Significance of Landfills in Modern Waste Management

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Abstract

Landfilling represents by far the oldest way of waste disposal. On a global scale even today the largest fraction of municipal solid waste is still landfilled. In the frame of the present paper the function of landfills in modern waste management is discussed, whereby special focus is given to the European waste hierarchy, which states that landfilling is the least desirable disposal option for waste. The results of the analysis conducted clearly shows that despite the requirements of the EU waste framework directive, landfills will still play an important role in future waste management. This is due to the main functions of landfills, which include the function as a safe sink for *hazardous* substances and the function as a temporary storage for potential secondary resources.

1. Introduction

According to the EU waste framework directive (European Parliament, 2008) member states of the European Union must emphize on the waste hierarchy to ensure that waste is dealt with in the priority order of:

1. prevention;
2. preparing for re-use;
3. recycling;
4. other recovery (for example, energy recovery);
5. disposal.

The waste hierarchy claims, that prevention of waste is more desirable than preparing for re-use, and reuse is again better than recycling, and so on. The most undesirable option is the final disposal of waste, which includes besides the combustion of waste (without energy recovery or with low energy efficiency) landfilling. Hence, only if all other measures (prevention, re-use, recycling, recovery) of waste management are not practicable, landfilling represents the last resort. The idea behind the waste hierarchy is to utilize as much waste as possible in order to substitute primary resources.

The main question that arises out of the waste hierarchy for landfilling is the following: Are landfills still required in future or are they becoming obsolete in a modern sustainable society.

The aim of the present paper is to discuss this question and try to answer it, whereby special focus should be given to the different developmental stage of the national economies of Europe. Thereto the historical role and development of landfills will be evaluated on the one hand, on the other hand the significance of landfilling in the anthropogenic metabolism is investigated.

2. Historical function and development of landfilling

Landfills, as a place where waste are disposed off, have been existing since millenniums. Already 5,000 years ago Cretan used landfills to dispose their wastes [14]. In Knossos they dug pits, put their waste inside and finally the waste pits were covered with soil.

An ancient landfill, which can be visited even today, is situated in Rome. It is the so called Monte Testaccio, which can be translated as *mountain made up by shards*. Over an area of 20,000 m^2 more than 50 Million amphora (clay vessels which were used to transport olive oil) have been smashed and disposed off [16]. The landfill has a volume of around 600,000 m^3 and a maximum height of almost 45 m. The fact that the olive oil vessels have not been reused or recycled (as construction material) as it was the case for other clay vessels, indicates that landfilling was the most feasible option in terms of economic conditions.

Figure 1: Monte Testaccio (left hand side: Picture of the 19th century; right hand side: photo of archeological investigations)

Source: Wikipedia

Economic rationale, although very shortsighted ones, have also been the reason for a *boom* of landfilling and dumping in Western Europe, during the second half of the last century. The enormous increase in consumer goods during this time, low commodity prices in conjunction with the premise of low cost waste disposal resulted in many open dumps and landfills, which were associated with a significant pollution of groundwater and soil [1, 12, 18].

The transition of open dumping to engineered landfills in the 1980ies resulted finally in a significant reduction of environmental pollution by landfilled waste. On the one hand sophisticated sealing systems isolated the waste body from the environment, and on the other hand remaining emissions (e.g. landfill gas and leachate) were captured and treated.

Better information and increasing knowledge about the long term emission behavior of landfills (in particular of Municipal Solid Waste landfills) resulted in a further step of landfill development at the end of the last century [3, 13]. Aftercare free landfills, or so called final storage landfills, were requested the first time by the Swiss concept on waste management [2]. Final storage landfills are defined as landfills whose emissions do not have any negative impact on the environment over short-, mid- and long-term periods. Substance flows from final storage landfills do not significantly chance geogenic flows and stocks (see Figure 2). This can be accomplished by different measure, so called barriers.

In general 3 barriers can be used to protect the environment and to ensure aftercare free landfilling:

1. Conditioning of waste material – only inert waste should be landfilled (barrier 1: waste as a barrier)
2. Sealing of landfilled waste material (barrier 2: technical barrier)
3. Usage of natural (geological) barrier – very low permeability of subsurface at the landfill site (barrier 3: geological barrier)

Since technical barriers (e.g., sealing systems) have a limited life time and geological barriers are seldom available at landfill sites, conditioning of waste prior landfilling often represents the only possibility to implement aftercare free landfills (final storage landfills). Many European countries (e.g., Austria, Germany, Switzerland, and Denmark) whose waste legislation requires intensive pre-treatment of waste prior landiflling are already on the right track to establish an aftercare free disposal of waste.

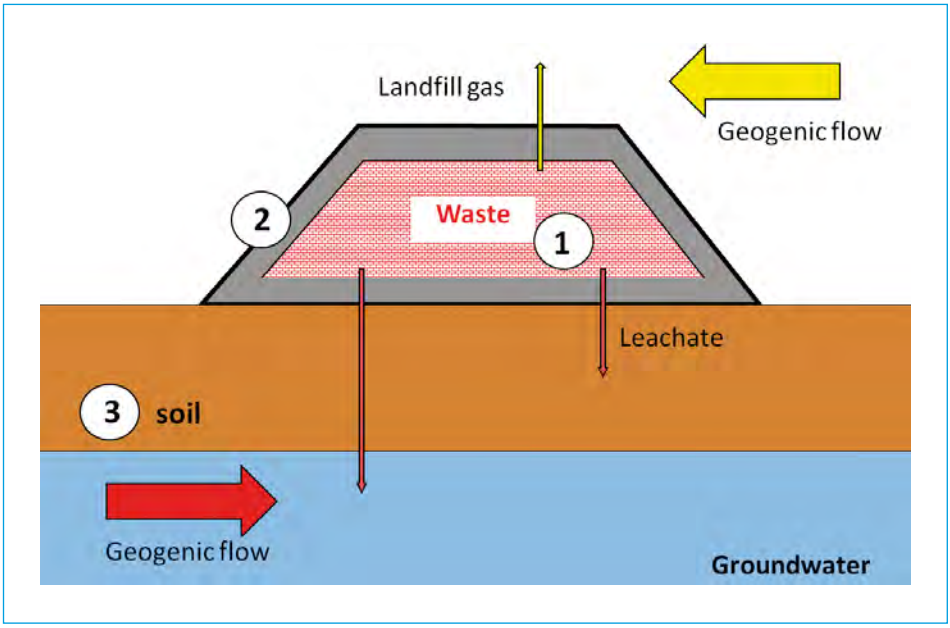

Figure 2: Concept of final storage landfill: substance flows of the landfill are insignificant in comparison to geogenic flows in the atmosphere, hydrosphere and pedosphere

Source: Brunner, P-H.: Wo stehen wir auf dem Weg zur *Endlagerqualität*? Österreichische Wasserwirtschaft. 1992, 44: 269-73

3. Function of landfill in waste management and in the anthropogenic metabolism

Despite the enormous development of landfill technology and also landfill operation during the last decades, the main function of landfills remained unaltered. Landfills are aimed to store waste and goods, for which no further usage is practicable or whose utilization would not be feasible from an economic point of view. Important in that context is that the major condition for landfilling – no further usage of the material is possible – has changed a lot during the recent years. Waste, which has been almost exclusively landfilled a few years ago, is currently recycled (either due to rising resource prices or due to technological progress).

Increasing commodity prices are also one reason for the ongoing discussion of landfill mining. Currently the mining of old municipal solid waste landiflls is intensively investigated [4, 11,15 17]. However, the results of different studies [10], indicate that the price of the material landfilled is usually negligible in comparison to the monetary value of the landfill space recovered or the reduction of aftercare costs.

Nevertheless, there are many examples concerning landfills containing industrial waste, that have been mined in the past in order to recover valuable resources.

Example A): Mining of coal tailings

The cement manufacture Wopfing (about 40 km in the South of Vienna) mines tailings (tailing *Richardschacht*) of a coal pit (located in Grünbach in Lower Austria) that has been closed 50 years ago [7]. The material mined (see Figure 3) contains only about 18 % of coal, but due to its high content of clay and marl it is qualified as input material for the cement plant. Indeed the mined material can be regarded as mixture of fuel and raw material for the cement kiln.

Figure 3:

Landfill *tailing Richardschacht – Grünbach (Lower Austria)* – Mining of tailings

Example B): Utilization of landfilled sludge originating from electroanalysis during Zinc-production

Landfilled slugde, which was generated during the Zn production at the site Bleiberg (Austria), has been conditioned and used to recover Germanium in the 1970ies and 1980ies. In this way about 5 tons of Germanium has been produced each year [8], which amounted to about 5 % of the global production of Ge (250 tons/a) at this time. By mining this *industrial landfill* Autria was for sometimes among the six most important countries for mining Ge.

Altogether about 174 tons of Germanium have been recovered from the landfill. Considering the actual market price of Ge of 1,100 €/kg, this equals almost 200 Million Euro.

When considering the total anthropogenic flows and stocks of materials, it however becomes clear that landfills are of minor significance for the future supply of raw materials, although the examples above indicate for single substances and on a regional level a different picture.

But landfills are much more important in another context:

Millions of tons of materials are being exploited from the earth crust, and processed into consumer and capital goods every year. A large part of this materials is recycled, but recycling represents only an intermediate solution for such materials. It prolongs the residence time in the anthroposphere, but for thermodynamic reasons, recycling cannot prevent the need for a final sink for these materials. As material input in our economy is steadily increasing, the amount of materials that need finally to be directed into final sinks will increase, too. Due to the fact that the intake capacity of environmental media (such as atmosphere, hydrosphere or pedosphere) for many substances is more and more reaching its limits (e.g., CO_2, Phosphor, CFCs), directing substances into landfills (as a final sink) will become more important in future [5]. Hence, the major function of landfills in the anthropogenic metabolism is the long term storage of *hazardous* substances (see Figure 4). Hazardous in this context means that the substance would cause environmental problems if dissipated in the environment.

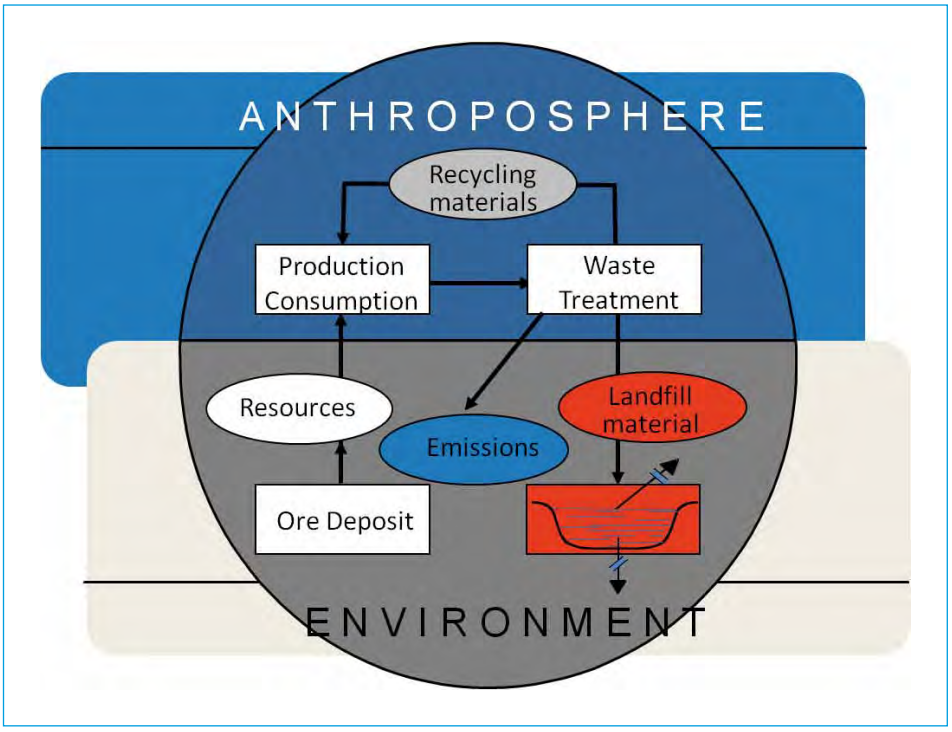

Figure 4: Landfills as final element of the anthropogenic metabolism

Source: Brunner, P.-H.: Wo stehen wir auf dem Weg zur *Endlagerqualität*? Österreichische Wasserwirtschaft. 1992, 44: 269-73

Recent investigations have shown that landfills could represent final sinks for heavy metals; in particular this is truth for heavy metals in l incineration residues. For many other substances (e.g., Cl, N) however, landfills do not represent a final sink. For those substances detail analysis are required whether their dispersion in environmental media is harmful or not. In case that no dispersion is allowed due to environmental pollution, landfilled waste should be conditioned a way that those substances remain for long time inside the landfill. A potential alternative would be to simply prevent the application of these substances in products.

4. Summary and conclusions

Despite the waste hierarchy of the EU waste framework directive und thereby induced recycling efforts, landfills will remain an important element of modern waste management. This statement is justified by the two major functions of landfills:

A) Landfills as a sink for *hazardous* substances, whose usage or recycling is (according to current conditions) not feasible

B) Landfills as a temporary storage for secondary raw materials, which can currently not be recycled due to economic or technological constraints

Hazardous substances and secondary raw materials could be identical in this context.

In order to evaluate whether recycling of specific waste is more preferable than landfilling, environmental impacts (over short and long term period) should be analysed in detail. Only if recycling is from an ecological and economic point of view superior to landfilling, waste should be recycled. In case that only an ecological benefit is given, but due to technical and economic restrictions recycling is not feasible, a landfill could represent a temporal storage for the waste until raw material prices are high enough, that recycling becomes practicable.

In general it can be summarized that the significance of landfilling is not only determined by the waste management system of the region, but also by the whole economy and the material flows of the anthropogenic metabolism.

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