AIUB Journal of Business and Economics [AJBE]

Volume 20, Issue 1, July 2023 Pages 15-29

Research Article

ISSN: 1683-8742 (PRINT) 2706-7076 (ONLINE) Homepage: https://ajbe.aiub.edu

Integration of Recycling into Supply Chain: A Cost-Effective Doorway to Ecologically Sound Business– An Empirical Study on the Pharmaceutical Industries of Bangladesh

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Abstract

Purpose of the study: The objective of the study is to analyze the feasibility of recycling pharmaceutical blister packs, a certain type of medical waste in order to reduce cost of production which in turn justify its commercial merit for environmental up-gradation.

Methodology: The study uses quantitative surveys based on in-person and telephonic interviews with 300 respondents equally divided into three categories e.g., general customers of medicines, employees of Dhaka City Corporation (South) and engineers of different pharmaceuticals companies. Questionnaires with both close and open-ended questions were used. Results were analyzed using simple frequency distribution method.

Findings: The results derived from the interview of engineers working at different pharmaceutical companies indicate that relying on cost data for both imported and recycled thermoplastics, recycling of blister packs for tablets/capsules will lessen cost of production of blister packs.

Implications: Recycling is critical for environmental sustainability. However, the recycling process has to be lucrative in case it is to be adopted commercially. This paper analyzes the feasibility of recycling pharmaceutical waste to reduce cost of production which in turn offers long run environmental implications.

Limitations and Future direction: In terms of limitations, many types and grades of PVC sheets are used to produce blister packs in reality; production of such variety after recycling may not be possible. In this connection, professional plastic recyclers could be consulted in future studies. And, the recycling process runs the risk of workers being affected by contamination of diseases. So, engineers' assistance should be sought for safe and sound design of the recycling process. Lastly, resource constraints impeded getting deeper into the study. A detailed study collecting and analyzing real life statistical data will provide more precise information about the costing of imported as well as recycled thermoplastics and will decisively prove or disprove the hypothesis in the context of Bangladesh.

Article History:
Received: 28 December 2022
Accepted: 25 June 2023
Online: 31 July 2023

Keywords:
Environmental Sustainability, Recycling, Supply Chain, Medical Waste, Cost Reduction, Blister Packs, Bangladesh

1.1 Introduction

In the ever-changing business arena, newer concepts and better business models are introduced incessantly. For the past couple of years, Supply Chain (SC) and its management systems have been the top-talk of the business field owing to its gravity in light of its functions. Even though SC had existed prior to the usage of this specific term, of course, it was not even close to as organized and integrated as it has become now. At this point of the 21st century, it is being pondered upon as to how SC can provide even more benefits to organizations. Here, it is worth mentioning that currently, when societal effects of businesses can no longer be ignored, the profitability alone are not regarded as an efficient measure, rather, the whole impact of a certain business operation on the society and surrounding environment is to be calculated and consequently, social-cost benefit analysis is often being stressed while seeking for loans or even for getting approval of new business projects. In line with current perspectives, Rakhimova (2022) emphasizes encouraging businesses to strive to make the most of their profits by offering harmless productions to save the planet. In this philosophical shift from making profit to putting green operations in the first place, SC has a serious role to play since it is inseparable from business operations.

According to Oxford English Dictionary (2022), Recycling refers to the process(es) or action(s) taken to convert waste into reusable materials. Not a few scientific studies have found out that recycling offers several benefits to environmental up-gradation. Lately, Lamma (2021) commented that recycling is the most effective method to secure earth's environment. By simply reusing the material instead of discarding them, the number of waste materials can be reduced and it can conserve future natural resources. In order to implement this concept, it is imperative that businesses worldwide realize the practicality of recycling and manage their operations accordingly while making profits. To illustrate, integrating recycling to SCs of different businesses promises a brighter scenario altogether. It has the potential of recycling used products and put those back into the factory for further production which may result in cost reduction, environmental benefits, and more employment possibilities- a few paybacks to mention.

Pharmaceutical industries in Bangladesh is one of the most important in terms of exported goods beside RMG, Processed Shrimps, Packaged Tea, etc. As a result of Drug Control Ordinance (1982) this sector has experienced a big leap in the volume of production and quality of product. The industry size was 265.95 Billion in 2022 as calculated by Manik, Sakib, and Ali (2023). Medical waste is among the most notorious ones that pollute the environment heavily. Due to the importance of pharmaceutical industry in the national economy and its contribution to waste production, this sector has been chosen for the empirical study to determine whether recycling will be rewarding enough here to prompt some real initiatives for recycling which will in turn bring about environmental benefits.

Apart from global literatures, several studies in the local level have been made in this respect to understand the Medical Waste Management (MWM) scenario. Later on Syed, Mutahara, and Rahman (2012) found that medical waste management and practices were much unsafe in Dhaka. Almost after a decade, Barua and Hossain (2021) found that although there have been some newly formulated guidelines for MWM after the COVID-19 pandemic, there are inconsistencies among those. A year forward, Rahman, Talukder, and Karim (2022) observed that improper waste collection, storage, transportation, and disposal practices still lead to various health hazards and environmental risks. If collecting and recycling medical wastes is introduced, this scenario can change rapidly and provide a greener and safer environment. Therefore, integrating recycling in the supply chain has valuable advantages to offer. It is likely to benefit diverse industries in several ways. In this article, however, only the implications of this concept in the pharmaceuticals industry will be taken into account.

1.2 Objectives of the study

The objective of the study is to analyze the feasibility of recycling pharmaceutical blister packs, a certain type of medical waste in order to reduce cost of production which in turn justify its commercial merit for environmental up-gradation.

1.3 Research Methodology

1.3.1 Research Structure

This study falls in the 'Applied Research' category with a view to exploring the possibilities of recycling in the pharmaceuticals industry. In order to gather information authors have used data obtained from both primary and secondary sources. Secondary data were collected from relevant websites, published books, research reports, journals and articles, etc. Besides, primary data were collected from 300 respondents of three categories e.g., general customers of medicines, cleaners and officials of Dhaka City Corporation (South) and engineers of different pharmaceutical companies (100 people are interviewed from each category). The customers of medicines represent the consumers and their interests. The cleaners of Dhaka City Corporation (South) represent the category who professionally collect the waste materials especially from the hospitals in that area. Along with that, officials of Dhaka City Corporation (South) were interviewed to understand the feasibility of recycling medical waste and its cost. And, the engineers working at pharmaceutical companies are the skilled personnel who have the knowledge and experience to comment on introducing recycled plastic materials in the manufacturing process. These people are selected using non-probability and convenience sampling method. Data were collected through direct interviewing, face-to-face communication. Questionnaires with both close and open-ended questions were used and written responses were gathered. To analyze the results, frequency distribution is used as a tool. It is assumed that the more the frequency, the more the weight. Simple percentage is used to indicate frequency.

1.3.2 Hypothesis

H^0: The *Null Hypothesis* for this study is; *recycling process will not decrease the cost and/ or increase cost of production of a single blister pack of tablets/capsules in the original operation*. This proposal would be considered feasible if the Alternative Hypothesis is proved to be true.

1.3.3 Level of Significance

The null hypothesis will be considered true if the majority of the respondents - only those working at pharmaceutical industries, (greater than 50% out of the 100 respondents surveyed) concur that recycling of pharmaceutical waste (here, only tablet/capsule blisters) will not reduce cost and/or not feasible for some other reasons, and in that case, alternative hypothesis will deem false. However, if the frequency distribution is such that greater than 50% of these types of respondents think that recycling of pharmaceutical waste will be profitable, then, the alternative hypothesis will be eligible for future field studies designed to derive cost data followed by statistical tests to either prove or not.

1.4 Limitations of the study

In terms of limitations, many types and grades of PVC sheets are used to produce blister packs in reality; production of such variety after recycling may not be possible. In this connection, professional plastic recyclers could be consulted. And, the recycling process runs the risk of workers being affected by contamination of diseases. So, engineers' assistance should be sought for safe and sound design of the recycling process. Lastly, resource constraints impeded getting deeper into the study. A detailed study collecting and analyzing real life statistical data will provide more precise information about the costing of imported as well as recycled thermoplastics and will decisively prove or disprove the hypothesis in the context of Bangladesh.

2.0 Literature Review

Supply Chain Management (SCM) is defined as – 'the program that integrates different issues from manufacturing operations, purchasing, transportation, and physical distribution into a unified program. An effective supply chain management, then, coordinates all of these activities into a

seamless process' (Zigiaris, 2000). After 4 years, Villarreal, González, Madero, and Prieto (2004) said that continuous improvement of supply chain has become an essential stratagem for companies to accomplish the vital enactment level to strive wide-reaching. Not long after, Henriksson and Nyberg (2005) concluded in this way- 'the companies can find a source of competitive advantage in supply chain management. Therefore, the fast-growth of a company could be at least partly explained by the utilization of supply chain practices.'

Although many years after the inception, according to Storey, Emberson, Godsell, and Harrison (2006), 'supply management is, at best, still emergent in terms of both theory and practice. Few practitioners were able– or even seriously aspired– to outspread their reach across the supply chain in the manner recommended in much modern theory.' The concept of recycling in SC is found when Pagell, Wu, and Murthy (2007) asserted 'until recently, end-of-life (EOL) a small number of firms that could progress in business and make money out of recycling and/ or remanufacturing. Now, shifting customer expectations and stringent product take-back conventions are imposing many goods manufacturing organizations to confront EOL product management, even in cases in which there is no clear economic incentive for doing so.'

Almost in the same way, Wong (2010) added 'recycling of different things such as metal, paper, wood, glass, and plastic is usually considered as an eco-friendly practice because it hoards energy, lessens raw material abstraction and fights climate change.' In respect to recycling in Pharmaceuticals, Whewell (2016) commented that to ensure a healthy environment, it must meet the community need following a vision, which is required both now and into the future. This vision will set the circumstances and outline within which business organizations can grow and delineate their services.' Rossetti, Handfield, and Dooley (2011) discovered that there is a radical shift in the edifice of the biopharmaceutical supply chain. They suggested that the future research regarding biopharmaceutical supply chain practices should give emphasis on the need to discover three main concerns: how will supply chain participant reward inspire the control of parties within the network? How will the role of supply chain mediators change the scenery of medication transfer to the end users? What effect will the role of supervisory restraints on product purebred and propagation have on this system?

Lu (2011) argued that 'over the last three decades, the notion and philosophy of business management have experienced insightful changes and improvement. Many longstanding customs of doing business have been dared and several innovative ideas and methodologies have been generated, among them are trade practice re-engineering, strategic management, lean thinking, responsive manufacturing, balanced scorecard, blue ocean strategy… just to name a few. Supply chain management is undeniably one of those new and well grown management methods appeared and rapidly developed across all industries around the world.' Salazar (2012) said, 'one of the most noteworthy changes in the paradigm of modern business management is that distinct businesses no longer able to compete as solely independent entities, but rather as supply chains. In this incipient competitive environment, the eventual triumph of the business will depend on management's ability to incorporate the firm's sophisticated network of business affiliations. Effective supply chain management (SCM) has become a theoretically treasured way of fortifying competitive benefit and enlightening managerial performance since competition is no longer exist between organizations, but among supply chains.' Scheinberg (2012) said, 'in 2000-2012, the global informal recycling sector came into focus as the base of the industrial value chain improved. Research and activism in this sector have evolved from persecution of waste pickers to a global discourse absorbed on attaining effective recycling by identifying, strengthening, and assimilating informal valorizes into city waste systems. With few exceptions, present reports and articles have examined the events, condition, and position of the informal enterprises and individuals, but have paid too little consideration to the situation: the waste management methods in the municipalities in which informal recyclers work.'

Gupte and Saptarshi (2012) also agreed with our view stating that 'supply chain management has become indispensable element of business management tactic. The technique may be applied to gathering, segregating, processing and removal of organic waste in a metropolitan.' Bravo and De Carvalho (2013) stated that 'a major paradigm change is happening in the pharmaceutical industry and an upsurge of yields and recalls has been seen; while this industry in known for the constant exploration for quality and governing acquiescence.' Therefore, from these considerations, it is

seeming that many playwrights agree when it comes to the competitive advantage crafting competences of supply chain of an organization and recycling itself can and now is truly regarded as a key to create diversity no matter whether the organization is in manufacturing industry or in the service selling.

3.Conceptualization of the terms

3.1 Supply Chain

Supply Chain (SC) refers to an integrated network of several businesses performing all the necessary processes to bring any product or service from the supplier to the end user. More precisely, it is regarded as the 'supply network' or, 'supply web.' To the very core, SC integrates the *Value Chains* of various organizations. In the opinion of the International Supply Chain Education Alliance (ISCEA), 'supply chain means all processes and activities to provide a product or service to a final customer. It has typically some stages which are customers, retailers, distributors, manufactures, and suppliers.'

SC is an integrated system that includes different organization, processes, information, and all other activities to produce any product/service and deliver it to the consumer. The activities of SC start form extraction process by which raw materials are made. Then, the materials are supplied to the manufacturer for production. Produced goods are then sent to distributors who re-send products to the retailers and from this point, customers get the products to use. Most of the supply chain related researches refer to the manufacturing industry related concern but, actually, applications of SC also hold good to the service industry as well. A typical supply chain model looks like this:

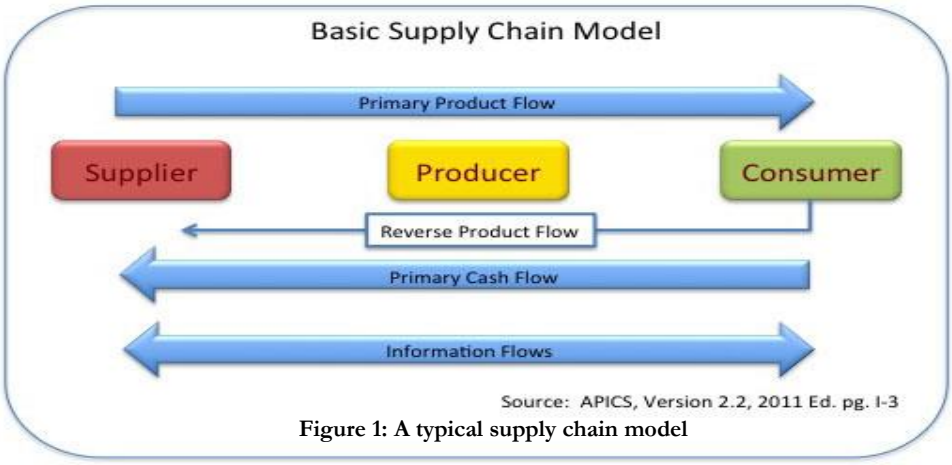

Figure 1: A typical supply chain model

It is to mention that supply chain is nothing new in the business arena. From the very inception of business, there has been supply chains mainly due to the inability of a single organization to do the whole process of extracting and handling raw materials, manufacturing products and selling those to the customers. Therefore, the supply chain is a must. Even from the Map of the 'Peryplus of the Erythrarean Sea' (1st Century CE) it is seen that global supply chains were prevalent at that time. What is new in the concept is the integration part which allows the channel parties, for instance, sellers, mediators, third-party service providers and consumers to collaborate and cooperate for better goods and services.

3.2 Recycling

Recycling is a prevalent concept in today's world. In simple terms, it means reprocessing of used materials into new products. The reason behind this reprocessing is reducing the amount of raw materials that is needed to produce entirely new goods. If some of the raw materials come from old/ used products, it saves the use of new raw materials to a good degree. In the firmest sense, recycling of a material mainly produces a fresh supply of the same material—for example; used office paper is converted into new office paper, or used plastics into new plastics. Recyclable materials comprise several kinds of glass, paper, metal, plastic, tires, textiles and electronics, asphalt, etc. Recycling helps prevent useful material assets from being fully wasted, decreases the consumption of raw materials and lessens energy usage, and hence greenhouse gas emissions, compared to virgin production. Therefore, it is a great way of controlling air, water and land pollution.

3.3 Integration

Integration, as a word, denotes the merger or amalgamation of two or more processes into a single unified one. When integration takes place, these processes are combined to produce a greater result than any of the original processes can produce on their own. In this study, recycling is proposed to be integrated with the supply chain of blister packs so that the recycled material can be used again and again resulting in lower usage of fresh raw materials and lower cost.

3.4 Cost-effective doorway

Cost effectiveness refers to the economy or savings of money while doing any particular job. It can also be defined as the relationship between monetary inputs and the desired outcome, such as between the expenditure on a project and increase in generated revenue. In case of this study, "cost effectiveness" is primarily used to describe the result of recycling which ensures savings in terms of monetary units.

3.5 Ecologically sound business

An ecologically sound business is somewhat different from a traditional business unit in the way that the former exhibits more sensitivity regarding issues concerning environmental factors. Simply put, a business can be called ecologically sound if it strives to lessen the deterioration of the environment caused by its normal business operation. In this study, any pharmaceutical industry which follow the recommended recycling process shown here will use up less resources or raw materials to produce new goods as a portion of the new goods (blister packs, in this case) will be produced from plastics taken from old, used blister packs and hence it will have a threefold environmental effect caused by the business. Firstly, the production process will use less fresh raw material; consequently the manufacturing cost will shrink. By the way, there will be less wastage come out in the environment which will help to keep it clean. Besides, the carbon footprint to manufacture new products will also drop down. Since these impacts will lead to a better environment to all, businesses using the prescribed method in this study can be safely termed as 'ecologically sound.'

3.6 Blister Packaging: The packaging system of leaves of tablets/ capsules

Blister pack refers to a kind of preformed plastic pack which is used, inter alia, for several types of pharmaceutical products, food, and comparably small-sized consumer goods, viz., toys, pens, etc. In the process of making blister packs, cavity is made on a special type of plastic foil made from thermoplastic. This foil is often called formable web in many instances. The tablets are put into the preformed pocket (cavity) and the back side of the foil is closed using lids made from either aluminum foil, or plastic. Pharmaceutical blisters are often made keeping unit-dose packaging in mind so that the consumer can easily identify the doses. PTP or Push-Through-Pack is a quite common name in many parts for blister packs as the former describes two of the main features of the pack. Firstly, the lid at the back must be brittle enough so that it becomes torn by the pressure of the tablet while it is being pushed from the top of the cavity and the cavity has to be semi-rigid and flexible to allow force push the tablet within from outside of cavity. As a result, the tablets/ capsules come out tearing the lid.

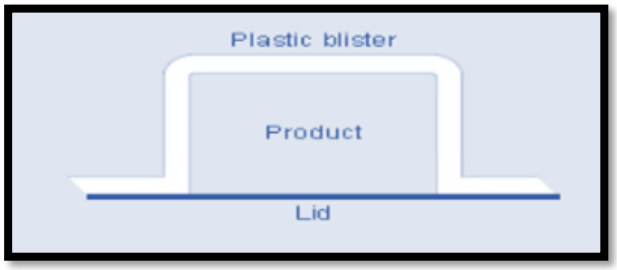

Figure 2: The basic configuration of Blister Packaging; Source: (Pilchik, 2000)

Pharmaceutical blister packs have four basic components, namely,

i. The forming film made from thermoplastic materials;
ii. The lidding material at the back of the forming film;
iii. The heat-seal coating, and
iv. The printing ink.

It is easily understandable that the forming film holds the tablets/ capsules within while the lid is used to close the opening of the cavity. On the top of the film, the heat-seal coating is used to provide protection to the medications and the ink is used to print the name of the manufacturing pharmaceutical company, expiry date etc.

4.0 Pharmaceuticals Sector in Bangladesh

After the war of liberation in 1971, Bangladesh achieved independence in 16th December of the year. Industrial infrastructure at that time was too poor to even expect any sort of industrialization; even though the scenario gradually improved. Yet, it was not before 1982 when the pharmaceuticals industry actually experienced a rapid boom. That growth was generated by the declaration of Drug Control Ordinance in that year which controls imports of raw materials for drugs or imports of drug itself without earlier approval of the authority.

The Daily Prothom Alo (September 30, 2014), a reputed national daily newspaper, reported that internal market of drugs is of 12 thousand crore BDT. Abdul Muktadir, Managing Director of Incepta Pharmaceuticals said that given the political scenario of the country is stable, the market can go beyond 13 thousand crore BDT with the growth rate of up to 15%. Bangladesh exported dugs of 466 and 506 crore BDT in 2012 and '13 respectively, he said. And the possible of upcoming drug export is even greater in term of the economic value, if the whole sale is concerned the picture is rosier. In 2007, pharmaceuticals sale was worth 4000 crore BDT. In 2010, it is nearly doubled and in 2011 it reached over 9000 crore BDT. Along with that at least one-hundred thousand people are explicitly dependent of this industry for their livelihoods whereas, when considering the overall picture, more than 15-hundred thousand people in the country are either explicitly or implicitly related to this industry.

Financial Express (January 2013) reported; there are 245 registered pharmaceuticals companies in the country. The local manufacturers cater to almost 97% of the demand within the country. This industry is now successfully exporting Active Pharmaceuticals Ingredients (APIs) to 83 countries worldwide. Apart from general products like tablets, syrups, capsules, etc., this industry is also exporting highly specialized products, such as, HFA inhalers, CFC inhalers, Suppositories, Nasal Sprays, Injectable, IV Infusions, etc. Along with already existing 83 countries, this industry wants to add another 37 countries in the list of countries where it exports medicine.

Most of the analyses on this industry say that the future of pharmaceuticals industry is bright provided the current momentum of growth is kept. Because of new rules regarding patent and abstraction of import barrier of drugs in many countries, especially the less developed ones, the prospective of this industry has never been better.

4.1 Necessity of integrating recycling of the raw materials (thermoplastics) of blister packs into Supply Chains of pharmaceuticals companies

The necessities of integrating recycling into supply chains of companies are imperative. The major benefits are manifold which are as follows:

i. This may result in cost reduction in the production process as the raw materials will be recycled.
ii. Generally, the raw materials for making leaves of tablets (thermoplastics) are imported and recycling and remanufacturing this material will reduce foreign currency expenditure and hence the foreign currency reserve will increase.
iii. Because of recycling, the whole process will become more environmentally friendly.
iv. Likely to generate more employment facilities.

v. Waste disposal is generally unscientific and unplanned in cities like Dhaka where the growth of population is exponential. Scattered waste disposal can cause health-related problems in these areas. This proposed system will reduce this risk to a great degree.
vi. The proposal calls for a well-designed waste disposal system that will facilitate recycling of many other types of wastes, like, plastic bags, iron/ steel made products, etc.
vii. If and when implemented, this system will facilitate other recycling program to be initiated easily resulting in overall betterment of the environment.

Therefore, considering these perceived advantages of the proposal, it should be given importance.

4.2 How to recycle the raw materials (thermoplastics) of blister packs

Following two figures show the currently practiced and our proposed ways to recycle the raw materials (thermoplastics) of blister packs-

4.2.1 The established supply chain of blister packs in Bangladesh

In general, the supply chain of blister packs and medicines looks like the figure given below-

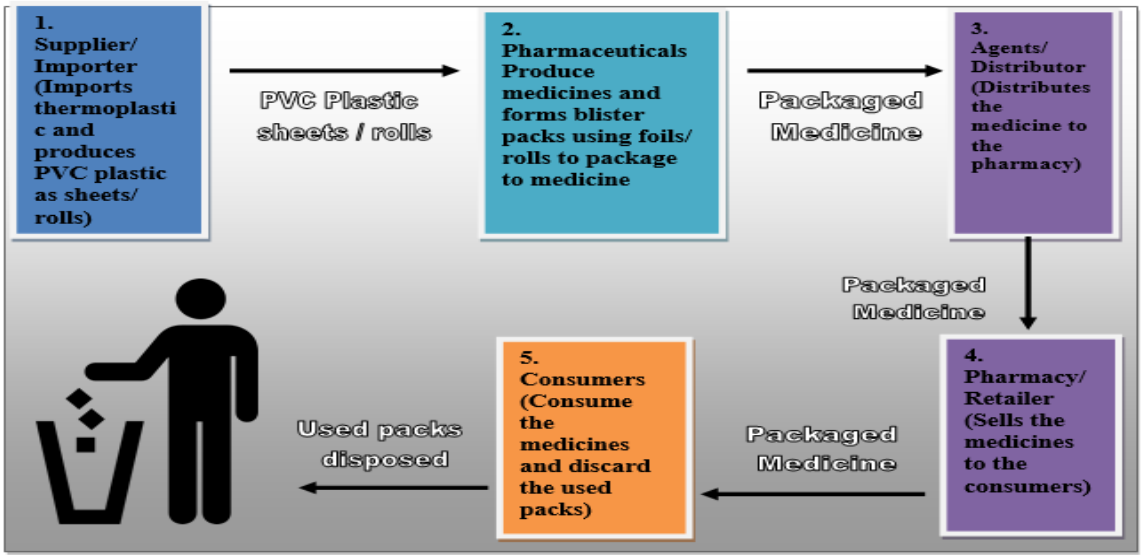

Figure 3: Supply Chain of PVC plastic sheets/ rolls and medicine
Source: Compiled by authors

This diagram works in the following manner-

i. PVC plastic sheets/ rolls are supplied to pharmaceuticals from the supplier.
ii. Pharmaceutical companies use the material for packaging tablets/ capsules.
iii. Then the packaged medicines are sent to the Agents or Distributors or Dealers of the company.
iv. The packaged medicines are circulated to the customer.
v. After using the medicines, customers dispose of the used packs.

4.2.3 Proposed recycling process

Authors of the study proposes the utilization of City Corporations to integrate the recycling process into the supply chain of pharmaceuticals companies. In Bangladesh, there are a number of city corporations including Dhaka North and Dhaka South, Chittagong, Khulna, Rajshahi, Sylhet, Barishal, Rangpur, Gazipur, Narayangonj, and Cumilla. Other major cities, like, Mymensingh, Jashore, Bogra, Dinajpur, Gopalganj, etc. are headed by an elected mayor.

The process of integration is much simple. A flow-diagram below will illustrate this easily.

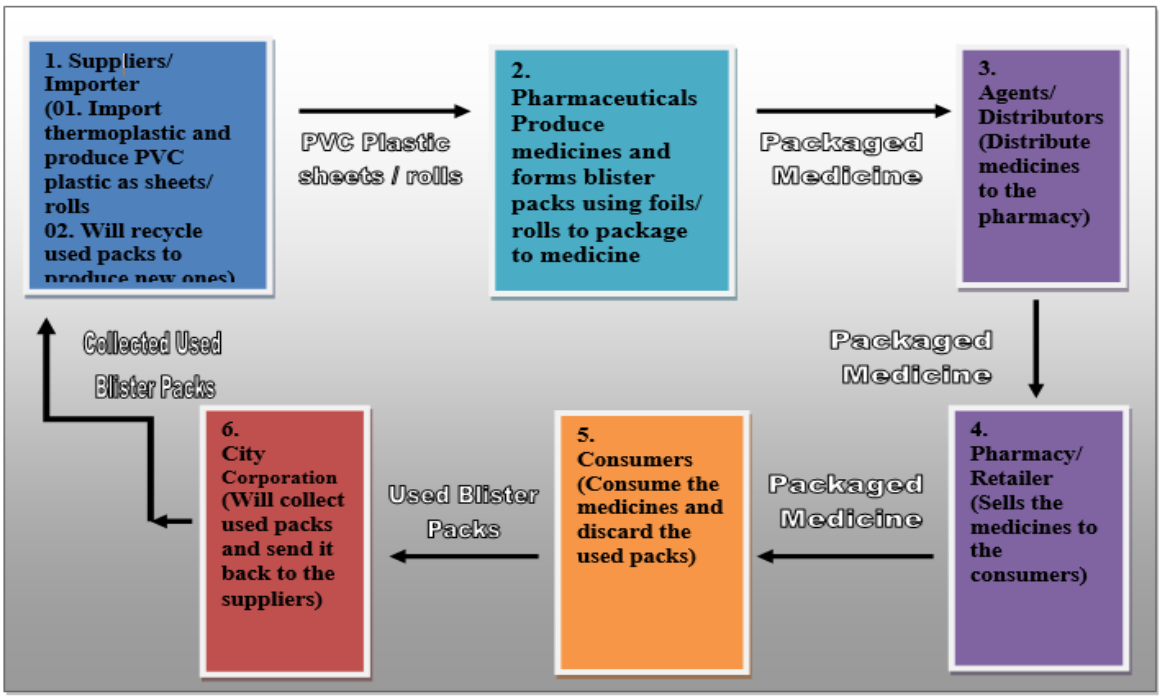

Figure 4: Reverse Supply Chain for PVC Plastic sheets of pharmaceutical products by Integrating City Corporation into Supply Chain of Pharmaceuticals Industry
Source: Compiled by authors

This diagram will work in the following manner

i. The PVC plastic sheets/ rolls will be supplied to pharmaceuticals from the supplier as usual.
ii. Pharmaceuticals will use the material for packaging tablets/ capsules
iii. Then the packaged medicines will be sent to the Agents or Distributors or Dealers of the
iv. The packaged medicines will be distributed to consumers.
v. After using the medicines, the consumers will put the packaging (leaves of tablet) separately
vi. Next, city corporation staff will collect those from the customers and submit to the original suppliers.

Upon the reception, the suppliers will convert those leaves into primary raw material (PVC Plastic) and put that back into the production process of manufacturing PVC plastic sheets/ rolls.

5.0 Analysis and Results

5.1.1 Analysis of the Questionnaires

Three questionnaires were used for conducting the present research. The first one is designed for the general customers, whereas the second one is for the municipal cleaners and officers. The last one is exclusively structured with questions for professional managerial accountants and process engineers working at the factory for medicine preparation and for each of the questionnaires, there were 100 respondent.

Table 1: Questionnaires for customers of medicine

Questions	*Percentage of Answers*	*Comments/Analyses*
01. Do you age more than or equal to 18?	100%	Responses from people aging more than or equal to 18 can be considered 'mature.'
02. Do you use medications for yourself and/or for your family members?	100%	Each of the respondents surveyed uses medications either for themselves or for their relatives.
03. What portion of your monthly budget is spent for medication?	▪ 83% people answered from 1% to 5% ▪ 8% people answered from 6% to 10% ▪ 5% people answered from 11% to 15% ▪ 2% people answered from 16% to 20% ▪ 3% people answered more than 20%	It is apparent from the result that most of the respondents (83%) do not outlay a big portion of their income for medication. However, those spending more than 16% of their monthly income mentioned special condition like the pregnancy, kidney problem, etc.
04. What do you think of the price level of local medications?	• 06% of the respondents answered 'Low' • 15%of the respondents answered 'Normal' • 72% of the respondents answered 'High' • 7% of the respondents answered 'Very High'	79% respondents think that the price of medicine is in the High to Very High range.
05. Do you think recycling is good for plastic-made medical products, like syringe, leaves of tablets, bottles of liquid medicines, etc.?	• Yes – 87% • No – 13%	Most of the respondents leaned towards a positive response knowing the promising sides of recycling.
06. Which of the following can be the most important benefits in this regard?	• Cost Reduction – 52% • Environmental Benefits – 28% • Employment Opportunities -20%	Showing the propensity of lower expenditure, most of the respondents ranked 'Cost Reduction' as their most important benefit.

Table 2: Questionnaire for DCC (South) Cleaners and Officers

Questions	***Percentage***	***Comments***
01. What is your designation?	• Cleaning staff - 45% • Officer – 55%	Out of 100 respondents surveyed, 45 were general cleaning staff and the other 55 were office workers of city corporation.
02. Is it possible to sort out wastes to filter the medical waste?	• Yes - 93% • No – 7%	Most of the respondents agreed that it is virtually possible to sort out wastage to filter the medical waste.
03. Please mention the most convenient way to do this.	I. Waste collection from hospitals - 81% II. Waste collection from households - 3% III. Separate waste disposal units - 16%	Most of the respondents preferred collecting waste from centralized locations like hospitals or sorted waste collection to collecting the same from individual households.
04. Will the cost of this process be significant?	• Yes - 6% • No - 94%	Because of the low cost of labor, it is assumed by most of the respondents that the cost of collection will not be significant.
05. How much a single piece of blister pack may cost?	1. 15% said (from BDT .05 to .07) 2. 75% said (from BDT .12 to .15) 3. 10% said (more than BDT .20)	From market, information is collected that 1 kg of used blister packs used to be sold for around Tk. 25-30 which contains around 200 leaves. Hence, price of a single blister would be within the range of BDT .12 to .15, as most the respondents said.
06. Which of the following can be the most important benefits in this regard?	• Cost Reduction – 72% • Environmental Benefits – 15% • Employment Opportunities – 13%	In these respondents as well, cost reduction got the maximum priority.

Table 3: Questionnaires for Employees of Pharmaceuticals Industries

Questions (Q)	***Percentage (%)***	***Comments***
01. What is your designation? Please tick.	• Managerial/ Management Accountant – 30% • Process Engineer – 70%	Most of the employees surveyed were Engineers (70 %) and some of them were Accountants (30 %.)
02. Is it possible to recycle blister packs and send recycled thermoplastics back into the production process?	1. Yes 100% 2. No 0%	All of the respondents replied positively in respect of the recycling possibility of used thermoplastics.
03. How much cost will it incur to recycle a blister pack including transportation and conversion cost?	1. 12% - around BDT .45 2. 83% - around BDT .50 3. 05%- around BDT .60	Most of the respondents believe that within BDT 500, the collected used blisters (5 KG packs each containing about 1000 pieces) can be recycled and converted into thermoplastics including all costs.
04. What is the usual importing price for thermoplastics for a single blister pack?	1. 08% - (BDT.45-.55) 2. 82% - (BDT .55-.60) 3. 10% - (BDT .60-.70)	Most of the engineers and accountants stated that cost of thermoplastics for a single blister ranges over from .55 to .60 BDT.
05. How much does it cost in normal operation to produce a single blister pack?	1. 85% - (BDT 0.50 – 0.80) 2. 10% - (BDT 0.80 – 1.00) 3. 05% more than BDT 1.00	Based on market price, most responded that the production cost of a single blister pack from thermoplastics varies from Tk. 0.50 to Tk. 0.80.
06. Do you think recycling will be profitable with given information?	1. 93% - Yes 2. 07% - No	Most of the respondents think cost will be less upon recycling of the used blister packs.
07. To what extent the cost will be reduced?	1. 08% - From loss to up to 10% 2. 82% - from 10% to 18% 3. 10% - from 18% to 30%	After calculation, most of the respondents replied that this process, if implemented, will result in at least 10% reduction in cost keeping the current process intact.
08. Do you think recycling is good for medical products, like syringes, leaves of tablets, bottles of liquid medicines, etc.?	1. 88% - Yes 2. 12% - No	Although most of the respondents think recycling is good for medical products, those (12%) thinking in a reversed way mentioned the health hazards, like the risk of contagious diseases for their opinion.

09. Which of the following can be the most important benefits in this regard?	1. 69% - Cost Reduction 2. 21% - Environmental Benefits 3. 10% - Employment Opportunities	In these respondents as well, cost reduction got the maximum priority.

5.1.2 Key Findings

From the analysis, it can be derived that most of the engineers in the production process agree that it is practically possible to introduce recycled thermoplastics as raw materials to produce blister packs (Q2, T3). In terms of costing, the projected cost of recycling may be up to BDT 0.60 for each blister pack (Q3, T3) and the maximum collection cost of the same can be BDT 0.20 (Q5, T2). Therefore, the cost of collection and conversion for a single blister pack can be BDT 0.80 in total if recycled thermoplastics is used.

In case of fresh thermoplastics, the least cost of import is BDT 0.45 and the conversion cost (Q4, T3) of to produce blister packs stands at BDT 0.50 in the minimum (Q5, T3). Here, the cost of a single blister pack from new thermoplastics is around BDT 0.95 in the least. Now, from the discussion above, it can be said that, theoretically, using recycled thermoplastics in the production process of blister packs will reduce cost of BDT 0.15 for each blister pack, which saves above 15% cost of production.

5.2 Results of the survey

From analysis of the questionnaires, it is evident that using recycled thermoplastics in the production process of blister packs can save at least 15% of the original cost. Likewise, relying on the cost data for both imported and recycled thermoplastics, most of the employees (93%) at pharmaceutical industries stated that recycling of blister packs for tablets/capsules will reduce cost (Q6, T3). Hence, it can be said that the alternative hypothesis is proved to be true and therefore eligible for future field studies to test it commercially. Opinion of the engineers that thermoplastics can be recycled is supported by Nieminen, Anugwom, Kallioinen, and Mänttäri (2020), who succeeded separating 95% of aluminum from plastics in used blister packs using lactic acid solutions. (Shukla, Halli, Khalid, and Lundström (2022)) have also succeeded in similar experiments and recovered 100% aluminum from Waste Pharmaceutical Blister Packages (WPBs).
Thus, backed up by several studies, it can be stated that from the engineering perspectives, it is indeed possible to recycle thermoplastics and aluminum from used blister packs. In addition, the integration of recycled raw materials is projected to be cheaper than the virgin ones and therefore is cost friendly.

6.0 Conclusion and Recommendations

6.1 Conclusion

Cost of a product or service is almost always a primary concern for the consumers. And, when the product is life-saving medicines, the concern is inevitably more because a high-price cure is not afforded by many. Recycling the blister packs of medicines can make the cost of medications slump to a good margin. That apart, recycling is also beneficial for the environment since there will be less wasted plastics around when recycling is operational. Owing to the greater goods, recycling should be done even if it is not profitable. In this study, it is primarily proved, predicated on cost data, that recycling can reduce costs of production. Therefore, this topic should be given enough importance so that recycling can come out of its pedagogical nature and become implemented in reality.

6.2 Recommendations for future studies

Further studies with actual cost data should be conducted in order to prove or disprove the alternative hypothesis whose fundamental feasibility is already proven in this study. In case of favorable results, specific supply chain models can be developed integrating recycling in order to cost reduction which is likely to incentivize environmental sustainability.

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Appendices

Terminologies:

1. Thermoplastics: The primary raw material from which the PVC sheets/ rolls are made.
2. Lidding Material: Flexible aluminum or plastic material with which the opening of the cavity/ the packet of a blister pack is closed.
3. PVC Sheets/ Rolls: The plain plastic sheets or rolls which are cut and mold to make blister packs.
4. Blisters/ Blister packs: The packs of tablets/ capsules when these are mold so that medicines can be put into the cavity/ pocket.
5. Cavity/ Pocket: The empty space surrounded by plastic on a blister pack in which the medicines are put.
6. SC: Supply Chain.