Progress of used beverages carton recycling system in
Indonesia: A review

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Abstract. The potential to recycle Used Beverages Carton (UBC) in Indonesia is quite promising. Based on data from packaging manufacturers in 2016, it is estimated that the potential number of UBC reaches more than 50,000 tons, with fiber content is around 74 %, while polyethylene (PE) and aluminium foil materials together are around 26 %. The UBC recycling process consists of a hydropulper, screen, thickener and wet lap machine process. In this study, the composition of recycled fiber from UBC consisted mainly long fiber (3-5 mm) of approximately 52 %. The study shows that UBC fiber quality exceeds OCC quality and relatively similar to NUKP quality, which has 52.5 % long fiber content, tensile index 50.49 Nm/g, tear index 9.4 mN.m²/g, and burst index 5.76 kPa.m²/g, respectively. PE and aluminium foil also have the potential to be utilized as composite raw materials with aluminium foil served as matrix, fiber served as filler, and PE served as bonding agent. The composite production involved pressing process with a pressure of 30 kg/cm² and high temperatures of around 125 to 165 °C. The resulting composite product has a mass density of approximately 0.81-0.93 g/cm³, which is above the minimum value to be categorized as high density composite (0.8 g/cm³). The composite products also have flammability properties ranging from 3.0 to 3.2 cm/min, and water absorption around 14 %.

Keywords: Used beverages carton, recycling, secondary fibre, coagulant, composite

1. Introduction
The demand for fast food and beverages continues to increase every year, along with the increasingly modern lifestyle of the community, including the demand for aseptic beverage cartons for milk and juice which also increases every year [1,2]. Increased production and demand for aseptic beverage cartons might result in an increase in the amount of used beverage cartons (UBC) waste which in turn will also result in high environmental burden. From a different perspective, UBC waste actually has the potential to be used as a source of raw materials, especially if it is recycled into products that have high economic value. At this moment, UBC is known to be quite difficult to recycle and mostly abandoned by scavengers. Most of UBC has been destroyed by burning or dumped in a public landfills or disposal area.

Indonesia as the largest paper producing country in ASEAN, is still importing waste paper for paper raw materials. The need for waste paper every year reaches 7 million tons, with around 60-70 percent or 4-4.5 million tons still imported [3,4]. Waste paper supplies are needed as raw material for the production of brown paper which is used every day as packaging paper by the domestic industry. Trends in demand for used paper as raw material for packaging paper from year to year continues to increase significantly. Unfortunately, the high demand for waste paper is not properly balanced by the
domestic supply of raw material in the country, which could only meet 30-40 percent of the demand. The growth of the national paper industry, especially the brown paper industry, has shown significant progress in recent years.

Likewise, the domestic UBC recycling industry could contribute to the markets and promising prospects for obtaining the raw material that meet the raw material requirement of the brown paper / paper packaging industry. Used Beverages Carton has six layers contains of fiber, polyethylene and alumunium foil (Figure 1), that protect the beverages product from environmental exposure that might caused damaged such as light, air, odors, moisture, and germs. The fiber content in UBC may reach 74 % of the total weight, while the remaining consist of alumunium foil (5 %) and polyethylene (21 %) [5,6]. The potential of UBC in Indonesia, based on data from packaging producers in 2016, is estimated to reach more than 50,000 tons, increase 5 % every year. As much as 65 % of this potential is spread in big cities in Java Island, 35 % spread in big cities outside Java Island such as Medan, Batam, Pekanbaru, Makassar, Menado, Balikpapan, Samarinda, Pontianak and other big cities [7].

The study was then developed towards the design of a technology package to decompose UBC into raw materials for the recycling industry of fiber, plastic and aluminium foil. This review is also intended to show some progress of potential evaluation for each UBC content such as fiber, alumunium foil and polyethylene and also UBC supply chain.

The research is important for implementation of UBC recycling process in Indonesia. The potential utilization of UBC has to be supported by the study of UBC supply chain to gain the comprehensive vision about the recycling process.

Figure 1. Used beverages cartons and its layers [6]

2. Methodology

2.1. UBC Separation process

The separation process consist of several steps including hydropulping, rotary drum screening, biffar screening and johnson screening, centricleaning, pressing, washing, thickening and sheet forming [2]. The machines and equipments of UBC recycling used are located in the innovation centre at Center for Pulp and Paper (CPP), such as hydropulper, rotary drum screener, jonson screen machine, presser screen machine, washer and thickener machine. Processes were based on the pulp recycle process and polyethylene-alumunium foil separation process which were discussed on the previous papers [2,8,9].
2.2. Liner paper production process
The separated recycled fiber was obtained from pilot scale process. The recycled fiber was mixed with Old Corrugated Cardboard (OCC) (both recycled fiber and OCC with 300 mL CSF freeness) with variation of (80, 60, 40 and 20 %), with approximately 15 % calcium carbonate addition as filler addition, cationic starch addition about 1 % and alkyl ketene dimer (AKD) for approximately 0.6 %. Paper was made approximately 125 g/m² in laboratory with hand sheet forming machine, and tested for grammage, tensile index, burst strength, water content, water absorption (Cobb120), and coarseness (Bendtsen).

2.3. Coagulant production process
The separated aluminium foil-polyethylene were obtained from pilot scale process. Aluminium foil-polyethylene were soaked in sodium hydroxide in a laboratory beaker glass. The soaked aluminium foil was dissolved completely and then the PE was separated. The remaining solution was then solved with sulfuric acid and hydrogen chloride. The solvent produced was then being added to Citarum river water and wastewater to coagulate the suspended solids with a jar test coagulation process. Wastewater used was taken from effluents of paper industry [9].

2.4. Composite production process
In the production process of composites, the plastic polyethylene separated from UBC may be utilized as adhesive or bonding agent while the fibre may play a role as filler, and aluminium foil as matrix. The processes were involved a hot press process at a temperature of approximately 125 °C, and a pressure of 25 kg / cm² to produce a strong and compact fibre-polyfoil composite board. The composites products were then tested and compared with the standard from vehicle component producer.

| No. | Parameters       | Standard       | Methods                    |
|-----|------------------|----------------|----------------------------|
| 1   | Specific Gravity | 0.78 – 0.94 g/cm³ | Density balance 01, ISO 1183E |
| 2   | Water Content    | 5 – 13 %       | Karl Fisher                |
| 3   | Water Absorption | Maks, 35 %     | Waterbath 01, ISO 62       |
| 4   | Bending Strength | 19.6 – 27.4 kPa | Universal testing machine 50 KB, ISO 14125 |
| 5   | Flammability     | Maks, 10 cm/min | UL 94                      |

Table 1. Luggage cover standards and testing methods.

3. Results and Discussions

3.1. UBC Separation results
The study showed that the separation process of UBC has successfully carried out both on laboratory scale and pilot scale. The recycled/secondary fiber has been successfully separated from the mixture of aluminium foil and polyethylene, the result can be seen at Figure 2 and Figure 3. Fibers was also successfully recovered with the fiber yield of 26-48 % on the laboratory scale [10] and slightly improved on the pilot scale with 42-56 % of fiber yield.

3.2. Recycled fiber quality
The composition of recycled fiber from UBC was consist mainly long fiber (3-5 mm) for approximately 52 %, medium fiber (2-2.9 mm) was only 1.5 %, while short fiber (1-1.9 mm) was 21 %, and fines (<1 mm) was 25 % (Table 2). The physical strength of recycled fiber from UBC may has exceed the OCC (old corrugating cartons) quality (Table 3) with level of freeness grinding degree at around 550-600 mL CSF with yield about 42-56 % [8]. The composition of recycled fiber from
UBC (Table 2) has a relatively similar quality with the quality of secondary fiber NUKP (Unbleached Kraft Pulp Needle) and might have adequate economic value.

Table 2. The fiber composition of UBC recycled fiber [8,10].

| No | Fraction of fiber | Fiber length (mm) | OCC fiber | NUKP fiber | UBC Recycled fiber |
|----|-------------------|-------------------|-----------|------------|--------------------|
| 1  | 30 mesh           | 3 – 5             | 21.0      | 70.0       | 52.5               |
| 2  | 50 mesh           | 2 – 2.9           | 1.5       | 15.5       | 1.5                |
| 3  | 100 mesh          | 1 – 1.9           | 34.1      | 12.5       | 21.0               |
| 4  | 150 mesh          | <1                | 16.2      | 2.0        | 3.0                |
| 5  | >150 mesh         |                   | 27.2      | 0.0        | 22.0               |

OCC = Old Corrugated Container  
NUKP = Needle Unbleached Kraft Pulp

Table 3. Fiber quality of UBC recycled pulp.

| No | Parameters               | UBC Recycled pulp [8] | OCC [8] | NUKP [11] | LBKP [12] | LUKP [13] |
|----|--------------------------|------------------------|---------|-----------|-----------|-----------|
| 1  | Tensile index (Nm/g)     | 50.49                  | 47      | > 65.00   | > 45.00   | > 50.85   |
| 2  | Tear index (mN.m²/g)     | 9.40                   | 7.40    | > 10.00   | > 5.50    |           |
| 3  | Burst index (kPa.m²/g)   | 5.76                   |         | > 5.50    |           | > 2.50    |

LUKP = Leaf Unbleached Kraft Pulp  
LBKP = Leaf Bleached Kraft Pulp

The quality of UBC fiber based on tear and burst indexes was also sufficient for NUKP qualities, while the tensile index was almost sufficient for LUKP qualities (Table 3). It was showed that the quality of UBC fibers was exceed OCC quality and relatively similar with NUKP quality with 52.5 % of long fiber content and qualities such as tensile index 50.49 Nm/g, tear index 9.4 mN.m²/g, and burst index 5.76 kPa.m²/g. Based on [13] bleaching process will reduce the tensile index of hardwood kraft pulp at 40 °SR (around 300 CSF) by (around) 13 %. This ratio will predict the tensile index of unbleached hardwood kraft pulp approximately around 50.85 Nm/g. Although the tensile index quality
of UBC recycled pulp is not higher than unbleached hardwood kraft pulp, the fiber composition, tear index and burst index of UBC recycled pulp showed a relatively similar qualities with NUKP fiber.

### 3.3. Liner paper production result

Table 4 shows that the combination of UBC and OCC subjectively tends to produce a better quality of liner paper. The percentage increment of UBC fiber amount tends to improve the quality of the resulting liner paper compared to the other variation with a lower percentage of UBC fiber amount. Paper liner grammage tends to increase in all composition variations of the mixture between OCC and secondary fibers, while coarseness quality tends to decrease by the decrement of UBC fiber percentage. Burst strength (or burst resistance) tends to decrease in the increment of UBC fiber percentage, while all variations of water content was above the required quality standards. All mixed variations between UBC secondary fibers and OCC compositions have water absorption values (Cobb120) acceptable to SNI, whereas the pure 100% of UBC or OCC secondary fibers cannot be accepted. The phenomena was happened because most of UBC fibers were long fibers, while OCC were mostly short fibers. Paper with majority long fibers will caused a strong properties of paper, but lack of short fibers to fill the gap between long fibers which caused poor drainage. While paper with majority short fibers will lost its strength.

#### Table 4. Liner paper production from UBC fibers.

| No | UBC Recycled fiber (%) | OCC (%) | Grammage (g/m²) | Coarseness (mL/min) | Burst strength (kPa) (kN/m²) | Water content (%) | Water absorption Cobb120 (g/m²) |
|----|------------------------|---------|-----------------|--------------------|-----------------------------|------------------|-------------------------------|
|    |                        |         |                 | Top     Bottom      |                             |                  |                               |
| 1  | 100                    | 0       | 121.1           | 1400   1875        | 79.4                        | 6.9              | 303.7                         |
| 2  | 80                     | 20      | 135.9           | 1060   2063        | 79.0                        | 6.0              | 20.4                          |
| 3  | 60                     | 40      | 146.3           | 888    1950        | 119.4                       | 5.7              | 22.7                          |
| 4  | 40                     | 60      | 144.5           | 888    1850        | 133.2                       | 5.6              | 23.6                          |
| 5  | 20                     | 80      | 148.5           | 625    1563        | 169.0                       | 5.3              | 24.7                          |
| 6  | 0                      | 100     | 120.2           | 475    1450        | 212.8                       | 5.9              | 259.8                         |

| Standard[14] | 125 | <1500 | A | B | <9.0 | <80 |
|--------------|-----|-------|---|---|------|-----|
|              | >2.5 | >2.0  |   |   |      |     |
|              | kN/g | kN/g  |   |   |      |     |

From all test results it can be concluded that UBC secondary fiber should be mixed with OCC as another paper raw material to obtain a better quality of liner paper. This fact is also being emphasized by the high price of UBC secondary fibers, thus one way to reduce the cost of producing liner paper is by the addition of OCC.

### 3.4. Coagulation result

Alumunium foil from UBC may be used to support the coagulation process in wastewater treatment. The study showed (Table 5) that a lower total dose of coagulant may be obtained to clean a similar wastewater by adding liquid from alumunium foil as a supplement to the coagulation process. The emerged ability of coagulant might be occured due to the formation of alumunium sulfate based of the following equation [15,16]:

\[
2\text{Al(s)} + 3\text{H}_2\text{SO}_4(\text{aq}) \rightarrow \text{Al}_2(\text{SO}_4)_3(\text{aq}) + 3\text{H}_2(\text{g})
\]
Alumunium dissolution occurred because it was caused by acidification by sulfuric acid [15–17]. The chemical equation also explains the occurrence of hydrogen gas release from the reactor during the dissolution of Al-foil process in the laboratory experiments. Alumunium sulfate is a compound that is widely known for commercial coagulants [18]. After the dissolution of aluminium, polyethylene will be separated at a higher degree of purity, this process may produce a clean polyethylene that might be appropriate to be recycled into plastic.

Other researches used methanoic acid to gain a greater separation process (100 %) [19,20], however, the separated Alumunium would going to need a further sedimentation process. Meanwhile another research concluded that benzene may separated Alumunium and PE with a shorter time while maintaining its 100 % separation, the waste mixture liquid resulted was also may be recycled and reused [21]. Polyethylene derived from the mixture of Alumunium foil-polyethylene by solvent extraction could also be successfully used in blown film extrusion process[22].

Table 5. Coagulation application [9]

| Water Source            | Coagulant dose with alumunium foil addition (ppm) | Coagulant dose without alumunium foil addition (ppm) | Chemical Reduction (%) |
|-------------------------|-----------------------------------------------|-----------------------------------------------------|------------------------|
| Citarum river           | 30-40                                         | 80-100                                              | 50-70                  |
| Recycling wastewater    | 250-550                                       | 1000                                               | 45-75                  |

3.5. Composites production

Another method to utilize the mixture of polyethylene and aluminium foil from UBC separation without undergo a purification process is composites production. The composites product may not need a pure aluminium foil nor polyethylene. Polyethylene may be directly utilized as adhesive or bonding agent while the aluminium foil may act as matrix. Fiber were also added to several variation of the composites and may play role as fillers. Table 6 shows the quality of roof composites from a mixture of aluminium foil and polyethylene.

Studies from [23–25] suggested that alumunium foil-polyethylene may be produced into a good quality of composites. Furthermore, [25] suggested that potential applications which require properties that may be improved by the presence of alumunium such as thermal and conductivity components. Based on those suggestions, in our further study we compared the quality of composites with standards for automobile component (Table 1). The study showed that some qualities of the composites already qualified with the standard from costumer (Table 7).

Table 6. Roof composite qualities

| No | Test          | Result                      | Methods                         |
|----|---------------|-----------------------------|--------------------------------|
| 1  | Fire Retardant| 150 s                       | ASTM E119-98                    |
| 2  | Bending Strength | 62.85 kgf/cm² (6.29 MPa) | ASTM D790-2000                 |
| 3  | Heat Resistance | 100 °C                      | ASTM D4502-92 (2011)           |
| 4  | Moisture Proof | Good                       | ASTM D4502-92 (2011)           |
|    |               | No color change             |                                |
|    |               | No delaminated              |                                |
|    |               | No deformation              |                                |
|    |               | No change of strength       |                                |

Data was based on data from the alumunium foil-polyethylene Roof Composite Industry
Table 7. Composites qualities compared to luggage cover standards [26]

| No. | Parameters       | Standard       | Lab. Scale Composites | Industrial Scale Composites |
|-----|------------------|----------------|-----------------------|-----------------------------|
| 1   | Density          | 0.78 – 0.94 g/cm³ | 0.83 g/cm³           | 0.81-0.93 g/cm³             |
| 2   | Water Content    | 5 – 13 %       | 1.2 %                | -                           |
| 3   | Water Absorption | Maks, 35 %     | 14.1 %               | -                           |
| 4   | Bending Strength | 19.6 – 27.4 kPa | 8.48 – 12.78 MPa     | 7.73 ± 0.66 MPa             |
| 5   | Flammability     | Maks, 10 cm/min| 3.0-3.2 cm/min       | -                           |

Composite plate specification test results show that several parameters have met the standard specifications of the interior components of the luggage cover. The values of the specific gravity, water absorption and flammability parameters indicate values that are within the acceptable range of specifications. Meanwhile, the value of water content and bending strength parameters still need further experiments.

3.6. Existing supply chain

One important factor for utilizing solid waste into products is the availability of raw materials. The continued availability of raw materials must be maintained to keep the recycling process running. Existing suppliers consist of aseptic producers, beverage manufacturers and distributors before the product reaches the consumers. UBC are collected before and after they reach the disposal facilities by scavengers and collectors. Due to transportation costs and minimum amount of shipping, the collectors may not transport UBC directly to the recyclers and sell it to collector agents instead. The collector agents then collects and transpors the collected UBC to the recyclers. Used beverages cartons are then recycled into fiber, alumunium foil and polyethylene in the recyclers. Raw materials in the form of fibers, alumunium foil and polyethylene are then recycled into paper and paper art, corrugated, and roof production (Figure 4).

The price of UBC will be higher if UBC has not reached the final disposal facility because usually UBC quality will be worse if it has reached the final disposal facility. The current recycling prosses includes the production of roof, corrugated, and paper. All production of the recycling processes are still not optimal yet due to the inefficiency and ineffective process and supply of raw materials.
4. Conclusion
Used beverages carton has a great potential to be recycled and utilized as paper, chemicals or composites products. The potential to utilize the long fiber is quite large enough especially for the substitution of imported long fibers in order to improve the quality of paper. Aluminum foil has potential to be utilized as a coagulant additive that can support the wastewater treatment process, which may also produce a clean polyethylene that more appropriate to be recycled into plastic. Together with polyethylene, aluminum foil also has the potential to be utilized as composites such as roofs, automobile components, etc. Compared to the standard of automobile component that has been used, this composite has good qualities of specific gravity, water content, water absorption, bending strength, and flammability. The sustainability of raw materials at the supply chain must be improved to keep the recycling process running well and sustainably.

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