# SUSTAINABLE WASTE MANAGEMENT SCHEMES – A NECESSITY FOR THE ENVIRONMENT

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**Abstract:** This paper presents the major environmental problems which exist within the waste management in our society. A presentation is made of sustainable waste disposal methods. Moreover, effective useful solutions are proposed in order not only to avoid any associated environmental risks and hazards but also to support a sustainable development of our society. In the end, useful discussion and conclusions are made so as to use protect the public health and the environment.

**Keywords**: solid waste disposal, waste management, environmental impacts, public health, sustainable development.

## 1. INTRODUCTION

Waste management is the discipline that is concerned with resources once society no longer requires them. In an effort to meet growing environmental awareness, most industrial companies include in their plan investments that are related to the protection of the environment. Solid waste includes all solid materials useless or unwanted as a result from the human activities and discarded by man. It is necessary to manage the waste in an sustainable way by minimizing the environmental impacts related to waste. Solid waste disposal starts to be problem when the amount and the environmental effects of such disposal arise and become an environmental public health risk. Then the improvement of the management solid waste systems is necessary.

Solid Waste Management (SWM) could be characterized as the most important parameter in life cycle of goods. It is well known that life cycle of particular goods includes: exploitation of raw materials and treatment; trading of goods; production of waste and waste management. The latter is verified due to the fact that on the effectiveness of SWM is dependent a huge amount of energy saving and exploitation, conserving our natural resources (Bilitewski, *et al.* 1994; Koliopoulos, 1999; Kollias, 2004; Paralika, 2003; Skordilis, 1994, 2001; Tchobanoglous *et al.* 1993).

Environmental impacts occur not only at using the products but also at all stages of the products' life cycle. That is, whether we want it or not, all our products affect in some way our environment during their life-span: during production, the environment is always affected by the extraction of raw materials and the associated produced emissions; when we buy the product, we will use it, and this utilization also results in some pollutions of the environment; at the end of the product lifetime, we dispose it and it pollutes the environment again, if the right measures and standards are not taken properly. In all life cycle phases of a product, there are transformation processes of energy and materials from one stage to another (fig. 1), affecting more or less the environmental balance. Life Cycle Assessment (LCA) is necessary to take place for a product so as to reduce any associated environmental impacts by the utilization and consumption of it. When recycling cannot take place more, then several waste disposal methods should be used.

## 2. LIFE CYCLE ASSESSMENT and WASTE DISPOSAL TECHNOLOGIES

The use of Life Cycle Assessment gives the possibility to compare the environmental impact of waste management and treatment. In addition LCA can provide information on the potential for improvement of the management and treatment systems, examining main sources of emissions and main impact of these emissions. Efficient eco-Design and Energy-using products (EuP) should be applied where it is feasible in the design of effective consuming and packaging materials, selecting the right ones, in order not only to increase the yield of a recycling scheme after the life-cycle of a product, but also to use proper products which consume low magnitudes of energy. Eco-Design and Energy-using products should be improved quickly and efficiently in any industrial sector which has not used them yet, enhancing product quality and environmental protection. Manufacturers should be encouraged to design products with environmental impacts in mind throughout their entire life cycle. Life Cycle Assessment is an internationally recognized methodology for assessing the performance of products and services in relation to their impact on the environment. It looks at all stages of product life cycle, from raw material extraction through production, transport, use and finally to recycle or disposal. It involves the consideration of product inputs and all the environmental by-products of each phrase across the products life cycle. LCA can, then, assists the product designer to think and design a more comprehensive environmental product.

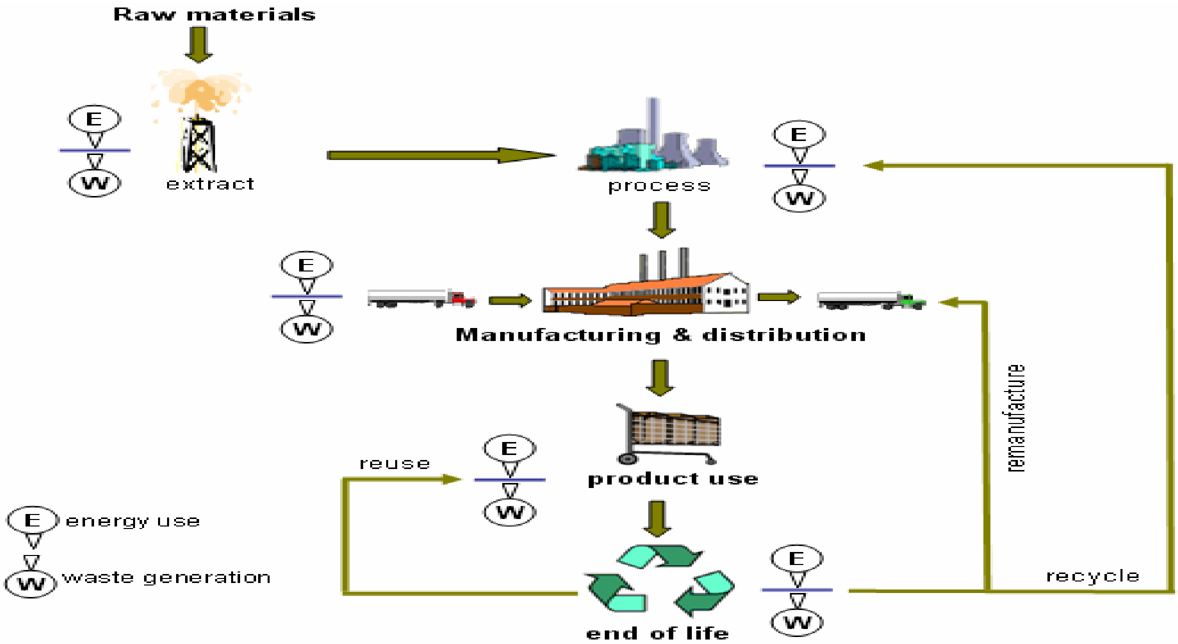


**Fig. 1 Life cycle of goods in the society**

In the last decades, the Life Cycle Assessment method was developed more so as to be applied not only on impacts of products but also on service systems. The goal and scope of LCA states the intended application, the reasons for carrying out the study, the indended audience and the functions of the system being studied (functional unit). The function of systems under comparison, is the main purpose that are designed. The functional unit is the reference unit of systems inputs and outputs i.e. the unit whose environmental impacts will be defined, usually expressed as an amount of product or material. All the above LCA factors might vary considerably as they depend on the subject and intended use of the study. Potential environmental impacts are investigated in the impact assessment. A Cost Benefit Analysis is necessary in a LCA so as to evaluate any possible alternative sustainable scenarios. The level of details' analysis, the choice of impacts evaluated and the methodologies used depend on the goal and scope of the particular study. In the inventory analysis data for all inputs and outputs are collected (Koliopoulos *et al.* 2002; Tchobanoglous *et al.* 1993).

As it was mentioned above, in order to minimize the environmental damage caused by a product, its entire life cycle should be taken into account. This means that a product might cause quite severe environmental damage in one process if it is able to compensate for this additional damage with reduction of the environmental impacts caused in rest of the product life cycle.

The end-of-life of a product refers to all that can happen to that product after the initial user has discarded it. In figure 2 the general preferences for the end-of-life of products are presented.

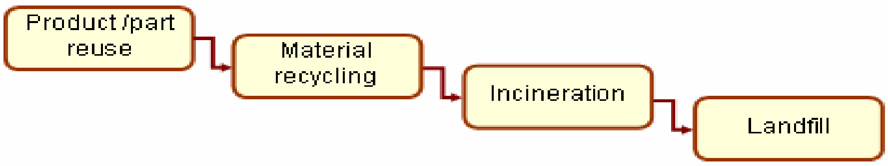


**Fig. 2 Preferences for the end-of-life destination**

In general, from an environmental perspective, the end-of-life alternatives should be preferred in the sequence presented in figure above. However, could be situation when incineration or recycling is preferred to reuse or remanufacturing (e.g. materials that contain hazardous substances is better to be incinerated than recycled). When product, component or material reuse and recycling are not possible, incineration, preferable with energy recovery, is another end of life option. Incineration is the process of destroying waste material by burning it at very high temperatures. Incineration is often alternatively named "Energy-from-waste" (EfW) or "waste-to-energy" because, in effect, incineration of waste allows to recover the useful energy content of the disposed materials. The heat produced by the incinerator can be used to generate steam which may then be used to drive an electrical generator. For instance, the typical range of net electrical energy that can be produced is about 500 to 600 kWh per ton of waste incinerated. Thus, the incineration of about 2 200 tons per day of waste will produce about 50 MW of electrical power (Bilitewski *et al.* 1994; Kollias, 2004; Tchobanoglous *et al.* 1993).

Incineration is recognized as a practical method in the treatment of hazardous waste and clinical wastes where pathogens and toxins must be destroyed by high temperatures. Incineration is particularly popular in countries such as Japan where land is a scarce resource. In Europe Sweden has been a leader in using the energy generated by incineration over the past 20 years and Denmark also extensively uses incineration in localised combined heat and power facilities supporting district heating schemes.

Though incineration has a series of advantages (reduces the stress on landfills, recovers the solid waste energy, treats waste emissions under controlled conditions), as an end of life alternative it is becoming controversial. And this is because of the incineration solid outputs: fly ash and bottom ash. The fly ash contains toxic heavy metals such as lead, cadmium, copper and zinc as well as small amounts of dioxins and furans that must be treated with expensive air pollution control equipment so to avoid carcinogenesis, acid rain and other associated secondary air pollution hazards like ozone depletion. However, advances in emission control designs and very stringent new governmental regulations have caused large reductions in the amount of dioxins and furans produced by wastes incineration.The bottom ash must still be disposed of into a landfill, or if it is toxic, it has to be disposed into a well designed facility for hazardous wastes (Bilitewski *et al.* 1994; Kollias, 2004; Tchobanoglous *et al.* 1993).

Landfills are the final resting place for all our noncombustible, nonrecyclable materials, as well as ash from incineration and residues from recycling. Even if landfills cost millions of dollars to build and tens of millions to maintain, landfill sites are still a predominant alternative of waste disposal in most countries. The United Kingdom, for instance, buries about 90 percent of its solid waste in landfills. In the United States, 57 percent of waste is buried in landfills. Efficiently managed sustainable landfill sites can generate considerable volumes of methane gas ($CH_4$), which can be exploited by landfill gas recovery installations for electricity production. Sanitary landfill remain an attractive disposal route for household, commercial and industrial waste, because, it is more economical than alternative solutions. The landfill biodegradation processes are complex, including many factors that control the progression of the waste mass to final stage (Koliopoulos *et al.* 2003, 2007; Kollias, 2004; Tchobanoglous *et al.* 1993). A landfill structure should be carefully designed, lined and built into or on top of ground topography. Its purpose is to bury the waste in an efficient way that it will control landfill emissions avoiding any groundwater pollution, or other associated risks by landfill emissions. In fact, when a landfill is in operation or it has been closed, should take place an effective spatial monitoring system and a maintenance system for up to 30 years or more in situ of the landfill. Therefore, based on the above any probable groundwater or associated risks of pollution next to landfill boundaries will be minimized or reclamated in time, preventing any eventual landfill emissions' leakages to the environment. Risk assessment numerical models are necessary to be used for the control and efficient operation of any sustainable landfill designs in order to control any produced landfill emissions and to avoid any environmental contamination before they become a toxic hazard to public health (Koliopoulos *et al.* 2003, 2007).

Before a landfill to be built, an environmental impact study must be done on the proposed site to determine:

- the area of land necessary for the landfill
- the composition of the underlying soil and bedrock
- the flow of surface water over the site
- the impact of the proposed landfill on the local environment and wildlife
- the historical or archaeological value of the proposed site.

Once the environmental impact study is complete and the results are favourable, the landfill can be constructed. The older landfills, built according to old, less strict directives, can create a number of adverse environmental impacts, including wind-blown litter, attraction of vermin, groundwater contamination by leachate emissions, fires, explosions caused by the improperly disposed of chemicals or methane gas migration that results from organic matter degradation and others. Any old dumps have to be closed and rehabilitated, protecting thus the environment and public health. The modern landfills should be designed and managed according to increasingly restrictive limits imposed by E.U. legislative directives, implementing them by the E.U. Member States, while they serve properly their purpose, preventing any of the above mentioned risks to public health and to environment. Modern ecological designs of sequential batch anaerobic bioreactors should be used replacing any old dumps (Koliopoulos *et al.* 2003, 2007).

## 3. EFFICIENT WASTE MANAGEMENT SCHEMES - A CASE STUDY OF A SUSTAINABLE SYSTEM

The software tools could be used for evaluation of several recovery and recycling demands, determining the final materials' balance quantities for the particular recovery technologies. After the recovery of recyclables materials there is the recycling and finally the use of them as goods in the society using proper technologies (recovery, recycle, reuse-3 R's policy). An important problem during the operation of a sustainable recycling scheme is the determination of the composition of recycled materials. Below is presented a relative useful application from a curbside recycling system. A lot of complicate long hand wrought calculations could be easily made in short time using new software technologies and numerical analysis principles. The developments and uses of flexible software tools are necessary with efficient algorithms and graphic environment (Aitken, 2000; Mousas, 2006; Tomaras, 1999). They should be friendly and to be easily accessible to any interested user. Such softwares could be used either in life cycle assessment stage of a product or in the control and evaluation of the selection of a design of particular sustainable waste management schemes.

In this section the examining case study estimates the composition of the recovered materials a curbside recycling system in which cardboard, mixed paper, mixed plastics, glass, tin cans, and aluminium cans are to be collected. Also the composition of recycled materials is estimated, if 60 % of the aluminum cans are removed prior to curbside recycling. Moreover, determination of materials recivered balances (ton/d) and loading rates (ton/h) for a Materials' Recovery Facity (MRF's), processing source-separeated papers. The remnants from any recovery/recycling scheme or incineration unit should be disposed into a landfill, applying properly ecological desgin and associated technologies. A software application was utilized, written in visual basic programming language, in order to calulate the relative requested estimations for the examining case study. The examining application should be used either as educational material to students or as a useful software tool in the carrer of graduates. Similar useful case studies, applications and references could be found in the outcome chapters of educational Erasmus Project *"Eco-design: An Innovative Path towards Sustainable Development"*, which is focused on the research of eco-design principles and use of efficient modern recycling and disposal technologies (Barsan, A., 2006; http://www.unitbv.ro/proiecte/modecodesign/index.htm).

The aluminum cans removed by homeowners are returned to buyback centers. The operational characteristics of the examining recycling system are the followings:

- a production of 2000 ton/day of MSW;

- the various separation MRF processes for paper material are based on 7 h/day operating time.

The following conditions have been assumed based on the bibliography (Tchobanoglous *et al.* 1993):

- recovery rates for recycled materials are taken the typical average ones, given in brackets: for mixed paper 40-60 (50); for cardboard 25-40 (30); for mixed plastics 30-70 (50); for glass 50-80 (65); for tin cans 70-85 (80); for aluminum cans 85-95 (90)
- removal 60% of the aluminum cans by the buyback centers
- the recovery factor of old corrugated card board (OCC) and contaminants is 95 %
- old newsprint (ONP) does not carry over into mixed paper or OCC
- the MRF is to be designed to handle 150 (ton/d)
- the baler has a capacity of 16 (ton/h)
- an average worker can manually sort approximately 2.5 ton/h of paper.

The examining waste synthesis by weight is the following: food wastes 47 %, paper 15 %, cardboard 5 %, plastics 8.5 %, textiles 2 %, rubber 0.25 %, leather 0.25 %, yard wastes 10 %, wood 1%, misc. organics 0%, glass 4 %, tin cans 2 %, aluminum 0.5 %, other metals 2 %, dirt, ashes, etc. 2.5 %.
The amount of material received at MRF less white goods, bulky goods, and other contaminants removed during first-stage manual presort is: 1980 ton/d. Therefore, based on the above assumptions for the examining waste systhensis, is made a computation to estimate the composition of recyclables materials, taking into account the removal of 60 % of the aluminum cans by the buyback center, which is presented below:
paper 42.56; cardboard 8.56; plastics 24.1; glass 14.7; tin cans 9.07; aluminum 1.01.
Moreover, below is presented the determination of materials balances and loading rates for a MRF processing source-separated paper. The number of required workers for manual sorting and the recovered quantities are determined. The examining of source-separated paper materials composition is: old newsprint (ONP) 70 %; mixed paper 20 %; old corrugated cardboard (OCC) 8 % and contaminants 2 %.
Therefore, the respective materials delivered quantities (ton/d) are the next for one MRF which handles 150 (ton/d): old newsprint (ONP) 105 (ton/d); mixed paper 30 (ton/d); old corrugated cardboard 12 (ton/d) and contaminants 3 (ton/d). The recovery yield factor is 0.95 for mixed paper, OCC and contaminants materials in the examining MRF unit. The final materials recovered quantities (ton/d) are the following: old newsprint (ONP) 108.2 (ton/d); mixed paper 28.5 (ton/d); old corrugated cardboard 11.4 (ton/d) and contaminants 1.9 (ton/d). The determination of the materials sorting recovery rate (rr) and time to accumulate (tta) 4 ton is: ONP (rr)=15.5 ton/h, (tta)= 0.26 h; mixed paper (rr)= 4.1 ton/h, (tta)= 0.98 h and OCC (rr)= 1.63 ton/h, (tta)= 2.5 h.
Hence, totally 114 workers needed on the short lines; 14 MRF examining units, with 150 ton/d capacity each, should be used and a heavy fraction quantity of the recovery/recycling remnants from initial production 2000 ton/day of MSW should be disposed into a landfill site. After the biomass life-cycle biodegradation and its energy exploitation at landfill, they stabilized wastes could be transfered to an incinaration unit. Different waste inputs and recycling rates have influence on the final waste composition which will be disposed into a landfill, and on the associated spatial landfill emissions' risks and control. Controlled ecological landfill design is considered as more economic waste disposal method than incineration one, without producing any toxic furans or dioxins in the atmosphere.

## 4. CONCLUSIONS

Proper modern environmental friendly designs and technologies should be used, as it was analyzed above, for a sustainable development of our society. An extended campaign is necessary so as to inform the importance of recycling participation to any parties of our society, from government, industry and organizations to schools, universities, small businesses and inhabitants at home. Educational comprehensive materials with useful case studies should be used and to be easily accessible to any one. We should follow a sustainable way, making sure that we recycle everything that can be recycled and purchasing as many products made by recycled materials as we can. Everybody can make recycling a part of his daily routine. As consumers of goods and producers of wastes, we actively can participate in any recycling schemes, making recycling a reality in our life. Therefore, following all the above there will be a continuous sustainable development of our community, creating new jobs and growing up local economies, defeating unemployment and minimizing any associated environmental impacts.
As all the remnants of any recycling waste management scheme or solid outputs of the incineration units are gathered into landfills, a special attention should be given in the design of efficient sustainable landfills.

Maintenance is needed for more than 30 years in a landfill site for the collection and treatment of the leachates and the monitoring of groundwater quality and landfill. Long-term landfill emissions could be a risk for groundwater contamination and other associated environmental impacts. Moreover, long-term biogas emissions could run the risk of causing explosions due to lateral gas migration. The design of a landfill site therefore fundamentally affects public health. The sequential solid waste batch anaerobic bioreactor principles should be followed in any efficient landfill ecological design. The batch sequential anaerobic bioreactor will not only reduce the long-term landfill emissions, but also reduce the public health risks that are involved. However, useful software numerical tools should be used for proper databases' utilization, in order to assess and develop efficient designs of sustainable technologies. The waste input characteristics and their particular properties have to be taken into account for the design of any sustainable waste management scheme and its associated technologies. Moreover, these tools could be used in comprehensive educational materials so as to improve students and graduates their skills. In this way, students and graduates are getting well qualified as they are gathering a proper professional level of modern knowledge; joining any future efficient internship among universities and industry.

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