WASTE TREATMENT TECHNIQUES

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ABSTRACT

A characterization of waste materials with regard to their treatment by mineral processing techniques shows that the processes proven in the dressing of mineral raw materials can also be applied to the processing of different waste mixtures. The separation of some wastes can, however, be achieved by the exploitation of property differences which are generally less distinctive for the mineral raw materials. State-of-the-art waste treatment technology is illustrated with selected examples.

KEYWORDS

WASTE TREATMENT, RECYCLING, CLOSED-LOOP ECONOMY, MINERAL PROCESSING TECHNIQUES
INTRODUCTION

The still-growing world population and more importantly the large demand for commodities related to the high living standard in the industrialized countries are resulting in an ever-increasing consumption of raw materials and thus in a flood of waste. Against the background of limited primary resources and also the decreasing availability of suitable waste disposal sites, especially in countries with a high population density, these developments have led to a change of attitude in large sections of the population. Both this recently developed environmental awareness as well as the high costs resulting from an environmentally acceptable disposal of non-reusable waste materials are causing the formerly dominant „throw-away“ attitude to be replaced by the idealized objective of a closed-loop economy.

The closure of material cycles resulting in the lowest possible occurrence of non-reusable wastes and corresponding high savings of primary raw materials is one of the two conditions to be met to achieve sustainable development; the other being the transition to renewable energy supplies. As such, the reuse of wastes is vital for the future of humanity and mandatory for the achievement of the aims set at the Earth Summit in Rio de Janeiro. In such an economy of closed material cycles a central role has to be played by the materials processing technologies. Such technologies are also becoming increasingly important in the preparation of materially non-reusable waste materials prior to incineration or landfilling.

Owing to the increasingly high waste disposal costs (already amounting to 40 to 200 DM/t in Germany) technical preparation processes with the aim of separating valuable materials from waste for recycling purposes are additionally gaining economic incentive. In many cases, not so much the value of the secondary raw materials recovered from waste, but rather the disposal cost savings related to recovery is decisive for the economy of waste treatment.

The high waste disposal costs frequently also justify the application of expensive preparation processes when these enable a clear reduction of the quantity of residual waste not able to be utilized. Often it is possible to significantly reduce the disposal costs of a waste by removing the environmentally harmful components.
It is one of the aims of this paper to demonstrate how the technologies commonly applied in minerals processing can be applied and adapted to the challenges described above. Commencing with a material characterization w.r.t. the applicability of mineral processing techniques, a short overview will be given over some of the newer developments in the field of waste treatment. In addition a number of flowsheets for the treatment of some typical solid wastes will be discussed. The interested reader is referred to a more detailed essay (1).

CHARACTERIZATION OF WASTE MATERIALS WITH REGARD TO THE APPLICABILITY OF MINERALS PROCESSING TECHNIQUES AND PROCESSES

According to information of the Organization for Economic Cooperation and Development (OECD), the total amount of all waste generated in the OECD countries reached about 9 billion tonnes in 1990 (2).

This total quantity can be classified into about 420 million t domestic refuse, almost 1.5 billion t industrial waste and about 7 billion t other waste (including residues from the production of energy, agricultural waste, mining spoil, demolition debris, dredge spoil and sewage sludge) as well as nuclear waste. In view of the danger for man and environment arising from waste, domestic and industrial waste materials as well as nuclear waste are of particular importance.

Many of these waste materials are characterized by a high heterogeneity of material composition. That applies to a particular extent for domestic refuse, in which both organic and inorganic materials are to be found in a great diversity of substances. Also a large number of industrial waste materials, such as light shredder product arising from reprocessing of scrapped cars or building rubble contaminated with domestic refuse as well as wood, insulating materials, plastics and glass, are of highly complex material composition. In comparison, wastes arising from the processing industry are frequently composed only of few materials or groups of materials with only slight fluctuations of their material composition.
As a rule, such waste involves mixtures of substances from which valuable materials can be separated by means of technical processing steps. In addition, some waste materials are composed almost entirely of valuable materials which can be practically completely recycled after separation.

In view of the large number of waste materials of varying composition as well as preparation processes and equipment, a description of the processes utilized would not be possible at this time within the scope of this paper. Prior to presenting some examples of typical applications for technical procedures for waste processing, some features of waste processing in comparison to mineral processing shall first be elucidated.

For treatment and particularly for separation of material systems which reveal a granular structure and for which the various material components differ in those properties which are also utilized in the processing of primary mineral materials, it is clear that in many cases the same processes and equipment can be applied. Thus similar machines to those for primary raw materials are widely used in waste processing for comminution, screening and classifying, but also for sorting. Since these should be known to all processing experts, a description at this stage can be dispensed with.

Many waste materials of mixed composition do, however, differ significantly from the majority of the primary mineral raw materials in a number of their physical properties relevant to the selection of a preparation technology. Apart from the already mentioned heterogeneity w.r.t. material composition the following distinctions should be noted: polyformity, the range of densities and larger differences in the magnetic and electric properties as well as in the optical characteristics. The importance of these waste-specific material properties for processing technology in waste treatment will be dealt with in the next sections. These will also introduce machines and appliances specially suited for the processing of wastes and which have partly been developed for the processing of specific waste materials.
The polyformity of wastes

Polyformity is particularly distinctive in domestic refuse. Particles with a grainy structure occur relatively seldom. Flat-spread particles such as plastic foils, paper and cardboard, and textiles, but also hollow objects such as glass bottles, plastic containers, tin-plate and aluminium tins as well as composite beverage packaging material are, on the other hand, important components of domestic refuse. In addition, the organic component of domestic refuse in particular contains large quantities of fibrous and stalky parts.

It is well-known that the particle shape plays an important role in screening, comminution and sorting processes:

In screening, flat-spread and fibrous parts can easily lead to clogging of screen apertures and thus lead to an impaired screening result. Thus sizing drums and other screening machines which warrant a rearranging of the material being screened have proved suitable for the screening of domestic refuse (3,4,5,6).

For the comminution of flat-spread materials which do not tend to brittle fracture, suitable equipment is based on subjecting the material to shearing stress. Thus size reduction of plastic waste is frequently carried out in rotary cutters while shredders, cutting rollers or scrap shears, depending on thickness, are used successfully for sheet and plate metal. Figures 1 and 2 show in simplified form the principle of operation of a rotary cutter and a cutting roller. In both of these the material to be processed is subjected mainly to shearing.

![Fig. 1: Rotary cutter](image1.png)

![Fig. 2: Cutting roller](image2.png)
In sorting, paper and plastic foils can be separated on the basis of their flat-spread shape with the aid of air classifiers, which are used mainly for classifying when processing mineral raw materials. These are easily separated from a material mixture if they occur in free form. For the separation of a domestic refuse rich in paper and plastics, zigzag air separators (6,7) have proved to be suitable. The principle of operation is shown in Figure 3. The paper/plastics mixtures can be separated into one product with a high paper content and another with a high plastics content by means of a selective comminution stage utilizing the different tensile strengths followed by a screening (sizing) stage.

![Zigzag Air Separator Diagram](image)

**Fig. 3: Zigzag air separator**

The separation of bottles, cylindrical tins and receptacles from paper and plastic foils can take place by utilizing the different rolling properties. The material mixture to be separated is fed onto a sloping surface where only components able to roll move down along the surface.
The density range of waste materials

In contrast to minerals, many waste materials consist, as already mentioned, of a material mixture also containing components of organic origin. Since the density of these materials generally lies around 1 g/cm³ and partially even below this value, the possibility of their separation from inorganic materials mostly of considerably higher density is achieved in a counter-current classifier using water as separating medium.

Density differences can also be exploited for the further separation of the light fraction thus obtained, and particularly for the sorting of plastics into different types. The consideration that floating or sinking can be accelerated by the application of a centrifugal field first led to the use of hydrocyclones for this type of separation (8, 9).

More recently a sorting centrifuge was developed in Germany for the sorting of plastics where high centrifugal accelerations of up to 1500 g enable a separation of mixed plastic waste into different types (10, 11, 12). The principle of this process is shown in the Figure 4. After a preliminary size reduction to a maximum grain size of 8-10 mm, the plastic mixture suspended in a separating liquid is fed through a hollow shaft into a double-cone centrifuge where it flows into a centrifuging water bath. Those particles which are of higher density than the separating liquid sink rapidly due to the action of the centrifugal force, while the plastics of low density float. Since only low flow velocities prevail in the centrifuge, the particle shape only plays a minor role for the separating action. Float and sink products are transferred respectively to the centrifuge ends by screw conveyors, dewatered and discharged in the conical part. A disk fitted to the screw barrel prevents the floats from passing into the zone of the sinks. The separating liquid leaves the centrifuge in the central part through overflow pipes, which keep the level of the liquid constant. By using water as separating medium, a polyethylene/polypropylene mix can be separated at the first cut-point as float product for recycling. In a further separating stage, the use of a NaCl solution with a density of about 1.1 g/cm³ enables polystyrene to be separated as float product. Polyvinyl chloride, polyamide and metals are concentrated in the sink discharge of the second separating stage.
This novel sorting centrifuge is currently being tested on plant-scale in a processing plant and will also be installed in combination with other sorting equipment in a pilot scale plant for the separation of mixed packaging waste.

![Sorting centrifuge diagram](image)

**Fig. 4: Sorting centrifuge**

**The magnetic and electric properties of wastes**

Many waste materials contain metals or alloys of metals suitable for recycling. Iron and ferrous compounds are separated from waste with conventional low-intensity magnetic separators. Owing to their high electric conductivity, however, non-ferrous metals can be separated from waste with high tension separators and lately with eddy-current separators where an alternating magnetic field is generated by a rapidly rotating wheel with pole ring (13, 14) as shown in the following figure (Fig. 5).
Fig 5: Eddy current separator

Here the magnetic field can be generated either by electromagnets or by strong permanent magnets such as iron-boron-neodymium magnets. The magnetic field induces an eddy-current, the magnetic field of which acts in the direction opposite to the primary field. This leads to repelling forces which deflect non-ferrous metals when discharging from the drum, thus enabling a separation from substances which are electrically non-conducting.

A further automatic separation of non-ferrous metals into individual metals and/or alloys of metals is provided by a process based on an analysis by classical atom emission spectroscopy and a subsequent mechanical separation (15).

Optical properties of waste components

Glass differs from most mineral raw materials amongst other properties by its translucence. This property can be used not only for the separation of glass from other materials, but also for the sorting of glasses by color.
Recycled glass is being used to a growing extent for the production of new bottles. This not only reduces the consumption of energy and raw materials, but also the demand for disposal sites. Mixed pieces of green, brown and uncolored glass can only be used for producing green glass. Thus only glass either collected separately or sorted according to colors can be used for production of clear or brown glass. For this reason, glass refuse is nowadays collected separately in many places. In addition, there is basically also the possibility of separating mixed colors of broken glass by using opto-mechanical separating processes. Initially devices with color reflection systems were tested for sorting color mixes of broken glass; these operate similarly to those used in mineral processing (16). Here the color is determined by a comparison of reflected light with the reflection of a colored background at a specified wave length. This method of measurement requires the glass pieces to be free of dirt and labels. Thus it is only possible to use these systems successfully when the glass pieces have been cleaned prior to sorting, for instance in a preceding washing stage or a wet separation process.

For an alternative process based on the translucence of glass, the color is determined by means of transmission measurements (17). Here the characteristic shape of a spectral transmission curve is used as recognition feature for the respective color. The color of a particle can be determined by a simultaneous transmission measurement at two different wavelengths of light and an analysis of the difference of the measured data.

Figure 6 shows a schematic representation of a separator for broken pieces of glass based on this principle. The measurement data from the color sensor is analyzed by a process control system which can actuate a flat-jet air nozzle by means of which the colorless particles accelerated along an inclined channel can be deflected from their direction of fall and be discharged separately.
The frequency of measurement is so high that even particles of only 10 mm particle size can be analyzed at least at 3 points. This enables particles to be recognized which are partly covered with a label. By measuring at two wavelengths and an analysis of the difference, the effect of glass thickness and surface soiling can be largely eliminated. Thus it is possible to separate uncolored glass from a mixture of broken glass without a preceding cleaning treatment.

Ceramic particles and other contaminants which differ from glass due to the missing translucence, can also be detected with transmission measurements and subsequently discharged by means of an air jet in a preceding separating stage.

TREATMENT OF TYPICAL SOLID WASTE MATERIAL BY MEANS OF MINERAL PROCESSING TECHNIQUES

In the past 25 years, technical preparation processes for material separation have been developed for a large number of different waste substances, of which only a part has found application on plant scale. Lacking quality of products, poor marketing prospects, inadequate profits, high costs or a change of objectives in waste management led to many proposed processes not succeeding in the practice. In the following sections the processing fundamentals for preparation shall be briefly
discussed for some typical waste materials such as domestic and packaging refuse, automobile scrap, electronic scrap, battery scrap and contaminated soil.

**Processing of domestic refuse and packaging waste**

Already in the early seventies several processes for domestic refuse had been developed and partly realized on plant scale in the USA. Here the industry mostly fell back upon know-how and experience related to their own field.

Thus the processes for waste processing developed by the US Bureau of Mines and Raytheon & Co. are based on the technology of ore dressing while a wet treatment for recovery of fibrous material from domestic refuse was developed by Black Clawson on the basis of technology for paper production (18).

Also in Europe and in Japan endeavors were made towards the development of processes for the sorting of municipal solid waste (MSW). In the mid-1970s the Department of Mineral Processing of the Aachen University of Technology (RWTH Aachen) developed and tested on pilot-plant scale a process with the aim of separating all valuable materials contained in domestic refuse at high recoveries and a quality suitable for recycling (7).

The experiences gained from this pilot plant were used in the planning and construction of two major refuse processing plants which were successfully operated for many years.

The experiences meanwhile gained throughout the world on the operation of domestic refuse treatment plants have shown that, owing to the strong contamination, only products of low quality can be separated at an economically justifiable cost. Moreover it has become evident that by a separate collection of valuable waste constituents and their subsequent processing considerably purer products can be recovered from MSW.

Apart from the separate collection of glass, paper and organic waste, Germany has therefore recently mandated manufacturers and sales organizations to take back packaging material (19). At
present, the packaging collected by consumers consists predominantly of plastic, metal and composite materials. Tins and other ferrous containers are magnetically separated while the recovery of other non-ferrous metals is achieved with the eddy-current separator. For want of appropriate mechanical sorting technologies the remaining fraction is currently sorted manually on picking belts to recover composite soft-drink cartons and the various plastic materials.

Recently the Institute for Mineral Processing at the Aachen University of Technology commenced work on a project funded by the Federal Ministry for Education, Science, Research and Technology, the aim of which is to demonstrate at pilot-plant scale a fully mechanized process for the separation and recycling of packaging waste. Figure 7 shows a simplified flowsheet for this process.

![Simplified flowsheet of a process for the separation of packaging waste](image)

**Fig 7: Simplified flowsheet of a process for the separation of packaging waste**
In the first separation step of the process, tins and other iron-containing materials are recovered magnetically. The non-magnetic fraction is then fed to a process step in which the paper and cardboard compounds are dissolved. The fibrous suspension is separated and sent to further processing. Non-ferrous metals and other heavy components are removed by use of density separation techniques. The clean plastics are subsequently sent to a comminution stage and then fed to a sorting centrifuge. Here the light polyolefins with a density of less than $1 \text{ g/cm}^3$ are separated in a water bath in the centrifugal field from the heavier plastics with a density exceeding $1 \text{ g/cm}^3$. Metals can then be recovered from the heavier fraction before polyvinyl-chloride is separated electrostatically from polystyrol and any other plastics.

Automobile recycling

Automobile scrap represents an important source of metallic and non-metallic raw materials. According to the latest surveys, the world-wide stock of cars and station wagons amounts to about 420 million. Some further 100 million trucks must be added to this. In all, the total quantity of motor vehicles which exist is estimated at about 550 million. The number of vehicles to be scrapped annually is stated to be more than 30 million (20).

An European compact car, 1978 model, as currently designated for scrapping, is composed of 69 % iron and steel, 10 % plastics, 6.5 % non-ferrous metals, 3.5 % glass and 11 % other materials (21).

The vehicles produced now contain a little less iron and steel, much more plastics, and more lighter non-ferrous metals, primarily aluminium.

The diagram in Figure 8 shows, in simplified form, the process of recycling of scrapped cars. Prior to shredding, recyclable assemblies and parts which can be recycled more economically by other means are dismantled. In addition, some parts and fluids must be removed for reasons of safety and environmental protection. Subsequently, shredding itself takes place. Approximately 600 shredder units are currently in operation throughout the world, where, in addition to scrapped vehicles, light collected scrap and mixed scrap from refrigerators, washing machines and other domestic appliances is processed. Shredders reduce the material to pieces of the size of the palm of a hand or less. A substantial proportion of light product occurs here, which is separated from the heavy
product by air separation. This material consists mainly of fibrous materials from upholstery and covers, thin wires, foamed materials, wood, rubber and plastic particles as well as inert material such as fine glass and dirt. Since these can also contain small quantities of mineral oil residues and polychlorinated biphenyls, disposal without previous thermal treatment has meanwhile become problematic.

Fig. 8: Simplified flowsheet for the recycling of scrapped automobiles
Iron and steel are separated by magnets and sold to the steel industry as high-grade metallic scrap. After removing the fine product of low valuable content from the non-magnetic material by screening, the non-ferrous metals are recovered by applying various sorting processes where primarily differences in density and electric conductivity are used for separation. They are recovered at a purity which allows a recycling as secondary raw material (22). Density separation can take place in counter-current sorting devices for separating non-ferrous metals from non-metals or in heavy medium separators for further separation. The material with a specific gravity below 2.4 basically consists of plastics, rubber and other non-metallic substances. The density fraction of 2.4 to 3.0 g/cm³ contains mainly aluminium as well as glass and stones, and can be purified using the eddy-current separator. Heavy metals with a specific gravity of more than 3.0 can be further sorted by hand-picking.

The present form of automobile recycling only aims at a recovery of metallic materials. In view of the increasing proportion of plastics in automobile production their recovery from automobile scrap will, however, gain importance in the future. It must be noted that currently about 40 different plastic materials are used in automobile production (23). Of these only 6 types account for 90% by weight of the plastics used (24).

These considerations have led to new ground being broken in recent times with the aim - instead of shredding the entire vehicle - to recover a large proportion of the plastics as well as other groups of materials as pure categories by means of a controlled dismantling. This initiative has the support of the automobile industry, amongst others by the provision of dismantling catalogues for a clear identification of plastics and by the design of vehicles better suited for recycling. Meanwhile, some promising pilot projects for the dismantling of scrapped cars have been started (21,25).

**Electronic scrap processing**

The increasing occurrence of waste from electric and electronic products such as domestic appliances, entertainment electronics, office machines for information and communication technology, equipment from measurement and control engineering etc. makes the requirement for an extensive recycling of these products with the aim of sparing environment and resources more and more urgent. Although precious metals contained in electronic components are currently being
recovered as long as this is of economic interest, residual waste is frequently incinerated or disposed on landfill sites for domestic refuse. Recycling of these materials requires a far-going separation into individual materials or groups of materials.

Already several years ago, a process was presented by the US Bureau of Mines which had been developed for sorting electronic scrap after a preceding manual dismantling (26). The sequence of principal operations is shredding, air classification, wire picking, magnetic separation, sizing and finally eddy-current and high-tension separation. By means of this process, the electronic scrap could be classified into an Fe-base fraction, an Al fraction, air classifier lights, and a minus 6 mm non-magnetic metal fraction. A magnetic-hydrostatic separation can be taken into consideration for a further separation of material below 6 mm (27).

However, scrap equipment is currently to a large extent still dismantled by hand and sorted manually according to utilization or disposal requirements (28); thus in some companies, a manual separation takes place, for example, into the fractions:

- Fe/non-ferrous metal scrap
- printed circuit boards
- plugs and plug-in connections
- cables and wires
- picture resp. cathode ray tubes
- plastics
- hazardous material (batteries, capacitors, grease, oil)

Just recently, increased efforts have also been made in Germany to develop appropriate technologies for mechanical processing of electronic scrap; these were also initiated by a planned legislation which is to obligate manufacturers to take back used equipment for recycling. The following figure (Fig. 9) depicts a simplified flowsheet of a process for electronic scrap treatment as it has been implemented by a German company.
After a preliminary manual dismantling of used equipment into their main components, electronic scrap is separated into various concentrates of valuable materials in a series of comminution, sizing and sorting steps.

Although some processes for electronic scrap have been developed in the past years and these have been partially tried and tested, there is still a considerable need for research and development in this field in view of the highly complex composition of the scrap.
Recycling of battery scrap

For many years, lead-acid batteries from motor vehicles have represented an important source for the recovery of lead. In the initial phase of battery recycling, the scrap was generally used directly in primary metallurgical plants, e.g. in a shaft furnace. Here the organic components were inevitably burnt and thus could not be recycled. In addition, it was not possible to obtain separately a crude lead of low antimony content from the paste components and a lead of high antimony content from cell connectors and grids (29).

Therefore, modern plants for battery recycling operate according to process concepts which include a recovery of all components of batteries (30-32).

Figure 10 shows a simplified flowsheet for recycling of battery scrap. The batteries are first fed into a crusher. Acid is released at this stage and can be recycled using appropriate processes. The paste is screened off in a subsequent stage. The lead sulfate in the paste can be converted into lead carbonate by addition of ammonium carbonate, sodium carbonate, or caustic soda. The screen overflow which consists mainly of polypropylene, ebonite, PVC and soft lead is subsequently subjected to multi-stage density separation.

![Simplified flowsheet for recycling of battery scrap](image-url)

**Fig 10: Simplified flowsheet for recycling of battery scrap**
Owing to its low density of about 0.91 g/cm³, the polypropylene floats in the water bath while ebonite and PVC can be separated from the metallic components in a counter-current washer. Polypropylene can be concentrated in downline cleaning stages to a highly pure product with purities in excess of 99.5%. Battery recycling represents an excellent example for closing material cycles using methods taken from mineral processing.

**Decontamination of soils**

In the last 10-15 years, public interest has increasingly focused on the remediation of former industrial sites and in particular, on the decontamination of soils. Spectacular claims for damages and efforts for restructuring entire industrial regions, primarily former locations of mining industry, frequently create the necessity to decontaminate large tracts of soil and ground water. The applied decontamination technologies have experienced an enormous boost in innovation in only a few years, particularly in the Federal Republic of Germany.

Principally a distinction has to be made between mechanical, thermal and biological processes for decontamination of soil. In contrast to thermal and biological processes, the mechanical decontamination of soil neither destroys nor immobilizes the contaminants or the contaminant carriers but only separates them from soil particles in the highest possible concentrated form. Thus they must subsequently be treated or disposed of as hazardous waste.

The state-of-the-art of soil washing technology is characterized by a consistent integration of separation processes as central process steps. Just a simple separation of a contaminated fines fraction is not sufficient for a satisfactory decontamination of highly polluted soils of complex mineral compositions (33).
The processing concept of modern washing plants basically involves, as can be seen from the simplified process flowsheet (Fig. 11), the steps soil liberation, sizing, density separation, flotation and dewatering. Analogous to mineral processing, the process step of contaminant liberation is of
particular importance since here the soil is prepared for subsequent separation stages. As a rule, this is achieved by attrition in suitable equipment with two process objectives being aimed at (34):

1. destroying soil agglomerates and suspending the soil components; and
2. cleaning contaminated particle surfaces.

Since the control objectives for the attrition can differ depending on the type of contaminant, the particle structure of the soil and the subsequent separation process, a two-stage attrition is frequently provided to enable optimum adjustment. The application of surfactants as washing aid for cleaning the particle surface is possible here but not always necessary.

Organic contaminants possess a distinctly high affinity to organic soil components of low specific gravity such as coal, wood, coke etc. and are thus able to be concentrated in the light product by means of density separation. Jigs are used for medium and coarse particle size ranges, while spiral separators and, with suitable pretreatment of the feed, elutriators are suitable for finer sizes.

Contaminants and contaminant carriers can only be separated from superfine particulates (<0.1 mm) by means of flotation processes. Owing to the changing surface properties of contaminated and clean particles, process control and reagent regime of flotation must be specially adapted to each soil. Consequently, a great demand for research and development will arise in this field in the coming years.

CONCLUSION

The treatment of waste and scrap by means of mineral processing technology has continued to gain importance in the past years. The most important objective of such a treatment is the recovery of recyclable products by separation of waste mostly of heterogeneous composition, into individual reusable materials and groups of materials, with the simultaneous separation of non-utilizable, interfering or contaminant-bearing components.

As applies to the processing of primary raw materials, differences in density, magnetic susceptibility, electric conductivity, wettability, stability and color can be applied to waste
processing. Accordingly, the preparation processes and equipment used will frequently correspond to those also used for processing of primary raw material.

In addition, for some waste materials there is a possibility of using other properties for separation such as the flat-spread particle shape of paper and plastic foils, the rolling ability of bottles and vessels, the transparency of glass or also the high electric conductivity of metals contained in the waste. A number of novel separating techniques developed in the last few years are based on these; some of them have been presented here.

The elucidation of the state-of-the-art technology for treatment of typical solid waste by means of processes based on mineral technology makes clear that a considerable development potential exists in many areas of waste technology. This applies particularly to the processing of synthetic materials such as plastics and electronic scrap, to the treatment of numerous industrial waste materials, and also to the extremely important field of soil decontamination.
REFERENCES


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