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Application of waste plastics for efficient flood protection systems

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Abstract: There are about twenty different types of plastic resins that are commonly used in packaging applications, whereby five of them are large-volume polymers, i.e. polyethylene (PE), polypropylene (PP), poly(vinyl chloride) (PVC), polystyrene (PS) and poly(ethylene terephthalate) (PET). Together, these polymers account for around 75% of all plastics demand in Europe and is the largest group of waste deposited on Municipal Solid Waste Landfills (MSW). However, waste storage may cause environmental pollution, and the integration of MSW incinerators with materials recovery is one of the most controversial aspects of waste management. In this article a new idea of plastics waste management, based on the production of composite materials with improved properties for flood protection systems, has been presented.

Keywords: plastics waste management, flood protection systems, composite materials.

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1. Introduction

Plastic is a type of polymeric material which can be molded by pressure or heat. It can be classified as thermoplastic or thermoset. Thermoplastic is a polymer that become soft when heated, that are molded or shaped with pressure when in the plastic state and become hardened when cooled to retain the mold or shape. The process is reversible and it can be repeated, this kind of plastic can be molded again, but then some their physical and chemical properties are going to get worse. Thermoset is a polymer which can't be reprocessed when molded once. The thermosets are infusible solids that decompose on reheating. Thermoplastics are subdivided on a cost-property performance basis into commodity, engineering plastics, advanced polymers, high-heat resistant polymers and others [1, 2]. There are about twenty different types of polymers that are commonly used in packaging applications, whereby five of them are large-volume polymers, i.e. polyethylene (PE), polypropylene (PP), poly(vinyl chloride) (PVC), polystyrene (PS) and poly(ethylene terephthalate) (PET). During the last years, several new families of high performance polymers and engineering plastics have been reported which find enhanced application potential in the more challenging application areas like aerospace, defense, energy, electronics, automotives etc. as compared to the commodity or conventional polymers. Production of large-volume plastics needs special care to protect the environment from pollution, taking into account primarily processing operations, as well as the recycling of used products [3]. The main threat to the environment are the synthesis processes of monomers and their polymerization. The monomers are very reactive compounds, which have high volatility, flammability, toxicity, and often creating an explosive mixture with air. For that reason, when handling in the chemical industry with these compounds, each apparatus must have a number of security features, do not allow to cause an explosion and penetration of these substances into sewage or into the atmosphere. Particularly highly toxic compounds are: acrylonitrile, formaldehyde, amines, vinyl chloride, and phenols. Working with these type of compounds needs special security, and supply personnel in gas masks and special protective clothing in case of emergency. It must also be remembered that the natural environment not only threaten the monomers but also low molecular weight products. It is the belief that only the chemical recycling processes that aim to recover mainly monomers and chemicals from post-consumer plastics for subsequent use as a feedstock for polymer production (i.e. monomer recovery) should be classified as 'material recovery'. As a consequence, when products of a chemical recycling process are mostly used as an alternative fuel in chemical or power plants, such operations should be considered as energy recovery. Powdered polymers create explosive mixtures with air, so in order to their pneumatic transport, an inert gas is used [4]. In the processing of polymers, different types of lead stabilizers additives of poly (vinyl chloride) (PVC) or ammonium stabilizers, antimony trioxide, flame retardants or organophosphorus plasticizers are introduced into polymers. They often have toxic properties and from non-toxic polymers can form plastics with limited range of action. It's important to re-use waste and used plastic products, which are thrown into the forests are very difficult to resorbable by nature and thus pose a huge threat to the environment [4, 5].

2. Discussion

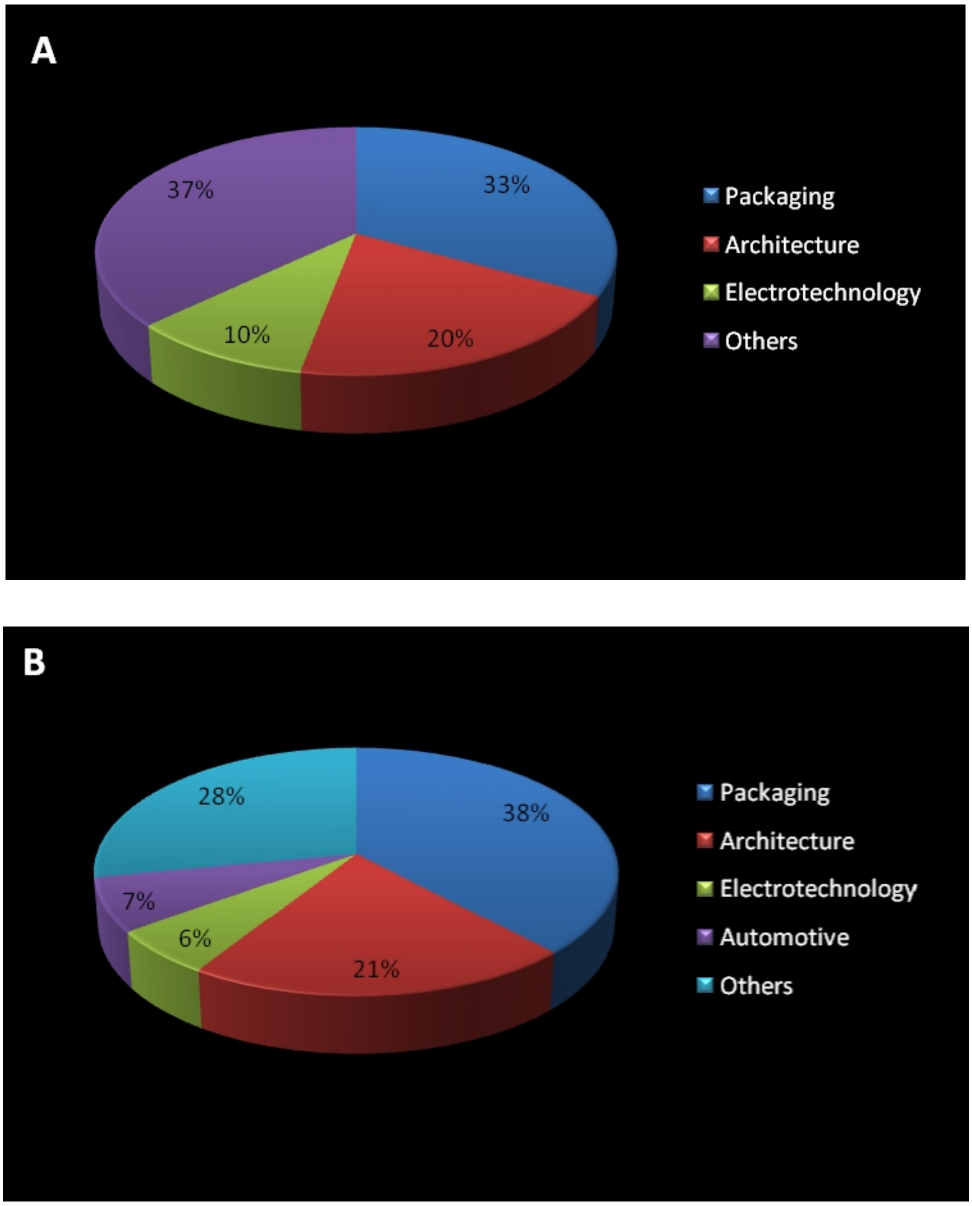
2.1. Problem of waste plastics management in whole world.

The huge development of plastics caused that they play a crucial role in many areas of economy. It's due to increased production of products which generate relatively higher levels of waste and unexpected waste generated by impurities mixed in with raw materials, which goes usually to Municipal Solid Waste Landfills (MSW). Since the production of plastics has in recent years, a growing trend, we can imagine the scale of the problem ourselves. For this reason, in countries with a high degree of industrial development, recycling has been became an important issue [3, 6].

Figure 1. Devastation of forests by human. Photos taken in the Polish forests in the Malopolska province.

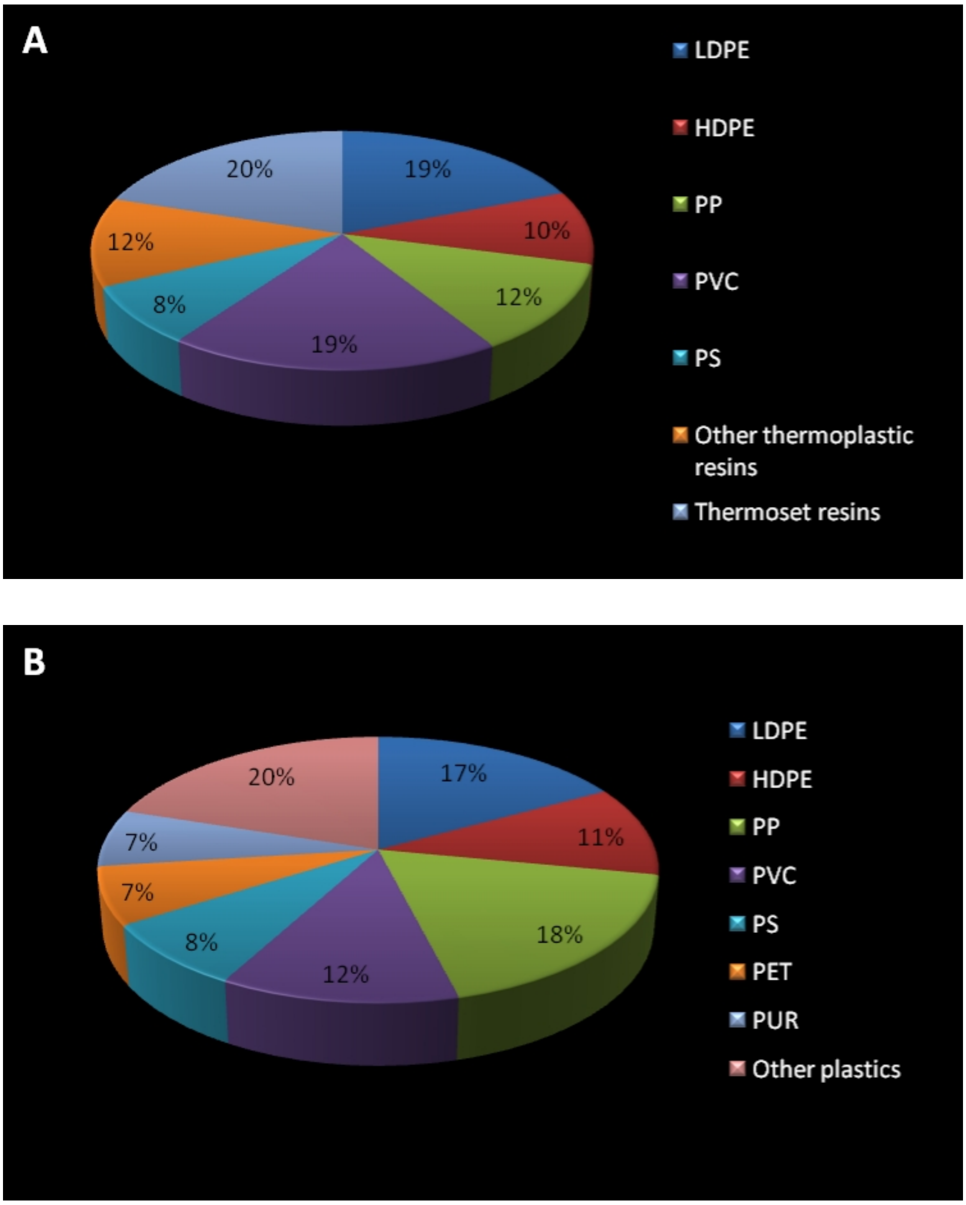
Recycling has become a 'hot topic' nowadays. The various available options (recycling via mechanical, chemical and biological routes) have made recycling more complicated for plastics materials. Originally, only direct polymer recovery and reuse via mechanical recycling were covered by the Directive. For mechanical recycling only thermoplastic materials are of interest, i.e. polymeric materials that may be re-melted and re-processed into products via techniques such as injection moulding or extrusion. Thermosets cannot be reprocessed in this way but may be chemically recycled back to feedstock or used as a carrier (e.g. cement kilns) [1, 2, 7]. Before the european directive's revision various chemical recycling routes, and even energy recovery, were promoted by some organisations in order to be also considered as recycling. In order to protect the environment, policies need support from the wider public, which requires effective communication strategies and an understanding of people's motivations. This is particularly the case since the revised Waste Framework Directive has set a minimum recycling target of 50% for household waste and 70% for building and construction waste, which must be reached by 2020 by all Member States of United Europe for each of the different materials, including plastics [3, 6]. The comparison of plastics consumption in Western Europe and in the whole world have been shown below. Despite the implementation of new methods of recycling, always remains a certain amount of waste, that are not suitable for recycling. Scientists have found some methods of plastic recycling which are working or in the developmental stages for more effective and efficient plastic recycling [1]. An innovative idea of use plastic waste, would be produced a re-polymer composites from them. Polymer composites are materials composed of two phases – organic polymer (continuous phase) and inorganic filler (dispersed phase), obtained mostly as a result of the modification of traditional polymeric materials by dispersing nanoparticulate fillers. As a polymer matrix both thermoplastic and thermosetting polymers can be used. Conventional fillers are materials in the form of particles (e.g. calcium carbonate), fibers (e.g. glass fibers) or plate-shaped particles (e.g. mica). Especially, montmorillonite (MMT) is very interesting filler, which is the main component of bentonite mined in the whole world, including Poland [8-10]. According to scientific reports published in [11-13] polymer – montmorillonite composites, are prepared by incorporating finely dispersed layered silicate materials in a polymer matrix. However, the layers are not easily dispersed in most polymers due to their preferred face to face stacking in agglomerated tactoids. Dispersion of the tactoids into discrete monolayers is further hindered by the intrinsic incompatibility of hydrophilic layered silicates and hydrophobic engineering plastics. Therefore, layered silicates first need to be organically modified to produce polymer–compatible clay (organoclay). Most popular method of surface modification of MMT is cation exchange reaction, where inorganic cations from interlayer space are displaced by organic ones, eg. ammonium or phosphonium cations [8–13].

Figure 2. The comparison of plastics consumption: **(a)** in Western Europe. **(b)** in the world. Adopted from [3, 4, 6].



There are four principal methods for producing polymer – layered silicate composites: intercalation of polymer or pre-polymer from solution, in situ intercalative polymerization, melt intercalation and template synthesis (sol-gel technology). The simplest way to obtain polymer composites is melt intercalation. This technique consists of blending the layered silicate with the polymer matrix in the molten state. Under such conditions – if the layer surfaces are sufficiently compatible with the chosen polymer – the polymer can crawl into the interlayer space and form either an intercalated or an exfoliated composite [8-12]. In general, composite materials, particularly those with exfoliated structures present significant improvements of modulus and strength. Improvements of storage and loss moduli are also reported by many authors. Other interesting characteristics of this class of materials include improved barrier properties, thermal stability and flame retardance. Previous research works were carried out using almost all types of polymers, including biodegradable polymers [5, 8-10, 12]. Therefore, production of re-polymer composites from the plastic waste wouldn't have any technical problems.

Figure 3. Production of various types of plastics: **(a)** in Western Europe. **(b)** in the world. Adopted from [3, 4, 6].



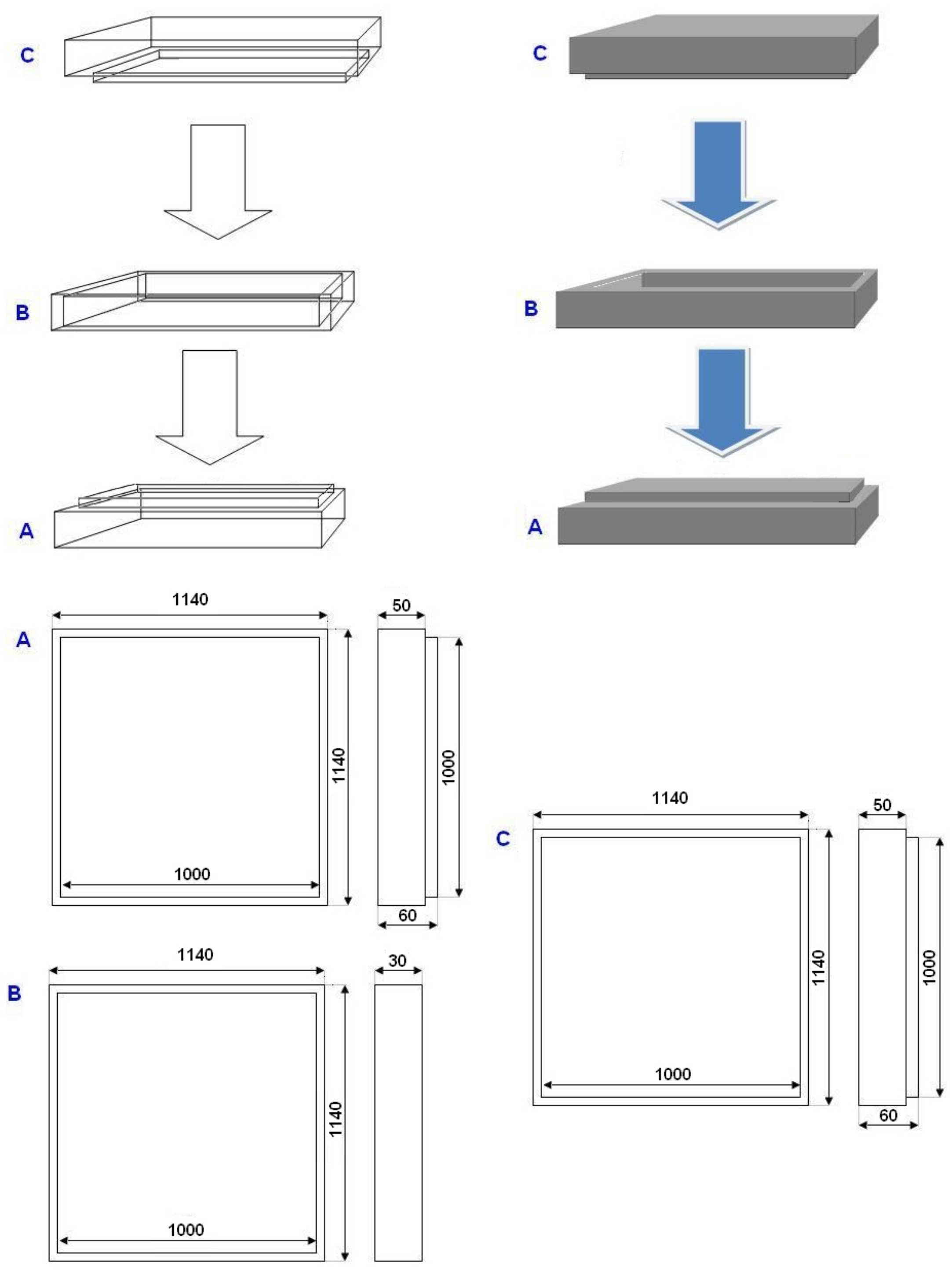
2.2. Preparation of Composite Insulating Materials from Waste Plastics.

The simplest products would be special composite panels with dimensions 1000x1000x100 (mm) produced from waste based on PET. These composite panels could be used as garage entrance ramps or terraces, or as a sealing plate of feed canals and melioration ditches. Flood embankments could, also be lined with these materials, using the barrier effect of Composite Insulating Materials and their aesthetics and ease of molding [14-17]. The production of these materials from PET plastic waste may take place in some related ways. First we need to start collecting plastic waste, that are carried out in factories, in trade, agriculture and in private households, at workplaces and hospitals, too.

Figure 4. Accumulation of plastic waste in Poland. Photo was taken in Tarnow, Poland.

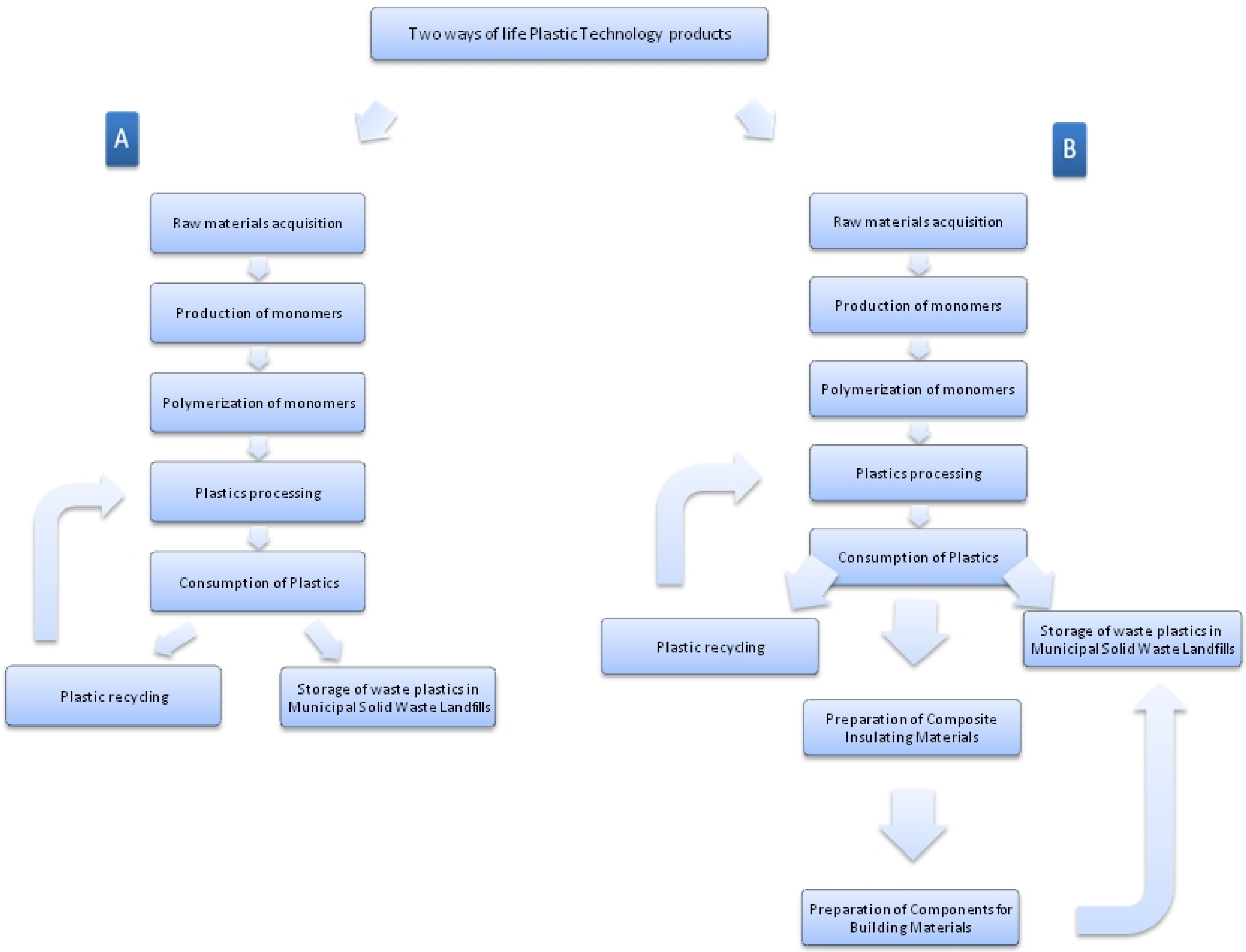
The second step is preparation of plastics waste for further processing including sorting, grinding and shredding, separation of foreign bodies from the plastics, sorting by type and drying. In the next stage, we produce a composite fiber composite from PET plastic waste and layered silicate material, using industrial twin screw extruders, with the specification contained in publications [15-19]. As already mentioned, composite synthesis via polymer melt intercalation involves annealing, usually under shear, of a mixture of polymer and layered silicate above the softening point of the polymer. During annealing, polymer chains diffuse from the bulk polymer melt into the galleries between the silicate layers. The advantages of forming composites by melt processing are quite appealing, rendering this technique a promising new approach that would greatly expand the commercial opportunities for composites technology. If technically possible, melt compounding would be significantly more economical and simpler than in situ polymerization or another methods. It minimizes capital costs because of its compatibility with existing processes. That is, melt processing allows composites to be formulated directly using ordinary compounding devices such as extruders or mixers, without the necessary involvement of resin production. The composite fiber is appropriately granulated (choosing the diameter of the pellets) in granulators [11, 13, 18, 20-23]. From the resulting of composite pellets were obtained that moldings using a press with heated punches. In Figure 5, the scheme of form to obtain Composite Insulating Materials from PET plastic waste, have been shown.

Figure 5. The scheme of form to obtain Composite Insulating Materials from PET plastic waste: **(a)** Bottom panel. **(b)** Middle panel. **(c)** Cover panel.



Of course, the shape of products would be larger and more complicated, depending on the demand for that item. The dye problem could be solved using different types of filler, already having its natural color. For example, colorless polypropylene waste when mixed with nanosilica gives the product a completely snow-white or cream, depending on process conditions [8-12]. Thanks to different colors of objects, composites not only would be used in construction, but also in everyday life, becoming an alternative for products made of pure plastic. But what to do with the dyed waste? The solution is to segregation of these materials depending on their color. Otherwise, we obtain gray, dark brown or black products. This is not a problem if we want to produce composite panels from PET plastic waste, that will be buried under the ground sealing the flood embankments. Dark colors could be dominate in the products made from dark plastic waste, mixed with coal (for example), in the melt. This idea solves the problem of buying expensive pigment and eliminates dye process, thus reducing production time and cost of obtaining the finished product [17-23]. Utilization of Composite Insulating Materials from PET plastic waste after their use, would consist grinding them into powder, and then added to the mortar. These powder could be used to produce materials of concrete and gypsum, if their properties do not get worse. The life of these materials would look like in the Figure 7B and it would be much longer than that which is so far, presented in the Figure 7A. And for sure, with the start of such a project, would appear new ideas for subsequent products that may use plastic waste [7, 14, 16, 21].

Figure 7. The scheme of form to obtain Composite Insulating Materials from PET plastic waste: **(a)** Traditional way. **(b)** New path. Based on [7, 14, 16, 21].



3. Conclusions

The growing scale of the stored plastic waste contributes to the development of new, cheap and simple methods of processing these materials. However, decreased mechanical and thermal properties, and limited color schemes of the treated waste decide to give up from introduction and use them again in everyday life. Therefore, this article presents the concept of waste polymer reuse, that gives a new light for recycling and many new applications. Thanks to this idea we could no longer care about the environment without the need for expansion of overcrowded Municipal Solid Waste Landfills and still be proud of reaching a new level of life, according to sustainable development.

Conflict of Interest

The authors declare no conflict of interest.

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