Circular economy of supply chain of recycled plastic bottle waste

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Abstract. Nowadays plastic bottle recycling is one of promising businesses. The plastic bottle recycling business involves supply chains of recycled material, which include participants such as consumers, waste banks, scavengers, small and large scale waste collectors, as well as recycling plants. Recycling plants can produce new products such as dacron material, strapping band and geotextile. Currently, only plastic bottle wastes made from HDPE and PET are recycled (included in circular economy). Meanwhile plastic labels, mostly made from PVC film, are burned or dumped, since they are not economically feasible to be recycled. One initiative to reduce plastic label wastes is conducted at a recycling plant of PT LJF. This recycling plant produce polyester synthetic fiber (PSF). The factory use plastic wastes that can not be recycled as a fuel mixture for a incinerator and oil heater, so that it can reduce the use of coal. Currently the factory use 499.82 kg of coal and 351 kg of plastic waste on average per day. The incineration process conducted in the recycling plant should be developed further to reach optimal condition so that the factory can get more heat energy from utilizing plastic waste as well as reducing fuel usage.

1. Introduction

According to Benton et.al (2014), circular economy is one where the resources coming into the economy are not allowed to become waste or lose their value[1]. Instead it would recover those resources and return them in productive use for as long as possible. Plastic bottle waste that is initially considered as rubbish, evidently could be cleaned and then be processed into a new product that has money value. In the case of plastic waste recycling business involves supply chains of recycled material, which include participants such as consumers, waste banks, scavengers, small and large scale waste collectors, as well as recycling plants. Previously, plastic bottle wastes were shredded and ground into small pieces, then, were exported to China. Meanwhile, many recycling plants thought that the business prospect will sooner or later decreased if they only depended on exporting recycled material. Therefore, they wanted to create a breakthrough in creating new products that are useful and can be sold locally.

Recycling plants can produce a new product that consisted mostly from recycled material of plastic bottle (PET) with the addition of some additives. Particularly, at recycling plant of PT LJF Tangerang, the recycled Polyethylene Terephthalate (PET) is processed into Dacron material, strapping band, and geotextile. This factory gets an average supply of PET bottle waste from 33 waste collectors at about 545 ton/month [2]. Recycling plant received more materials of clean PET bottle waste that means...
bottle with no labels and caps attached. But, there are some unclean PET bottles that still have labels and caps attached, especially those come from other country.

Waste banks are parts of the supply chain of recycling PET bottle, such as “Bank Sampah Berlian” in South Tangerang and “Bank Sampah Gawe Rukun” in Tangerang. They differentiate clean waste (bottle without label, cap and ring) from unclean waste (bottle with label, cap and ring), for plastic bottle wastes that have been deposited by their customers. In community waste recycling facilities in Bintara Bekasi, and Bantar Gebang, the scavengers separate the bottle caps made from HDPE (high density polyethylene) and label that are mostly made from PVC (polyvinyl chloride) from PET bottle [3]. Later on, only HDPE and PET plastic waste will be processed further; meanwhile, plastic label will be burned or dumped in the landfill, because they are not economically feasible to be recycled. But, the needs of beverage industries of packaging design cannot be avoided, because it will become a part of their marketing strategy.

In fact, there are several factors that influence the price of recycled PET material [4]. The first factor is the fluctuating world price of crude oil. Since PET pellet is made from crude oil, therefore the domino effect will happen. When the crude oil price is decreased, the PET pellet price is also decreased, that will cause a decrease in recycled PET price as well. Industry would rather use PET pellet than recycled PET material due to its high quality. The second factor is the coalition of recycling players and their competitors in price formation. The third factor is the shape (pressed or grinded or flakes) and the color of plastic bottle waste. The fourth factor is the quality of recycled material. If the quality of recycled material is low (contains dirt and contaminants), then the price is low as well and the material is categorized as second class. In the market, there is a price gap between unclean PET bottle waste (Rp 2.700/kg) and clean PET bottle waste (Rp. 3.750/kg). In other words, the price of clean bottle waste is 28% higher than the unclean one.

2. Problems
Currently, only plastic bottle wastes made from HDPE and PET are recycled (included in circular economy). Meanwhile plastic labels, mostly made from PVC film, are burned or dumped, since they are not economically feasible to be recycled. Based on the interview with Mr Dasta, Member of Indonesian Plastic Recycler Entrepreneur Association (ADUPI), it was found that the reason plastic labels were not profitable to process was due to economies of scale. According to Mr. Dasta, it is known that from 0.5 tons of plastic bottles collected, only 10 kilograms of plastic labels gained [5]. Meanwhile, the minimum amount of plastic that is profitable to process is 1 ton. So, 50 tons of plastic bottles is required in order to meet the minimum amount of plastic to start the recycling process. It took 344 sacks to contain all the plastic labels, therefore too many spaces needed for storage. The scavengers usually remove the plastic labels from PET bottles and HDPE caps (as shown in figure1). The pile of plastic labels after they have been removed from the PET bottles and HDPE caps usually are dumped in the landfill (figure 2).

Figure 1. The process of sorting PET bottles
3. Initiatives

Recycling plant LJF, is a company that involves in recycling PET bottle wastes. Currently, on average, the company receives for about 94.74% of supply material that is clean (without labels and caps), and about 5.26% unclean material [2]. One of its recycled product is Polyester Synthetic Fiber (PSF). PSF has a synthetic cotton look, that can be sold in three forms: socap, hollow conjugate (HC), or hollow conjugate silicon (HCS). Three types of PSF can be seen in figure 3.

![Figure 3. Three types of Polyester Synthetic Fiber (PSF)](image)

(a) socap        (b) HC                      (c) HCS

Production process of PSF consists of 5 steps, as follows (figure 4):

1. Hotwash. PET bottle wastes are cleaned by using chemicals such as Texapon® and caustic soda. After the cleaning process, the PET bottle wastes are ground into small flakes and put in a 500 kg jumbo bag.

2. Drying. Drying process is conducted to reduce water content until it reaches a standard of 2% maximum. In this process, there is an addition of coloring agent: optical bright and titanium dioxide to make PET flakes look brighter and clean.

3. Spinning. PET flakes are transferred to the spinning machines by using blower. Spinning process begins with the flakes from hopper fill into screw extruder to be melted down, then pass through nozzles that will produce straight filaments like yarns.

4. Drawline. Drawline process is conducted to form the straight filament into the form of synthetic cotton ball by using crimper. The process begins when the filament pass through the roller conveyor to adjust the filament’s strength, then pass through a container filled with steam from hot water and oil to eliminate its electrostatic property.

5. Packaging. The product is packed manually into a 250 kg jumbo bag.
The factory has production support facilities which are incinerator and waste water treatment to support hotwash process, as well as oil heater system to support drawline process. Basically, incineration process is a combustion process of waste at specific temperature that produce ashes, flue gas and heat. In this factory, heat evolved from that process is used as energy source for hotwash process. The incinerator uses coal and plastic as its fuel. Coal is used at the bottom of the furnace to increase the temperature of combustion chamber to 800°C (minimum), in order to produce flue gas that is safe for the environment. Furthermore, the plastic wastes used as fuel come from variety of plastic types from reject products as well as plastic labels and other plastic that are not economically feasible to be recycled.

4. Monitoring and evaluation

Based on the interview with factory manager, it is known that plastic waste can be used to reduce the usage of coal as incinerator fuel. The reason is that coal is used only in the beginning of incineration process. When the temperature is reached 800°C, the flue gas is safe for the environment. In this research, the flue gas composition has not been analyzed, but as seen in the display of the incinerator the temperature in the combustion chamber has reached 800°C. Furthermore, visually the smoke produced from incinerator is not black in color as is generally the smoke resulted from burning plastic waste in open space. In addition, the process of loading plastic waste into incineration is done continuously using a shovel that allows a stable temperature of at least 800°C. The loading process is not done all once since it can cause the temperature to decrease.

Actually, in incineration process, the factory use 499.82 kg of coal and 351 kg of plastic waste on average per day. This means the input of raw materials in the process of incineration is 58.74% in the form of plastic waste. Furthermore, the oil heater process also use plastic waste and coal for its fuel, but only small amount of plastic waste is used. On an average, the amount of plastic waste used in the oil heater process is about 4.39% of total amount of coal used. It is because, there is a filter in the oil heater machine that can be covered by melting plastic material if the amount of plastic waste used is too much. In this case, the plastic waste is used to increase combustion temperature due to the natural characteristic of plastic. Since in this process, the plastic waste usage is not significant in amount, therefore the oil heater process has not been a final solution yet to overcome plastic waste problem.

Figure 4. The PSF production process flow chart [6].
5. Result and Reflection
The incineration process conducted in LJF recycling plant should be developed further to reach optimal condition, so that the factory can get more heat energy from utilizing plastic waste as well as reducing coal usage. Recycling plants should collaborate with beverage industries to develop a new policy regarding producers and consumers responsibility to solve PET bottle waste problems. This is because, in plastic bottle waste, there is a plastic label containing brand of beverage industry that has not been recycled yet (not included in the circular economy).

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