Global NEST Journal, Vol 13, No 2, pp 150-161, 2011

MUNICIPAL SOLID WASTE MANAGEMENT AND LANDFILL SITE SELECTION IN GREECE: IRRATIONALITY VERSUS EFFICIENCY

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Received: 08/10/10
Accepted: 16/03/11

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ABSTRACT

Municipal solid waste (MSW) collection and disposal is a major problem of urban environment in the world today. MSW management solutions have to be technologically feasible, legally and socially acceptable and environmentally and financially sustainable. European policy is pushing to a rational management of natural resources; a promising technological perspective today is waste valorization, a process that becomes possible through sorting at the source, combined with material recycling and waste-to-energy methods. On the other hand, technologies like mechanical sorting, or disposal of MSW in landfills do not really improve MSW management efficiency. Landfills should become the ultimate disposal site of a few inert residuals from MSW valorization. Despite all this, conventional landfills for disposal of mixed MSW are still being constructed, with landfill site selection being a major social problem due to the lack of public acceptance; objectivity in landfill site selection is therefore extremely important. In Greece, we find several examples of inefficient MSW management and curious landfill site selection. In this paper, we criticize environmental policy issues for MSW management in Greece and identify weak points in the criteria used for the selection of landfill sites. We conclude that there is a real need for rational MSW management based on high quality scientific input.

KEYWORDS: MSW, valorization, solid waste management, sorting at the source, recycling, WTE, mechanical sorting, landfill, site selection, efficiency.

1. INTRODUCTION

Municipal solid waste (MSW) collection and disposal is a major problem of urban environment in the world today. Lack of appropriate MSW management leads to significant soil, water, air and aesthetic pollution, associated human health problems, as well as an increase in greenhouse gas emissions (Weigand *et al*, 2003). In advanced, environmentally-conscious societies, MSW management is dealt with as an integrated issue, leading to MSW management solutions that are technologically feasible, legally and socially acceptable and environmentally and financially sustainable.

The notion of "waste" is non existent in natural systems. Natural biogeochemical cycles ensure continuous flow of chemical substances; decomposers convert the excretion and detritus of different organisms to nutrients that are, in turn, completely reused by other organisms (Hadjibiros, 2007). Similarly, prior to the dawn of the industrial age, human societies used most waste products as fertilizers. Waste pollution is intrinsically connected to industrial production and thus constitutes the culprit responsible for most environmental problems in the modern world. In a post-industrial age, technology will be widely employed to attenuate environmental problems aiming at minimizing, if not gradually abolishing, waste disposal, using pollution prevention methods (Stegmann, 2006).

Zero-waste emission and, generally, a zero-waste concept is especially promoted by the European Union (EU) through the implementation of an advanced environmental policy and relevant legislation. A promising technological perspective today is the complete “valorization” of waste through its transformation into useful raw materials or energy. In the case of liquid waste (Steinfeld and Del Porto, 2007), modern technology has supplied acceptable solutions in order to incorporate it in the natural water cycle. This type of solution does not require active participation of the general public, other than financial contributions in the form of taxes or levies, to cover the costs of constructing and operating such facilities. In the case of MSW, technological solutions are less developed, mainly due to the great diversity of waste materials. The ideal technological solution to the MSW problem would be the use of a “perfect robot” that would efficiently and accurately separate mixed MSW into numerous categories, to enable its ultimate valorization as “clean” materials without leaving any waste left over. However, in the absence of such mature technology (Haferkamp *et al*, 1997), active citizen participation is necessary to ensure MSW valorization. Efficient material recovery is only possible if effective sorting at the source takes place.

In EU territory, problems related to MSW management constitute the object of legislative regulations following the axes of evolving European environmental policy. The modern environmental policy is mainly based on pollution prevention and the “polluter pays” principles. European Directives for MSW management (Pretz *et al*, 2001) constitute advanced examples of environmental legislation and reflect these principles. It is remarkable that their statements are so radical in matters of waste valorization that gradually converge with positions of the Green movement. These directives have become acceptable as the outcome of complicated decision-making mechanisms of the European Union that generally promote compromises between opposing trends. The fact that they were voted by the responsible bodies, European Council and Parliament, shows the current level of consensus, signifying that big steps have been made towards the political objective of better environmental quality. Thus, Europe is presently mature for a rational management of natural resources, through waste valorization. On the other hand, local societies are not easily convinced by trivial arguments for accepting nuisance from MSW facilities in their area. Negative social reaction expressed against the placement of a landfill, or a mechanical sorting facility in some areas constitutes a real fact that should be viewed as an important factor and should be adequately taken into account in planning and decision-making processes.

2. METHODOLOGICAL ASPECTS

MSW management schemes

MSW management is nowadays a difficult and complicated issue, mainly for the following reasons:

- Collection and disposal is a major environmental problem related to human health, urban environment quality, greenhouse effect and natural and urban landscape aesthetics.
- Nuisance—the significance of which is often subjective— caused by the passage of MSW collection vehicles, the smells, the sight of landfill areas, the negative feelings from neighboring with an MSW collection facility, the worry for potential public health risks and the not-in-my-backyard (NIMBY) syndrom understandably creates a negative social attitude towards MSW treatment and landfilling.

On the other hand, in most developing and in some developed countries, MSW management is nothing more than uncontrolled dumping. Discharge into a riverbed has been the traditional way of getting rid of refuse for thousands of years. Environmental impacts used to be tolerable when refuse mainly contained biodegradable organic matter, but are becoming increasingly important with increasing waste volume, toxicity and non-degradability.

The EU MSW management policy is implemented through legal documents and framework programs that predominately aim at the following (Pretz *et al*, 2001; Hadjibiros and Dermatas, 2007):

- *Sorting out waste material and energy recovery with specific targets that become more stringent with time*. The primary goal here is to achieve maximum recovery of raw materials through MSW sorting at the source, recycling of raw materials and combined with composting of the fermentable MSW fraction, so that only a small fraction of “inert” residual is disposed of in sanitary landfills. The secondary goal is sorting and recovery at the source of specific waste materials (e.g. metal, glass, high quality paper) with residual incineration, in order to achieve efficient energy recovery (waste to energy principle, WTE), so that only waste ashes get first stabilized and then have to be disposed of in sanitary landfills.

- *Maximum recovery and optimum reuse of waste packaging,* with the corresponding minimization of landfilling and implementation of the “polluter pays” principle.
- *Mandatory treatment of the organic fraction of MSW (putrescibles and paper)* aiming at a gradual minimization, all the way down to full elimination, of the organic MSW fraction to be landfilled.
- *Minimizing both quantity and hazardous content of MSW* at the source in the spirit of pollution prevention. The MSW quantity is to be minimized by conservation and reuse measures, whereas the MSW hazard is to be minimized by pollution prevention measures or timely segregation of toxic or infectious waste.

Modern technology offers different alternatives for MSW management (Hadjibiros and Dermatas, 2007):

Sanitary landfill is an organized mixed MSW disposal site that constitutes a net improvement relatively to uncontrolled MSW dumping. However, MSW landfilling (Christoulas *et al*, 1999) clearly does not aim at material or energy recovery and poses significant environmental threats. A sanitary landfill remains biochemically active for many decades to come, while producing and releasing toxic liquid or air pollutants as well as greenhouse gases. Thus, it requires long-term monitoring and maintenance measures and entails various significant failure possibilities with the liner and/or pipe collection network, associated with poor construction, poor maintenance, accidents, or natural hazards. Therefore, it violates sustainability principles by passing along to future generations a significant environmental problem. European legislation aims at gradually minimizing the organic portion of MSW in landfills because of its biochemical activity. A sanitary landfill is not the best available technology for MSW management and there are serious difficulties in obtaining public acceptance.

Mechanical sorting includes a treatment “train” of costly technologies that, universally, have not proved their capacity to significantly contribute to MSW management; these technologies present poor perspectives of technological improvement (Tchobanoglous, 2009). They promise relieving citizens from their social obligation to be involved in MSW management by sorting at the source recyclables out of mixed MSW. Mechanical sorting facilities are planned to produce compost and/or combustible residues (refuse derived fuel—RDF, solid recovered fuel-SRF, etc.). However, since mechanical sorting is inherently imperfect, these products are of poor quality (Bertossi *et al*, 2000; TEE, 2006; Economopoulos, 2007) and they cannot serve as usable materials; there is, therefore, no real interest by public or private entities in reusing these products even for free. Large quantities of mixed MSW compost have been piling up unusable at the Kouroupitos facility in Greece since 2002 (Hadjibiros and Dermatas, 2007). It is clear that combining mechanical sorting and landfill facilities does not really improve MSW management, as MSW volume remains practically unchanged after treatment; in practice, waste streams produced by mechanical sorting also end up as waste in the landfill. Additionally, mechanical sorting facilities entail large capital and operating costs associated with frequent equipment failures and are generally low-efficiency operations.

Valorization of waste is a promising technological perspective today that is possible through *sorting at source;* almost all of the MSW produced can be transformed into useful raw materials or energy (Bilitewski, 2003). An integral MSW management scheme should aim at producing zero wasteful product (Stegmann, 2006), mainly through recycling which becomes possible only if effective sorting at source takes place; it is an environmentally friendly MSW management process that conserves natural resources and is technologically guaranteed. This way, no mixed MSW is collected, transported or landfilled; thus, the negative environmental impacts associated with mixed MSW transportation, handling and final disposal are minimized. Separate collection of packaging waste, followed by manual sorting of useful raw materials is an easy-to-apply method that gives significant material recovery when detailed sorting at source faces difficulties. Given the significant fraction (18-35%) of waste paper in MSW, implementation of a recycling scheme where paper is collected separately improves material recovery. More detailed sorting at the source can maximize the exploitation of waste materials such as metal, glass, plastic and construction waste (Masters and Ela, 2008). MSW sorting at the source also allows for effective recycling of special waste, such as batteries, electrical appliances, car tires, machine oil, etc. Biowaste (mainly food residuals and yard waste without impurities) also constitutes a significant fraction of MSW (20-50%, depending on the model of development and on food characteristics; thus, a sorting at the source approach should be adopted. Biowaste can be collected in separate bins and exploited as raw material for biogas production, household or industrial composting, depending on the local culture and population density. It should be stressed that for compost to be usable, it has to be pure and practically free of other waste materials (Zorpas *et al*, 2001). When the derived compost product is of good quality, it has a resale value, as it can be readily used in organic produce farming (Hansen, 1996). For rural areas, biowaste sorting and collection at the source is more advantageous due to the larger volumes of yard waste being produced and the possibility of combining other "clean" farm and agricultural waste to produce high-quality, readily marketable compost. This is especially true for countries like Greece, where conventional farming is rapidly shrinking; the "clean" biowaste-derived compost might become one major outlet for market-displaced farmers who are willing to become active in organic farming.

Waste to energy (WTE) constitutes the only widely-applied technological alternative to material recovery that does not defer the problem to future generations (Bilitewski, 2003). Incineration and other thermal treatment technologies have significant financial, operating and environmental impacts. The capital and operating costs of WTE technologies are generally high, a long-term commitment is therefore required; the associated environmental impacts may be uncertain when strict environmental policy is missing (Tsiligiannis *et al* 1997; TEE 2006); moreover, MSW management becomes less flexible due to the seasonal fluctuation of MSW volumes. WTE technologies become more sustainable when effective sorting at the source takes place. Biowaste in combination with low quality paper waste and chlorine-free plastic can enter a WTE scheme creating an interesting alternative to biowaste recycling when large scale composting faces various difficulties. Metal, glass and plastic sorting at the source allows the incineration of residuals (mainly biowaste and paper), while minimizing associated environmental burdens. It should be noted that effective recycling of all paper and plastic waste may not be compatible with incineration, as the heating value of waste is significantly reduced.

A good example of a successful management scheme is the Viennese example, (Hadjibiros and Dermatas, 2007) one of the most advanced yet environmentally friendly household waste management systems in Europe. Only about 25% of the total amount of waste produced in the city of Vienna, Austria ends up being incinerated, while the rest is effectively recycled and reclaimed. The Municipality has a rigorous recycling plan involving separation at the source. There are waste bins for clear glass, colour glass, plastic, metal, paper, carton, biowaste and residual waste. It is only the residual waste that finds its way into the incineration plant. Biowaste is readily converted to compost, while the rest gets effectively converted to the respective raw materials. The facility, being located in the midst of a heavily populated district in the vicinity of the city center, serves as a perfect example of a well-operated incineration plant with advanced state-of-the-art air filtering devices. It is linked with the city heating network and is also a famous tourist attraction, with an estimated 50.000 visitors per year, as the previously functional structure was transformed into a unique work of art (due to the plant design by Viennese artist Friedensreich Hundertwasser). It is an example of the fusion of technology, ecology and art; it most importantly serves as a monument of "green" activists, local residents and government coming together, finding the common "grounds" to provide a solution satisfactory to both economic and environmental sustainability demands.

Landfill site selection criteria

Evolving EU MSW management policy implies that landfills will no more be a significant MSW management option in Europe in the next decades. Landfills should finally become the ultimate way of disposal of a few inert residuals from MSW valorization. A "residual waste landfill" would have much less environmental impact than a conventional landfill because the presence of fermentable materials and, consequently, the production of organic liquid or air pollutants are minimized; therefore, it would also be more easily accepted by local societies. During a long transitional phase, however, many conventional landfills for disposal of mixed MSW are still going to be constructed in some european countries.

Social reaction from local governments or activists against the construction of landfill and waste management facilities in their neighborhood is a particularly important issue that it is not always adequately taken into account in decision-making processes. Planning and decision making may be influenced by economic interests of both corporations that mostly push towards solutions based on poorly informed technical approaches, and local government lobbyists that have a tradition of illegal profits from different construction activities. This may result in non-sustainable solutions that do not only defy acceptable current practices but also plain common sense. Positive terms like "mechanical recycling" and "integrated waste management facility" are used to refer to mechanical sorting and the combination of mechanical sorting and landifilling, respectively. Such language is clearly misleading, since there is no significant recycling and certainly no integrated management involved.

Landfill site selection is a major social problem because public acceptance is often lacking; in many cases local societies revolt against landfill placement in their area, sometimes leading to strong negative reactions. To face this difficulty, objectivity in landfill site selection is extremely important. Decisions on the selection among candidate sites for landfill placement should not be based on dubious comparative evaluation methods. Landfill projects have to be reliable and have to analyze and minimize any adverse environmental impacts, in order to gain public acceptance. Reports for the comparative evaluation of candidate sites for the placement of MSW landfill facilities should not ignore rules deriving from scientific experience, or even simple common sense; they should adhere to the following guidelines (Hadjibiros and Laspidou, 2009):

- Scientific arguments must be sound and transparent regarding possible lack of reliable data; evaluation and scoring of parameters relevant to different landfill placement sites must not be done with cursoriness; technologies that give dubious results, or when their environmental efficiency is not generally acceptable should not be presented as "ideal solutions for the best candidate site".
- Environmental or other considerations should not be used as a pretext to justify *a priori* decisions. Environmental impact assessment studies should not underestimate either the negative environmental consequences or the technical deficiencies of the facilities.
- Studies must also evaluate the "do-nothing" alternative among other alternatives for MSW management; they should not be limited to the mere comparative evaluation of alternative candidate landfill sites.
- Objectivity in scoring and in obtaining relevant criteria weights must be proved; scores on criteria that are not similar should not be added.
- Landfills should be constructed in proximity to places where MSW is produced and not in remote, poor and disadvantaged areas that are not the optimum solution, but are simply places where landfills are faced with less social reaction.
- Studies conducted for comparative evaluation of candidate sites should not be limited to general information available in the literature that could be applicable to any landfill design or any area; a specialized analysis should be conducted, taking into account the specific project local conditions.
- Criteria for comparative evaluation of candidate sites must be simple and clear. Scoring from complex multi-criteria analysis often gives results that had been decided upon *a priori.* Using a large number of irrelevant and superficially complex criteria that are weighed by "fuzzy" coefficients and are added together leads to conclusions of doubtful value, promote confusion and are not overall convincing to society.
- Negative environmental impact, as well as social stress associated with nuisance should be considered important aspects and should be adequately taken into account in decision-making processes. Negative social reaction may be intensified, when *a priori* decisions are promoted by a supposedly scientifically objective selection method.

For landfill site selection to be efficient, factors such as serious environmental threats and nuisance associated with a landfill installation and operation and with the transport of MSW, as well as lack of social acceptance associated with them should be adequately considered. Any site not satisfying minimum environmental criteria or being within a small distance from a prohibitive location should be rejected and not simply scored low on a set of criteria. Among the rest of the candidate sites for which social and environmental impacts are not prohibitive, selection could be made based on objective, simple and largely acceptable criteria, such as economic ones; in other words, they could take into account the cost of construction, operation and maintenance, the cost of transporting MSW (Economopoulos 2009b), the cost of all necessary measures to alleviate impacts, the life span of the landfill, etc.

3. EXAMPLES OF INEFFICIENT MSW MANAGEMENT

Some european countries and many countries in the rest of the world have not been able to develop appropriate and efficient MSW management schemes. The lack of rational approach seems to dominate decision-making in most cases of MSW management in Greece (Tsiligiannis *et al*, 1997; Andreadakis *et al*, 2000; Hadjibiros and Dermatas, 2007; Hadjibiros and Laspidou, 2009). The National and Regional Planning for Solid Waste Management actually promotes the construction of a high number of new sanitary landfills associated with mechanical sorting facilities. Choices of inappropriate technologies (Economopoulos 2009a) risk spending large amounts of money for the years to come, thus consuming European funds allocated for the construction of useful infrastructure works and environmental protection projects. On the other hand, Greece continues to suffer from heavy environmental problems related to MSW. Although municipal taxes, levies and other associated charges are multifold when compared with most EU counterparts and in spite of numerous "MSW management projects" that have been discussed during past decades, there is not a single example of an efficient MSW management scheme applied on local or regional level. The quantitative EU targets on recycling and fermentable MSW fraction landfilling are not achieved. Consequently, the associated public health, quality of life and tourism-related impacts of this MSW management practice in Greece are significant.

Concrete legal obligations are related to the existing frame of EU directives, but, in the short term, this does not seem to significantly influence decision making on MSW management. There seems to be a sustained effort to effectively bypass EU environmental legislation. An example is the "official" violation of the EU 99/31 Directive for limiting the landfilling of biodegradable waste; the target reduction implementation deadline has arbitrarily been extended from 2006 to 2010, by using the stipulation of article 5 paragraph 2, which was never valid for Greece anyway, since in 1995, 80% of Greek MSW was not disposed in sanitary landfills, but a large part of it was illegally dumped. On the other hand, financial cost does not really play a decisive role, given the rather easy way of exploiting European structural funds, as well as the pressing need for rapid "absorption" of these funds that might be "lost". Environmental considerations are extensively used as a pretext to justify *a priori* decisions, for example the rejection of any pilot project related to thermal treatment of MSW. Moreover, some environmental impact studies seriously underestimate the negative environmental impacts of sanitary landfills, making them documents that simply serve the bureaucracy without appropriately addressing the real technical issues.

In light of this evidence, the observed lack of social acceptance for solutions proposed for MSW is not surprising. The public is not convinced by less than well-founded scientific substantiation, while it is obvious to all that EU environmental legislation is being by-passed somehow. Since public participation procedures are usually inadequate, it is only natural that concerned citizens oppose MSW management schemes. Regardless of whether their opposition is justified or not, it is true that they have a long history of false promises by officials and generally do not trust any official assurances (Andreadakis *et al* 2000).

The "Attica model": Mechanical sorting and landfilling

The problem of MSW for the greater Athens, Greece area is a typical example of lack of good management. The non-solution issue has dominated for the last 30 years. Following successive failures due to lack of public acceptance, dead-end efforts to site a new landfill facility continue. Interestingly enough, technical deficiencies and excessive cost have not prevented the construction of an enormous but non-operational mechanical sorting plant for Athens MSW. This plant was meant to start operating in 2000, but has not effectively operated during the last ten years; it has cost more than 75 million euros officially, while unofficial estimates are higher. This lack of rational technological approach that has lead the problem in Athens to a dead-end seems to dominate decision-making in many other cases of MSW management; the same pattern is expanding in most Greek regions, despite EU regulations and significant fines that will be imposed by the EU in the future due to violation of directives 94/62 and 99/31. The National and Regional Planning for Solid Waste Management is vague, full of contradictions and lacking well-founded rationale (TEE 2006;

Economopoulos, 2007). It promotes erroneous non-attainable goals, such as a high number of mechanical MSW sorting facilities and landfills under the title “integrated waste management facilities”; in some cases, these facilities are intended to be placed in the poorest of the candidate districts, so there will be easier to deal with public acceptance issues. These high financial and social cost solutions are bound to fail, as suggested by previous MSW management experience. If the National and Regional Planning is applied and the proposed facilities are actually built, Greece will have plenty of costly yet ineffective MSW management facilities to operate.

Even in major studies, significant inconsistencies and contradictions emerge between scientific analyses and respective recommendations. While the drawbacks of mechanical sorting are dully pointed out in a study by the Chamber of Engineers in Greece (TEE, 2006), what is finally proposed is the adoption of mechanical sorting facilities as the predominant MSW management scheme. Moreover, manual packaging waste sorting is characterized as “simplistic” (sic), while sorting at the source and household composting are not recognized as reliable solutions (TEE, 2006). In contrast with modern ecological approaches, it seems that traditional engineering thinking cannot easily conceive solutions not based on “engines”; thus simple but efficient socially based interventions, are generally underestimated. Unfortunately, the complexity of MSW management, which, other than technical and economical, it also has broad-based social and environmental aspects, seems to be difficult to comprehend. Moreover, the strong special interests and respective pressure exerted by large private companies that actually promote the various MSW technological solutions is obvious. It seems that planning is strongly influenced by lobbyists; they promote methods that do not require any effort by the citizens, except paying high operational costs. Nevertheless, money and power games do compromise the objectivity of planning. A characteristic example is the unfounded criticism expressed for the Hellenic Recovery Recycling Corporation (HERRCO) that operates packaging recycling (TEE, 2006), while no real criticism has been done for the Association of Communities and Municipalities of Attica that has been responsible for the unsuccessful MSW management in the greater Athens area for several decades.

The recycling programs based on sorting at the source still remain a poorly recognized technology, both in legislative and financial frameworks in Greece. A realistic scheme of partial sorting at the source (Razis *et al*., 1997, Andreadakis *et al*., 2000) that involves two streams (one for recyclable packaging including paper, plastic, glass and metal and one for the rest of the MSW) is operated by the non-profit organization HERRCO. Even if dual-stream recycling is not adequate, it presently constitutes the only actual mainstream effort that tries to abide by the relevant EU recycling policy. The activities of HERRCO have not been adequately supported by the Ministry of the Environment, Physical Planning and Public Works until recently; unofficially, they were undermined, directly or indirectly, by interest groups representing more profitable MSW management alternatives. For the years 2007 and 2008, HERRCO was mandated by the Ministry to reimburse the Association of Communities and Municipalities of Attica that has been responsible for the operation of the mechanical sorting facility of Athens; this decision was based on the false premises that RDF production contributes to the recycling goals. Sadly enough, the tens of thousands of tons of this financially reimbursed RDF ended up in the landfill (ECOREC, 2009), while in 2009 the mechanical sorting facility became non-operational because of technical problems.

Although MSW sorting at the source and recycling are activities with a positive social picture, no significant awareness campaign to promote them has ever been launched in Greece and existing recycling activities remain largely unknown, or marginal at best. On the other hand, mechanical sorting is promoted by the government, many Mayors and the Chamber of Engineers in Greece, as the method of choice that can recycle mixed MSW without participation of the citizens. This practice irreparably damages the positive disposition of an increasing citizen involvement in recycling by sorting at the source.

4. A CHARACTERISTIC EXAMPLE OF LANDFILL SITE SELECTION

A typical example of a curious procedure for the placement of an MSW landfill facility in Greece is presented herein as a case study. A series of MSW management studies for constructing one facility per prefecture at an "appropriate" site have been prepared over the last decade. We present (Hadjibiros and Laspidou, 2009) a study for the site selection of a landfill facility for MSW in the prefecture of Messinia (about 3000 km^2) in the Peloponnese, trying to show how various erroneous criteria are used for the comparative evaluation of candidate sites. The selected MSW management technology is a typical “integrated waste management facility” that combines a sanitary landfill with a mechanical sorting facility. The methodology of the study (Study Team, 2005) does not satisfy most of the site selection guidelines presented in the methodology section. The same pattern of decision-making process is repeated in a large number of cases in Greece; many of the paradoxes presented here are not specific to this example but are common practice in most cases of MSW management.

The construction of a landfill in the prefecture of Messinia should be proposed as a short-term solution needed to solve an urgent problem. On the contrary, it is presented (Study Team, 2005) as the best long-term solution available among alternatives. While a mechanical sorting facility will be constructed, calculations of landfill dimensions are based on the hidden assumption that all of the MSW will be disposed of in the landfill, that is, even the products and not only the residuals of the sorting facility. Thus, without clearly stating so, the study is based on the fact that the volume of MSW after mechanical sorting will not be smaller than that before sorting. The landfill then will be available to accept all refuse: untreated MSW as well as products of mechanical sorting. The landfill lifespan is expected to extend to 20 years with the potential to expand to a nearby field for 20 more years. Thus, a sanitary landfill is proposed as the best available MSW processing method for the following 40 years, even though the suggested technology does not even meet the demands of current european legislation.

The comparative evaluation of candidate sites is based (Study Team, 2005) on many different criteria, weighed by coefficients. We consider that many of the criteria are inadequately substantiated, but superficially complex. They are divided in five categories:

- *Location criteria* are considered in the study those related to the distance of the facility from various places; short distance from an archaeological site, for example, instead of being prohibitive, takes a low score. What needs to be "scored" accordingly, however, is distances from residential areas when they are higher than a preset minimum. Short distances from other places (like archaeological sites) or activities should not be "scored," but should simply serve for rejecting candidate sites when they are lower than the preset minimum.
- *Environmental criteria* are considered in the study those related to climatic conditions, prevalent wind, visual isolation of the site and easiness of restoration works completion; biodiversity has not been taken into account as an environmental criterion. The objectivity of many of these criteria is under discussion, since appropriate data are missing. For example, the study refers to prevalent winds that direct smells away from some housing settlements, without referring to the winds that have different directions potentially affecting other housing settlements. Similarly, the mountainous relief of the area creates a particular wind pattern that is not recorded in the study. On the criterion related to the visual isolation of the site, only the visual contact of houses with the site is taken into account as a negative impact; but what about the negative impact of the site being visible from other points? No such impact is considered. Easiness of restoration works should not be considered as an environmental criterion; it should be taken into account as a technical criterion and be scored based on cost.
- *Geological-hydrogeological criteria* are considered those related to aquifer characteristics and to soil and subsoil conditions. Some of these criteria should belong to the “environmental” category; they should simply serve to reject candidate sites with geological-hydrogeological conditions worse than a certain level. Other such criteria are simply technical and should be scored based on cost.
- *Functional and general criteria* are named those related to the greater area’s existing pollution load, the facility’s life span, easiness of project execution, availability of cover material, transportation networks and accessibility. In other words, an incongruous medley of unrelated factors are all grouped under this title, making scoring, for the most part, not objective. Besides, the criterion of site accessibility is actually scored twice: the first time as "distance of the site from the area served" and the second time as “waste transportation cost“.
- *Social criteria* are those related to social acceptance. Their overall weight is comparatively low and their role in the overall score is small; moreover, no objective methods are used to evaluate them accurately.

The site finally chosen as a result of such criteria scoring seems to be, in the present case-study as well as in many other cases, the one that had been decided upon *a priori*. The complication of the selection method adds artificial complexity to the multi-criteria analysis; as a result, arbitrary decision-making becomes easier. When we used a different simplified approach with a less arbitrary set of criteria, even if we maintained the same scores given by the study, the result was the selection of a different candidate site (Hadjibiros *et al*., 2008).

Following the guidelines developed in the methodology section, the following criteria that are often used to score candidate sites (Study Team, 2005) should actually be criteria only for rejecting a site when conditions are worse than a certain level (Hadjibiros *et al*., 2008; Hadjibiros and Laspidou, 2009):

- Existence of serious geological faults in the area, risk of seismic activity
- Existence of permanent water flow in the candidate site
- Thickness of impermeable subsoil layer
- Depth of aquifer top level
- Use of groundwater by residents
- Rainfall height, intensity and frequency of snowfall and frost
- Current aesthetic status
- Availability of cover material
- Large slopes in the area
- Residential pressure
- Property status
- Farming and animal-raising activity
- Distance from:
    - Industrial units
    - Archaeological sites
    - Airports
    - Military establishments
    - Forest or reforested areas
    - Protected areas or areas of ecological importance

5. DISCUSSION AND CONCLUSIONS

An MSW management scheme is a complex system of social, economic, legal, political, environmental, technical and operational nature. Rational decisions cannot be taken and applied unless a complete and accurate picture of the whole MSW problem is available and a hierarchical classification of the system components can be produced. First of all, thorough waste composition and volume studies that follow the high standards set by environmental researchers and practitioners (Weigand *et al* 2003), should be implemented. Irrational mix and match of different systems is not possible; rational management implies the selection of mutually inclusive technological alternatives and the elimination of mutually exclusive ones. For example:

- No sorting at the source entails that end-products of MSW treatment such as compost and RDF will be mostly unusable.
- No sorting at the source entails that incineration would be more costly and carry a higher pollutant load than otherwise.
- Massive investment in mixed MSW transfer stations undermines sorting at the source and, indirectly, favors mixed MSW landfilling, mechanical sorting, or incineration.
- Full recovery of waste paper undermines incineration with energy recovery.
- Household and/or industrial composting following “clean” biowaste sorting at the source minimizes environmental problems related to MSW organic fraction landfill.
- Prioritizing mechanical sorting and landfilling of mixed MSW makes the problem of landfill site selection more difficult and strengthens the associated social reactions.
- Imposing placement of landfill sites to poor areas through unreliable studies undermines possibilities for positive social cooperation towards efficient MSW management.

Any MSW management scheme has to follow the founding environmental principles, such as pollution prevention and polluter liability. External costs that are directly or indirectly implied by its application should be carefully considered and weighed. In order for the management scheme to be rational, components that lead to irrational solutions should be neutralized. Sometimes, these may represent dominant aspects of the decision-making system, like the curious selection of specific technologies that usually goes along with the associated profits of implementation, the incompetence and/or suspicious interests of municipal or government authorities, the pressures exerted by certain guilds or trade unions etc. Technologies that would not work have to be bluntly eliminated during early stages. Instead, site-specific, strongly founded, transparent technical approaches based on the current state-of-art practices of sustainable MSW management, should be applied on a case by case basis.

Landfilling is proposed by various studies, private companies and state agencies as the best solution for MSW management in Greece; this mentality seriously delays any serious efforts to valorization of waste. Some studies even support that landfill construction has a positive impact, since it enforces environmental consciousness in people; it is difficult to understand how the environmental nuisance and grotesque sight of a landfill can contribute to environmental awareness; strong social reaction to installation of landfill facilities proves the opposite. Conversely, recycling activities have generally a positive social picture; social desire for participation in recycling and social opposition to landfill construction are both significant (Dimitriou *et al*., 2005).

The main challenge in applying MSW sorting at the source programs has to do with the correspondingly high level of citizen involvement in dispensing the different waste materials that comprise MSW into different waste bins, either inside or outside the household. This is why there is an ever increasing need to implement long term education and publicity initiatives aimed at changing the citizens' culture and ensuring a wide public participation in MSW management (Frantzis, 1989; Dimitriou *et al*., 2005). Informing the public on the achievements of MSW recycling efforts, aggressive and persistent awareness campaigns should be introduced concurrently, in order to ultimately attain a waste-responsible social culture. Environmental education and awareness should start from elementary and pre-school, where, among other more conventional approaches, all recycle bins should be present in the classroom and recycling should be practiced in real life by children on a daily basis. This provides the cornerstone where the "environmentally aware" culture of citizens should be effectively built upon. This, indirectly, also entails moving towards a "minimalist" culture of consumption, which, to a certain degree, contradicts some of the modern principles of the free market economy that seem to rely on increased consumption of goods to sustain high profits and subsequent economic growth. However, we can change the nature of our economy - we can shift back from a quantity to a quality powered economy in which economic growth is still possible without the environmental costs of current forms of economic conduct.

Cost-effectiveness of MSW recycling with effective material sorting at the source varies depending on type and quality of waste material and usually requires some form of subsidy in order for it to be financially sustainable (Razis *et al*., 1997). This subsidy can be based on the "polluter pays principle" following EU Directives and its level is significantly lower than the cost of other technological alternatives, especially if the associated externalities are taken into account. Overall, there is a clear present need for more effective collection and appropriation of recycle materials as well as a plan for managing the waste generated, while the system is still recycling-deficient, as the general public is slowly catching up with the newly created environmentally-sensitive and eco-responsible culture. On the other hand, challenges associated with lack of public acceptance for the placement of a new sanitary landfill facility are far greater and significantly more complicated to effectively resolve, as recent experience from Athens, Thessaloniki and rural regions in Greece shows.

In this paper, we criticize environmental policy issues for MSW management in Greece and focus on weak points in the criteria used by relevant studies for the selection of sites for MSW landfills. There is a real need for a rational MSW management based on high quality scientific input. This translates to a reversal of the currently practiced MSW management planning in order to fully comply with the EU framework. Given the urgent need to update MSW management practices, the demands of current european legislation, the fundamental weaknesses of landfill site selection methods, as well as the intense and extended social protests, solutions have to be searched towards the following directions:

- The country should go from open dump to recycling, by sorting at the source directly (Stegmann, 2006).

- Actual National and Regional MSW management planning schemes should be revoked.
- Implementation of an ambitious 10-year program in public education and awareness aiming at specific targets of recycling by sorting at the source for the whole country after the first 5 years, gradually increasing the targets thereafter; this program should be negotiated with the EU, together with achievements in ceasing of open dumping and minimization of organic waste landfilling, in order to reach realistic compromises aiming at gradually achieving the targets of Directives 94/62, 99/31 or 08/98 and heavy penalties in case of failure.
- MSW sorting systems at the source and public awareness campaigns could be financed by EU structural funds earmarked for mechanical sorting and landfill facilities.
- Ceasing the promotion of new mechanical sorting facilities and gradual shut down of existing ones; drastic reduction of the number and respective capacity of proposed sanitary landfills around the country.
- Applying simple and universally accepted criteria for placement of landfill facilities; based on objective rejection criteria, locating appropriate sites for landfilling of only residual waste and finally choosing a site after good scientific documentation and social dialogue on the basis of minimum integrated cost.
- Development and rational distribution of compost facilities following sorting at the source; concurrent promotion of biowaste sorting at the source especially in rural environments; promote the use of relevant equipment for household composting in urban environments; mandate by law biowaste sorting for restaurants, hotels, hospitals, military facilities, etc.
- Promote at least one pilot incineration or thermal treatment plant after partial sorting at the source in some Greek region and mandate scientific follow up of its operation.

REFERENCES

1. Andreadakis A.D., Razis Y., Hadjibiros K. and Christoulas D.G. (2000), Municipal solid waste management in Greece. In N. Buclet and O. Godard (eds): Municipal Waste Management in Europe, Kluwer Academic Publishers, London, pp 171-202.
2. Bertossi, P., Kaulard A. and Massarutto A. (2000), Municipal waste management in Italy. In N. Buclet and O. Godard (eds): Municipal Waste Management in Europe, Kluwer Academic Publishers, London, pp. 121-169.
3. Bilitewski, B. (2003), Waste and sustainability in Europe. *Proc. 8th Int. Conf. on Environmental Science and Technology*, University of the Aegean, pp. 94-103.
4. Christoulas, D., Andreadakis A., Razis J. and Hadjibiros K. (1999), The municipal solid wastes regime in Greece and relevant european policies. *Proc. 6th Int. Conf. on Environmental Science and Technology*, Vol. C, University of the Aegean, pp. 110-117 (in Greek).
5. Dimitriou, A., Hatzinikita V. and Christidou V. (2005), Solid waste management: Greek citizens' knowledge and attitudes. Proc. 9th Int. Conf. on Environmental Science and Technology, University of the Aegean, pp. 289-298.
6. ECOREC (2009). www.ecorec.gr
7. Ekonomopoulos, A. (2007), Management of household waste. Technical University of Crete (in Greek).
8. Ekonomopoulos, A. (2009a), Formulation and comparative evaluation of alternative MSW management plans for Greece. Proc. 2nd Int. Conf. on Environmental Management, Engineering*, Planning and Economics,* Mykonos, pp. 959-972.
9. Ekonomopoulos, A. (2009b), Sitting of integrated waste management facilities. A methodology with an application in Crete. Proc. 11th Int. Conf. on Environmental Science and Technology, Vol. A, University of the Aegean, pp. 277-284.
10. Frantzis, Y. (1989), Sorting at source: a dynamic method for recycling of municipal waste. Proc. 1st Int. Conf. on Environmental Science and Technology, Vol. A, University of the Aegean, pp. 614-621 (in Greek).
11. Hadjibiros, K. (2007), *Ecology*. Symmetria, Athens (in Greek).
12. Hadjibiros, K. and Laspidou C. (2009), A criticism of municipal solid waste management and landfill site selection in Greece. Proc. 11th Int. Conf. on Environmental Science and Technology, Vol. A, University of the Aegean, pp. 404-410.
13. Hadjibiros, K. and Dermatas D. (2007), Irrationality versus efficiency in municipal solid waste management schemes. Proc. 10th Int. Conf. on Environmental Science and Technology, Vol. A, University of the Aegean, pp. 448-456.

14. Hadjibiros, K., Kyritsis E., Simou D. and Sifakis A. (2008), Design of a municipal solid waste management plan, Research project report, National Technical University of Athens, Athens, Greece (in Greek).
15. Haferkamp, Bach H. F.R., Burmester I. and Goede M. (1997), New identification and sorting strategies for solid waste management and a closed-loop recycling process. *Proc. 5th Int. Conf. on Environmental Science and Technology*, Vol. A, University of the Aegean, pp. 186-193.
16. Hansen, J.A. (1996). Management of urban biodegradable wastes. James & James Science Publishers Ltd, London, UK.
17. Masters, G.M. and Ela W.P. (2008), Environmental engineering and science. 3rd edition, Prentice Hall.
18. Panagiotakopoulos, D.C. (2001), Economic and sustainability issues for municipal solid waste management systems. Proc. 7th Int. Conf. on Environmental Science and Technology, Vol. B, University of the Aegean, pp. 690-698.
19. Pretz, T., Nikou N. and Kontos Ch. (2001), The effects of the European Directives 94/62 and 99/31 to the waste management sector in Greece. Proc. 7th Int. Conf. on Environmental Science and Technology, Vol. C, University of the Aegean, pp. 440-446.
20. Razis, Y., Koumenides C. and T.D. Lekkas (1997), The recycling project of HERRA and five municipalities in Athens, Greece. Proc. 5th Int. Conf. on Environmental Science and Technology, Vol. A, University of the Aegean, pp. 32-40 (in Greek).
21. Stegmann, R. (2006), Future development in waste management, Proc. 8th Int. Conf. on Protection and Restoration of the Environment, Technical University of Crete and Stevens Institute of Technology.
22. Steinfeld, C. and Del Porto D. (2007), Reusing the resource: Adventures in ecological wastewater recycling. EcoWaters.
23. Study Team (2005), Environmental impact preliminary assessment of landfill facility in the Prefecture of Messinia, Technical report, Region of Peloponese, (in Greek).
24. TEE (2006), Management of solid waste in Greece. CD ROM, Chamber of Engineers in Greece, Athens (in Greek).
25. Tsiligiannis, Ch., Kavvadas Ch., Kornaros M. and Lymberatos G. (1997), Comparative assessment of solid waste treatment and disposal technologies and sites for Attica. Proc. 5th Int. Conf. on Environmental Science and Technology, Vol. A, University of the Aegean, pp. 138-145 (in Greek).
26. Tchobanoglous, G. (2009), Introductory speech. Proc. 2nd Int. Conf. on Environmental Management, Engineering, Planning and Economics, Mykonos.
27. Weigand H., Fripan J., Przybilla I. and Marb C. (2003), Composition and contaminant loads of household waste in Bavaria, Germany: Investigating effects of settlement structure and waste management practice. Proc. of the 9th International Waste Management and Landfill Symposium, Cagliari, CD-ROM.
28. Zorpas, A., Vlyssides A., Chiou G., Arapoglou D., Petrou S. and Loukakis H. (2001), Compost characterization and the affect of compost product in deferent cultivation. Proc. 7th Int. Conf. on Environmental Science and Technology, Vol. C, University of the Aegean, pp. 600-604.