Appropriate landfill technology

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SUMMARY: By describing four different cases from the Netherlands it is pointed out that there are possibilities to counteract negative environmental effects of uncontrolled landfills at low costs. In transient economies where expenditure on waste management is necessarily restricted it is recommended that improvements should be made gradually. Furthermore it is shown that even in a developed country like the Netherlands financial constraints sometimes require very simple environmental protection measures.

INTRODUCTION

In Romania as in many countries in the world there is attention for a change towards ecological landfilling. The reason is that the present waste management practices are considered to have too many negative impacts on the environment. The main problems in Romania seem to be (Chiriac, 1999; author's site visits):

- inefficient collection resulting in waste lying in the streets or along the road to the landfill;
- bad or no landfill management resulting in fires, smoke, dust, vermin, windblown litter and exposure of waste to citizens and animals;
- absence of measures to control leachate, ground- and surface water contamination and landfill gas emission.

It should be stressed however that this situation is not much different from the situation in many south European countries. In many western European countries where sanitary landfills now are state-of-the-art similar situations existed only 20 to 30 years ago. In that respect it is justified to say that Romania and countries with similar situations only have to do a little bit of catching up. Sanitary landfills with acceptance control, registration, double bottom liners, capping with double top liners, leachate treatment, landfill gas extraction and utilization, groundwater monitoring and arrangements for aftercare may be ecologically sustainable. But in transient economies they are probably not economically sustainable. National regulations in countries with transient economies often set standards for environmental protection from landfills that are far above what can reasonably be afforded (Pugh, 1999). As a result the regulations are often ignored. The WHO (Macfarlane, 1996) has calculated that up to 0.5% of the gross national product is an acceptable cost level for waste management, i.e. collection and disposal. Accepting that figure it can be calculated that an ecological landfill is hardly affordable to the Romanian population. The gross national product per Romanian citizen being around 1,600 Euro per year means that around 8 Euro per inhabitant per year can be spend on waste management. This will probably finance only the collection system, leaving very little money for sanitary landfill. Therefore a sharp increase in gate fees at landfills in the present economic situation is probably not possible. Moreover if an ecological landfill is close to a non-ecological landfill the difference in gate fee cannot be higher than the difference in transport cost. Otherwise the ecological landfill will not receive any waste. The need for incremental improvement from uncontrolled tipping towards sanitary landfill is crucial if such changes are to be sustained. It took the Netherlands 30 years to arrive

where it is now. Romania can probably do that faster, butgradual improvements are advised. In this paper four cases from the Netherlands will be presented with the intention to point out possibilities to gradually improve landfill practices. The first case is a landfill with present day standards. The environmental protection measures, acceptance procedures, monitoring system as well as operational aspects and cost levels will be presented. The second case is a landfill operated between 1977 and 1993 with less protection measures and lower cost level. This landfill is still monitored. The paper will show that in this case a lot of the environmental improvements of the first case are reached at considerable lower cost. The third case is a landfill remediation project with extensive protection measures financed by re-opening the landfill. The fourth case is a landfill remediation project in a nature reserve. Re- opening in this case was not possible and therefore funding was very limited. Consequently only very simple environmental measures could be implemented.

CASE 1: NAUERNA

The Nauerna landfill was opened in 1985. The total surface of the landfill is 73 ha. The total permitted volume of the landfill is 8.5 million m_3. The landfill accepts 400,000 to 500,000 tonnes of waste per year. Due to the fact that in the region household waste was incinerated since the 1970's the landfill mainly receives contaminated soils, sludges, residues of construction and demolition waste recycling and some commercial and industrial waste. There also is a permit to accept the least harmful category of hazardous waste. Waste delivery has to be announced before hand. According to the waste composition permission is granted to deliver it to the landfill. Upon arrival at the landfill the acceptance documents are checked. At regular intervals waste is sampled at random to check the composition. The trucks are then directed towards the tipface. At the tipface a supervisor gives instructions on where to unload the waste. During unloading the supervisor checks the waste for irregularities. Unacceptable loads or loads containing items that require other treatment or disposal methods are refused. This waste is immediately reloaded on the truck to be taken away. Refusal of acceptance is reported to the authorities in order to prevent illegal disposal. Waste that is accepted is immediately processed

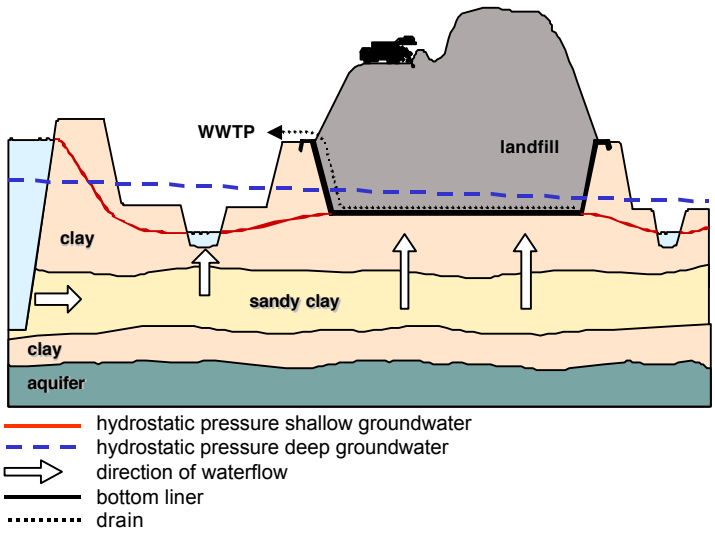

Figure 1: Geohydrological situation Nauerna landfill

by bulldozers and/or compactors. According to the nature of the waste daily or weekly cover is applied against wind-blown litter and vermin. Since 1997 all Afvalzorg landfills have an ISO 14001 certificate for their environmental management system. All actions on the landfill are written down in procedures. All non-compliances are reported, stored in archives and when necessary reported to the authorities. At regular intervals internal and external audits are held to continually improve the landfill practice and to check compliance with the certificate's requirements. The landfill has its own leachate treatment plant, which produces a high quality effluent that can be discharged to surface water. Unlike many other landfills landfill gas is already extracted during operation of the landfill in order to minimize the emission of methane (a strong green house gas) to the atmosphere. With the aid of numerous boreholes that are checked for water levels and water quality the landfill is monitored to control the effectiveness of the environmental protection measures and thus prevent spreading of contaminants.
The landfill was constructed in compartments of 2 to 6 ha according to the need. The last compartment was constructed in 1997. All compartments have a bottom liner. Apart from that the geohydrological control system gives an extra protection. The water level in the compartments by controlled discharge is kept at a lower level than the groundwater level (see Figure 1.). In case the bottom liner should fail leachate is not leaking out but instead groundwater will flow into the compartment. This will immediately be noticed since the amounts of leachate from each compartment are measured separately.
The actual costs of landfill operation can change with changing yearly waste input. The average operational costs of the Nauerna landfill are given in Table 1.

Table 1: Operational costs Nauerna landfill

Aspect	Euro per tonne
Depreciation and interest	4.30
Waste acceptance and disposal	1.90
Administration and overhead	1.10
Site maintenance	0.30
Waste water treatment and landfill gas extraction/utilization	0.30
Site inspection and monitoring	0.10
Capping fund	3.50
Aftercare fund	2.20
Total	13.70

The capping fund allows for investment in capping the waste with a double top liner several years after ending landfill activities. The aftercare fund through investments should generate enough money to allow it to grow during landfill operation and to be able to finance aftercare for an unlimited period of time. The gate fee at all Afvalzorg landfills is 36 Euro. This allows Afvalzorg to operate other landfills that have higher operational cost and thus help society to overcome problems with old landfills as shown in Case 3.

CASE 2: VELSEN LANDFILL

The Velsen landfill was the first geohydrologically controlled sanitary landfill in the region. It was opened by Afvalzorg in 1977 and was operated until 1993. Monitoring and aftercare are carried out continuously and will be in the future. In total 4.5 million m3 of waste after compaction were landfilled. The first part of the landfill was constructed without bottom liner as was standard practice in the 1970's. Later parts of the landfill do have a bottom liner. For this paper only the part without bottom liner

will be discussed. The site for the Velsen landfill was selected with great care and especially with respect to geohydrology. Leachate control and discharge are obtained by controlling water levels under and around the landfill. Around the landfill at a proper depth a drainage system is installed. Around the drainage system a ditch was installed. In this ditch a relatively high water level is maintained with respect to the lower water levels of the surrounding polders (see figure 2.)

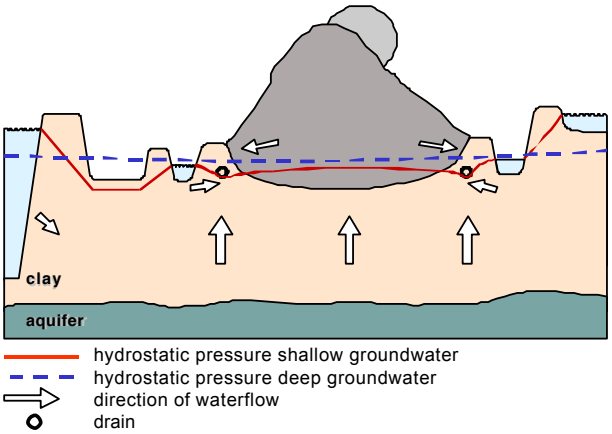

Figure 2: Geohydrological situation Velsen landfill.

By pumping water from the drainage system under and around the landfill the water pressure is lower than the pressure form the deep ground water and from the surrounding ditch. In this way the prevailing water flow is directed towards the drainage system and all the leachate is caught. Since the landfill is situated in clay the water velocity is very low, which means that relatively little groundwater is mixed with the leachate and transported to a nearby communal sewage works for treatment. The direction of the water flow also prevents spreading of contamination into the sur rounding groundwater. The groundwater quality is monitored periodically in boreholes around the landfill. More than 20 years of monitoring have not resulted in any indication that contaminants are spreading.
Acceptance procedures and waste disposal methods were very similar to the ones described for the Nauerna landfill. The Velsen landfill is capped with a 1 m thick layer of clay soil. It is standard Afvalzorg policy to find a useful destination for landfill after operation. The Velsen landfill is now a recreation area. It is covered with rich vegetation housing a lot of wild-life. There are facilities for horse-riding and open air concerts. Mountaineers can practice their skills on a special wall. There are tracks and paths to walk, cycle, mountain bike and skeeler. And last but not least there are ski-slopes and a restaurant. Recalculated to present day price levels an indication of the operational cost for a landfill like Velsen is presented in table 2.
In the 1980's the gate fee was 5 Euro per tonne. The difference with the cost level for the Nauerna landfill is mainly caused by the lower investment cost, i.e. no bottom liner and a much cheaper capping. Since periodic repair and replacement of top liners (the lifetime of hdpe liners is estimated at 50 years) makes up a major part of the cost of aftercare (Ritsema, 1999), the aftercare fund for the Velsen landfill can be a lot smaller than the aftercare fund for the Nauerna landfill. And thus the reservation per tonne for aftercare is also considerably smaller than for the Nauerna landfill. The geohydrological isolation requires a larger volume of waste water to be treated. Especially when compared to landfills that are capped with a double impermeable liner. But the costs for the extra waste water treatment are at least 10 times smaller

Table 2: Indication of operational costs Velsen landfill

Aspect	Euro per tonne
Depreciation and interest	0.70
Waste acceptance and disposal	1.80
Administration and overhead	1.10
Site maintenance	0.30
Waste water treatment and landfill gas extraction/utilization	0.40
Site inspection and monitoring	0.10
Capping fund	1.30
Aftercare fund	1.10
Total	6.80

than the costs for periodic replacement of the top liner.
Finally it should be noted that technical measures for geohydrological isolation in most cases can be installed at the perimeter of the landfill. This means that they are suitable to retrofit on existing landfills. Thus the environmental impact of former and existing landfills can be greatly reduced. Financing of such measures is often possible by continuing or extending the landfill operation and establishing a small gate fee. An example of this principle with very extensive isolation measures is given in Case 3.

CASE 3: SCHOTEROOG LANDFILL

The Schoteroog landfill site is situated near the city of Haarlem and encompasses 24 ha of former marshy meadowland. The landfill was constructed in 1971 by the community of Haarlem. Part of the topsoil was removed prior to landfilling but no bottom liner was installed. To prevent contamination of soil and groundwater a drainage system for collection of leachate was installed. Leachate was collected in a ditch and pumped to a nearby communal waste water treatment plant. Monitoring and maintenance were very poor. In later years very little evidence of the collection system's existence could be found. Between 1973 and 1977 1.5 million m_3 of waste was disposed of at Schoteroog. Initially only coarse household waste was landfilled, but from 1974 onwards household waste was also included, as much as 50% of the total input. Furthermore waste water treatment sludge and industrial waste (absorbent clay and paint residues) were landfilled. The waste extended over 15.3 ha with an average thickness of 4.5 m. The Schoteroog landfill was closed in 1977 when the Velsen landfill site was opened. Surveys showed that the groundwater was seriously contaminated. The most important contaminants were benzene, monochlorobenzene and PAH's. Comparison with national standards and laws indicated that remediation was required. The same year a plan was drawn up to prevent spreading of pollution by installing a perimeter drainage system and a clay capping. However financing of these measures was a problem. The community of Haarlem, the owner of the Schoteroog landfill, was not able to allocate the necessary budget, while funding by the Provincial or National Authorities could not be expected before the year 2010.
In 1992 Afvalzorg made a proposal for the remediation of the Schoteroog landfill (Scharff, 1997). The proposal included realization of environmental protection measures, re- opening of the landfill and financing the remediation by means of the landfill fee. Afvalzorg has the organisational structure to finance protective measures, to create aftercare funds and to carry out aftercare. In consultation with the Local and Provincial Authorities it was decided that Afvalzorg would initiate and realize the Schoteroog project, would process the waste, would create an aftercare fund and will

carry out aftercare in the future. Studies revealed that a vertical cut-off wall in combination with deep wells to reduce the water level within the cut-off wall would be the best remediation method. This scheme combines the highest level of geohydrological isolation with minimizing removal of water to maintain water levels. Moreover it requires little maintenance, which is important in view of the fact that, after capping the landfill, the area will be prepared for intensive recreation. In 1995 and 1996 2,550 m cut-off wall with an average depth of 12 m and 21 deep-wells with an average depth of 7.5 m were installed. The deep-wells were connected by discharge pipes to a pumping-station. The pumping-station transports the mixture of leachate and groundwater to a nearby communal waste water treatment plant. Reduction of the water level within the cut-off wall results in an inward and upward water flow (see Figure 3). This prevents leakage of contaminants into the underlying aquifer.

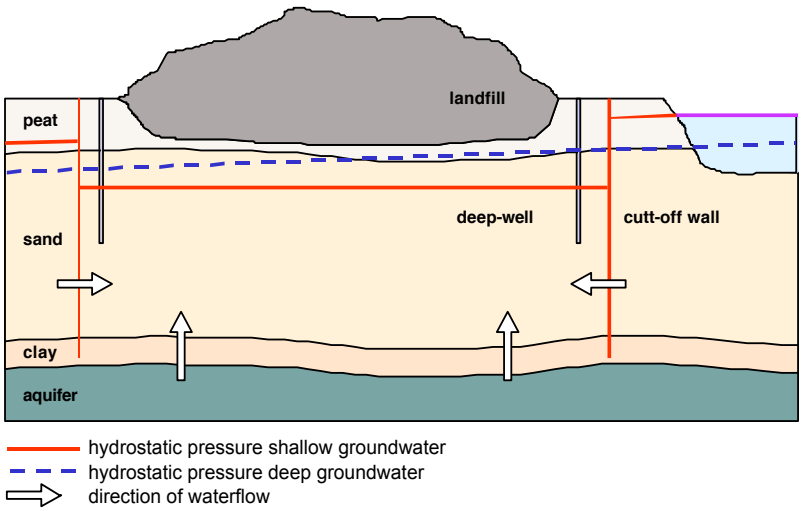

Figure 3: Geohydrological situation after remediation of Schoteroog landfill.

By March and April 1996 the rest of the required infrastructure was installed. This included fences, gate, asphalt roads, shed, weighbridge, computer system, office and personnel quarters. The Schoteroog landfill was re-opened from May 1996 to April 1998. In this period 450.000 m $_3$ of waste were landfilled. To allow for settlement the capping will be installed in 2002. The overall cost of the Schoteroog landfill is 34.90 Euro per tonne of waste (see Table 3). By spreading cost and income Afvalzorg is able to use a uniform landfill fee on all landfill sites. This ensures that the waste transport distance is as small as possible because it is not influenced by differences in gate fee.

Table 3: Operational costs Schoteroog landfill

Aspect	Euro per tonne
Depreciation and interest	8.90
Waste acceptance and disposal	2.80
Administration and overhead	1.10
Site maintenance	0.70
Waste water treatment and landfill gas extraction/utilization	0.40
Site inspection and monitoring	0.20
Capping fund	12.80
Aftercare fund	8.00
Total	34.90

Since groundwater around the landfill site was already contaminated, groundwater monitoring will focus not on standards for natural groundwater but on deterioration of the present situation. This is not an easy task because around the landfill industrial activity has also caused groundwater contamination. Follow-up actions to monitoring data require careful analysis of parameters specific for landfills and consideration of geochemical processes. Three years of monitoring Schoteroog landfill have revealed fluctuations in parameter concentrations. So far the data indicate that a stable situation has been reached that puts an end to contamination of the aquifer.
A similar approach can be used for many former or existing landfills. However in some cases re-opening a landfill is not possible. This makes it extremely difficult to finance remediation measures. An example of remediation without re-opening is Case 4.

CASE 4: ILPERVELD

In pre-historic times the Ilperveld and similar regions were bogs that had developed in lagoons behind dunes that protected them from the sea. In later days human settlements dug for peat and thus created a landscape with lots of water in between meadows with very high water tables. Until several decades ago the area was mainly used for cattle farming. From the 1960's onwards this was gradually abandoned because all transport had to be carried out with boats. Due to its inefficiency cattle farming could no longer compete with other regions. Already several decades earlier the area was considered useless land and therefore suitable to landfill waste from neighbouring industries, villages and cities. This was stopped around 1980 when sanitary landfills were opened that provided a better environmental alternative for waste disposal. At the moment the Ilperveld is a 600 ha nature reserve where ecological and cultural heritage is preserved. In this nature reserve at least 30 small sites with waste deposits and 6 larger landfill sites are present. At the time the large sites operated with a permit. The smaller sites received material that was generally considered construction material rather than construction and demolition waste. Due to a lack of supervision and enforcement many sites received hazardous materials. The waste was transported in barges. Eye-witnesses have declared that when the shore for unloading was occupied by other barges also the opposite shores were used. At many occasions waste was spilled and fell in the water.
Recent surveys have indicated that close to the landfills sludge on the bottom of the waterways is contaminated to such extent that regulations require that when dredged it is transported to special treatment facilities or sanitary landfills. The foundation that manages the nature reserve has no funds for either the treatment of the sludge or remediation of the landfills. Therefore sludge accumulates in the waterways. This not only hinders recreational activities on the water, but also reduces visibility in the water which has many effects on the water ecology.
When at distance from living areas the risk of contact of people with contaminated material is small. There are adverse effects to nature but in priority ranking of the national government the effects are not urgent and do not require measures on short notice. This means that at least until 2008 no government budgets will be made available for remediation of the landfills in the Ilperveld.
Afvalzorg has drawn up a plan to combine dredging of sludges and remediation of the landfill sites. The philosophy of the plan is that the contamination of the sludge is caused by leaching of the landfills or spilling of waste. The landfills have operated with a permit according to standards that were acceptable at the time. Therefore no

legal directions can require removal of the waste. If seen as an area related problem the contamination of the sludge should have been confined to the landfill sites. Contrary to present government policy Afvalzorg has proposed to deposit the contaminated sludges on the landfill sites. Furthermore it was proposed to remove smaller landfill sites and deposit the waste on the larger sites. And finally Afvalzorg proposed to cap the waste with non-contaminated sludges form the area (Figure 4).

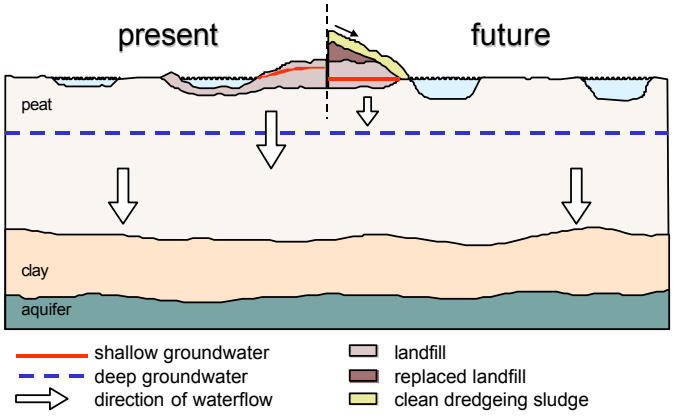

Figure 4. Geohydrological situation before and after remediation of the Ilperveld landfills.

The effect should be that in the first place the waterways are cleaned and the water ecology could restore itself. Secondly the production of leachate is reduced by reducing the total surface of contaminated material and reshaping the sites to promote run-off instead of percolation. Some leachate production is considered to be acceptable. The situation of infiltration can not be reversed by geohydrological measures. When low groundwater levels are realized in peaty soil, the peat will oxidise and disappear gradually. For reasons of conserving cultural heritage this is not acceptable. The infiltration is however very small because the low permeability of the underlying clay induces low water velocities. Furthermore surveys at various landfills have shown that contaminants hardly spread in peaty soil. This is attributed to sorption of contaminants and to natural processes of degradation called natural attenuation. At the moment a major research programme is carried out in the Netherlands at 150 former landfill sites to gather more information on natural attenuation processes.
The competent authorities welcomed the initiative, but wanted confirmation of the expected effects. Therefore in February 1998 a pilot project was started on a 2 ha landfill site. Sludge was deposited on this site and several monitoring systems were installed to determine the effects on soil, groundwater and surface water quality. One and half year of monitoring have not indicated any adverse effects. The results are preliminary and monitoring will continue. Nevertheless because of the positive results so far there is an agreement to start preparations of the first phase of full-scale remediation of the Ilperveld landfills.
It is estimated that 40,000 m3 of contaminated sludge and 140,000 m3 of waste need attention in the Ilperveld area. Based on the pilot project the cost for remediation was estimated at 4.6 million Euros (see Table 4). The costs for total removal if contaminated sludge and waste and disposal at a sanitary landfill would be at least three times higher.

Table 4: Remediation costs Ilperveld landfills (based on 40 ha finished surface).

Aspect	Euro
Replacement of waste	2,545,000
Disposal of contaminated sludge	273,000
Covering with clean sludge	491,000
Landscaping and seeding	1,023,000
Project management	289,000
Total	4,621,000

DISCUSSION AND CONCLUSION

In the Netherlands the change from uncontrolled waste tips in more than 1,000 communities to sanitary landfills required investments the individual communities could not supply. The communities had to start regional cooperation. In the 1980's approximately 80 corporations operated landfill sites. More stringent legal requirements for double bottom liners, capping with double top liners, leachate treatment, landfill gas extraction and utilization, groundwater monitoring and arrangements for aftercare have caused many regional corporations to reconsider their landfill operation. At the moment only 20 corporations are operating landfills. These are mainly privatised companies owned by national, provincial or regional authorities. The number will probably decrease until 6 to 10 companies remain. It can therefore be expected that for Romanian communities without regional cooperation it will be difficult, not to say impossible, to start landfills according to ecological standards overnight. The World Bank (Rushbrook, 1999) strongly advises to include intermediate stages in the transition from open dumping to sanitary landfilling:

- designated dumping: i.e. within a designated site, but with no control of operations;
- controlled tipping: i.e. in a supervised site, with organised disposal in layers and periodic covering of the waste;
- engineered landfilling: i.e. where the impact of waste on the environment has been assessed and engineering measures have been taken to limit such impacts.

Having gone through these stages the step towards sanitary landfilling and minimizing environmental impacts is feasible. Realizing new landfills does not change the problems caused by present and former landfills. Continuing waste disposal at present landfills and implementing gate fees and better landfill management provides the opportunity to counteract the negative impact of existing landfills. It is possible to retrofit simple environmental control measures. Thus the public could be shown that improvements are realized. They could gradually be convinced that it is important to spent money on proper waste disposal. When the public gradually gets used to increased costs for sanitary landfilling, while in the mean time economic development continues, in time the basis for higher expenditure on waste management will grow.

The paper has shown that with appropriate measures improvements are reached. In existing undesired conditions at least something is achieved. Whereas otherwise the uncontrolled contamination of the surrounding area would have continued. Also in a developed country like the Netherlands sometimes suboptimal solutions are the only ones feasible. Appropriate site specific measures in combination with natural attenuation processes can reduce the negative environmental effects of landfills to a great extent at relatively low costs.

The approach followed in the Netherlands reflects the idea that the highest priority should be given to health and safety. Environmental protection comes second. In order to improve health and safety hygiene is most important. Hygiene is served by avoiding human contact with waste. This requires most of all efficient collection

services. Secondly minimizing the number of people present on the landfill and proper processing of waste on the landfill are important. Proper landfill management can be implemented at relative low cost even on landfills with very little environmental protection measures. When larger budgets become available environmental protection measures can be improved. Allocation of available budgets should always be accompanied by a proper weighing of priorities.
In conclusion it is suggested to Romanian landfill owners to start with spending a fraction of the money required for west-European standards and achieve a lot of improvements. Then it would be possible to gradually move on while in the mean time public acceptance of increased gate fees, environmental awareness and also the purchasing power of the population has grown.

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