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Pilot trial on separation conditions for diaper recycling

Kyung-Shin Kim [a], Hee-Sun Cho [b,*]

[a] Innovation Center, Yuhan-Kimberly, Seoul, Republic of Korea
[b] Dept. of Urban Environment Engineering, Kyungnam University, Republic of Korea

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ABSTRACT

By utilizing laboratory-scale tests, the optimal separation conditions for diaper recycling were identified, and then, these conditions were validated by a pilot trial. In this research, we determined the mass balances derived during various processing steps and identified the most feasible procedures to use for separating each material in the output flow. The results showed that drum screening was not able to remove all the fiber and super absorbent particles (SAP) in the plastic-rich fraction and that cellulose enzyme treatment can be a good solution. To achieve better separation of fibers and SAP, slot screening followed by a cleaner is a potential option. A feasible diaper recycling process was recommended based on these results. This process involves screening and enzymatic treatment for the plastic fraction, and screening, cleaning, and thickening for the fiber fraction. Treatment procedures were also proposed for the SAP fraction and rejected materials.

1. Introduction

Research indicates that over 90% of parents use disposable diapers since they are comfortable, hygienic, healthy, cost effective, and convenient (Ministry of Environment, 2014). In fact, these commodities are now considered an essential item for childcare (Espinosa-Valdemara et al., 2014). Out of the 240 thousand tons of used diapers that are generated each year in Korea, 141 thousand tons of used diapers (58%) were generated at daycare centers (Kim and Kim, 2015).

Most diapers are basically composite materials that contain plastics (such as polyethylene and polypropylene), cellulose fibers, and super absorbent particles (SAP), all of which are valuable resources (Aumonier et al., 2008; Mirabella et al., 2013). The composition of diapers has changed significantly in recent years, and technical improvements have enabled the production of lighter and smaller diapers (Torrijos et al., 2014). Importantly, the proportions of materials used in diapers have varied over the past several decades. In the 1980s, 80–90% of diapers consisted of a mixture of cotton (fluff cellulose), natural fibers, and synthetic fibers (Juarez and Garcia, 1989). In the 1990s, many efficient features were applied to diapers, thus making it possible to find them in a variety of shapes, sizes, and styles (Espinosa-Valdemara, 2014).

After diapers are used and disposed of, they do not degrade readily. Diaper waste is mainly composed of organic matter (cellulose pulp, feces, and urine), and it is generally collected together with household refuse and disposed of in municipal landfills or incinerators (Manfredi et al., 2010). The main environmental problems associated with landfilling waste include methane emissions from biodegradable materials, which contribute to global warming, possible percolation of leachate to groundwater, land occupation, noise, and bad odors (Smith et al., 2001). There are mitigation strategies that can solve these problems depending on the technology used and local regulations (Colon et al., 2013). In Korea, local regulations for diaper waste are very unique. According to the Act on the Promotion of Saving and Recycling of Resources, in order to restrict the generation of wastes and prevent the waste of resources, the Minister of Environment shall impose fees and collect for expenses incurred from the treatment of wastes derived from goods, materials, and containers. Disposable diapers are one of the items subject to waste charges since they are likely to cause problems in the management of wastes (Kim and Kim, 2015).

As discussed above, most disposable diapers are destined for landfills or waste incinerators after they are thrown away. However, there are other possible solutions including biological treatment and composting being proposed and experimented in other countries. Biological treatment includes both mechanical treatment and biological treatment processes, which may involve aerobic and anaerobic stages or a combination of both. After biological treatment biowaste is stabilized at a reduced volume and low moisture content. Normally, the compost obtained from biological treatment is of low quality and is difficult to commercialize (Slater and Frederickson, 2001).

* Corresponding author.
E-mail address: elegsun@kyungnam.ac.kr (H.-S. Cho).

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Since the 1990s, several laboratory experiments have been undertaken on the composting of diapers. Stegmann et al. (1993) concluded that SAP caused no adverse effects on the degradation of diapers. Cook et al. (1997) studied the composting process of SAP together with municipal waste. However, composting can be difficult to implement at municipal waste facilities because of several problems that diapers are generally compacted and subjected to a shredding device to open them up before composting.

One alternative solution to composting diapers involves recycling, but this cannot be accomplished easily because it is often difficult to implement multiple separation processes for each kind of material such as plastics, cellulosic fibers, and SAP. Various methods have been proposed to separate absorbent sanitary paper byproducts. After application of the process described in an early patent (U.S. patent no. 5,558,745 in 1996), the plastic fraction will still contain SAP and fiber, which is not desirable. In a more recent patent (U.S. patent no. 8,177,151 in 2012), a new approach was proposed by Knowaste in order to improve the cleanliness of the various fractions. The principle of the Knowaste recycling process is described in Fig. 1.

According to Knowaste, diapers are collected separately from general consumer waste and are transported to a treatment plant, where they are shredded, washed, and separated into various components. The plastics are removed from the stock through finger conveyors, and these materials are then pressed and pelletized for sale. The rest of the pulp stream containing SAP passes through a series of coarse screens and is treated with inorganic salt to deactivate the SAP; this allows these materials to be separated via a cleaning process. The fiber-rich portion is submitted to a mechanical washer, cleaner, and screening process to generate a clean fiber fraction. This process can divert up to 84% of the materials from landfills and waste incinerators (Colon et al., 2011). However, there are some issues associated with the Knowaste process that relate to water and alum consumption. In order to solve these problems, the optimal size and influencing factors such as retention time, temperature, and consistency were investigated in laboratory-scale tests. Influencing factors including a 60 min retention time, 30 °C processing temperature, and 5% consistency were further investigated in a pilot trial to verify the appropriateness of these separation conditions. The overall objectives of this research were to determine the mass balances of the components in diaper waste during the various processing steps investigated through a pilot trial and to identify feasible processing solutions that can produce three recoverable fractions that are as pure as possible.

2. Materials and methods

2.1. Pilot-scale experiment

In order to test the pilot-scale experiment of recycling used diapers, the research design is illustrated in Fig. 2. This pilot equipment consists of HC batch pulper, drum screen, slot screen and cleaner. These are commonly used in recycling and deinking lines in the paper industry. The pulping stage can be viewed as a process where fragmentation phenomena such as defibering occur (Fabry and Carre, 2002). The drum screen is used to separate big plastics and cleaning is spinning the pulp slurry in a cleaner, causing materials that are denser than pulp fibers to move outward and be rejected. Screens with slot are used to remove contaminants that are larger than pulp fibers.

The right side of Fig. 2 shows the processes used to treat the accept part of the drum screening output, which consists of mainly fibers and SAP. Through the use of a cleaner, we can separate fiber by specific gravity. The terms reject and accept flow are the usual terms used by pulp engineering. Reject stream corresponds to the stream that the papermaker does not want to use for their produc-

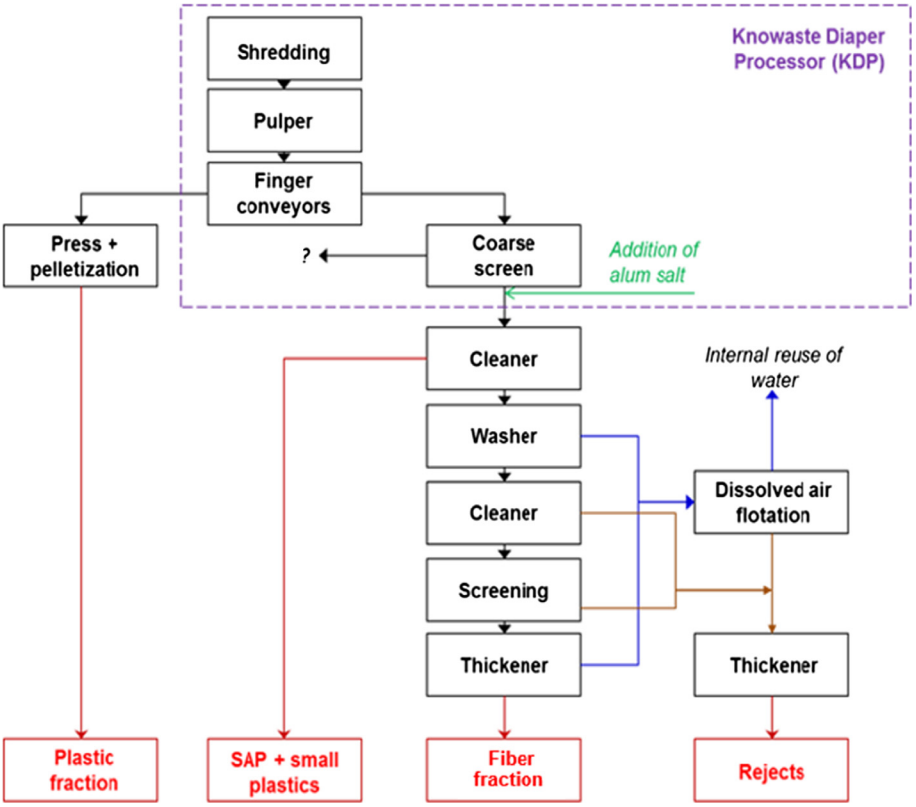

Fig. 1. Principle of the process proposed by Knowaste. SAP, super absorbent particles.

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