Hrybovychi municipal solid waste landfill reclamation and coherent pollution prevention in holistic approach

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This work is an attempt to analyze the state of Hrybovychi municipal solid waste landfill and the recent work done on the way to landfill reclamation according to the Ukrainian and EU legislation in landfill construction and operation. Also the suggestions on future steps on landfill reclamation have been made. The primary analysis of possible methods of leachate treatment has been made. It was proven experimentally that the process of one stage deammonification process can be used as the method of nitrogen removal from leachate.

Key words: Landfill, Reclamation, Leachate, Legislation, Anammox

INTRODUCTION

Landfilling is the oldest method of treatment the wastes, but it is still widely used. When landfill is not properly managed it can cause adverse impact on environment. Among the most dangerous effects that landfilling causes is pollution of soil, surface and ground waters and emission of landfill gas that has high greenhouse potential and strong smell.

However, new landfills, which are build according to European Union (European Commission, 1991) or national (Derzhbud Ukrainy, 2005) legislations are advanced engineering objects with the minimal impact on environment which allow handle wastes with low cost and remove energy from it in the form of landfill gas in the same time.

Landfilling of municipal solid wastes is the most used method of wastes treatment in EU-27 countries where, according to ETC/RWM (2008), the share of landfilling was 41% in 2006. The same can be said about Ukraine, where the situation with the waste management is even worse. Two waste incineration plants are in operation (Kyivenerho, 2009) in Kyiv and Dnipropetrovsk and incinerate wastes from about 1.3 million p.e. All the other wastes are kept at about 4500 landfills all around Ukraine (MHMEU, 2008).

Among them, Hrybovychi municipal landfill is the biggest and is one of the biggest in Europe (TzOV “Hafsa”, 2008a). It is situated 7 km from the city of Lviv, 500 m from the village of Velyki Hrybovychi and 700 m from the highway Lviv-Kyiv. The area of the landfill is 38.8 hectares where 26.5 hectares are already occupied by landfilled wastes. During its more than 50 years operation 6.0 million tons of wastes were landfilled there (TzOV “Hafsa”, 2008b). The landfill has almost reached its capacity, so the maximum time of operation is evaluated to be 4 years. Most of the territory of the landfill is not in the operation and has to be reclaimed. Since the landfill is situated in a ravine, the depth of landfilled wastes is not the same and varies from 5 to 40 m (TzOV “Hafsa”, 2008a). Since the landfill was designed in the middle 50-th there was not enough attention put to environment-protective measures such as building the bottom geological barrier, leachate collection and treatment and landfill gas collection and utilization.

The landfill is identified as one of the most dangerous objects in Lviv region in the scope of impact on environment and health of people. There were number of cases when the ground water in neighboring villages was found to be contaminated with landfill leachate and the smell of the landfill was heavily deteriorating air quality in residential areas (Gazeta.ua, 2009; ZIK, 2009).

Taking into account the above mentioned considerations there have been decided to close the landfill in 4 years transform the landfill into environmentally safe object.

The aim of this paper is to evaluate the measures that have been taking in this direction and to propose future steps of landfill reclamation.

METHODOLOGY

The big part of this work is purely theoretical, where a literature review was made regarding the implementation of environmental measures at the landfill and comparison of them with the front-end technologies of landfilling in the world.

Also, the visit to the landfill has been made in order to evaluate the conformance of the information in the literature with the real situation. The sample of leachate was taken in order to evaluate the possibility of Anammox process application in removing nitrogen from it. The analysis of it was made. Specific Anammox activity measurement was made using the methodology developed by Adamczyk and Gabrys (2008) where leachate and water solution were used as a substrates. Three days batch test was made using leachate as the source of nitrogen using the process of one stage deammonification.

The information about 2 analyses of leachate from Hrybovychi municipal landfill was taken from the State Department of Environment Protection in Lviv Region (SDEPLR).

RESULTS

The evaluation of already taken measures

As was mentioned above, due to the biological processes in the depth of the deposited wastes, the landfill gas is produced. As long as it can be used as the source of energy, the aspect of degassing of the landfill was of the main interest during last years. As far as in 1991-1993 few boreholes were made in order to evaluate gas production rate and the content of landfill gas. The results showed that 50% of the landfill gas (by volume) composes from methane (Hvozdevych, 2003). Theoretical calculation of methane reserve at Hrybovychi municipal landfill (Hvozdevych, 2003) using Landfill Gas Generation Model, recommended by US EPA has shown that the annual generation of the methane gas at the landfill lies between 12.4 and 18.54 million m^3 and this value depends whether the landfill will continue to be used or will be closed.

However, building of the gas collection system, together with the infrastructure of energy transformation and delivery, require high costs. That is why the implementation of the degassing project has been postponed, until the 2006 when the contract between TzOV “Hafsa” from one side and Carbon Capital Markets and C6 Capital from the other was signed, where the first company is the technical executor of the project and the latter two – investors.

According to the project description (TzOV “Hafsa”, 2008a), the work can be divided into three parts:

- Partial technical recultivation – leveling the surface of landfill, covering it with 0.5 m of clay with water permeability not lower than 10^{-6} m and compressing it to avoid water penetration, landfill gas leakage out from the waste depth and air penetration into the waste depth;
- Degassing system construction – construction of 150 boreholes, connection of them into system of pipes with total length of 10 km, installment of equipment for landfill gas monitoring and incineration;
- Leachate collection system construction – lowering the level of leachate in the depth of waste, construction of 15 boreholes with a piping system for leachate transportation to leachate collection ponds.

It is worth mentioning that according to the project, only small part of landfill gas is incinerated for the purpose of electricity generation (which is used to run the vacuum pumps and incineration equipment), while the biggest part of it is incinerated in the high temperature landfill gas incineration unit HOFGAS-Ready produced by Hofstetter Umwelttechnik AG. According to Adrian Loening, director of the company "Carbon Trade", that works in the area of carbon dioxide emission trading, it is a common practice to incinerate the gas without energy recovery the first year of operation in order to receive information about the stability of landfill gas production, since the installment of electricity generators require big investment. It is worth mentioning that the economical driving force of the project is based on selling CO_2 quotas within the Kyoto Protocol, since the incineration of landfill gas decrease the emission of greenhouse gases into the atmosphere.

The work done within the described project is evaluated according to TzOV "Hafsa" (2008c) and private observation of the system.

Concerning the first part of the project (leveling and covering with clay) it may be concluded that the work is done according to the project. It resulted in decreased number of birds that were feeding from the landfill and decreased smell in the nearby situated villages (Vysokyy zamok, 2009).

Concerning the second part of the project (degassing), the system was successfully constructed, tested and started its operation in May 2009. However, visual inspection of the system showed that the piping system needs improvement, since the airtightness of the system can not be guaranteed in long term perspective since many joints between pipes are with rubber ring tightening additionally sealed with silver duct tape, while for reliable connections of PVC pipes that are used for transporting a gas, welded joints are required. Also, most of the borehole and manifold wells are not covered, which is required by the legislation (Derzhbud Ukrainy, 2005).

The third part of the project has not been made according to the project. Instead of making the boreholes for leachate pumping-out, the system of trenches around the landfill was made with the natural flow to leachate collection pond. However, this system does not allow collect the leachate that is created inside the depth of waste, but rather to collect the precipitation waters. Since the most of the landfill has been covered with clay (some part is still not covered since the wastes are still being deposited at the landfill) the precipitation waters do not have the contact with wastes and are comparably clean. Collection and monitoring of such waters is also required by Directive 1999/31/EC but it has lower impact on the pollution of the ground waters.

Proposed measures for limiting impact on environment and people's health

Leachate collection system

The first problem, that was discussed before is the leachate collection. Since the leachate collection boreholes were not constructed and the landfill was almost completely sealed with clay on the top, the only possibility for leachate is to penetrate through the bottom of the landfill to the ground waters, especially taking into consideration the fact that the bottom geological barrier is absent.

There are two possible possibilities for construction of leachate collection system – either to make separate leachate collection boreholes, as was planned, or rebuild some of the gas collection boreholes so they could be used both for gas and leachate extraction. Such a system would have the benefit because of the fact that the underpressure in the gas collection boreholes would force the leachate to flow into the boreholes, while in separate leachate collection boreholes the level of the leachate would be the same or lower than in the waste mass. The leachate has to be pumped to the separate collection pond so it can be further treated before discharge. The treatment options are discussed further on.

New part of landfill

As was already mentioned above the landfill is still in operation and estimated time of closure is in 4 years. During these 4 years the landfill will not increase in height but rather grow in width. It is planned to fill in a region with the area of 2.2 hectars with the wastes on the height of 16 meters (TzOV "Hafsa", 2009).

The important task in the development of new landfill area is to follow the recommendations in landfill construction. Ukrainian legislation (Derzhbud Ukrainy, 2005) regulate only the designing and construction of the new landfills but not the extension of the existing ones. European Union Legislation (European Commission, 1991) require closure of such landfills that does not comply with the requirements so, in other words, the new region of the landfill has to be considered as a completely new landfill, which in turn has to be designed according to the requirements.

As long as the new part is the continuation of the old landfill, such recommendations in the design can be made:

- Construct a geological barrier on the bottom of the landfill with a tilt in the direction to the outside border of the landfill. This will ensure that the leachate, that is formed, will flow into the direction of collection system and not into the old landfill mass. The requirements for permeability of geological barrier and thickness of it are the same in EU (European Commission, 1991) and Ukrainian (Derzhbud Ukrainy, 2005) legislation and are 10^{-9} m/s and 1 m respectively.
- Construct a leachate collection system. According to Directive 1999/31/EC geological barrier have to be covered with artificial sealing liner followed by drainage layer, in which perforated pipes for leachate removal are mounted. According to DBN V.2.4-2-05 artificial liner is not required.
- Construct a landfill gas collection system. DBN V.2.4-2-05 recommends construction of gas collection wells in parallel with filling the area with waste. Every 2 m horizontal perforated pipes are connected to the central wells to increase the gas extraction efficiency and decrease the number of required vertical wells.

Landfill recultivation

Since only partial technical recultivation of the old part of landfill has been made by TzOV "Hafsa", it has to be finished according to the national legislation. The mineral sealing layer has to be extended to the thickness of 1 m, followed by artificial sealing liner, drainage layer with thickness of 0.5 m and soil cover 1 m thick. After the technical recultivation, biological one has to be made, which means planting the vegetation. The only differences in recultivation layers described in Directive 1999/31/EC is that artificial liner is not required and the thickness of mineral sealing layer is not regulated.

According to Haidyn et al (2007) all required mineral materials required for complete recultivation are present in the direct vicinity to the landfill, which decrease the cost of the recultivation.

Leachate treatment

Currently, the leachate from the landfill and polluted precipitation waters are collected in a pond, where it is stored and regularly transported to the inflow of Lviv municipal wastewater treatment plant. Since the content of contaminated water, that is stored in the pond, is strongly dependent on the proportion between precipitation waters and leachate coming to, it varies a lot with a time (Table 1).

According to the Rules of acceptance of wastewaters from the enterprises into communal and departmental sewages of municipality (SCBARPU, 2002), it is not allowed to accept wastewaters that contain salts of heavy metals and the wastewaters where COD:BOD ratio is higher than 2.5. From the results of analysis it is seen that in one case COD:BOD ratio was higher than the limit and the contaminated water have rather high concentrations of heavy metals, especially chromium, cobalt and lead. That is why the discharge into the municipal wastewater treatment plant or to surface waters should not be allowed and the leachate has to be treated before the discharge.

Table 1. Result of analyses of three leachate samples.

Parameter	Dimensions	14.03.2008 (source - SDEPLR)	30.07.2008 (source - SDEPLR)	25.03.2009 (own analysis)
Color		Brown	Brown	Brown
Smell	Point	5	1	-
Transparence	Cm	2.0	2.0	-
pH		7.91	7.05	7.82
Hardness	meq/dm^3	21.5	21.8	-
Alkalinity	mmol	45.0	15.0	13.0
Hydrocarbonates	mg/dm^3	2745	915	-
Sulphates	mg/dm^3	75.3	91.14	-
Calcium	mg/dm^3	90.18	240.48	-
Magnium	mg/dm^3	206.72	119.17	-
Na+K	mg/dm^3	3939.25	627.25	-
Chlorides	mg/dm^3	4697.12	1418.0	-
Mineralisation	mg/dm^3	11753.57	3411.04	-
Dry residue	mg/dm^3	11521.0	3125.0	-
Suspended solids	mg/dm^3	352.5	145.2	-
Ammonium nitrogen	mg/dm^3	141.5	20.6	175.3
Nitrites	mg/dm^3	0.0	3.26	<1.64
Nitrates	mg/dm^3	29.75	34.5	<22.14
Phosphates	mg/dm^3	1.38	0.387	-
BOD_5	mg/dm^3	1092.5	185.6	-
COD	mg/dm^3	2732.4	461.2	593.0
Total Iron	mg/dm^3	1.0608	0.715	-
Synthetic surfactants	mg/dm^3	0.12	0.14	-
Conductivity	mS/cm	13.4	5.28	6.55
Zink	mg/dm^3	0.0774	0.0243	-
Cadmium	mg/dm^3	0.0514	0.013	-
Nickel	mg/dm^3	0.6386	0.193	-
Cobalt	mg/dm^3	0.1705	0.056	-
Lead	mg/dm^3	0.2337	0.076	-
Copper	mg/dm^3	0.1511	0.129	-
Chromium	mg/dm^3	1.4856	0.158	-

Steensen (1997) has analyzed 100 systems of leachate treatment plants in Germany. More than 60% of them used biological treatment as the first step of treatment. This can be explained by the fact that usually leachate has rather high BOD and ammonium concentrations (especially leachate from the young landfills) which have to be decreased.

Among the biological processes the most widely used is the activated sludge process. It has a wide range of applications and allows removal of the big fraction of BOD and transformation of ammonium into nitrogen gas through nitrification/denitrification process.

The other way of high-efficient removal of ammonium is the application of one-stage deammonification process (partial nitritation-Anammox). It is especially useful when the COD:N ratio is too low to remove nitrogen using nitrification/denitrification process. Since the results of three analyses showed different values of COD and NH_4-N concentration, it can not be decided if activated sludge, one-stage deammonification or the combination of both methods should be used. The result can be made when the leachate collection system is improved and stable results of analyses are achieved.

Biological treatment is often hampered by toxic substances (such as polyaromatic hydrocarbons (PAH), adsorbable organic halogens (AOX), polychlorinated biphenyls (PCB)) and by the presence of bio-refractory organics (such as humic substances or surfactants) (Wiszniowski et al, 2006). In order to check if Anammox and one-stage deammonification processes are not inhibited by any possible substance of the leachate, the tests on determination of specific Anammox activity, and 3-days batch test with one-stage deammonification process were made. The results of activity measurement using leachate and water solution as substrates have shown that the rates of nitrogen transformation were on comparable level (4.79 and 4.25 $gN \cdot m^{-2} \cdot d^{-1}$ respectively). During the 3-days batch test 87% of nitrogen was removed. These results have shown that no inhibition was observed in the short and medium time scope.

Treatment of leachate usually is not limited only to biological processes but in most cases is a combination between biological and phisico-chemical methods. These methods allow removing the substances that can not be removed by biological transformation – e.g. heavy metals, PCBs, etc.

One of the most used phisico-chemical method for treatment of leachate is coagulation-floculation. Aluminum sulphate, ferrous chloride and ferrous sulphate are the most famous coagulants. The method allows removing small colloidal particles by creation of flocs which are readily sedimented. Application of this method allows removal of color of the leachate and suspended solids. Amokrane et al. (1997) reported the 75% removal of COD from leachate coming from partially stabilized landfill and 25-38% removal for leachate coming from young landfill.

The classical way to reduce the concentration of heavy metals is the application of chemical precipitation. The use of lime allows reducing heavy metal content by up to 90% (Amokrane, 1997) with a low cost. Also, some COD reduction can be expected.

If the application of flocculation and chemical precipitation methods does not allow removing heavy metals and persistent organic pollutants to required level, the method of adsorption can be applied as a polishing step. The most widely used adsorbent for leachate treatment is activated carbon (Wiszniowski et al, 2006). Also Petros et al (2003) have reported rather high removal efficiency of heavy metals with the use of zeolite as an adsorbent, the use of which can reduce the treatment cost substantially.

CONCLUSIONS

Summarizing the presented information, it can be said that the process of transformation of Lviv municipal landfill into environmentally safe object has already started. The start of degassing process is substantially cut the emissions of greenhouse gases into the atmosphere. Partial recultivation that was made allowed decreasing the smell in the neighbouring villages.

Yet still a lot has to be made. The biggest problem identified is the poor leachate collection system that is causing the ground water pollution and making high risk for human health. Without extensive research it is hard to choose the combination of the treatment methods that would allow efficiently treat the leachate with the lowest cost possible. However the processes that with high probability will give good treatment efficiencies were described. Also, it was proven that Anammox process can be applied for nitrogen removal from the landfill.

In order to avoid precipitation water penetration to the waste mass the process of recultivation has to be finished.

It is important to make sure that the new part of landfill will be designed and filled in accordance with the best available methods described in national and EU legislation.

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