Rubbish to Resource: Turning Waste into Biodegradable Microbeads

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Abstract

Microbeads are soft and tiny microplastic, which size is less than 5mm, mostly made from polyethylene, and can be easily found in any cleansing products such as, soap, toothpaste, body scrub, and others. The daily use of cleansing products containing microbeads can cause environmental damage, especially the aquatic ecosystem. Based on research that has been done by scientists in the University of Plymouth, South England, UK, a cleansing product containing microbeads can release about 4,500-94,500 microbeads to the waterways in every single use. Because of its tiny size, the city water treatment system unable to capture these microplastic particles, so they overflowed and ended up in waterways. The size of microbeads that are only no more than 0.1 µm in diameter, make marine biota often get mistaken them for phytoplankton. Not only marine biota, but freshwater biota also consumes these microbeads, which are accumulated on the water surface.

In the water, microbeads act like sponges. Microbeads have pores that can absorb toxic chemicals such as poly-aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and bisophenol-A (BPA). These toxin chemicals will not only end up inside the aquatic biota digestive system but also inside the human body. The presence of toxic chemicals in the human body can potentially affect human health. Therefore, an effective innovation is needed to change microbeads. Polyethylene, the main composition of microbeads, can be replaced by cellulose in order to become biodegradable. Cellulose is chosen because it is the most abundant biopolymer on earth, can be degraded naturally, and safe to be consumed by the aquatic biota. In this case, the cellulose solution is extracted from oil palm empty fruit bunches waste. Indonesia is the world's largest palm oil producers, so not only do we reduce the amount of the waste, but also recycle and reuse the oil palm empty fruit bunches waste. This implementation of biodegradable microbeads in Indonesia not only will accomplish one goal, but four sustainable development goals at the same time, which are clean water and sanitation, responsible consumption and production, climate change, and also life below water. Hence, the number of microplastic in water cycle can be effectively reduced without increasing environmental damage and potentially create a sustainable future.

Keywords

Biodegradable microbeads, Cellulose, Oil palm empty fruit bunches waste, Environment.

1. Introduction

An estimated 4,500-94,500 microbeads are released into aquatic ecosystem in one daily use of cleansing products containing microbeads (Napper et al. 2015). The use of these products can lead to major environmental problems, such as pollution. Nowadays, approximately one quarter of the sampled fish in Indonesia fish markets contained microplastics in their entrails (Rochman et al. 2015). If this number keeps increasing, it will be very detrimental to the aquatic environment. In the waterways, microbeads weren't able to be filtered by the sewage treatment system because of its tiny

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sizes, so they overflowed throughout the water. Aquatic animals that have been contaminated by microplatics will affect other organisms through food chain biomagnification, which accumulate more contamination as the level of organisms get higher in the food chain. Furthermore, microbeads have sponge-like structure that can absorb toxic chemicals such as poly-aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and bisophenol-A (BPA). These toxic chemicals will not only end up inside the aquatic biota digestive system but also inside the human body.

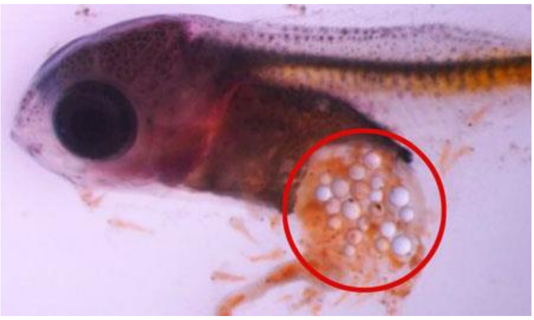

Fig. 1. Microbeads found inside fish entrails (Source: fishforever.org.nz)

2. Microbeads

Microbeads are soft and tiny beads generally made of synthetics polymers (polyethylene), which sizes are more than 0.1 μm and less than 5mm. These microbeads are produced in variety of different types of products such as cosmetic care products (soaps, facial cleansers, toothpaste, and scrubs), industrial products (printer toner, explosives materials, and automotive molds), plastic products (anti-slip materials), and medical products. Their tiny sizes often make aquatic biota, like fishes, mistakenly seen them as food. The contamination of microplastics in the food chain will not only increase the death risk of aquatic biota, but also threaten human health. Exposure to bisophenol-A (BPA) can increase the risk of conditions like male genital dysfunction, endocrine system disorders, and changes in the DNA methylation process (Ribeiro, Ladeira, and Viegas. 2017).

Polyethylene, the main components of microbeads, are difficult to break down naturally by the environment because they form very strong double bonds to produce long monomer chain (Tokiwa et al. 2009), making these plastic particles accumulated in the water for long period. Due to the solar radiation emission, microbeads accumulation on the water surface has the potential to release greenhouse gases, such as methane and ethylene (Royer et al. 2018). If it keeps increasing, these greenhouse gasses can cause global warming and climate change.

Fig. 2. (Left) Size of microbeads, (Right) Microbeads (Source: osof.org)

The enactment to ban the production and sale of microbeads-contained cosmetics in several countries has made some industries eliminating microbeads from their products. Although there have been several ways to replace microplastic with other ingredients, substitute materials that have similar characteristics to those microplastic particles have not been found yet. Therefore, a sustainable alternative innovation that is environmentally friendly, can be produced on a large scale, has similar functions, and can be broken down into a harmless product is needed (Coombs OBrien et al. 2017). One of the alternatives is cellulose.

3. Oil palm empty fruit bunches waste as the raw material for biodegradable microbeads

Cellulose is chosen because it is the most abundant biopolymer on earth. It can be estimated that there are 1.5 x 1012 tons of cellulose produced in the biosphere each year (Klemm et al. 2005). This biopolymer is composed of glucoses, which make it easily degraded by nature, hence cellulose is a potential substitute for polyethylene in microbeads (Peŕez et al. 2002). Although, cellulose is the most common organic compound on earth and available in all types of plants, yet, specific plants with certain cellulose are still sought.

Indonesia is known as the world's biggest producer of palm oil. The oil extraction is obtained from the palm oil tree's fruit flesh and inner core, which will leave oil palm empty fruit bunches. These oil palm empty fruit bunches waste are rich in contents such as, lignin, cellulose, holocellulose, pentosan, ash content, and extractive substances (Darnoko, 1995). However, only 10% of these empty fruit bunches waste have been utilized for boiler fuel and compost, the rest are still remain waste (Ngadi and Lani. 2014).

Contents	Concentration (%)
Water	8.56
Lignin	25.83
Holocellulose	56.49
Cellulose	33.25
Hemicellulose	23.24
Extractive Substances	4.19

Table. 1. Concentration of empty oil palm fruit bunches (Source: Dewanti. 2018)

Based on research conducted by Dewanti (2018), cellulose from oil palm empty fruit bunches waste has the potential to be used as raw material for bioplastics. The cellulose concentration contained in empty fruit bunches waste are around 38.76% with fiber content reaching 72.67% (Herawan and Rivani. 2010). Bioplastics from cellulose are also biodegradable and have the ability to decompose up to 67% within 2-3 weeks on active sludge media for wastewater treatment (Puls. 2011). Thus, with high cellulose concentration, oil palm empty fruit bunches waste are chosen to be the proper raw material for biodegradable microbeads. In this case, not only do we reduce the amount of waste, but also reuse and recycle the oil palm empty fruit bunches waste into another material that have more economic value.

4. Biodegradable Microbeads

Turning oil palm empty fruit bunches waste into biodegradable microbeads is not a piece of cake. Lots of processes are needed to obtain the physical form of it. Despite turning oil palm empty fruit bunches waste into biodegradable microbeads has never been done before, most of the processes that are needed in the making have already been done. The production of biodegradable microbeads from oil palm empty fruit bunches will be done by this scheme.

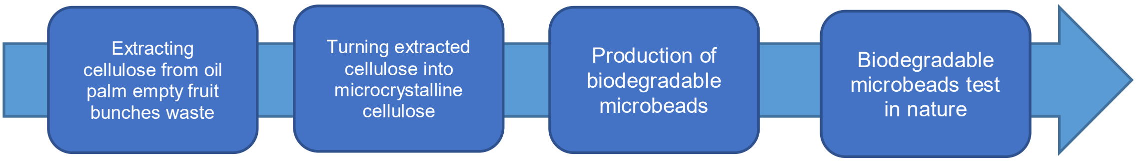

Figure. 3. Biodegradable microbeads production scheme (Source: Author)

- Extracting cellulose from oil palm empty fruit bunches waste

  Cellulose extraction can be done in two stages, which are delignification using 12% of sodium hydroxide (NaOH) solution in 3 hours at 90-95 ^oC and followed by bleaching process using 10% of hydrogen peroxide (H_2O_2) solution within 1.5 hours (Biswas et al. 2007).
- Turning extracted cellulose into microcrystalline cellulose

  Extracted cellulose that used as the raw material is the α-cellulose. Converting α-cellulose into microcrystalline cellulose can be done through strong acid hydrolysis at controlled temperatures. Based on research conducted by Nosya (2016), microcrystalline cellulose formation was carried out with variable concentration of hydrochloric acid (HCl) (2; 2.5; 3N) for strong acid hydrolysis. It followed by centrifuging at speeds of 3500 rpm till neutral then cellulose is ultrasonified for 10 minutes. Afterwards, a characterization of microcrystalline cellulose has to be done by Fourier Transform Infra-Red (FT-IR), Scanning Electron Microscope (SEM), Differential Thermogravimetric / Differential Thermal Analysis / Thermogravimetri Analize (DTG / DTA / TGA), Particle Size Analizer (PSA), and X-ray Difractometer (XRD) testing.
- Production of biodegradable microbeads

  The production of biodegradable microbeads has already been done before via membrane emulsification. It used microcrystalline cellulose from wood pulp as the basic material, yet the species of the wood itself is not explained. The production starts with making stabilized microdroplets of cellulose dissolved in 1-ethyl-3-methylimidazolium acetate solutions in a sunflower oil-Span 80 continuous phase. This phase used a cross-flow membrane emulsification−phase inversion process. Furthermore, the emulsion is coagulated with an antisolvent, producing in the formation of solid and biodegradable cellulose microbeads (Coombs OBrien et al. 2017).
- Biodegradable microbeads test in nature

  The solid biodegradable microbeads are subsequently tested in nature. Here, biodegradable microbeads will be proven whether it will manage to degrade naturally or not.

5. Expectation on biodegradable microbeads

The utilization of extracted cellulose from oil palm empty fruit bunches waste as the raw material is expected to optimize microbeads become biodegradable and environmentally friendly. By replacing polyethylene with cellulose, the use of biodegradable microbeads can minimize the amount of accumulated microplastics in the water. In nature, cellulose will be degraded into its monomers (glucose), while polyethylene is a synthetic polymers, therefore it takes time to be able to degrade.

Whereas microorganims like bacteria can easily colonize microplastics in the water, there is still no strong evidence of potential degradation during colonization (Lobelle and Cunliffe. 2011). Biofilm degradation by microorganisms is subsequently releasing chemical pollutants such as polypropylene and polyethylene, which are generally most toxic. The newly found bacteria, *Ideonella sakaiensis*, has the ability to break down and consume poly(ethylene terephthalate) (PET) as a sole carbon and energy source, yet the ability of this species to survive in different habitats may cause disruptions to particular ecosystems. That is why, careful considerations are needed before releasing *Ideonella sakaiensis* in other habitats for PET breakdown (Yoshida et al. 2016). Hence, biodegradable microbeads will be one of the leading solutions to minimize the number of microplastics in the water.

In addition, looking at number of processes that have to be done to obtain solid biodegradable microbeads, the production of these beads cost lots of money and time. Further research needs to be done to find a better and more efficient way to produce these beads. Hence, the industries would want to use biodegradable microbeads in their products. The implementation of biodegradable microbeads in Indonesia will not only accomplish one goal, but four sustainable development goals at the same time, which are clean water and sanitation, responsible consumption and production, climate change, and also life below water.

6. Conclusion

The presence of microplastic particles can threaten both the aquatic biota and the food chain. Therefore, an innovation is needed to minimize the number of accumulated microplastics, which is making microbeads become biodegradable and environmentally friendly. Biodegradable microbeads are obtained by converting polyethylene to cellulose as the main constituent. The cellulose is extracted from oil palm empty fruit bunches waste because it contains high cellulose concentration. In this case, not only do we reduce the amount of waste, but also reuse and recycle the oil palm empty fruit bunches waste into another material that have more economic value.

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