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Integrated recycling technology

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ABSTRACT

Purpose: In this article, apart from description and analysis of the exemplary technologies of materials recovery, the general recycling model was proposed.
Design/methodology/approach: The proposed model makes possible the identification and second waste processing of various groups of materials on the example of one production plant. The technological process and beginning of the presented model formation waste material and a finish product which is a product or pure raw material necessary to new goods production.
Findings: In this article the analysis of methods and principles connected with the recycling were presented. Several technologies nowadays used in the aim of the raw materials recovery and second waste processing were also presented.
Research limitations/implications: This model is build on the basis of the recycling technological processes with various groups of materials. The only difference is that in the model technologies are connected in total creating the production plant which realizes the whole recirculation process.
Practical implications: Presented in this work the general, universal recycling technology model can be a preamble to starting of many investigations in direction of its practical implication.
Originality/value: The integrated recycling technology model is a new approach to waste management making possible a significant waste reduction and minimization of raw materials usage.
Keywords: Environmental management; Recycling methods; Integrated recycling technology; Integrated recycling technology model

1. Introduction

Recycling is a complex method of environment protection, which aim is the limitation of the raw materials consumption and decrease of waste quantity. It should be a multiple system of the same materials using in the next material and usable goods.

In the literature, there appears many definitions of recycling. Recycling is reprocessing of old materials into new products, with the aims of preventing the waste of potentially useful materials. Another meaning of recycling is taking a product or material at the end of its useful life and turning it into a usable raw material to make another product. In accordance with Act on Waste recycling shall mean recovery which involves re-processing of substances or materials included in waste in the manufacturing process in order to obtain substances or material of original or other designated usage, including also limited recycling, excluding energy recovery [1].

In practice, recycling is often the necessity and it always becomes the only reasonable strategy of the working if consider waste formation in the End of Life phase – EoL [2]. Every product has to be designed, produced, sold, consumed or exploited and every product, after time, doesn't satisfy the needs because of the physical or moral consumption [2, 3]. It becomes waste.

The EoL analysis leads to resources sustainment model. Product recovery as an elongation of product life cycle can concern the whole products, theirs components and materials and raw materials, generally recovered value. The basic possibilities of recovery: reuse, remanufacturing, reclaim, recycling (Fig. 1).

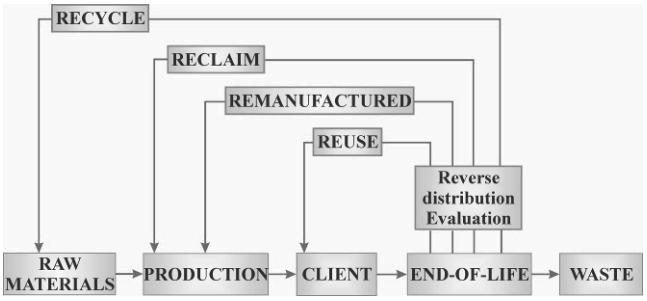

Fig. 1. Schema of EoL recovery system [2]

2. Recycling methods

The most beneficial and durable way of waste problem solution is avoidance of waste formation. The healthy for the environment life style, goods consumption and waste treatment promotes 3R principle.

The first principle (Reduce) reminds about possibility of waste quantity reduction by limitation of unnecessary products consumption.

The second one (Reuse) takes into consideration a possibility of products reuse which are generally recognize as disposable. It decreases environment pollutions scale which are formed during technological process or waste accumulation.

The third principle (Recycle) speaks that not all waste can be avoidance like not all kinds of products can be repeatedly usage.

The recycling stages consist of initial and secondary processes.

To the first one include:

- sorting and separation;
- washing;
- size reduction;
- pressing;
- briquetting and granulation.

The secondary processes consist of [4, 5]:

- composting of solid waste (biological processing);
- combustion and pyrolysis (thermal processing);
- biogas generation (biochemical processing);
- electrochemical metals recovery (electrochemical processing).

Waste processing technologies containing the secondary processes make possible waste utilization on the basis of methods:

- chemical recycling;
- resources recycling;
- thermal recycling;
- material recycling;
- biological recycling.

Chemical recycling is the process of recycling waste products by partially altering their chemical structure with chemical processes for example fuel oil production from plastics, heat-insulating materials production, package production etc.

Resources recycling consists in macromolecule degradation on fractions about molecular lesser mass, for example: hydrolysis, alcoholysis, hydration and pyrolysis methods which can be reused as monomers or resources to the same (or others) chemical products production.

Thermal recycling is used for waste materials assumed to be in the final disposal phase. It involves waste materials combustion using the resultant heat generated as energy. It contains production from these waste liquid, solid and gaseous fuels in the aim of energy recovery [4].

Material recycling is the most available and the most often usage method of recycling. It depends on following direct waste processing in the aim of material obtaining which is full value raw material to the further processing.

Biological recycling contains oxygen treatment even composting of solid waste or oxygen-free treatment of waste which are subject to biodegradation in condition control with microorganism's usage [5]. As a result of this transformation an organic matter or methane are generated.

3. Example of materials recycling

In the practice, there exist many recycling technologies [6, 7, 8]. It depends mainly on kind of material and its complexity.

Recovery and recycling of electric and electronic equipment are developed quite well and recycling systems are organized and realized by individual companies [9]. Recycling of such waste can be divided on the three degrees.

The I degree recycling (Fig. 2) concerns of repairing and renovation in the aim of product reuse. It is a unique case because of waste usually are not suitable to the second circulation.

Recycling of the II degree (Fig. 3) contains disassembly or elements recovery which is suitable to the second usage in the production process.

Sorting and size reduction of components are a part of III degree recycling (Fig. 4). This is a proper recovery. The result of this working is mass of many kinds of fraction from usual metals, through the plastics, gum, wood, glass and many others. The part of materials and raw materials is transferred to final receiver, to the different kind of usage. The small part of them is transferred to render harmless in specialist installations [10].

The reuse of electronic and electric product elongates theirs lifetime, energy and raw materials resources protection which are necessary to new products production. These activities limit in consequence the environment pollution connected with production and energy consumption. The best method of old electronic equipment management (from the point of the environment protection) is these products reuse.

Many electric and electronic companies worked out recycling systems. They are developed very well and include whole Poland area. Unfortunately, there are many things to do. The companies usually deal with recovery of scrap or components and lots of waste are thrown on the scrap-heap (60-80%).

Used packagings are one of the secondary raw materials on which we should pay the special attention mainly because of growing their quantity.

To the end 2002 the waste recovery in Poland covered the material recycling only. It was caused by lack of suitable installations to thermal waste treatment. However the possibility of packagings utilization as an alternative fuel appeared [6].

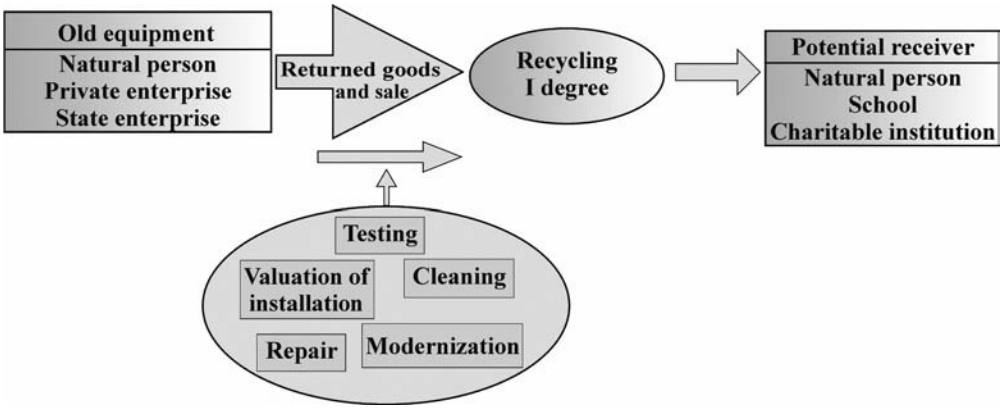

Fig. 2. Schema of WEEE (Waste from Electrical and Electronic Equipment) I degree recycling [10]

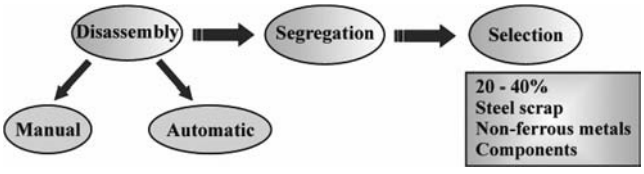

Fig. 3. Schema of WEEE II degree recycling [10]

The recycling of waste paper mainly consists in reversion to original condition waste from paper and the container board. It is realized by material recycling technologies (Fig. 5).

The waste paper for which recovery of all its material features is not possible because of the high degree of damp or soil, it may be usage to compost production (by biological recycling usage). In the last time the interest of fuel production from waste paper grew up. It is because of the high fuel value of waste paper [7].

The used wrapping glass is the comfortable secondary raw material which can be many times recycled (Fig. 6).

The second processing in the glass-works is the most proper direction of cullet utilization The delivered cullet should be clean, without pollutions above 0.5 % mass, sorted according to kinds and colours, devoid of nuts and labels.

The curiosity may be that the recycling 1 Mg of the glass lets save: 603 kg of sand, 196 kg of calcined soda, 196 kg of limestone and 68.5 kg of feldspar. Whereas the production of the new product from the cullet limits e.g.: energy consumption about 25-32% and the air pollution about 14-20%.

The largest cullet recovery is necessary. However doesn't exist organized waste selective collection of this raw material [6].

The waste of plastics are the one of more difficult problems in the whole waste management [11, 12]. The source of these waste formation are: packaging industry, automobile industry, electronic and electrotechnical industry, building engineering and agriculture. Difficulties in procedure with these waste result from: their large volume in the relation to the mass, the large variety of the composition, chemical passivity and indestructibility in spite of ageing.

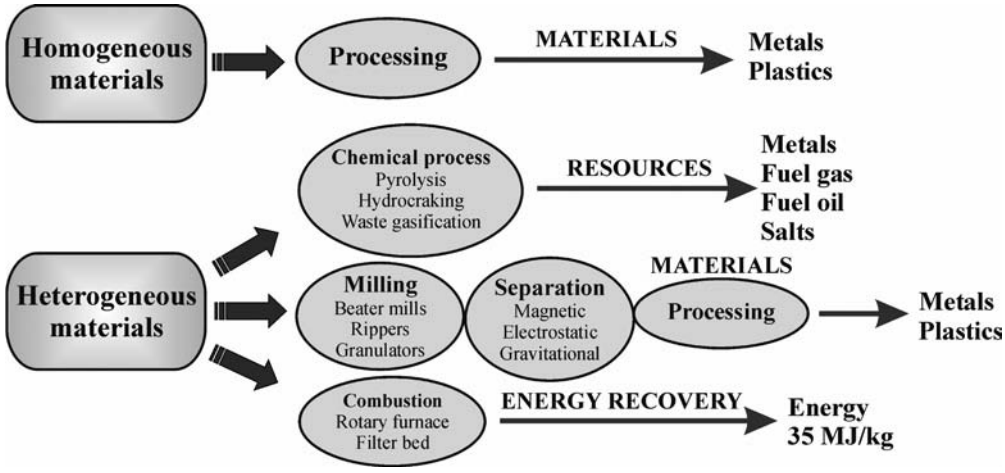

Fig. 4. Schema of WEEE III degree recycling [10]

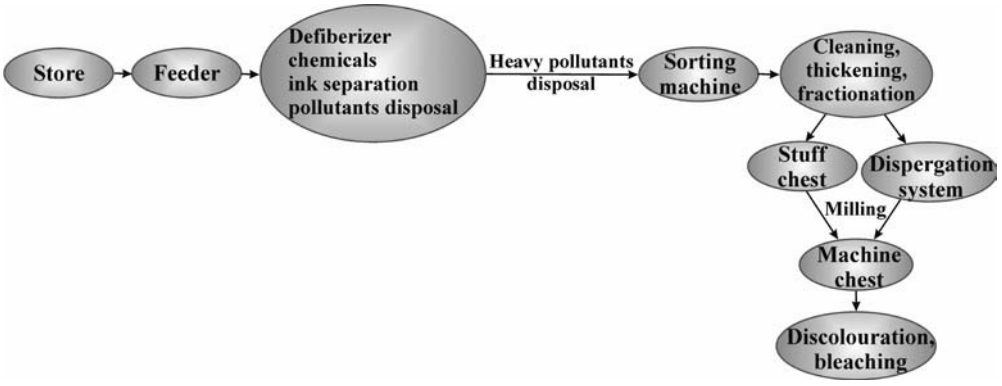

Fig. 5. Schema of waste paper recycling

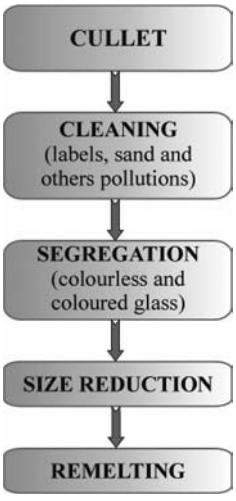

Fig. 6. Schema of cullet recycling

Material recycling (Fig. 7) is the simplest method of the plastics recycling. It consists in recovery from the plastics waste of the clean and full value fractions of polymers about the suitable properties which are suitable to recycle. Obtained products, called recyclate, can be both independent raw materials to new products production and complementary raw materials to material output.

The thermal recycling of plastics consists in destructive conversion of polymers, contained in materials, to the small molecule compounds and their usage as chemical raw materials or fuels. In this aim usage processes: pyrolysis, hydrocracking, gasification and also combustion.

The installations to resources recycling are very complicated and unfortunately expensive. They consist in chemical degradation of polymer to fractions about smaller molecular masses or monomers. This kind of recycling usage because of the high monomer price, first of all to condensation polymers, e.g. PET.

4. Conception of the integrated recycling technology

Experiences in connection with the waste recycling show, that there is no universal method of their processing and removing from a rubbish dump.

None of them guarantees the total waste reduction, and except of recovered products, they generate new waste which second processing required. Owing to waste heterogeneity it is possible processing of their parts only with one method usage. There is no possible to avoid waste in general.

The complex waste management in spite of many advantages (like decreasing waste quantity in rubbish dump, increase of environmental advantages) didn't fulfil expected results. This system is very complicated and it has many specialist devices. It is necessary to sorting carry out.

Increasing waste quantities require the continuous search and using of new technological solutions in the practice. Such methods and technologies which do not require large financial expenditures, are available and do not negative influence on the natural environment are advisable. The integrated recycling technologies usage is the most rational [13].

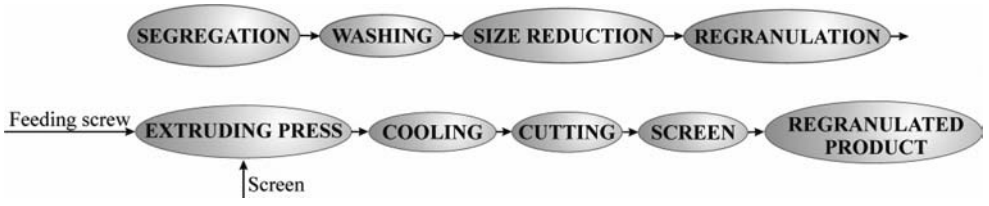

Fig. 7. Schema of plastics material recycling

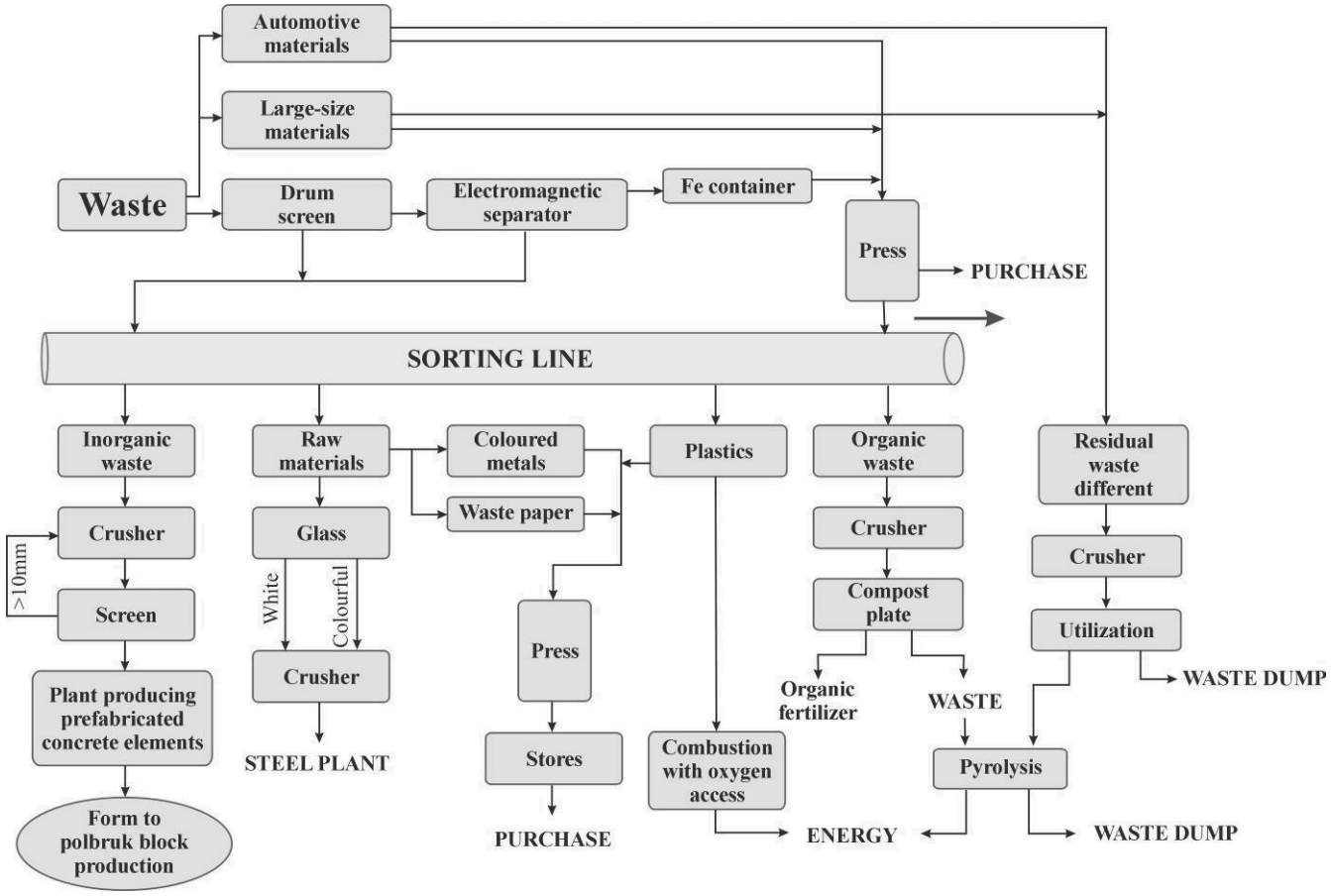

Fig. 8. Schema of the proposed integrated recycling technology model [14]

The "integrated" definition means the connection and adaptation to oneself of elementary technological processes which in the result of the integration of their working create one universal, complex technology, and co-operating with oneself intensified their effectiveness.

The integrated recycling technology has to be so universal to making possible complex processing and waste recovery which do not be selection on useful products early, eliminating the necessity of their deposit in a rubbish dump. It means that the preliminary segregation and separation of waste differing in fractions in this case are useless. Creating such technology should consider factors, which influence on the quantitative and qualitative waste indicators, and especially all ecological requirements and financial conditions. The essence of these assumptions fulfilment is introducing of solutions on the basis of complementarity and elasticity of the integrated recycling technology.

The complementarity consists in many existing method usage. Its aim is one technology creation which characterizes connection of many elementary processes suitable for different recycling technologies.

The elasticity consists in such comparison of technologies and prognostication of theirs development possibilities to adapt the production plant to variable external conditions e.g. waste quality, materials and energy demand, etc.

4.1. Proposed model of the integrated recycling technology

It is necessary to search for new recycling technology solutions because of waste quantity still grow up. Previous solutions have many defects. Some technologies have the only pilotage character. The high cost of recycling and lack of outlets for secondary raw materials are the cause of that.

The conception of the integrated recycling technology requires spacious knowledge concerning of basic raw materials go into composition of mixed waste. The kind and structure of such mixture influence on creation of the technical elementary processes conception and the technical conception of the recycling directly. The improper selection of the technology can contributes to the occurrence of problems connected with raw materials deficiency or dissipates difficult exploitation and production of successive waste. The problem of scale, frequency and popularity of adequate technology usage is the essence.

After the accurate analysis and the comparison of the main recycling technologies applied in the practice, we can distinguish new possibilities and tendencies of future using in the field of waste

management. Basing on recycling techniques and technologies used, their similarities, defects and advantages, and aiming to the largest advantages achievement in relation to economic and ecological area, the model of the integrated recycling technology was designed (Fig. 8) [14]. This technology converts different municipal and industrial waste streams e.g. organic and inorganic waste, glass, waste paper, plastics, coloured metals, etc.

This model characterizes generality, frankness, complementarity and elasticity what means that it can be adapted to various social-economic conditions and does not require earlier waste sorting. It does not generate too high costs (in comparison with expenditures born by particular recycling technologies) and the most important thing - it is ecological and technically practicable. The advantage of this technology is the fact, that in contrast to others recycling technologies, during process carried out additionally do not form others waste, but the useful products. Whereas, to ecological advantages we can include: reduction of waste which are accumulated in the waste dump and maybe their total elimination, decrease of air pollutions and minimization of resources usage. The basic element of exploitation costs is energy which is recovery partially in the recycling process.

The above-mentioned features permit classify the integrated recycling technology model as a future solution taking into consideration necessary investigations and additional improvements.

5. Conclusions

Recycling is a method preventing accumulation the excessive waste quantity through their second processing and utilization in the production process of new materials. Nowadays it is considered as a method developing the most spectrum of the environment protection.

None of actually well-known recycling technologies is ideal and every one of them involves the necessity of additional natural materials utilization which is necessary to the process of the second materials processing.

Many years' discussions relating to finding the ideal recycling technology of all materials groups with the omission of sorting on subgroups seem unsuccessfully. All the time lasts recycling improvement so that it causes the smallest losses of the material and assures the maximization of matter utilization in further production process.

In the work, the general, universal recycling model was proposed. It makes possible the identification and second waste processing of various groups of materials on the example of one production plant. Because of that, the model concentrates many useful devices in this aim.

Construction of the total and universal recycling system is the unusually difficult undertaking. Presented in this article the recycling technology model can be a preamble to starting of these investigations in the direction of waste minimization and resources protection [15].

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