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WASTE MINIMIZATION BY REUSE AND RECYCLING

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ABSTRACT

Recently, pollution prevention directs attention towards the elimination or reduction of undesired by- products within the production process itself before treatment. On the long term, pollution prevention through waste minimization and cleaner production is more cost-effective and environmentally sound than traditional pollution control methods.

The objective of this work was to carry out a feasibility study to define and implement an integrated pollution prevention and control measure in order to minimize waste and therefore to achieve compliance with the Romanian Environmental law.

KEYWORDS: pollution prevention, waste minimization

1. Introduction. Solid wastes

Waste is defined as any losses produced by activities that generate direct or indirect costs but do not add any value to the product from the point of view of the client (Formoso et al., 1999). Symonds Group Ltd, ARGUS, COWI and PRC Bouwcentrum (1999) define waste as any substance or object which the holder intends or is required to discard.

According to the Directive 2008/98/EC of the European Parliament and of the Council of 19 November 2008 on waste and repealing certain Directives:

1. „waste" means any substance or object which the holder discards or intends or is required to discard;

2. „hazardous waste" means waste which displays one or more of the hazardous properties listed in Annex III;

3. „waste oils" means any mineral or synthetic lubrication or industrial oils which have become unfit for the use for which they were originally intended, such as used combustion engine oils and gearbox oils, lubricating oils, oils for turbines and hydraulic oils;

4. „bio-waste" means biodegradable garden and park waste, food and kitchen waste from households, restaurants, caterers and retail premises and comparable waste from food processing plants;

5. „waste producer" means anyone whose activities produce waste (original waste producer) or anyone who carries out pre-processing, mixing or other operations resulting in a change in the nature or composition of this waste;

6. „waste holder" means the waste producer or the natural or legal person who is in possession of the waste;

7. „dealer" means any undertaking which acts in the role of principal to purchase and subsequently sell waste, including such dealers who do not take physical possession of the waste;

8. „broker" means any undertaking arranging the recovery or disposal of waste on behalf of others, including such brokers who do not take physical possession of the waste;

9. „waste management" means the collection, transport, recovery and disposal of waste, including the supervision of such operations and the after-care of disposal sites, and including actions taken as a dealer or broker;

10. „collection" means the gathering of waste, including the preliminary sorting and preliminary storage of waste for the purposes of transport to a waste treatment facility;

11. „separate collection" means the collection where a waste stream is kept separately by type and nature so as to facilitate a specific treatment;

12. „prevention" means measures taken before a substance, material or product has become waste, that reduce:

(a) the quantity of waste, including through the re-use of products or the extension of the life span of products;

(b) the adverse impacts of the generated waste on the environment and human health; or

(c) the content of harmful substances in materials and products;

13. „re-use" means any operation by which products or components that are not waste are used again for the same purpose for which they were conceived;

14. „treatment" means recovery or disposal operations, including preparation prior to recovery or disposal;

15. „recovery" means any operation the principal result of which is waste serving a useful purpose by replacing other materials which would otherwise have been used to fulfill a particular function, or waste being prepared to fulfill that function, in the plant or in the wider economy. Annex II sets out a non-exhaustive list of recovery operations;

16. „preparing for re-use" means checking, cleaning or repairing recovery operations, by which products or components of products that have become waste are prepared so that they can be re-used without any other pre-processing;

17. „recycling" means any recovery operation by which waste materials are reprocessed into products, materials or substances whether for the original or other purposes. It includes the reprocessing of organic material but does not include energy recovery and the reprocessing into materials that are to be used as fuels or for backfilling operations;

18. „regeneration of waste oils" means any recycling operation whereby base oils can be produced by refining waste oils, in particular by removing the contaminants, the oxidation products and the additives contained in such oils;

19. „disposal" means any operation which is not recovery even where the operation has as a secondary consequence the reclamation of substances or energy. Annex I sets out a non-exhaustive list of disposal operations;

20. „best available techniques" means best available techniques as defined in Article 2(11) of Directive 96/61/EC.

2. The waste management hierarchy

Presently, waste management represents one of the most important issues for the sustainable development of all Countries in the world, in particular for the most industrialized ones. UE directed a considerable effort to steer a management strategy which could allow all States to consider waste as a resource, whose recovery can save much raw materials and energy.

A comprehensive knowledge, in a life cycle perspective, of waste management, not only municipal but also deriving from agricultural and industrial activities, is required at all levels, since the problem is closely related to all three dimensions of sustainable development: economical, social, environmental.

There are different ways of waste management in order to minimize risk to public health and the environment. For a long time, waste management was conducted in a divided and relatively unplanned way. Experience has shown that a more sustainable resource use and waste management is required. The step towards the integrated approach to waste management was done in 1962, when this approach has been described as treating the problem as a whole interconnected system operations and functions. Recognizing the complexity of management practices and the acceptance of waste that mathematical modeling and analysis systems are needed to optimize operations management was the fundamental step towards the concept of integrated waste management.

Recognizing that the implementation of integrated management systems must be different from case to case occurred in 1978 when the Environmental Protection Agency in the U.S. stated that "methods of waste management equipment and practices should not be the same throughout the country as long as conditions vary and it is vital that procedures vary to meet". This was the transition from a hierarchical approach to waste management approach which is more flexible in application.

In 1991, a working group of the European Economic Community has published a draft regional strategy for integrated waste management that defines the integrated waste management as a process of changes, where the concept of waste management is gradually expanded to include the possible need to control the flow of gas, liquid and solid materials from the human environment. Thus, the concept of integrated waste management includes all types of waste, the option of using a range of treatment technologies depending on the situation. Also in the same period has developed the concept of sustainable development as "development which aims to present needs without compromising the ability of future generations to meet their needs". The Brundtland Report of the World Commission for Environment and Development (WCED) entitled "Our Common Future" clearly emphasizes that sustainable development can only be achieved if society in general and industry in particular have learned to produce "more from less", more goods and services with fewer resources (including energy) and less pollution and wastes.

The integrated waste management systems combine waste streams, waste collection, methods of treatment and disposal in a waste management system that aims at sustainable development, economic and social efforts acceptable to any specific region. This is achieved through a combination of options for waste management including waste reduction, reuse, recycling, composting, anaerobic fermentation (biogazification), thermal treatment and landfill (Figure 1). It is vital neither how many options for waste management are used, nor if they are used at the same time but how they are combined in an optimal way as part of an integrated approach. The integrated waste management considers the entire system and finds the best combination of methods to minimize costs and maximize environmental and social benefit.

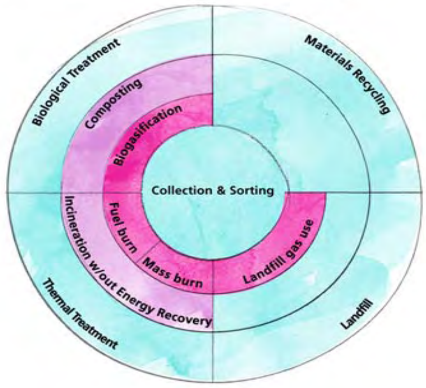

Fig. 1. *The elements of integrated waste.*

The principles of the integrated waste management are:

• integrated waste management makes it possible that the decisions to be based on the best practices and transparent costs. The lower amount of waste produced the incumbent generators costs of waste are lower. This provides incentives for the users to reduce the amount of waste they generate;

• integrated waste management takes into consideration all options (collection, recycling, composting, anaerobic fermentation, thermal treatment with heat recovery and landfill) for the whole flow of the solid waste;

• dividing responsibilities. Manufacturers, distributors, merchants and consumers have the responsibility to support integrated management of waste. Each group is responsible for properly managing the waste they produce;

• are considered three criteria: the action on the environment, economic efficiency and social acceptability;

• flexible application to different communities and regions;

• transparent costs for waste management;

• recovery and recycling-oriented market;

• continuous evaluation for accommodation to changes in quantity and quality of the waste stream.

Integrated waste management is a concept that has different local applications and which depends on many variables such as composition of the waste flow, infrastructure, markets for recyclable materials, budget, legislation and local availability of land for storage. Integrated Waste Management is seeking the best options for waste management with emphasis on evaluation of all available strategies to provide more sustainable systems.

3. European policies for waste management

Every year, some 2 billion tones of waste - including particularly hazardous waste - are produced in the Member States, and this figure is rising steadily.

Stockpiling waste is not a viable solution and destroying it is unsatisfactory due to the resulting emissions and highly concentrated, polluting residues.

The best solution is, as always, to prevent the production of such waste, reintroducing it into the product cycle by recycling its components where there are ecologically and economically viable methods of doing so.

The EU has a framework for coordinating waste management in the Member States in order to limit the generation of waste and to optimise the organisation of waste treatment and disposal.

The main European legislative instruments are:

• Council Directive 75/439/EEC of 16 June 1975 on the disposal of waste oils;

• Council Directive 78/176/EEC of 20 February 1978 on waste from the titanium dioxide industry;

• Council Directive 82/883/EEC of 3 December 1982 on procedures for the surveillance and monitoring of environments concerned by waste from the titanium dioxide industry;

• Council Directive 86/278/EEC of 12 June 1986 on the protection of the environment, and in particular of the soil, when sewage sludge is used in agriculture;

• Council Directive 91/689/EEC of 12 December 1991 on hazardous waste;

• Council Directive 92/112/EEC of 15 December 1992 on procedures for harmonizing the programmes for the reduction and eventual elimination of pollution caused by waste from the titanium dioxide industry;

• European Parliament and Council Directive 94/62/EC of 20 December 1994 on packaging and packaging waste;

• Council Directive 96/59/EC of 16 September 1996 on the disposal of polychlorinated biphenyls and polychlorinated terphenyls (PCB/PCT);

• Council Directive 1999/31/EC of 26 April 1999 on the landfill of waste;

• 2000/532/EC: Commission Decision of 3 May 2000 replacing Decision 94/3/EC establishing a list of wastes pursuant to Article 1(a) of Council Directive 75/442/EEC on waste and Council Decision 94/904/EC establishing a list of hazardous waste pursuant to Article 1(4) of Council Directive 91/689/EEC on hazardous waste (notified under document number C(2000) 1147) (Text with EEA relevance);

• Directive 2000/53/EC of the European Parliament and of the Council of 18 September 2000 on end-of life vehicles - Commission Statements;

• Directive 2000/59/EC of the European Parliament and of the Council of 27 November 2000 on port reception facilities for ship-generated waste and cargo residues - Commission declaration;

• Directive 2000/76/EC of the European Parliament and of the Council of 4 December 2000 on the incineration of waste;

• Directive 2002/95/EC of the European Parliament and of the Council of 27 January 2003 on the restriction of the use of certain hazardous substances in electrical and electronic equipment;

• Directive 2002/96/EC of the European Parliament and of the Council of 27 January 2003 on waste electrical and electronic equipment (WEEE) - Joint declaration of the European Parliament, the Council and the Commission relating to Article 9;

• Regulation (EC) No 2150/2002 of the European Parliament and of the Council of 25 November 2002 on waste statistics (Text with EEA relevance);

• 2003/33/EC: Council Decision of 19 December 2002 establishing criteria and procedures for the acceptance of waste at landfills pursuant to Article 16 of and Annex II to Directive 1999/31/EC;

• 2005/270/EC: Commission Decision of 22 March 2005 establishing the formats relating to the database system pursuant to Directive 94/62/EC of the European Parliament and of the Council on packaging and packaging waste (notified under document number C(2005) 854) (Text with EEA relevance);

• Commission Regulation (EC) No 1418/2007 of 29 November 2007 concerning the export for recovery of certain waste listed in Annex III or IIIA to Regulation (EC) No 1013/2006 of the European Parliament and of the Council to certain countries to which the OECD Decision on the control of transboundary movements of wastes does not apply (Text with EEA relevance);

• 2008/312/Euratom: Commission Decision of 5 March 2008 establishing the standard document for the supervision and control of shipments of radioactive waste and spent fuel referred to in Council Directive 2006/117/Euratom (notified under document number C(2008) 793);

• Directive 2008/1/EC of the European Parliament and of the Council of 15 January 2008 concerning integrated pollution prevention and control (Codified version) (Text with EEA relevance);

• Commission Regulation (EC) No 669/2008 of 15 July 2008 on completing Annex IC of Regulation (EC) No 1013/2006 of the European Parliament and of the Council on shipments of waste (Text with EEA relevance).

4. Minimization and use of grit waste from surface cleaning operations - Case study

In Romania, as in other countries, the impact of waste on the environment has increased alarmingly in recent years, its inadequate management generating soil and groundwater contamination, as well as emissions of methane, carbon dioxide and toxic gases, with direct effects on health population. Facilities for landfill have reached saturation and finding new ones has become a big problem.

The industrial waste management consists of recovery, storage, landfill or incineration. In Romania the share of these options is approximately the same each year, namely: storage, 81%, 15% recovery, temporary storage 3.3% and incineration 0.7%. Since over 80% of the generated waste is stored, in the years has accumulated a large amount of smaller and powdery wastes. Also, total deposits of industrial waste, at least 50% do not have any arrangement for environmental protection; very few deposits have specific arrangements, but do not meet all the European conditions necessary for the environment protection.

For Romania, waste recycling is a priority strategy for sustainable development for the following reasons:

- natural resources for some raw materials are insufficient or poor. The industrial working of poor resources are uncompetitive, the import of raw materials can not be done but within the limit allowed by current account balance;

- to complement the resources through waste recycling can be achieved with lower costs as a result of significant saving in energy, water, other materials, labour and significant reductions in pollution and mining waste, compared with extracting useful substances from ore [14].

In Table 1 are presented some benefits of recycling ferrous, nonferrous and non-metallic materials reported to energy consumption and water reduction, pollution and amount of waste reduction.

Table 1. *Advantages of the materials recycling*

Recycled material	Consumption reduction [%]		Pollution reduction [%]		mining waste reduction
	energy	water	air pollution	water pollution	
Steel	47-74	40	85	76	97
Aluminium	90-97	8-10	95	97	10-12
Paper	23-74	58	74	35	-
Glass	4-32	50	20	-	80

Considering that a healthy environment is essential to ensure the prosperity and quality of life and the reality that the costs and damages caused by pollution and climate change are considerable, policies that are promoted in Romania follow the implementation of concept for economical growth by promoting *eco-efficiency* (which also includes waste capitalization by reintroducing them into the economic circuit), by interpretation of high standards for environmental protection and by creating new markets and business opportunities.

Stephan Schmidheiny with the Business Council for Sustainable Development (BCSD) have written the book "*Changing Course"* with the aim to change the perception of industry as being part of the problem of environmental degradation to the reality of its becoming part – a key part – of the solution for sustainability and global development [20].

The book sought to develop a concept that, by marrying environmental and economic improvements, would make a business out of the challenge of sustainability. That concept was *eco-efficiency*. "*Changing Course"* defined eco-efficient companies as those which create ever more useful products and services – in other words, which add more value – while continuously reducing their consumption of resources and their pollution [20].

Eco-efficiency is a management philosophy which encourages business to search for environmental improvements that yield parallel economic benefits. It focuses on business opportunities and allows companies to become more environmentally responsible and more profitable. It fosters innovation and therefore growth and competitiveness.

As defined by the WBCSD: *Eco-efficiency* is achieved by the delivery of competitively-priced goods and services that satisfy human needs and bring quality of life, while progressively reducing ecological impacts and resource intensity throughout the life-cycle to a level at least in line with the earth's estimated carrying capacity. In short, it is concerned with creating more value with less impact [20].

The eco-efficiency is not limited simply to making incremental efficiency improvements in existing practices and habits. It should stimulate creativity and innovation in the search for new ways of doing things.

Eco-efficiency calls for businesses to achieve more value from lower inputs of materials and energy and with reduced emissions. It applies throughout a company – to marketing and product development as much as to manufacturing or distribution. It is concerned with three broad objectives:

- **Reducing the consumption of resources:** This includes minimizing the use of energy, materials, water and land, enhancing recyclability and product durability, and closing material loops;

- **Reducing the impact on nature:** This includes minimizing air emissions, water discharges, waste disposal and the dispersion of toxic substances, as well as fostering the sustainable use of renewable resources;

- **Increasing product or service value:** This means providing more benefits to customers through product functionality, flexibility and modularity, providing additional services and focusing on selling the functional needs that customers actually want. This raises the possibility of the customer receiving the same functional need with fewer materials and less resources.

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4.1. Case study

Currently, the naval and metallurgical industry in Romania give considerable amounts of waste resulting from the technological operations of cleaning metal surfaces with various abrasive materials. After several cycles of use in blasting operations, the material used consisting of mixtures of metal shot, grit made of iron or steel and sand loses its abrasive properties, entering into the category of waste. Grit fractions of waste material can be recycled and used in other applications. The grit with spherical form is produced from steel wire cold drawn with average carbon content, or from stainless steel, with several degrees of roundness, according to standards.

These wastes are stored on the ground creating environmental problems. Since there is still not a technology, the recovery of fractions separated from waste material is insignificant. It is therefore necessary to improve the efficiency of separation of metal components, and non-metallic fraction of paint that enriches the material used in the process of cleaning the metal surface. This required a detailed analysis of chemical, physical and granular characteristics of the material separated from the waste so that it can find the fulfilment of specific technical conditions imposed by the applications for materials capitalization.

Compared with the practice and trends manifested in the world, naval and metallurgical industry recorded deficiencies both in the collection, transport and storage of all categories of waste, as well as the technology of recovery by recycling and/or reutilization.

The „Dunarea de Jos" University of Galati conducted in collaboration with university centres with prestigious activity in the field of waste recovery and materials study (Pannon University from Hungary, University of Bologna from Italy) analyses on waste samples. In the cleaning operations of metal surfaces of new or repaired ships are used mixtures of metal shot, grit (made of iron or steel) and natural sand (derived from natural or artificial crushing of rocks).

The researches undertaken by „Dunarea de Jos" University of Galati aim at finding solutions to obtain new products, partial replacement of cement or fine aggregate in concrete or mortar. In looking for ways to use the waste resulting from cleaning process, the proposed solution could be to implement the technology of stabilized mixtures (granular aggregate with binders using treated waste asserted), following the example of Europe. In the study were compared the analysis of chemical composition of analyzed wastes with standard bulletins of classical materials used in the manufacture of cement and of building materials.

This required study of the waste materials with advanced methods of analysis to identify the chemical composition, mineralogical and phase composition at the micro and macrostructure.

Determining the elements of waste material composition was performed using Energy dispersive x-ray spectrometry technique. The energy dispersive X-ray spectroscopy (EDS, EDX or EDXRF) is an analytical technique used for the elemental analysis or chemical characterization of a sample. It relies on the investigation of a sample through interactions between electromagnetic radiation and matter, analyzing x-rays emitted by the matter in response to being hit with charged particles. Its characterization capabilities are due in large part to the fundamental principle that each element has a unique atomic structure allowing x-rays that are characteristic of an element's atomic structure to be identified uniquely from each other.

It is the only characterization technique with simultaneously access in the direct space (through image) and reciprocally (by electron diffraction), able to provide at the same time complementary information on morphology, structure and chemistry both at micrometric scale and localized at atomic or nanometric scale (Figures 2-4).

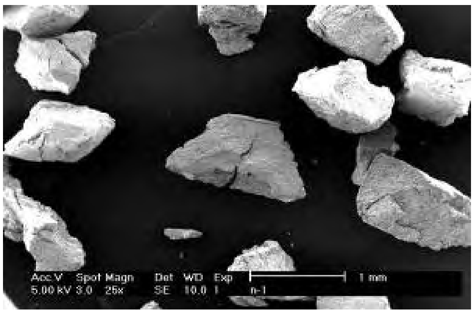

***Fig 2.** Overview of unused grit; (Magnification x 25) [13]*

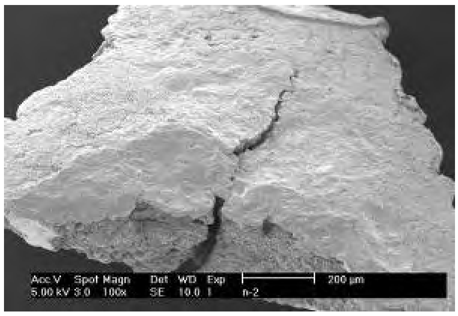

***Fig 3.** Single grit particle image (original sample) (Magnification x 100) [13]*

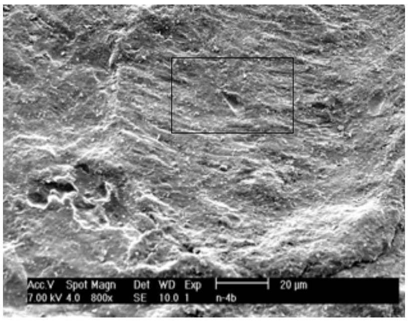

Fig. 4. *The grit particle with the place for chemical analysis (Magnification x 800) [13]*

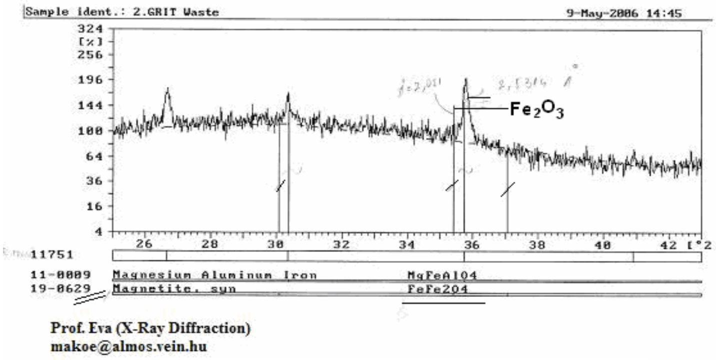

Fig. 5. *X-ray diffraction analysis [13].*

Table 2. *Chemical composition of the waste of Grit and chemical binders for theoretical puzzolanic.*

Material	**Element,** [%]								
	Mn	**SiO_2**	**S**	**CaO**	**MgO**	**Cr_2O_3**	**Al_2O_3**	**Fe_2O_3**	**P.C.**
Waste grit	0.28	42.78	0.70	6.72	6.36	1.20	7.10	31.17	0.09
Puzzolanic binder	0.39	39.28	-	6.7	6.57	1.20	7.56	38.28	-

The advantage of this method of analysis is that samples are not destroyed in the analysis, X rays fall on the sample surface with the characterization of chemical elements. Samples for quantitative analysis should have polished surfaces and are in the form of pills with a diameter of 40 mm and thickness of 2 mm.

The study put in evidence that the grit composition does not suffer significant deviations from its original one. The composition of analyzed waste is based on Si and iron oxides. Composition is similar to that which is formed to strengthen the hydraulic material. A rough texture, characteristic to aggregates, ensures larger adhesion forces between the granules of aggregate and cement, which is extremely important for concrete roads.

Thermogravimetry (TG) can be defined as the study of weight change function of temperature and time in a given environment. The method is useful in determining the purity of the sample, concentration of water, the carbonates, in general for study of any thermal decomposition reactions. By heating or cooling with constant speed of the material, it can suffer a series of both physical and chemical transformations that can be emphasized by measuring simultaneously the sample mass and temperature thereof. The registered changes in mass lead in some graphical representations called thermograme (Figure 3).

The thermogravimetry studies (TG) were carried out under air current and the isothermal absorption/desorbtion of N_2 were registered with the Micromeritics ASAP 2000.

To study the formed oxides was determined the particle surface area by obtaining the size pores using a surface area and pore size analyzer by gas adsorption (BET) (Figure 5).

By X-ray diffraction were determined the inorganic and organic compounds with crystalline structure, such as the determination of $Si0_2$

concentration in powders and other silicates (zeolite), of various metal oxides, carbonates, sulphates, and some metals.

5. Conclusions and Results

Results interpretation shows that the waste grit has physical and chemical properties similar to the sand used in the composition of road asphalt:

1. an angular grain, less round (influencing the strength of concrete);
2. a silico-alumina composition (compounds are similar to those that formed on the strengthening of building materials, puzzolanic cement, formed mainly from reactive silica and aluminium oxide).

Among the materials used in road construction, waste of grit can be placed on hydraulic/puzzolanic binders, along with sand and furnace slag.

In Table 2 are compared the chemical composition of the proposed recycling grit obtained with the PCA (Principal Components Analysis) with the chemical composition of puzzolanic binders.

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