Department of Water and Sewage Management and Waste Technology

Recycling

LABORATORY 2

Topic: SEPARATION, SEGREGATION, SHREDDING

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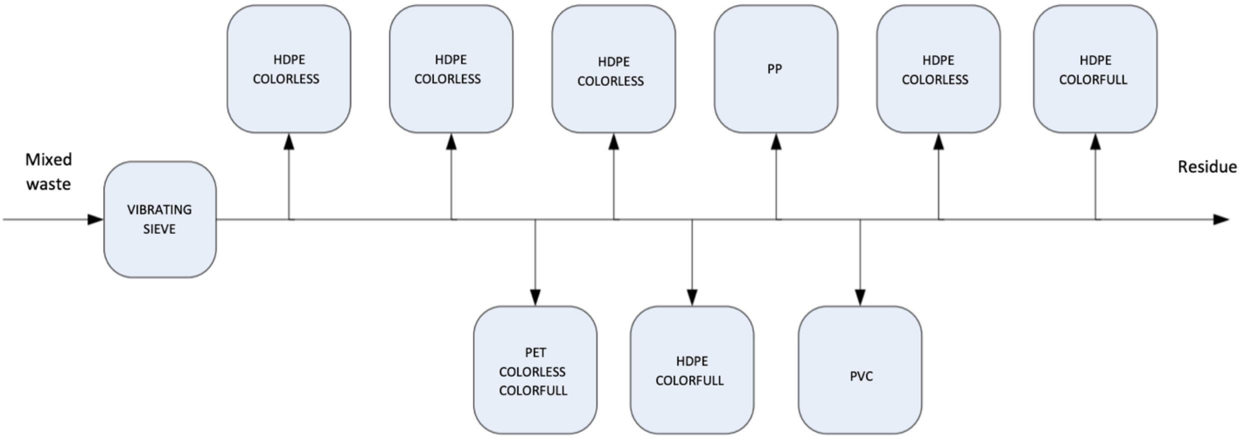
1. Separation of Plastics

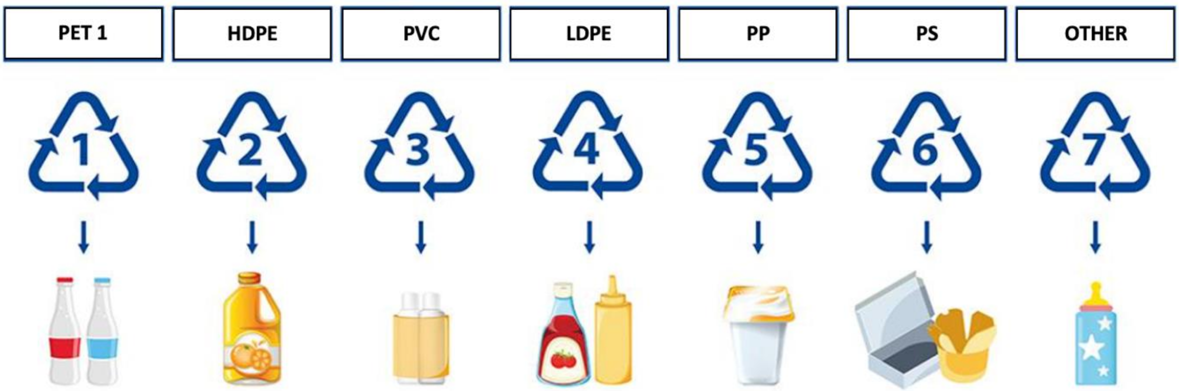
The separation of individual types of plastics from waste streams is a key issue in the context of recycling.

2. Types of Separation Methods:

- **manual sorting** – products must be clearly labeled (Figure 1). Components are manually separated based on the labels (symbols) on the products. The accuracy of this method largely depends on the qualifications of the worker.



Rysunek 1. Schematic of plastic separation during manual sorting [1]



Rysunek 2. Oznaczenia kodowe tworzyw sztucznych [2]

- **automated optical sorting** – sorting lines are equipped with various scanners using X-rays, UV radiation, near-infrared spectroscopy, Raman spectroscopy, optical or thermo-optical properties.
- **electrostatic separation methods –** separation into individual material streams is possible due to differences in the triboelectric properties of polymer plastics. When the mixture components are electrostatically charged through contact and friction, positive and negative charges accumulate on the surfaces of the plastics. In the high-voltage electrostatic field of a plate or roller separator, the charged polymer particles are separated by moving toward the appropriate electrode.
- **separation based on melting point differences –** separation occurs due to the adherence of semi-melted components of the plastic mixture (plastics with lower melting points) to the metal surfaces of the conveyor.
- **methods based on differences in physical properties:**
  - density of plastics (static flotation) – this method uses the hydrophilic and hydrophobic properties of ground mixture components. Sorting centrifuges, hydrocyclones, and pneumatic classifiers are used.
  - polarity,
  - solubility (selective dissolution method) – using a suitable solvent and temperature regulation allows the isolation of a polymer from the mixture through selective dissolution [3].

3. Metal Separator – operating principle:

The all-metal separator (SM) is designed to separate portions of plastic contaminated with metal inclusions before being fed into the plasticizing unit of the processing machine. It is especially useful in recycling processes due to the relatively high contamination levels. The separator can be installed in gravity feed systems directly above the machine's hopper or near shredders. The purpose of the metal separator is to capture metal elements from plastics. Processing temperatures do not allow metals to be plasticized, which could damage processing equipment if not eliminated from the waste stream in time. The laboratory separator consists of a hopper, two nozzles (one for discharging plastics and the other for metals), a sensor, and a shutter (Figure 3). This device operates with the help of compressed air. Plastics in the form of flakes or granules are poured into the hopper. If no metal is present, the plastic passes freely and exits through one of the nozzles. If metal is detected, the sensor triggers the shutter to close, and compressed air blows the metal out through the second nozzle.

Figure 3. Metal separator for ferrous metals

4. Static flotation – "Float-Sink" separation:

This is a gravitational separation method in water with the addition of surfactants. It serves to separate plastics based on their density (the threshold is the density of water, i.e., 1 g/cm³). For example, polycarbonate (ρ = 1.2 g/cm³) and polyethylene (ρ = 0.92 g/cm³). The lighter material floats on the surface, while the heavier one sinks to the bottom (Figure 4).

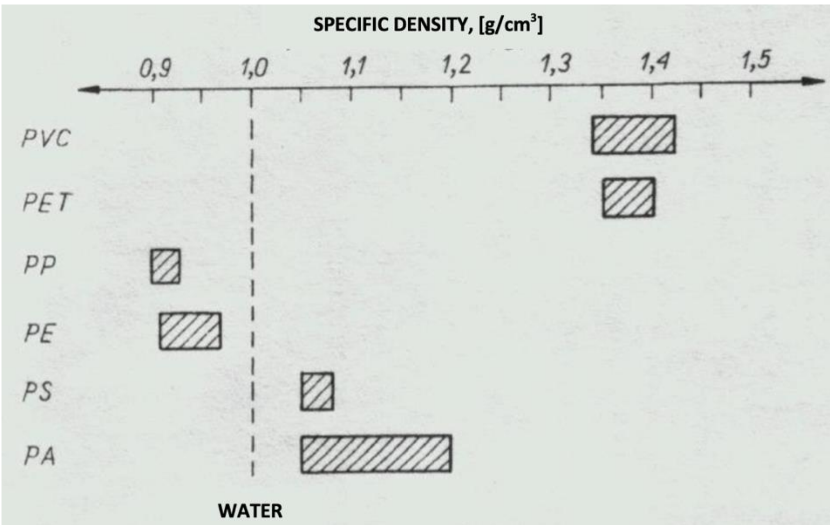


Figure 4. Density comparison of plastics

A separation tank consists of three chambers (Figure 5). In the first chamber, a sieve submerged in water with an additional mixer is installed to preliminarily clean the waste and initiate its separation (1). The next step is transferring the waste to chamber number two, where the actual separation takes place (2). The light fraction is then moved to a centrifuge (3), which removes excess water and transfers the material to a discharge container (4). The heavy fraction, after draining the water, ends up in a separate container (5).

Advantages: simplicity of the device and preliminary cleaning of the separated plastic mixture achieved before grinding and wet milling.

Disadvantages: time-consuming due to long retention times, the need to control the process (including liquid density as temperature changes or water evaporates), ensuring uniform size of mixture components, proper moistening of the plastic to prevent flocculation, low separation efficiency for components with similar densities, and potential contamination of the liquid in the tank by residues such as labels.

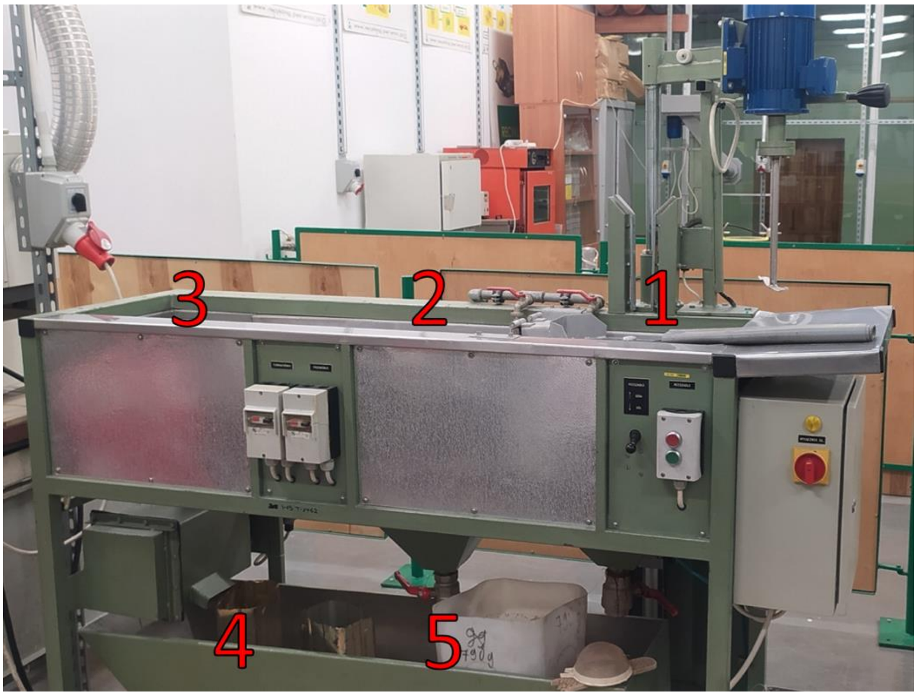


Figure 5. Flotation tank

5. Moisture analyzer

A moisture analyzer is a laboratory device used to determine the relative humidity of small samples of various materials. It consists of two parts: a precision scale and a drying chamber with two halogen heating lamps. The drying temperature (set by the user) is controlled by an automatic regulation system. The moisture analyzer may also include a thermometer to monitor drying temperature or determine the temperature correction factor for the dried material. In many cases, quick moisture determination is essential for quality control in laboratories and research centers directly involved in production. The traditional method of weighing, drying for several hours in an oven, and re-weighing is impractical due to time constraints. A moisture analyzer provides rapid and accurate moisture measurements. The principle of thermogravimetry, which determines weight loss during sample heating, is used in moisture analyzers. The sample is weighed before and after heating, and the weight difference is calculated.

The name comes from a Latin three-part name:

hermo = heat, gravi = weight, meters = method

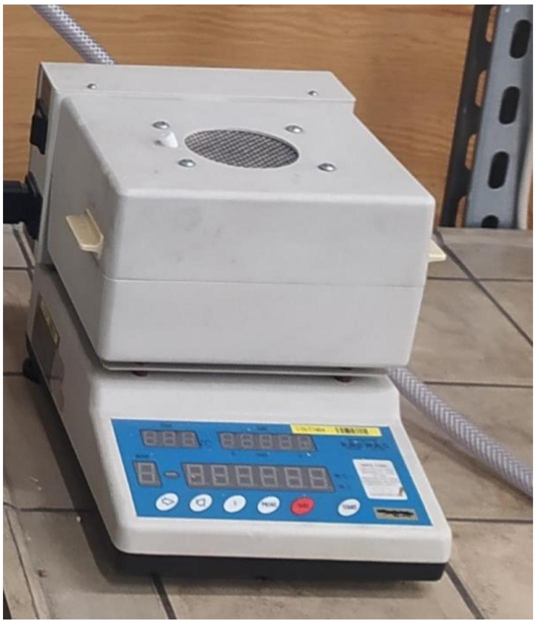


Figure 6. Moisture analyzer

The moisture analyzer consists of a precision laboratory scale and a drying chamber connected to it, ensuring a stable drying temperature during measurement. This design means that the method of measuring relative humidity differs from the method considered traditional.

The essence of a moisture analyzer comes down to:

- weighing the tested sample: before during drying until it is completely dry without having to remove it from the oven,
- automatic end of measurement when the moisture has completely evaporated from the sample (drying to a constant mass) or when the set drying time has elapsed,
- calculation of drying results according to the formula for the adopted method of work,
- transfer of measurement data to a printer or computer when it is necessary to prepare measurement documentation.

What is material moisture?

Material moisture is a set of all components present in the sample that evaporate during its heating. This leads to a loss of mass. Most users do not notice the difference between moisture and water content in the sample. In thermogravimetric methods (including moisture analyzer), all changing components evaporate during the heating of the sample. Therefore, moisture content is not only the evaporation of water but also fats, oils, alcohols, organic solvents, spices and other components that may arise as a result of thermal decomposition (combustion products). The total loss of all components results in a loss of mass. The difference in mass before and after drying allows determining moisture. It is not possible to separate the loss of pure water from the loss of other components.

Methods for determining humidity

There are many methods for determining the moisture content of materials. In general, these methods can be divided into two categories: absolute moisture determination and deductive moisture determination. When using absolute methods, the moisture content is determined directly, e.g. as the ratio of mass before drying to mass after drying. In the case of deductive methods, the moisture content is determined indirectly. Physical properties that are related to moisture in the tested substance are measured (e.g. absorption of electromagnetic radiation or electrical conductivity).

6. Shredding

The primary form of plastics is usually granulate, and for recycled plastics, it is regranulate. This form has many advantages: it is easily divisible and measurable, saves space, and poses no problems in transport or storage. Additionally, during processing, the small granules heat evenly, ensuring the appropriate consistency of the plastic throughout. To transform used, often contaminated, plastic products of various shapes and sizes into clean, homogeneous regranulate, plastic waste must undergo mechanical processing.

The most commonly used devices for mechanical plastic processing are crushers (commonly referred to as shredders) and mills.

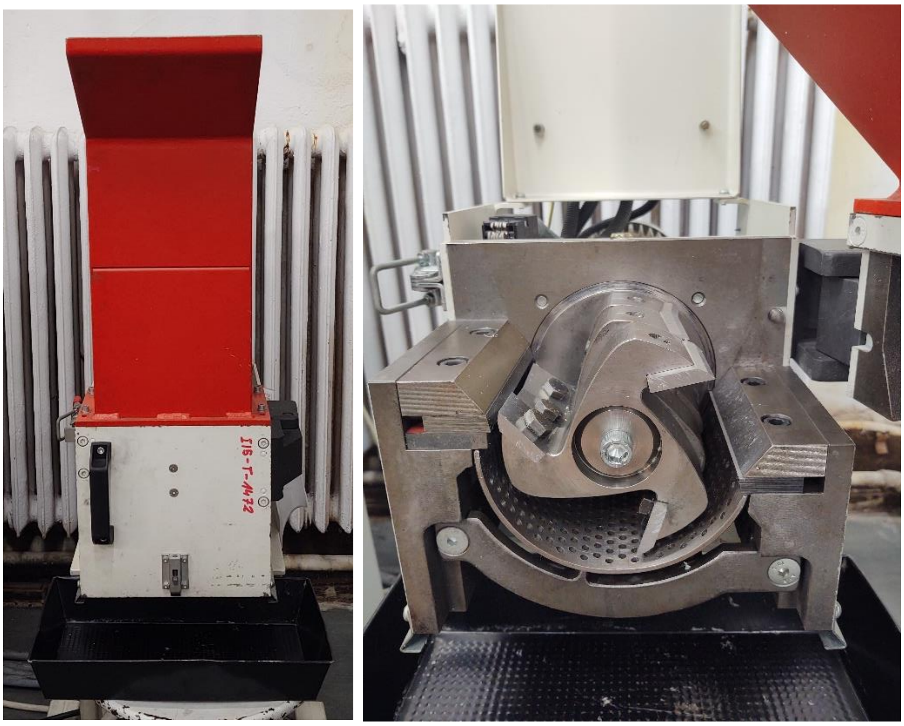


Figure 7. Knife mill

7. References:

[1] Kozłowski M., et al.: "Fundamentals of Plastic Recycling," OWPWr, Wrocław, 1998
[2] www.pajlo.pl
[3] Królikowski K., Piszczek K., Żuk T.: "Separation of Polymer Mixtures with Different Hardness," Chemical Engineering Applications, 2014, 53(2), pp. 91-92