:47–59. doi:10.2147/IPRP.S354810
26. Nguyen PH, Dang TVK, Nguyen PT, Vo TMH, Nguyen TTM. 5-year inventory management of drug products using ABC-VEN analysis in the pharmacy store of a specialized public hospital in Vietnam. *Pharmacia*. 2022;69(2):517–525. doi:10.3897/pharmacia.69.e84348
27. Mohammed SA, Workneh BD. Critical analysis of pharmaceuticals inventory management using the ABC-VEN matrix in Dessie Referral Hospital, Ethiopia. *Integrat Pharm Res Pract*. 2020;9:113–125. doi:10.2147/IPRP.S265438
28. Jobira T, Abuye H, Jemal A, Gudeta T. Evaluation of pharmaceuticals inventory management in selected health facilities of West Arsi Zone, Oromia, Ethiopia. *Integrat Pharm Res Pract*. 2021;10:1–11. doi:10.2147/IPRP.S298660
29. VUEMED. (2019). Waste not, want not: how hospital inventory management prevents waste. Available from: https://vuemed.com/hospital-inventory-management-prevents-waste. Accessed Oct 21, 2024.
30. Avery Dennison Corporation. *The Missing Billions: The Real Cost of Supply Chain Waste*. Avery Dennison Corporation. 2022.
31. nVentic. *Big Pharma Inventory Trends Benchmarking Report 2023*. 2023.
32. Tull K. Drug expiry standards in developing countries. *Inst Develop Stud*. 2018;2018:1–18.
33. Perry L, Malkin R. Effectiveness of medical equipment donations to improve health systems: how much medical equipment is broken in the developing world? *Med Biol Eng Comput*. 2011;49(7):719–722. doi:10.1007/s11517-011-0786-3
34. Trueman P, Taylor DG, Lowson K, et al. (2010). Evaluation of the scale, causes and costs of waste medicines. Report of DH funded national project.
35. Diaconu K, Chen YF, Cummins C, Jimenez Moyao G, Manaseki-Holland S, Lilford R. Methods for medical device and equipment procurement and prioritization within low-and middle-income countries: findings of a systematic literature review. *Glob Health*. 2017;13(1):1–16. doi:10.1186/s12992-017-0280-2
36. Kumar A, Shukla AC. Selective inventory control using ABC and FSN analysis in retail sector: a case study. *Int J Res Appl Sci Eng Technol*. 2022;10(5):2020. doi:10.22214/ijraset.2022.43648
37. Finale Inventory. Chapter 2: fast, slow, and non-moving (FSN) method. https://www.finaleinventory.com/online-guides/essential-inventory-management-techniques/fast-slow-and-non-moving-fsn-method. Accessed Oct 21, 2024.
38. Sauls C (2016). Trend in revenue loss due to expired medication at a large urban hospital in Johannesburg, South Africa. Master's thesis. University of the Witwatersrand.
39. Wan EL, Xie L, Barrett M, et al. Global public health impact of recovered supplies from operating rooms: a critical analysis with national implications. *World J Surg*. 2015;39(9):9–35. doi:10.1007/s00268-014-2834-2
40. Rigante L, Moudrous W, de Vries J, Grotenhuis AJ, Boogaarts HD. Operating room waste: disposable supply utilization in neurointerventional procedures. *Acta Neurochirurgica*. 2017;159(12):2337–2340. doi:10.1007/s00701-017-3366-y