From Sanitary to Sustainable Landfilling
- why, how, and when?

1st International Conference on Final Sinks
23rd – 25th September 2010, Vienna

Vienna University of Technology & Helsinki University of Technology, Lahti Center

From Sanitary to Sustainable Landfilling - why, how, and when?

1st International Conference on Final Sinks; 23rd – 25th September 2010, Vienna

Vienna University of Technology
A-1040 Vienna, Karlsplatz 13/226
Austria

Dr. Johann Fellner (Ed.)
j.fellner@tuwien.ac.at
ISBN 978-3-85234-115-6

Vienna 2010

International Program Committee

Johann Fellner (Austria) (Head of Committee)

Franz Adam, AWEL Zurich (Switzerland)

Agamuthu Pariatamby, University of Malaya, (Malaysia)

Morton Barlaz, North Carolina State University (U.S.)

Paul H. Brunner, Vienna University of Technology (Austria)

Klaus Fricke, TU Brunswick (Germany)

Henning Friege, AWISTA Düsseldorf (Germany)

Dominique Guyonnet, BRGM (France)

Stefanie Hellweg, ETH Zurich (Switzerland)

Christian Holzer, BMLFU (Austria)

Juha Kaila, Aalto University (Finland)

Vladimir N. Korotaev, Perm State Technical University (Russia)

Karl E. Lorber, University of Leoben (Austria)

Hwong-wen Ma, National Taiwan University NTU, (Taiwan)

Cecilia Öman, International Foundation for Science (Sweden)

William Powrie, University of Southampton, (U.K.)

Debra Reinhart, University of Central Florida (U.S.)

Heijo Scharff, Sustainable Landfill Foundation (The Netherlands)

Yasumasa Tojo, Hokkaido University (Japan)

Goran Vujic, University of Novi Sad (Serbia)

Yue-hwa Yu, National Taiwan University NTU (Taiwan)

Program

23rd September 2010

08:45 - 09:30	Registration	
09:30 - 09:45	Welcome address	Johann Fellner *(AT)* & Juha Kaila *(FI)*
09:45 - 10:15	Keynote: **The need for final sinks** Paul H. Brunner *(AT)*	

10:15 - 11:40 Session A – Landfilling Strategies and Concepts

Chairperson:	*Juha Kaila (FI)*
Derek Greedy *(UK)*	Sustainable Landfills under the EU Concept
Stefan Bayer *(DE)*	Sustainability Gaps in Municipal Solid Waste Management: Dry Tomb and Bioreactor Landfills in an Intertemporal Perspective
Raffaello Cossu *(IT)*	Pretreatment of Waste for a Sustainable Landfill Disposal
11:40 – 12:40	*Lunch Break*

12:40- 14:20 Session B – Understanding the Landfill Body

Chairperson:	*Helmut Rechberger (AT)*
Daniele Di Trapani *(IT)*	Formation of Hanging Water Tables in Municipal Solid Waste Landfills
Sahadat Hossain *(US)*	Monitoring Moisture Movement within Municipal Solid Waste in Enhanced Leachate Recirculation Landfill using Resistivity Imaging
Diana Caicedo *(UK)*	Exploring the Use of Micro-focus Computed Tomography for a Better Conceptual Understanding of Flow and Structure in Landfilled Waste in the Context of Post-Closure Management for Landfills
Kai Münnich *(DE)*	Long Term Monitoring of Leachate Flux into Drainage Pipes of MSW Landfills

14:20- 14:50 Poster session

14:50 - 15:10 *Coffee Break*

15:10 - 17:00	**Session C - Modeling & Monitoring of Landfill Emissions I**

Chairperson:	*Heijo Scharff (NL)*
Sally Donovan *(UK)*	Gas Emissions from Biodegradable Waste in Landfill
Franco Tassi *(IT)*	Flux Measurements of Volatile Organic Compounds (VOCs) from Landfill Cover Soils
Giordano Montegrossi *(IT)*	Degradation Pathways of VOCs in Biogas from Solid Waste Disposal Sites
Torleif Bramryd *(SE)*	Impact of Sustainable Landfilling on the Global CO_2 concentration

19:00 – 22:00 **Wine Tavern**

24th September 2010

09:00 – 09:30 Keynote: **Learning from the Nuclear Sector**
Niklaus Waber *(CH)*

09:30 - 10:40	**Session D - Modeling & Monitoring of Landfill Emissions II**

Chairperson:	*Pariatamby Agamuthu (MY)*
Loretta Y. Li *(CA)*	Evaluation of PFAs and PBDEs in Engineered Landfill Leachates
Yasumasa Tojo *(JP)*	Monitoring of Leachate Quality Stored in Gas Ventilation Pipes for Evaluating the Degree of Landfill Stabilization
David Laner *(AT)*	Environmental Compatibility of Closed Landfills – Assessing Future Pollution Hazards

10:40 – 11:00 *Coffee Break*

11:00 - 12:40	**Session E - Landfill Stability and Aftercare I**

Chairperson:	*Karl E Lorber (AT)*
Heijo Scharff *(NL)*	Landfill sustainability and completion criteria
Ena Smidt *(AT)*	Monitoring and Assessment of Landfill Stability Using Simultaneous Thermal Analysis
Takayuki Shimaoka *(JP)*	Influence of Air Injection on the Stabilization of Landfill Adopting the Aerobic-anaerobic Method
Gaël Bellenfant *(FR)*	Natural attenuation in groundwater around landfills: implications for landfill post-closure

12:40 – 13:40 *Lunch break*

13:40 - 15:40	**Session F - Landfill Stability and Aftercare II**	

Chairperson:	*Heinz Brandl (AT)*
Willem van Vossen *(NL)*	Sustainable Emission Reduction at Closed Landfills Based on Natural Biochemical Processes. - Final Results of a Full Scale Bioreactor Project at the Vlagheide Landfill (NL)
Sato Masahiro *(JP)*	Investigation of polycyclic aromatic hydrocarbons (PAHs) content in several incineration residues and simple estimation of their fate in landfill
Fan Lu *(CN)*	Biostabilization of Municipal Solid Waste with High Water content and Putrescible Waste prior to Landfill
Marion Huber-Humer *(AT)*	The fate of nitrogen relating to in-situ aeration of landfills
W.-U. Henken-Mellies *(DE)*	Long-Term Performance of Landfill covers: Results of Lysimeter Test Fields in Bavaria (Germany)
15:40 - 16:00	*Coffee Break*

16:00 - 17:40	**Session G - Landfills – Resource and Hazard**

Chairperson:	*Stefan Gäth (DE)*
Antonis Mavropoulos *(GR)*	Landfills, Complexity and Biogas Risk Assessment
Roland Weber *(DE)*	Persistent Organic Pollutants and Landfills - Past Experiences and Future Challenges
Kai Münnich *(DE)*	Developing a Concept for Mining of old Landfill Sites
Ingo Hölzle *(DE)*	Experiences of Landfill Mining Projects in Bavaria under Consideration of the German law (TASi)
17:40 - 17:50	**Poster Award Ceremony**

25th September 2010

08:30 - 10:20	**Session H - Landfilling in Transition and Developing Economies I**
Chairperson:	*Antonis Mavropoulos (GR)*
Pariatamby Agamuthu *(MY)*	Challenges and Issues in Sustainable Landfilling in a Transitory Country - Malaysia
Christia Meidiana *(AT)*	The New Waste Law: Challenging Opportunity for Future Landfill Operation in Indonesia.
Mohammad Aljaradin *(SE)*	Municipal Solid Waste Landfills in Jordan, Current and Prospective Future
Pooja Singh *(IN)*	Chennai Open Dumps, from Environmental Health to Climate Change – a Case Study
Bob Couth *(UK)*	Sustainable Landfilling through CDM Waste Composting in Developing Countries in Africa
10:00 - 10:20	*Coffee Break*
10:20 - 11:40	**Session I - Landfilling in Transition and Developing Economies II**
Chairperson:	*Yakov Vaisman (RU)*
Goran Vujic *(RS)*	From Landfill to 3R, Pathway in Developed as well in Developing Countries
Ira Stanic-Maruna *(AT)*	What You Sow Today, You Will Reap Tomorrow - The Future of Landfilling in Croatia
Gunnar Hädrich *(DE)*	Procedure Supporting Creation of Landfill Concepts in Low and Middle Income Countries
Cecilia Öman *(SE)*	Proposed Actions for Landfill Improvements in Economically Developing Countries
11:40 – 12:40	*Lunch break*
12:40 - 14:00	**Session J - Landfilling in Transition and Developing Economies III**
Chairperson:	*Cecilia Öman (SE)*
Wilmer Castano *(UK)*	Waste Management Options for Reducing Landfilling in Cali, Colombia
Shahul Fauziah *(MY)*	Landfills in Malaysia: Past, Present and Future
Gamze Turan (*TR)*	Solid Waste Landfilling Operations in Developing Countries: The Case of Turkey
Veronica Di Bella *(IT)*	Study and Implementation of Appropriate Technologies for Municipal Solid Waste Landfilling in Somaliland
14:00 - 14:20	**Closing of the Conference**

Content

The Need for Final Sinks

Paul H. Brunner and Ulrich Kral
Vienna University of Technology

The man made turnover of materials has tremendously increased during the last 200 years. As a consequence, two issues have become of prime concern in the 20ieth century: resource availability, and emissions into the environment. Resource use and environmental loadings are linked to each other, which is best illustrated by global warming: the large input of fossil fuel carbon into the anthroposphere results in a similarly large output of carbon dioxide. The accumulation of THG emissions in the sink atmosphere is a key driver for climate change.

Cities are hot spots of material turnover because of the high density of people with their needs for materials and energy. Also, they are the fastest growing settlements on a global scale: it is estimated, that in 1900 urban-dwellers made up only 13% of the global population. In 2005 49% of the world population lives in cities, and this fraction is expected to increase to 60% in 2030 (United Nations, 2008).
In general, the "metabolism" of a city depends entirely on the so called "Hinterland": all material resources are imported, and most of the wastes and off-gases are exported. While the supply of goods to cities is mostly controlled by market systems, the disposal depends more on regulation and technical and natural attenuation processes. Hence, cities are vulnerable on both sides of their "metabolic system": their sustenance and growth may be limited by insufficient supply at the front side e.g. of water, fuel, and food, and they may be limited by the possibilities to dissipate materials at the back end of the urban system. The latter is one reason why many former cities have been developed along large river systems allowing to use the dilution principle not only for off-gases but also to dispose of their solid and liquid wastes.
During the course of history, many cities faced the problem of limiting sinks regarding their wastes. The first such collection and treatment systems have been established more than 2000 years ago. During the nineteenth century, it became common knowledge that a healthy city needs a waste water collection and treatment system, and in the twentieth century, such systems have been established in all cities of world rank. A key person driving this metabolic view of cities was Abel Wolman who states in his famous publication on the "The Metabolism of Cities": " … the need for sinks, where materials can be disposed of in an appropriate way, i. e. without endangering the environment" (Wolman, 1968). He pointed out that, without having appropriate sinks, the environmental system could eventually become overloaded by the output of urban activities.
Today, with Megacities having a population exceeding 10 million inhabitants, and a material turnover of more than 200 tons per capita and year, the question arises if such intense metabolic systems are limited by the availability of sinks in water, air, and soil. The focus lies not on the traditional issues of waste and waste water treatment or air and soil pollution control. The centre of attention is an integral assessment of entire substance flows from a city over time, comprising classical emissions as well as emissions resulting from the use of materials like e.g. erosion and weathering processes of city surface materials, of public and private vehicles, and of processes for energy conversion. In addition, the pathways to the environment and the accumulation or depletion of materials in water, air, and soil have to be taken into account. Methods to evaluate these flows in view of constraints for urban development must be developed.

There are several past and present examples of substances that have been restricted in their use due to limited availability of sinks:

- The use of DDT as a pesticide was phased out because it resulted in the accumulation of DDT in the sink "biosphere" finally causing serious effects for certain wildlife (bird eggs with shells too brittle to survive).

- The use of certain halogenated hydrocarbons (CFCs) was banned because they accumulate in the sink "stratosphere". This build up has a destructive effect on the ozone layer that protects the earth surface from excessive UV radiation which can harm biological organisms such as plants, animals and humans.
- The large scale use of fossils fuels as well as other anthropogenic activities (land-use and agriculture) result in huge amounts of greenhouse gas emissions such as CO2 and CH4, consequently increasing the concentration of these gases in the sink "atmosphere" with implications for global climate. Measures to curb the use of fossil carbon are discussed on the global level.
- Due to the fact that mercury is toxic and accumulates, among others, in the sink biosphere, the European Commission has proposed to ban exports of elemental mercury from the European Union by 2011. In the US, the Congress has passed the "Mercury Export Ban Act of 2008" that will prohibit the commercial export of elemental mercury by 2013.
- These examples show clearly, that 1. a lack of appropriate sinks for certain substances has already been documented, and 2. that on a national as well as global level mechanisms to control certain substances that lack of an appropriate sink are developed. Thus, it is urgent to address the sink issue on a city level because this is the level of highest densities of material flows and stocks.

As of today, the term "sink" is a vague concept despite some excellent literature on this issue (Tarr, 1996). Thus, definitions of the expressions "sink" and "final sink" must be improved in order to make it operational for environmental protection, for urban planning and for resource management. Man-made flows of several elements of the periodic table surpass geogenic flows (Klee and Graedel, 2004), indicating that anthropogenic activities interfere with natural processes on a large scale. It is necessary to investigate in as far as this interference leads to elevated concentrations in water air and soil.

During the past 10.000 years, many cities have been destroyed by natural and manmade disasters, disappearing temporarily or forever. From a material point of view, this implies that most resources brought into the city have been released from the city, be it as contribution to the local soil, or to the "conveyor belts" water and air which transport these materials over short and long distances. In addition to material flows due to disasters, there are losses of materials from urban activities during their "regular" operations, such as nutrients form the activity "to nourish", metals from the activities "to transport" and "to reside", persistent organic chemicals from the activity "to clean" etc. (Baccini and Brunner, 1991; Baccini and Bader, 1996). All these materials have to be collected, treated and – if not transformed - ultimately exported from the city, and they have to be directed to appropriate sinks where they exert no negative effect for long time periods. Recycling is an appropriate strategy to minimize resource consumption and hence the need for sinks during resource extraction, production, consumption and waste disposal. However, a) the loss of substances during recycling cannot be completely prevented due to thermodynamic reasons, and b) most substances have to be disposed of in a final sink after the "last possible cycle". Hence, also a society that is based on circular use of materials will need sinks.

As a working hypothesis, a "sink" for a material flow from a city can be a conveyor belt such as water or air that transports materials out of the city boundaries, it can be a transformation such as an incinerator that completely mineralizes organic substances, and it can be a storage process such as a landfill where substances are disposed of. In contrast, the working hypothesis for a "final sink" denominates a place on the planet where a particular substance has a residence time of >10.000 years. It may consist of an underground salt mine, an ocean sediment or a place on the globe where sedimentation processes prevail erosion processes. For organic substances, a "final sink" may also be a transformation or mineralization process. A systematic approach to define and identify appropriate sinks and final sinks for specific substances of the urban metabolism represents a new challenge for research. Hopefully, many researchers will engage in this fascinating and rewarding interdisciplinary project.

Literature

Baccini, P. and H.-P. Bader (1996): Regionaler Stoffhaushalt: Erfassung, Bewertung und Steuerung (Regional metabolism: Analysis, Evaluation and Design), Heidelberg: Spektrum, Akad. Verl. 420.
Baccini, P. and P. H. Brunner (1991): Metabolism of the anthroposphere, Berlin u.a.: Springer. XII, 157 S.
Klee, R. J. and T. E. Graedel (2004): Elemental cycles: A status report on human or natural dominance; Annual Review of Environment and Resources, 29: p. 69-107.
Tarr, J. A. (1996): The search for the ultimate sink: urban pollution in historical perspective, Akron: The university of Akron press.
United Nations (2008): Urban Population, Development and the Environment 2007. Economic & Social Affairs: United Nations.
Wolman, A. (1968): The Metabolism of Cities; Cities: A Scientific American Book.

Session A – Landfilling Strategies and Concepts

Sustainable landfills under the EU concept

D R Greedy

Environment and Economy, Warwickshire County Council and Chair, Landfill Working Group, International Solid Waste Association, UK

The paper will consider the following by putting into context how the Landfill Directive attempts to deliver sustainable landfilling.

- Attempt to define what is generally understood to be sustainability
- Landfill Directive requirements
- Landfill Engineering
- Emissions management

Sustainability has been defined by a number of eminent people but the one that is most respected is that of Bruntland in 1987. The International Waste Working Group has then used this base definition to define what it believes reflects sustainable landfill. In essence this is:-

- reaches functional stability such that the undisturbed contents do not pose a threat to human health and the environment;
- during the process towards functional stability no unacceptable emissions should occur;
- the stable situation should be reached in approximately one generation (30-50 years); and
- the funding for completion of aftercare and minimal (custodial) care beyond completion has been secured.

The paper will then attempt to put into context the overall objective of Landfill Directive which is to ensure that there are procedures and guidance to prevent or reduce as far as possible negative effects on the environment, in particular the pollution of surface water, groundwater, soil and air and on the global environment, including the greenhouse effect.

It will consider the Landfill Directive requirements and how this might lead to sustainable landfill and particularly the:-

- Landfill Classification
- Diversion of Biodegradable Municipal Solid Waste from Landfill
- Reduction/control of Direct Emissions

The paper will also debate whether, in the opinion of the author, the landfill does entirely deliver sustainable landfill.

Full sanitary landfill vs. final disposal – different concepts to reach the Same ends? - "How landfilling strategies developed in the USA and Switzerland"

D. J. Lang (1) and R Lifset (2)

(1) Institute for Environmental Decisions, Natural and Social Science Interface, ETH Zurich, 8092 Zurich, Switzerland (daniel.lang@env.ethz.ch) & Department for Sustainability Sciences, Leuphana University Lueneburg, 21335 Lueneburg
(2) Center for Industrial Ecology, School of Forestry and Environmental Studies, Yale University, New Haven, CT06511, USA (reid.lifset@yale.edu)

At least since the industrial revolution, handling municipal solid waste has been a major challenge for industrialized countries. Though the problems these countries faced in different periods (e.g. sanitary/health problems, environmental problems, loss of resources…) as well as the options considered to handle them (e.g. landfilling, recycling and composting, incineration) were relatively similar, the waste management systems established today reveal considerable differences. This paper aims at contributing to a better understanding of reasons for the evolution of such differences, i.e. about driving forces that influence decision-making, including strategy development and selection, on a national level. Landfills have played an outstanding role during the development of waste management in all industrialized countries and will do so, at least to some extent, also in the future. For this reason, we selected the different landfilling strategies of Switzerland and the USA as an exemplary focus for our elaborations. Whereas in the US the predominant landfilling concept is the "sanitary landfill", i.e., well constructed and managed facilities to securely dispose off untreated municipal solid waste, in Switzerland the analogous concept, "final disposals", refers to facilities for disposal of pretreated waste that is rock- or ore-like. These concepts have both direct and indirect implications for the entire waste management system of the two countries. We begin our examination with a description of the current state of waste management in the two countries focusing on the landfilling strategies, and a review of current literature looking at the impacts (economic, ecological and, to a lesser extent, social), the outlined strategies, and waste management systems might have. To analyze how the different landfilling and related waste management strategies evolved, partly building on a framework to explain differences in policy outcomes developed at the Freie Universität Berlin, we consider three domains of driving forces – physical and socio-economic background conditions (such as population density); legal, policy and market, i.e. structural framework conditions (such as the distribution of responsibilities among private and public agents); and situational as well as historic contexts (such as the history of waste management legislation). Applying this framework yields evidence that drivers from all three domains contributed to the evolution of the landfilling and waste management strategies, and that considering only one of these domains seems to be insufficient for comprehensively understanding the decisions underlying these strategies. This comparison reveals the emphasis on risk management in shaping US approaches to landfilling and the greater role of the precautionary principle in Swiss approaches. We conclude with some thoughts about the implications of the differences in approach with respect to future choices in waste management policy, the guiding idea of sustainable development in general, and the definition(s) of a 'sustainable landfill'.

Sustainability gaps in municipal solid waste management: dry tomb and bioreactor landfills in an intertemporal perspective

PD Dr. Stefan Bayer (1) and Dr. Jacques Méry (2)

(1) Führungsakademie der Bundeswehr, Fachbereich Sozialwissenschaften, D-22585 Hamburg, Germany, (stefanbayer@bundeswehr.org),
(2) Hydrosystems and bioprocesses research unit, French institute of agricultural and environmental engineering research (Cemagref), B.P. 44, F-92163 Antony, France, (jacques.mery@cemagraf.fr)

We analyze two different technological types of municipal solid waste disposal landfills: (i) bioreactor or active landfill and (ii) dry tomb landfills. Both types of landfills induce different external costs in different temporal distributions. Firstly, these distributions are quantitatively and qualitatively estimated. Secondly, external costs of bioreactor- and dry-tomb-landfills are evaluated and calculated. Thirdly, to address the very long-term impacts of both types of technology we apply a 600-year time-horizon using two different discounting techniques: (a) constant conventional discounting and (b) generation adjusted discounting (GAD). Obviously, discounting is crucial with respect to such a long time-perspective. It is shown that the generation adjusted discounting method takes into account intergenerational equity as well as efficiency criteria which is not the case whenever constant discounting techniques are applied. Obviously, we have to deal with many different types of uncertainties in a 600-year framework. We concentrate on the most important three different types of uncertainties which are decisive in waste policy decisions: A physical uncertainty is captured by introducing three different scenarios. A macroeconomic uncertainty is taken into account by calculating present values using different real growth rates. And last, a microeconomic uncertainty is considered having the opportunity to apply different sorts of individual peculiarities through their subjective time preference rate. GAD integrates micro- as well as macroeconomic uncertainty through the discounting procedure due to the possibility of the choice of the above mentioned parameters. Our findings show clearly, that whenever there is a low average GDP-growth of less than 1 % (real growth), the bioreactor type generally dominates the dry tomb case. This statement is the more pronounced the lower the growth rate is given and holds even for negative (real) growth rates. However, whenever there are high positive growth rates, the dry tomb case is – in general - more efficient than the bioreactor one. Additionally, to once again demonstrate the sustainability deficiencies of constant discounting sustainability gaps are defined and calculated. The reference case for these calculations is generation adjusted discounting which takes into account the basic requirements of sustainable development, namely intergenerational equity. Our calculations show that constant discounting usually involves discount rates that are too high to be in accordance with fundamental sustainability criteria leading to biased political suggestions. However, our economic analysis is not solely restricted to landfills. It could be used as a guide to quickly check whether the results of social cost-benefit analyses of long-term public projects are in accordance with fundamental sustainability criteria.

Pretreatment of waste for a sustainable landfill disposal

R. Cossu (1), T. Lai (2) and B. Sartorello (3)

(1) IMAGE Department, University of Padua, Italy (raffaello.cossu@unipd.it)
(2) IMAGE Department, University of Padua, Italy (tiziana.lai@unipd.it)
(3) IMAGE Department, University of Padua, Italy (bruno.sartorello@gmail.com)

A sustainable landfill represents the most recent evolution in the management of waste. Although no conventional definition of sustainable landfill has been established, there is general consensus throughout the scientific community that a landfill can be considered sustainable if emissions do not significantly modify the quality of the surrounding environmental compartments: air, water and soil (Cossu et al., 2007; Hjelmar and Hansen, 2005; Stegmann et al., 2003).
In particular, the long-term pollution potential of a landfill is determined by the residual concentrations of compounds present in leachate. The longest lasting environmental impacts of a landfill are caused by the presence of ammonia nitrogen in leachate (Butti and Cossu, 2009); on the contrary, several studies have demonstrated that metals reach environmentally sustainable concentrations in leachate over long periods (Revans et al., 1999).
This study aims to assess the effects produced by lab-scale washing tests applied to several significant residues from integrated management of solid waste: residues produced following the recovery of recyclable plastic packaging collected by means of separate collection, residues resulting from mechanical-biological pre-treatment, residues from the shredding of vehicles and residues obtained following thermal treatment of waste. Washing tests were carried out on a laboratory scale using distilled water at different treatment times and liquid-solid ratios.
The efficiency of washing pretreatment was investigated by evaluating the leachate composition of treated waste. Moreover, column tests were performed to study leachate quality in landfill over time.
Prior to the washing test all samples were characterised by means of solid composition analysis. The following parameters were analysed on solid fractions: Total Solids (TS), Volatile Solids (VS), Respiration Index (IR7), Total Kjeldahl Nitrogen (TKN), Total Organic Carbon (TOC), metals (As, Cd, Cr, Cu, Hg, Mo, Ni, Pb, Se, Zn). Batch leaching tests were performed in accordance with UNI EN 12547-2. Eluates were analysed for the following parameters: Dissolved Organic Carbon (DOC), Chemical Oxygen Demand (COD), TKN, metals (As, Cd, Cr, Cu, Hg, Mo, NI, Pb, Se, Zn), chlorides, fluorides and sulphates.
Once washing tests had been completed, the same parameters analysed at time of initial characterization were evaluated for each leachate.
The effects of waste washing on long-term impacts have been evaluated by applying a model for prevision of long-term emissions (Belevi and Baccini, 1989; Heyer and Stegmann, 1997) to concentrations assayed in eluates from column tests carried out on the wastes after washing treatment.
The findings obtained demonstrated that washing constitutes an effective treatment aimed at reducing leachate released from wastes prior to landfill disposal: this implies a decreased release of compounds into leachate by the waste, leading to the achievement of an environmentally sustainable landfill over a considerably shorter period of time.

REFERENCES

Belevi H. and Baccini P. (1989). Long-term behaviour of municipal solid waste landfills. Waste Management and Research 7 (1989) 43-56.

Butti L. and Cossu R. (2009) La discarica sostenibile. CISA Publisher. (in press)

Cossu R., Lai T. and Piovesan E. (2007) Proposal of a methodology for assessing the final storage quality of a landfill. In Proceedings Sardinia 2007, Eleventh International Waste Management and Landfill Symposium. CISA, Cagliari.

Heyer K.U. and Stegmann R. (1997) The long-term behaviour of landfills: results of the joint research project Lanfill body. In Proceedings Sardinia 1997. Sixth International Waste Management and Landfill Symposium. CISA, Cagliari.

Hjelmar O. and Hansen J.B. (2005). Sustainable landfill: the role of Final Storage Quality. Proceedings Sardinia 2005. Tenth International Waste Management and Landfill Symposium.

Revans A., Ross D., Gregory B., Meadows M., Harries C. and Gronow J. (1999) Long term fate of metals in landfill. In Proceedings Sardinia 1999. Seventh International Waste Management and Landfill Symposium. CISA, Cagliari, vol. I, pp. 199-206.

Stegmann R., Heyer K.U., Hupe K. and Ritzkowski M. (2003). Discussion of criteria for the completion of landfill aftercare. Proceedings Sardinia 2003. Ninth International Waste Management and Landfill Symposium.

Session B – Understanding the Landfill Body

Formation of perched leachate zones in MSW

G. Di Bella (1), D. Di Trapani (2), G. Mannina (3) and G. Viviani (4)

(1) Dipartimento di Ingegneria Idraulica ed Applicazioni Ambientali, Università degli Studi di Palermo, Viale delle Scienze 90146, Palermo, Italia (dibella@idra.unipa.it), (2) Dipartimento di Ingegneria Idraulica ed Applicazioni Ambientali, Università degli Studi di Palermo, Viale delle Scienze 90146, Palermo, Italia (ditrapani@idra.unipa.it), (3) Dipartimento di Ingegneria Idraulica ed Applicazioni Ambientali, Università degli Studi di Palermo, Viale delle Scienze 90146, Palermo, Italia (mannina@idra.unipa.it), (4) Dipartimento di Ingegneria Idraulica ed Applicazioni Ambientali, Università degli Studi di Palermo, Viale delle Scienze 90146, Palermo, Italia (gviv@idra.unipa.it)

Municipal solid waste (MSW) landfills are usually considered a big biological reactor where the MSWs undergo anaerobic digestion producing gas and liquid emissions. Nevertheless, many physical phenomena occur, coupled with biological transformations. All these phenomena will modify the waste (density) and landfill features (morphology). In particular, MSW settlements within the landfill strictly influences the management during both operation and after-care phases. Indeed, thanks to landfill settlement, it is possible to obtain actual advantages in terms of site capacity. On the other hand, the waste settlement in large landfills, and the consequent increase of its density, can negatively affect landfill management. In particular, the increase of waste density inside the landfill corresponds to a proportional decrease of waste permeability, and may cause serious problems in the leachate drainage through the landfill body, with the possible formation of the so-called "perched leachate zone" (Koerner and Soong, 2000). Indeed, the low hydraulic conductivity in an intermediate layer prevents the leachate to be conveyed downwards as fast as it is infiltrating from the upper layers. Consequently, a temporary perched leachate zone may appear in an intermediate layer. This situation is emphasized in very high landfills, where, due to the great decrease of the effective porosity, the infiltration of water from the upper waste layers (mainly due to precipitation) can be higher than the water amount that move down towards the lower layers. The most important disadvantages related to this phenomenon are the following:

1. an increase in the landfill internal strains, with possible instability of landfill edges;
2. lateral leachate migration (due to the higher horizontal permeability compared to the vertical one), enabling its escape from the landfill edges, with the possibility to contaminate external areas;
3. a reduction of the flow obtained by the leachate collection system (LCS).

The forecast and the prevention of such perched leachate zones may constitute an useful help for landfill management. With this respect, mathematical models may constitute useful tools for landfill managing. With this aim, the present study presents a simplified model, mainly based on the mass balance equations, that enable one to simulate the formation of perched leachate in a landfill for MSW. Moreover, direct measured data from Palermo landfill (Bellolampo), as well as experimental results from technical literature (Powrie and Beaven, 1998-1999) have been used. Specifically, the authors, employing a compression cell where vertical stress in the range of 60-600 kPa (depth: 6-60 m), have evaluated a relationship between porosity variation and applied vertical strain. Such relationship has been applied in the present study in order to relate vertical strain to waste porosity. On the other hand, referring to the measured data, the response of wastes under high constrictions at different depths (up to as maximum depth of 31.5 m) within Palermo landfill has been studied. On the basis of such results, an equation which correlates waste density with landfill depth has been derived. From such a relationship, the values of vertical strain within the landfill have been calculated, correlated with the landfill depth, and thereafter introduced in Powrie and Beaven equation, to obtain the values of waste porosity, used as model input.

The model for the simulation of leachate drainage has been applied to two ideal landfills of different heights (e.g.., 28.5 and 33.6 meters). The model considers the landfill divided in several layers, characterised by the same thickness. For each layer the model applies a balance taking into account different fluxes: the inlet water (from the upper layers, considering the infiltration due to precipitation), the moisture variation within the waste (moisture distribution in the waste column) and the leachate conveyed at the landfill bottom. The refuse layer which could not convey the leachate downwards as fast as it is infiltrating was the one where the perched leachate zones appear.

With the aim to taking into account several realistic scenarios, each time the following input parameters have been varied: rain intensity and length, waste water content and the initial compression degree of the waste. The present study showed that a leachate mound appears above the LCS in almost every simulation and, referring to the specific boundary conditions considered, the formation of perched leachate zone in the intermediate layers, whose thickness and time length is mainly related to the reached compression degree and, as a consequence, to the permeability of the layers below.

References

- Koerner R.M and Soong T.Y. (2000). Leachate in landfills: the stability issues Geotextiles and Geomembranes 18 293}309
- Powrie W. and Beaven R.P. (1998). *Hydraulic conductivity of waste – current research and implications for leachate management*. Waste management, 1998.
- Powrie W. and Beaven R.P. (1999). *Hydraulic properties of household waste and implications for landfills.* Proceedings of the Institution of Civil Engineers, Geotechnical Engineering 235-247, 1999.

Monitoring Moisture Movement within Municipal Solid Waste in Enhanced Leachate Recirculation Landfill using Resistivity Imaging

Hossain, M.S. (1), Kemler, V. (2), Dugger, D. (3), and Penmethsa, K. (4)

(1)Assistant Professor, Department of Civil Engineering, The University of Texas at Arlington, 417 Yates Street, NH 404, TX 76019, (hossain@uta.edu)

(2) Director of Solid Waste, The City of Denton, 1527 S. Mayhill Road, Denton, TX 76208, e-mail: vance.kemler@cityofdenton.com

(3) Landfill Manager, The City of Denton, 1527 S. Mayhill Road, Denton, TX 76208, e-mail: David.Dugger@cityofdenton.com

(4) Graduate Research Assistant, Department of Civil Engineering, The University of Texas at Arlington, 417 Yates Street, NH 404, TX 76019, e-mail: kirankumar.penmethsa@mavs.uta.edu

Enhanced leachate recirculation (ELR) landfills are designed and operated for rapid waste stabilization, waste decomposition and increased rate of gas generation. The fundamental process improvement involved in the operation of landfills as ELR landfills is the addition of water and/or the recirculation of leachate into the landfill's waste mass. The study of moisture movement within Municipal Solid Waste (MSW) due to leachate recirculation plays an important role in developing the design and optimizing the operation of a leachate recirculation system. This paper presents the preliminary results of moisture distribution and moisture movement within the MSW in an ELR landfill in Denton, Texas, USA. The study is performed using resistivity imaging. The City of Denton landfill uses horizontal recirculation pipes for the water addition and leachate recirculation. A series of resistivity imaging tests were performed at the City of Denton landfill. First set of tests were performed along the recirculation pipes to identify the vertical moisture movement through individual pipes during recirculation. And then, second set of tests were performed across the recirculation pipes to determine the zone of lateral moisture movement due to horizontal leachate recirculation system. The preliminary results shows that the moisture movement can be mapped using RI. The preliminary results are presented in Figure 1a and Figure 1b.

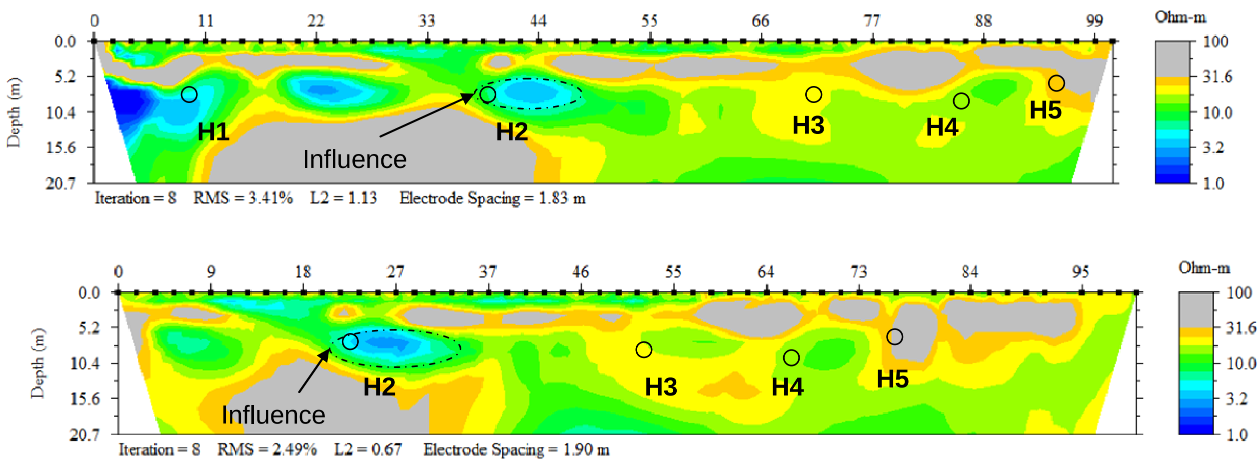


Figure 1b Leachate Recirculation Effect around Recirculation Pipe H2 (Date: 7/29/09)

Exploring the use of Micro-focus Computed Tomography for a better conceptual understanding of flow and structure in landfilled waste in the context of post-closure management for landfills

Caicedo Concha. DM (1) , Watson, GVR (2), Richards, D.J (3) and Powrie , W (4)

(1) University of Southampton , UK (dmc1x07@soton.ac.uk)
(2) University of Southampton , UK (g.watson@soton.ac.uk)
(3) University of Southampton , UK (djr@soton.ac.uk)
(2) University of Southampton , UK (wp@soton.ac.uk)

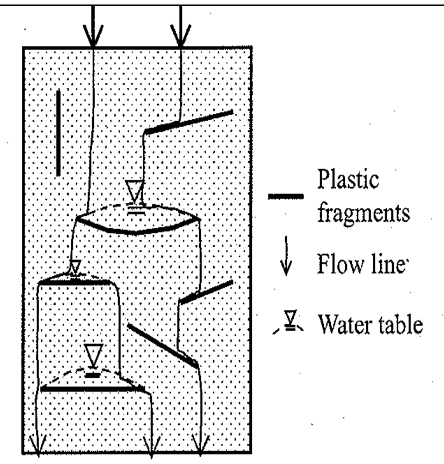
Research suggests that contaminant substances contained within landfills are likely to persist for centuries rather than decades. The concept of "sustainable landfilling" however requires that the pollution threat is not passed to the next generations. Transition from sanitary to sustainable landfilling has triggered the investigation of engineering technologies to accelerate the degradation and removal of contaminants from landfill sites e.g. flushing and aeration. These technologies are based in the flow of fluids, e.g. water, air, leachate , which is substantially influenced by the physical structure of the waste.

Research suggests that Municipal Solid Waste (MSW) once disposed into landfills can constitute highly structured materials. This can be the consequence of the high variation in composition, material's size/shape and deposition method. Degradation taking place after placement can produce changes in the initial structure. The mechanical behaviour of Mechanical Biological Treated Waste (MBT), introduced in Europe to comply with the 1999 EU Landfill Directive, is still not very well understood though. Research at the University of Southampton, evidenced that the hydraulic conductivity in MSW samples is a function of the density, which depends on the total stress applied. Some of the factors controlling the density and the structure of the pore space in waste, e.g. particle size and particle shape, are currently being investigated by the authors of this paper. Particularly, the authors believe that some materials, due to their shape, could change or block the flow, as may be the case for plastic sheets and compressed plastic packages. Xie et al., 2006, explained that in MBT plastic fragments could block the flow under saturated flow and allow pooling of water above horizontally oriented fragments under unsaturated conditions (Figure 1).

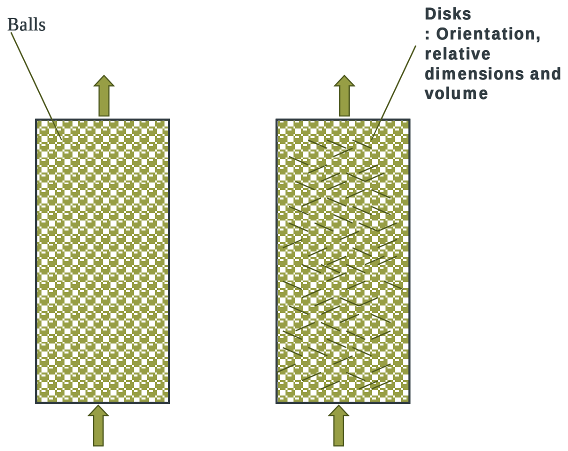
The aim of this paper is to present the methodological approach utilized for the study of the impact that sheet like materials have on the hydraulic conductivity of a matrix material. The paper describes the selection of the different materials, sample preparation, what parameters were studied and the use of Micro-focus Computed Tomography (µCT) for a detailed analysis of the samples' structure.

Firstly, the results of the characterisation of a sample of MBT, reported in Velkushanova et al., 2009, were used to produce a simpler although representative initial conceptual model of waste. The sample was considered as an initial case of study since it represents well the results achieved during pre-processing waste in the UK for final disposal. During the characterisation, special effort was made to make a description in terms of the shape of the particles following the dimensionality definition of Kölsch, 1995, e.g. particles are defined as being 0, 1, 2 or 3D. The MBT sample analysed contained around 8 % by mass and 20% by volume of sheet like plastics, that according to Kölsch can be described as 2D. The analysis of the particle size distribution (PSD) in the sample evidenced that around 58% by mass of the materials have a size <5mm and could not be visually separated into individual materials. This fraction was considered as the sample matrix with 50% by mass of its particles having a size of ~ 1 mm. It was then hypothesised that the size of a 2D particle must be significantly greater than that of a matrix particle -perhaps by a factor of at least 3-5 to be considered as a “potentially flow blocking” . So, this MBT material was seen , in terms of flow characteristics, as 2D particles with a particle size > 3 mm in a matrix of fines of ~ 1 mm.

Sand grains of 1mm size were selected to build the matrix. Three parameters of the 2D particles are considered to play an important role. These are the orientation, relative dimensions and %volume (**Fehler! Verweisquelle konnte nicht gefunden werden.Fehler! Verweisquelle konnte nicht gefunden werden.**). Two types of polystyrene discs: 3 mm and 6 mm diameter, were selected as 2D particles, to test the impact of the relative dimensions. The characterization of the MBT sample showed 20% by volume of 2D materials. Thus 5 and 20% by volume of plastic discs were mixed with sand for the study of the impact of the % by volume. The mixtures were placed by pluviation at the maximum dry density into a 75 mm diameter and 238 mm height permeameter for hydraulic conductivity tests. Preliminary results during hydraulic conductivity test are presented in Figure 2, suggesting that 2D particles with 3 times the size of matrix particles do not substantially impact the saturated hydraulic conductivity. More experiments are currently in progress to identify the critical relative size where substantial changes begin.



a. Thin-sheet conceptual model for flow through solid wastes (from Xie et al., 2006)



b. Parameters related to the 2D particles that can influence flow

Figure 1 Conceptual explanation of the objectives of this research

Micro-focus Computed Tomography (μCT), a novel non-destructive methodology to analyse internal structure, has been used in this research to look at the orientation of 2D particles. The scans are currently been run using a X-Tek Benchtop CT 160Xi equipment. The equipment settings were selected as 120 KV, 56 μA, 2s of exposure, and no filter, after several other conditions were previously tested until the necessary resolution and contrast were found. Once the scan is run, the data is reconstructed, a 3D volume visualized and prepared for a quantitative analysis using different commercial software’s. The algorithm to obtain the orientation of 2D particles is based in gray value threshold, calculation of the average line connecting the two ending surfaces of each 2D particle and final calculation of the angle for this line. The research is still on going and results linking the orientation with the hydraulic conductivity tests are not presented within this abstract. The scan of a subcore of one of the samples is presented in **Fehler! Verweisquelle konnte nicht gefunden werden.**.

The research has shown that the combined approach selected for the conceptual study of the role of some particular materials over the flow characteristics in landfilled waste can bring some better understanding of the controlling factors. This fundamental understanding can help into better implementation of the remediation technologies to achieve sustainable landfilling.

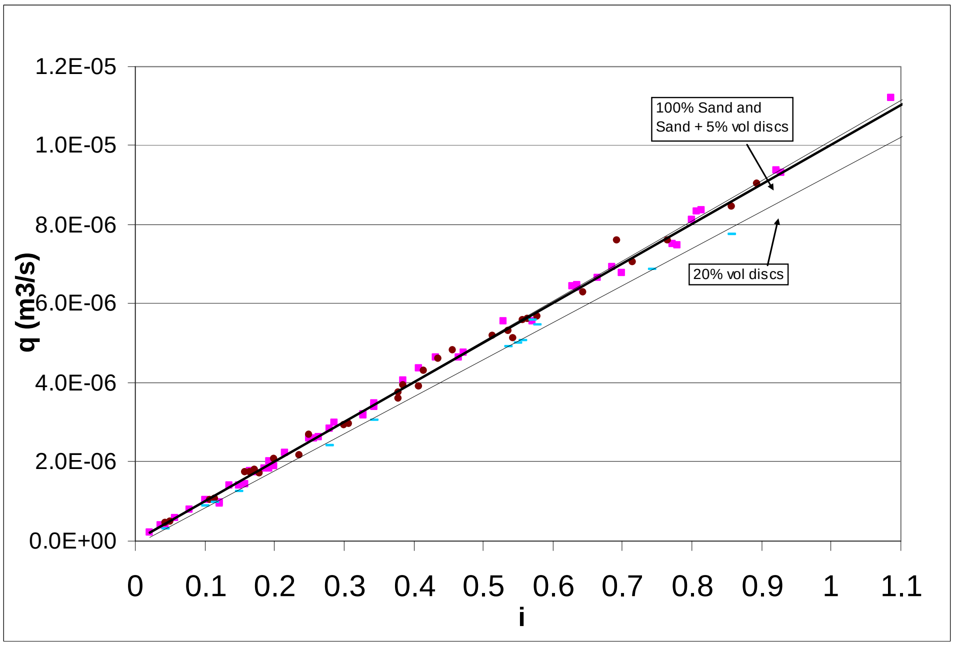


Figure 2 Hydraulic conductivity tests in sand specimens (1 mm) modified with 2D particles plastic discs (3mm)

Long term monitoring of leachate flux into drainage pipes of MSW landfills

K. Münnich, J. Bauer, K. Fricke

Leichtweiss Institute, Dept. of Waste and Resource Management, Technical University of Braunschweig, Germany (k.muennich@tu-bs.de)

The measurement of leachate quality and quantity is an essential part of the monitoring of landfills in the different phases during the lifespan of landfills. These measurements are important in the face of

- the evaluation of the decomposition processes in the landfill and the determination of the necessary phase of leachate collection and treatment,
- the survey of the efficiency of technical installations (e.g. top cover systems) for the reduction of leachate generation,
- monitoring the leachate distribution during recirculation.

Normally measurements of leachate volumes are made at the outlet of larger sections of the landfill or at the input of the purification plant, which means an integration of the whole landfill with its different phases of activity. As an identification of smaller parts within the landfill section is not possible, the specific discharge per unit area is often assumed to be constant for the landfill in total. This assumption is made although due to the inhomogeneity of the disposed waste, the distribution of the biological activity, the problems with incrustation processes in the drainage layers, the partial accumulation of leachate etc., a non-uniform discharge might be expected to be more realistic.

In the framework of a long-term monitoring of a MSW landfill the leachate volume has been determined over a period of more than seven with different measurement devices. With the help of one type of device the discharge volume and the quality in terms of electrical conductivity has been recorded continuously. Four of these devices were installed at the outlet of single drainage pipes. With these measurements the catchment area is reduced from the total area of the landfill to an area of about 0.9 hectares. The data from these measurements show the influence of changes in operation (waste disposal with temporal stoppages and reuptakes, closure of the landfill with placement of top cover systems, leachate recirculation etc.) and also point out the in part large differences in discharge of parallel drainage pipes. To get an impression of the flux into the drainage pipe along the length of up to 375 m a measurement device was developed on the basis of a camera lafette. With this system it is possible to measure at user defined points, so that small scale changes in leachate discharge can be determined along the pipe. The results show that even at short distances between the drainage pipes (30 m) the differences in the influx might be very high (fig. 1, left), in this case the maximum values are generated by the infiltration of surface run-off. The repetition of the measurements in regular time intervals often showed a quite different distribution with the maximum outflow in other drain pipes. In the case of the measurement six years after the first one (fig. 1, right), the maximum value has been determined in the same drainage pipe, but the discharge distribution is more irregular than in 2003, although the operation phase had been stopped in 2005.

Furthermore out from all measurements made it is obvious that in this landfill as longer the landfill is in operation the main discharge in the drainage pipes occurred on the last 100 m before the outlet at the slope of the landfill body. Together with the discharge the quality – determined as electrical conductivity (EC) – and the temperature of the leachate were determined. While the distribution of EC at the basis changes with the fluctuation of the leachate discharge, the local temperature differences remain small.

One main reason for the variation of the fluxes in the drainage is the status of operation (waste disposal, closure with application of top cover sealing systems, leachate recirculation). In addition deformations and torsion of the HDPE-pipes, unequal settlements of the soil were identified in this part of the base of the

landfill, which may have an influence on the discharge in the pipes and the efficiency of the drainage system and which might have an influence on the stability of the landfill body.
In this paper the different measurements devices will be presented in detail and with the results of the long term measurements the need of a more detailed leachate discharge monitoring will be pointed out.

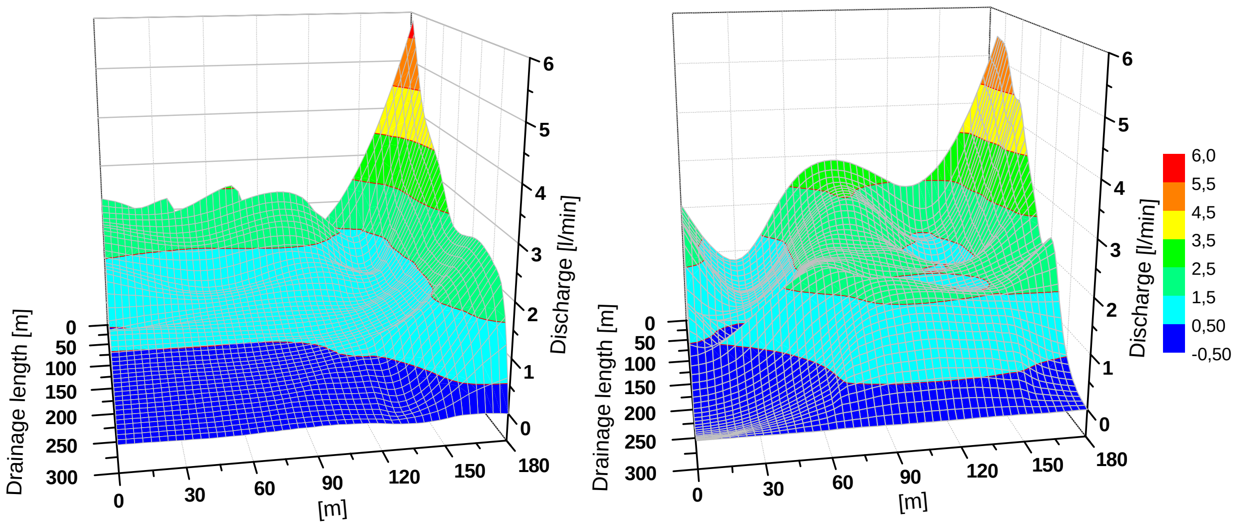


Fig. 1: Discharge at the base of the landfill in June 2003 (left) and June 2009 (right)

Session C - Modeling & Monitoring of Landfill Emissions I

Gas emissions from biodegradable waste in landfill

S. M. Donovan, J. Pan, T. Bateson, J. R. Gronow and N. Voulvoulis*.

Centre for Environmental Policy, Imperial College London, UK * Presenting author (n.voulvoulis@imperial.ac.uk).

The aim of this research was to predict how gas emissions from landfills would be affected by the biodegradable municipal waste (BMW) diversion targets in the European Union landfill directive (99/31/EC). Understanding the way gas emissions will be affected is important for landfill operators to be able to continue to effectively mitigate these emissions.

The work was undertaken in three stages using the GasSim model (v1.03) developed by the Environment Agency (England and Wales). The first stage considered the contribution to gas emissions each biodegradable component of the waste stream makes, in order to determine which would be the most important for diversion. The second stage considered how gas emissions would be affected from a landfill accepting biodegradable wastes with reduced biodegradable content. The third stage looked at the contribution to gas emissions from real samples of municipal biodegradable wastes that had been biologically pretreated. Samples were taken from four different treatment processes.

For the first two stages, data on the waste components was available in the model. For the third stage samples were obtained from four different biological treatment facilities and the parameters required in the model were determined experimentally.

The results of the first stage, shown in Figure 1, indicated that in the first 15 years of the landfill the putrescible fraction makes the most significant contribution to gas emissions. After this time the contribution from the paper/card fraction becomes the most significant. The second stage, shown in Figure 2, found that cellulose and hemicellulose content must be reduced by at least 60% to achieve a reduction in overall methane generation. The third stage, shown in Figure 3, found that emissions from samples of biologically pretreated BMW would result in a significant reduction in gas emissions over untreated waste, particularly in the early stage of the landfill lifetime, up to about 15 years, however low level emissions would continue to occur for the long term. This makes sense as most biological treatment processes encourage the degradation of the most readily degradable components, especially food and garden waste, while the fractions that make more significant contributions to gas emissions in the long term such as woods, paper and card would be little affected by biological pretreatments.

Thus for landfill management, in particular to be able to mitigate gas emission, it is important that the slowly degradable fractions of the waste stream are considered with equal importance as the readily degradable components. Otherwise the managment of low level gas emissions from landfills must become a focus for research.

Flux measurements of volatile organic compounds (VOCs) from landfill cover soils

F. Tassi (1,2), G. Montegrossi (2), O. Vaselli (1,2), A. Morandi (1), F. Capecchiacci (1), B. Nisi (2)

(1) Department of Earth Sciences, University of Florence, Via G. La Pira, 4, 50121 Florence (Italy); franco.tassi@unifi.it

(2) CNR-IGG Institute of Geosciences & Earth Resources, Via G. La Pira, 4, 50121 Florence (Italy); montegrossi@igg.cnr.it

Anaerobic decomposition of organic matter from municipal solid waste produces biogas, commonly constituted by CH_4 (~50-60 % by vol.), CO_2 (~40 % by vol.) and minor concentrations (up to 1% by vol.) of non-methane volatile organic compounds (VOCs). Organic volatiles released from landfills exert a significant environmental burden. Their effects are mainly related to i) the global warming potential (GWP), for instance CH_4 has a GWP 25 times higher than that of CO_2 [1], and ii) health problems, e.g. prolonged exposure to aromatics causes chronic intoxication and irreversible neurological damage to the central nervous system [2,3]. Three are the main methods that can be adopted to mitigate the biogas impact on the air quality, as follows: 1) installation of a biogas recovery, collection and treatment system, which reduces the biogas release and provides a source for energy production; 2) injection of lime slurry and fly ash to inhibit methanogenesis; 3) emplacement of a cover soil, where bacteria-driven oxidative activity takes place. This explains the extremely large range (from 0.003 to > 1,000 $gm^{-2}d^{-1}$) of the measured CH_4 flux from waste disposal landfills [4]. Besides of CH_4, methanotrophs can also metabolize C_2-C_{13} aliphatic compounds, whereas CFC and aromatics are less efficiently destroyed [5]. Therefore, VOCs may represent a significant portion of the biogas effectively released into the atmosphere from a landfill. Nevertheless, a standardized protocol for a correct evaluation and monitoring of VOCs dispersed in air from landfills is not still available.

This study presents a method for the determination of the soil flux of selected hydrocarbons, i.e. benzene and toluene. This new sampling and analytical approach is based on the "static chamber" method, commonly adopted for the measurement of the CH_4 flux from the soil. The chamber, consisting of a plastic cylindrical vase with a volume of 6,280 cm^3, is up-side-down positioned onto the ground at the sampling site. At periodic intervals, i.e. each 30 minutes, a small aliquot of gas (10 mL) is spilled from the chamber, using a syringe equipped with a three-way valve, and placed into pre-evacuated Exetainer® vials tapped with a porous membrane. Benzene and C_7H_8 concentrations are determined with a GC equipped with a flame ionization detector (FID). Soil fluxes of the two analyzed species are calculated on the basis of: i) the rate of concentration increase in time, ii) the dimensions of the chamber and iii) atmospheric pressure and temperature. By applying CG-MS techniques, this approach can allow to calculate the soil flux of each organic gas species in the range of 40-400 a.m.u.

Methane, C_6H_6 and C_7H_8 fluxes were measured at 36 sampling points within the Case Passerini landfill, located a few km N of Florence (Italy). Carbon dioxide fluxes were measured at the same sites using the "accumulation chamber" method [6]. The values of the CH_4, C_6H_6 and C_7H_8 fluxes are up to 25350, 36, and 89 $\mu mol\ m^{-2}\ day^{-1}$, respectively. The CH_4/CO_2, CH_4/C_6H_6 and CH_4/C_7H_8 ratios of the flux values are significantly lower than those measured in gas recovery wells, representing the "pristine" biogas composition adjacent to the sites where the flux measurements were carried out. This suggests that, during the biogas release through the soil cover, CH_4 is affected by degradation processes activated by oxidizing bacteria at higher extent than the other gases. Benzene has the highest stability at oxidizing conditions. Toluene behavior only partially resembles that of C_6H_6, likely because, at oxidizing conditions, de-methylation processes and oxidation to benzaldehyde and/or benzoate require less energy than that necessary for the rupture of the aromatic ring. These results are in agreement with the relatively high C_6H_6, ketones and aldehydes concentrations commonly measured in air in proximity of waste disposal sites [7]. According to these considerations, the impact of biogas from anthropogenic emission sites, usually ascribed to CO_2 and CH_4, seems to be strongly dependent on the presence of aromatics and O-bearing VOCs, the latter being produced by degradation of long-chain hydrocarbons.

References

[1] Hansen, J., Sato, M., Lacis, A., Ruedy, R, Tegen, I., Mathews, E., 1998. Proc. Natl. Acad. Sci., 95, 12753-12758.

[2] Allen, M.R., Braithwaite, A., Hills, C.C., 1997. Environ. Sci. Technol., 31, 1054-1061.

[3] Kuran, P., Sojak, J., 1996. J. Chrom. A, 733, 119-141.

[4] Bogner, J., Spokas, K., Burton, E., Sweeney, R., Corona, V., 1995. Chemosphere, 31, 4119-4130.

[5] Kjeldsen, P., Dalager, A., Broholm, K., 1997. J. Air Waste Manage. Assoc., 47, 1268-1275.

[6] Chiodini, G., Frondini, F., Raco,, B., 1996. Bull. Volcanol., 58, 41-50.

[7] Dincer, F., Odabasi, M., Muezzinoglu, A., 2006. J. Chrom. A, 1122, 222-229.

Degradation pathways of VOCs in biogas from solid waste disposal sites

G. Montegrossi (1) and F. Tassi (1,2)

(1) CNR - IGG, Italy (montegrossi@igg.cnr.it), (2) Department of Earth Sciences, University of Florence, Italy (franco.tassi@unifi.it)

Microbial-driven VOC degradation in biogas released from landfills through the cover soil proceeds within both anaerobic and aerobic zones, involving a large variety of methanogens and methanotrophs, respectively. Degradation processes depends on i) composition of the waste material, ii) presence and activity of microbial consortia, iii) nutrient substratum and iv) physical-chemical parameters, such as temperature, leachate composition and O_2 availability (Lawrence, 2006). A conceptual model describing the theoretical pathways of microbial metabolism processes affecting biogas can be constructed on the basis of the Biodegradation/Biocatalysis Database (BBD) compiled by researchers of the University of Minnesota (Ellis and Wackett, 2006), accessible via the Internet at http://umbbd.msi.umn.edu Ellis. This approach allows to predict biodegradation pathways of aliphatics, aromatics, halocarbons, and N-, S- and O-substituted compounds. Different biodegradation pathways tend to converge toward a 84-member set of key compounds, i.e. metabolic intermediates, used by both anaerobic and aerobic bacteria to produce energy proceeding up to the C_1 cycle, which is the last step of the whole degradation process. BBD is continuously implemented by new biotransformation rules and comments on the existing rules, although most of the natural degradation pathways cannot still be completely duplicated by a known metabolism. BBD can be applied on different initial organic matrix whose degradation may produce both aerobic and anaerobic patterns. On the basis of the key compound set produced by BBD it is possible to discriminate active and inactive degradation pathways. The latter are commonly related to the presence of chlorinated species (Mc Donald et al. 2002), and heavy metals (Essa et al. 2002) that are able to inhibit microbial metabolism.
In this work, compositional data of biogas from a solid waste disposal site at the final stage of cultivation were processed using the BBD to model the degradation pathways of 43 VOC compounds measured in the biogas. The results show that the theoretical degradation patterns from BBD are mainly related to piruvate metabolism. This degradation pattern is associated with slightly oxidative conditions not allowing decomposition of benzene and chlorinated compounds, that can occur only at relatively strong oxidizing conditions (Scheutz et al. 2003). By contrast, the degradation of other aromatics, such as ethyl-benzene, proceeds through hydroxylation, producing alcohols from the aliphatic group. Hydroxylation of alkanes leads to the formation of several intermediate hydroxylated compounds up to the C_1 cycle.

References

Ellis LBM, Roe D, Wackett LP, (2006), The University of Minnesota Biocatalysis/Biodegradation Database: The First Decade. Nucleic Acids Research, 34: D517-D521

Essa AM, Macaskie LE, Brown NL, (2002), Mechanisms of mercury bioremediation. Biochem Soc Trans, 30:672-74.

Lawrence SJ, (2006), Description, properties, and degradation of selected volatile organic compounds detected in ground water - A review of selected literature. USGS, Open File report 2006-1338

McDonald IR, Warner KL, McAnulla C, Woodall CA, Oremland RS, Murrell JC, (2002), A review of bacterial methyl halide degradation: biochemistry, genetics, and molecular ecology. Environ Microbiol, 4:193-203

Scheutz C, Bogner J, Chanton J, Blake D, Morcet M, Kjeldsen P, (2003), Comparative oxidation and net emissions of methane and selected non-methane organic compounds in landfill cover soils. Environ Sci Technol, 37:5150-5158

Systems of landfill biogas purification with the subsequent hydrogen production.

M.P. Fedorov, V.V. Korablev, V.I. Maslikov, A.N. Chusov

Saint Petersburg State Polytechnical University, Russia
E-mail: expert1@gpu.neva.ru

Municipal solid waste landfills generate a significant amount of biogas, where the main component is methane, a valuable energy raw material and a strong greenhouse gas. The annual emission of methane from landfills of the world is comparable with its natural sources. Today the problem of reducing anthropogenic emissions of greenhouse gases is very acute. In addition, landfill methane is often seen as a local low-cost renewable energy. In many countries the projects on energy recovery of landfill methane are implemented, in which it is mainly used as fuel in various heat-and-power plants. A general imperfection of biogas burning technology is the formation of toxic and greenhouse exhaust gases. Therefore, an important task of environmental protection is to reduce emissions of harmful substances during the biogas utilization. One of the promising methods for solving this problem is a deep cleaning of biogas, production of biomethane, biohydrogen and electricity in hydrogen fuel cell, characterized by high efficiency and the practically absence of harmful emissions.

Hydrogen production from landfill biogas, suitable for fuel cells, is a complex scientific and technological task, because biogas contains a large number (over 100) of impurities, requiring expensive treatment systems. We have solved the task of developing a relatively inexpensive way to clean biogas with further production of enriched methane with conversion into hydrogen for use in a fuel cell. In SPbSPU the laboratory complex has been created to conduct investigations at all stages of the process. The complex includes a module of biogas generation (Fig. 1)in which bioreactors with loaded solid waste are placed. The generated biogas containing 40-65% methane, enters the accumulation module with cumulating tank for the deposit of the daily generated biogas, from which it is downloaded to tanks-accumulators under the required pressure.

The use of tanks-accumulators provides for an uniform operational regime of biogas treatment systems and maintaining the required pressure under unstable emission of biogas from bioreactors. Biogas from the tanks-accumulators is supplied through a reducer to the purification unit to remove carbon dioxide, hydrogen sulfide, water vapor, etc. and product enriched methane (96%). Further methane comes in the reformers where hydrogen is produced (96%), and its purification is realized. The purified hydrogen comes in the polymer fuel cell, where electrical energy is produced. The laboratory complex is equipped with the modern high-precision test equipment, allowing to obtain the necessary information at all stages of the studied processes. The laboratory complex and its individual components are described in the report.

Impact of sustainable landfilling on the global CO_2 concentration.

T. Bramryd and M. Johansson

Department of Environmental Strategy, University of Lund, Campus Helsingborg, PO Box 882, SE-251 08 Helsingborg, Sweden (Torleif.Bramryd@miljostrat.lu.se ; Michael.Johansson@miljostrat.lu.se)

Environmentally controlled landfills, and different types of landfill bioreactor cells for residual wastes, play a role as long-term storage for organic carbon, and therefore counteract increased atmospheric CO2 concentrations. Provided that a reliable and efficient biogas collection system is installed strictly controlled landfilling thus could be a technique to counteract global warming. New techniques from e.g. Sweden show promising results for such improved efficiency in landfill gas collection. Landfilling of organic carbon is one of the few available carbon accumulating processes in the human society, and landfilling can be compared to the natural peat and sediment accumulating processes in natural ecosystems. In a landfill reactor-cell, treating approximately 100 000 tons of waste per year, and where the fermentation residues are left in the landfill, a long-lived organic fraction corresponding to about 45 000 metric tons of carbon dioxide is long-term accumulated each year. This compensates for the annual carbon dioxide emissions from about 15 000 cars, provided that each one runs 15 000 km per year with fossil fuel. To this should be added the benefits of replacing fossil fuels with the collected biogas. Long-lived organic matter in a landfill further helps to immobilize e.g. heavy metals and decrease leaching.

In the 1980´s the annual accumulation of organic carbon in the World´s landfills was estimated to around 100×10^6 metric tons of C. However due to increased material recovery and increased incineration the present figure is probably somewhat lower, in spite of increased waste volumes. The size of the long-term accumulated fraction depends on the conditions for decomposition in the landfill.

Municipal solid waste normally contains approximately 23-25 % organic carbon, while industrial waste with lower water content and normally a higher proportion of paper, wood and plastics contain somewhat higher proportions of organic carbon. Plastics and rubber are rather unaffected by biological degradation and is left in the landfill. Under anaerobic conditions also lignine is resistant to degradation and will remain in the fermentation residue.

Most of the organic carbon in fossil derived products, like plastics and other synthetic materials, during landfilling will be brought back to long-term accumulation. As these products only to a very small extent take part in the methane gas production, the landfill gas (biogas) can be regarded as a true biofuel. In contrast to incineration, high moisture content in the waste will not decrease the yield of energy per ton of waste.

If the waste instead would have been incinerated, most of the organic carbon would be emitted as CO_2, including carbon derived from fossil material. Due to high moisture content in municipal solid waste, energy will be consumed and CO_2 produced during the evaporation of water. This contributes to the negative effects of waste incineration on the atmospheric carbon balance.

The irrigation with leachates in vegetation systems, like short rotation forests planted within the controlled landfill area, increases the capacity of the waste treatment system to act as a carbon sink. This is both related to increased standing biomass and increased concentrations of organic matter in the soil. This increases the effect of landfills as carbon sinks, and compensates for emissions of fossil carbon dioxide (e.g. from traffic).

In one leachate irrigation system outside Stockholm in Sweden the productivity of pine in the irrigated areas increased over a period of 5 years with about 20% compared to the reference area, while the productivity of spruce increased with almost 40 % and birch with 30 % compared to control.

With a larger standing biomass, more organic carbon is accumulated in irrigated areas than in reference areas. The increased carbon sink in an irrigated full-scale plantation can compensate for anthropogenic CO2 emissions, e.g. from traffic, comparable to the annual CO2 emissions from up to 3 000 - 5 000 cars. The technique thus gives an additional environmental effect than just to clean the leachate to prevent the release of eutrophic substances or toxic compounds into water systems.

Session D - Modeling & Monitoring of Landfill Emissions II

Evaluation of PFAs and PBDEs in Engineered Landfill Leachates

L.Y. Li (1), T.Gorgy (2), M.N. Danon-Schaffer(3), B. Li(4), J.R. Grace (5) and M.G. Ikonomou (6)

(1)(2)(4) Department of Civil Engineering, University of British Columbia, Canada (lli@civil.ubc.ca), (3)(5) Department of Chemical and Biological Engineering University of British Columbia, Canada, (jgrace@chbe.ubc.ca), (6) Department of Fisheries and Oceans, Canada (Michael.Ikonomou@dfo-mpo.gc.ca)

Corresponding author and presenting author: Loretta Y. Li

PBDEs (polybrominated diphenyl ethers) and PFAs (polyfluorinated alkyls) were added to the classification of persistent organic pollutants (POPs) according to the Stockholm Convention in May 2009. These contaminants are all found in people, mammals, fish, birds, sediments and air samples, causing major environmental concern. PBDEs are used as flame-retardants in plastics, textiles, electronic circuitry and insulation material. Most have been banned in many countries to reduce the amount of PBDEs in plastics, textiles and electronic equipment. However, old products are still in use, and some are discarded in landfills. PFAs are used in many industrial and commercial applications, for example, in fire-fighting foams, industrial surfactants, insecticides, and surface treatments for paper and textiles. Landfills are the ultimate destination of many PBDEs-containing used products and PFA-containing materials due to their widespread in consumer and industrial goods. These contaminants may leach from the refuse in contact with landfill leachate. Research is needed to determine how these materials are entering the environment and whether current engineered landfill clay barriers can contain their spread and their bioavailability.

The major objective of this presentation is to present research on PBDEs, and PFAs in leachates from engineered landfill sites carried out at the University of British Columbia. We will discuss unique experiments including: (1) Characterization of leachates and soils in landfills to determine the extent of contamination. (2) Investigation of the interaction between these two classes of compounds and soil/clay, in particular theie adsorptivity onto clay barrier materials and soil. (3) Examination of their mobility and migration in clay liner and soil via leaching column tests. (4) Determination of whether or not there is any correlation among these two classes of POPs.

This on-going study is providing a unique dataset that can be helpful in management and establishing regulations. The results of this research will also be useful to determine whether landfill liners now in service are capable of preventing these classes of compound from migrating into the environment, as well as providing information for regulators to develop better waste management practices. This research will provide guidance for rational design of proper containment systems and contribute to environmental geo-technology for both short and long term prevention of their migration beyond landfill sites where household and industrial products containing these compounds are disposed.

Monitoring of leachate quality stored in gas ventilation pipes for evaluating the degree of landfill stabilization

*Y. Tojo (1), M. Sato (1), T. Matsuo (1) and T. Matsuto (1)

*(1) Graduate School of Engineering, Hokkaido University, Japan (tojo@eng.hokudai.ac.jp)

Monitoring of leachate quality is the essential measure in post-closure care to evaluate waste stabilization. Generally, the most common way of leachate monitoring is executed at the outlet of main leachate collection pipe or by obtaining crude leachate sample at inlet of leachate treatment facility. The leachate obtained at these points may reflect overall characteristics of the site. Of course, continual monitoring on the overall characteristics can provide useful information to determine landfill completion from viewpoint of emission. However, heterogeneity and inhomogeneity are typical in the ordinary landfill. Therefore, even if the quality of leachate monitored at the outlet of main leachate collection pipe fulfills the discharge criteria of nearby water body, it does not necessarily imply complete stabilization of the site. Perhaps, some parts of the landfill may be still under active degradation/reaction phase. Thus, not only the methodology focusing on the discharge to determine the termination of post-closure care but also the methodology that is capable to seize the degree of stabilization of entire waste in landfill must be necessary. In this study, monitoring of leachate quality stored in 68 gas ventilation pipes was conducted and degree of waste stabilization at each location in the landfill was estimated by statistical approach using the results obtained by monitoring.

Investigated site was operated from 1986 to 2003. Until its closure, mixed MSW, sewage sludge and C&D waste were mainly disposed of without any pre-treatment. Locations where these wastes were disposed of were not recorded. At the time of closure, leachate quality monitored at the inlet of treatment facility was strangely lower than the discharge criteria. The leachate was thought to be diluted by ground water flowing from the surroundings and less representativeness of it was evident. Since the waste being still under active degradation phase was obvious, countermeasure work for promoting stabilization was initiated from 2004 and 68 gas ventilation pipes had been installed until 2006.
Leachate samples were obtained from these gas ventilation pipes at almost three-week intervals. And analysis was conducted for pH, EC, temperature, TOC, TN, IC, Cl^-, and NH_4-N.

Leachate characteristics varied significantly by each pipe but seemed to reflect the waste condition of nearby location. High concentration region was identified in the vicinity of the center of the site. And every items analyzed were commonly high at there. On the other hand, concentration of every item was low at peripheral area. Therefore, correlation among the analyzed items was quite high. Namely, the difference of leachate quality seemed to be categorized by only the level of concentration but not specific characteristics. To confirm this, Euclidean distances of dissimilarity were calculated by multi dimensional scaling by using six items of leachate quality and temperature. By interpreting the results, two factors (thickness of leachate and concentration of TOC and EC) that distinguish leachate characteristics appeared. Next, to indicate the degree of stabilization by location, spatial distribution of TOC were estimated by using ordinary Kriging methodology. Before executing Kriging, several points at where leachates quality highly fluctuated and were significantly affected by rainfall were eliminated by examining their responses to rainfall of a few days ago. As the result, it was estimated that the area of which TOC exceeds 100 mg/L was nearly 37%.

Environmental Compatibility of Closed Landfills – Assessing Future Pollution Hazard

D. Laner, J. Fellner, and P.H. Brunner (1)

(1) Institute for Water Quality, Resources and Waste Management, Vienna University of Technology, Karlsplatz 13, 1040 Vienna, Austria (d.laner@iwa.tuwien.ac.at)

Municipal solid waste (MSW) landfills need to be managed after closure. This so-called aftercare comprises the treatment and monitoring of residual emissions as well as the maintenance and control of landfill elements. The measures can be terminated when a landfill does not pose a threat to the environment any more. Consequently, the evaluation of landfill environmental compatibility includes an estimation of future pollution hazards as well as an assessment of the vulnerability of the affected environment. An approach to assess future emission rates is presented and discussed in view of long-term environmental compatibility. The suggested method consists a) of a continuous model to predict emissions under the assumption of constant landfill conditions, and b) different scenarios to evaluate the effects of changing conditions within and around the landfill. The model takes into account the actual status of the landfill, hence different methods to gain information about landfill characteristics have to be applied. Finally, assumptions, uncertainties, and limitations of the methodology are dis-cussed, and the need for future research is outlined.

Keywords: Landfill; Emissions; Aftercare; Environmental evaluation; Scenario modelling;

Session E - Landfill Stability and Aftercare I

Landfill sustainability and completion criteria

Heijo Scharff

Afvalzorg Deponie BV, Assendelft, Netherlands, h.scharff@afvalzorg.nl

Common use of the term sustainability began with the 1987 publication of the World Commission on Environment and Development report entitled 'Our Common Future.' This document coined the well known and widely referenced definition of sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs." Although the general concept of sustainability is being increasingly embraced by the waste management industry, regulators, environmentalists, and the general public, shared definitions of "sustainable landfill" and "landfill stability" were until recently not available.
Since landfills are a reality and will be among us for a long time, we will have to do the best we can to reduce their emissions. Sustainability is not a clear concept and in relation to landfill it causes opposition among regulators and the general public. Moreover once it is sustainable, can it still be called a landfill? Or should it be considered a harmless part of the earth?
The landfill industry and the regulators essentially need a definition in order to agree on completion. Completion is the moment at which the responsibility for remaining risk is transferred from the operator to society. The key issue is more about a desired 'end-point', risk and risk assessment than about sustainability. Consequently we should emphasise striving for acceptable risk rather than achieving sustainability.
Functional stability cannot be separated from the surrounding environment and from the proposed after-use. Consequently risk can only be assessed for a specified situation and after-use. Considering the above a group of international scientists recently agreed on the following definition (or framework) of acceptable risk for landfills in the context of aftercare completion:

1) The landfill reaches functional stability (based on site-specific physical, chemical, and biological characteristics of the waste mass and its location) such that the landfill, taking into account its proposed after-use, is unlikely to pose an unacceptable risk to human health or the environment;
2) During the process towards stability no unacceptable risk should occur;
3) This situation should be reached as quickly as possible and within the financial provision time;
4) The funding for completion of aftercare has been secured and allows for appropriate after-use of the site with minimal (custodial) care.

An essential element of sustainable methods for landfilling is rapid stabilisation of the waste with which the landfill is constructed. Stabilisation can be accelerated by optimal use of naturally occurring processes. These processes are different for different types of waste. This means that certain wastes should receive a dedicated sustainable landfill approach. A distinction can be made in at least three different main approaches:
1) The Bioreactor approach for biodegradable wastes. This approach aims at acceleration of the biodegradation processes. This is mainly achieved by means of injection and recirculation of water. Methane production is stimulated and capture rates are optimised. This results in a very low methane emission and optimised energy recovery. The 'carbon sink' in combination with the energy production in terms of fossil fuel saved makes that a Bioreactor Landfill is a net reducer of green house gasses.
2) The Equifill approach for inorganic wastes. Specific types of inorganic wastes can neutralise each other's negative effects. Processes such as adsorption and precipitation can be stimulated based on better knowledge of the waste materials. This results in irreversible storage inside the landfill body and consequently to lasting low levels of emission.
3) The Monolith approach for hazardous wastes. Contaminants in certain types of hazardous waste can be immobilised in minerals by mixing them in a dedicated immobilisation plant. Mineralisation can be optimised with a binding agent. A new material emerges that has the properties of concrete. This material can either be

applied as blocks or in layers to build a Monolith Landfill. The treatment results in lasting low levels of emission.

The remaining levels of emission from these landfills can be considered that marginal that isolation measures are no longer required. Long-term risks can be considered negligible. The landfill can be "handed over to nature" without concern. Consequently this would also be the moment to formally end aftercare. Further involvement with the site depends on the after-use, but could be minimised comparable to park maintenance. Landfills are usually not located very far away from the waste producers. That means that many are situated in or close to urban areas where the pressure on land is high and there is a growing interest in recreational facilities. Closed landfills provide excellent opportunities to create such facilities. When it is finally handed over to society as a 'safe landscape', a well designed, managed and constructed sustainable landfill provides solutions for more than just waste management needs of society.

Monitoring and assessment of landfill stability using simultaneous thermal analysis

E. Smidt*, K. Böhm and J. Tintner

Institute of Waste Management, University of Natural Resources and Applied Life Sciences Vienna, Austria (ena.smidt@boku.ac.at)

According to the Austrian Landfill Ordinance mechanical-biological (MBT) or thermal pretreatment of municipal solid waste is a prerequisite prior to landfilling in order to minimize gaseous emissions and the release of environmentally relevant compounds via leachate. MBT-materials intended for landfilling have to comply with limit values regarding stability. In the context of climate change monitoring of abandoned landfills from the past that still feature metabolic processes and remaining gaseous emissions is required in order to decide on appropriate remediation measures. Biological tests are state of the art to evaluate the stability of MBT-waste and landfilled organic waste. With respect to inorganic residues such as municipal solid waste incinerator (MSWI) bottom ash, chemical ageing processes (e.g. carbonation) are monitored to provide information on progressing stabilization.

This study focuses on the application of simultaneous thermal analysis as monitoring tool in terms of stability assessment. Simultaneous thermal analysis comprises thermogravimetry/mass spectrometry (TG/MS) and differential scanning calorimetry (DSC). The presented investigations concentrate on the evaluation of MBT-waste intended for landfilling and landfilled waste without any pre-treatment and additionally on the carbonation process of MSWI bottom ash. The thermal behavior depends on physical properties of chemical components and the chemical composition of waste materials. The TG- and DSC-profiles characterize the material in a comprehensive way. Stabilization of organic matter and carbonation are paralleled by changes of the mass losses (TG), combustion gases (MS) and the heat flow (DSC). The enthalpy is calculated by integration of the peak area below the heat flow curve. During the biological treatment the enthalpy of the whole waste system decreases with progressing mineralization. By contrast, the enthalpy of the remaining organic matter increases. The ratio of enthalpies provides information on the stabilization process.
Due to the huge data pool generated by thermal analyses, data evaluation is supported by multivariate statistical methods. Several examples are demonstrated in terms of the applicability of this method to answer relevant questions in waste management regarding the performance of the pretreatment, process control, stability and classification of landfilled materials. DSC-profiles of MBT-materials from ongoing processes and MBT-landfills are compared to DSC-profiles of abandoned landfills by means of a principal component analysis (PCA) to reveal the efficiency of the biological treatment in terms of shortening the aftercare phase. Different landfilled waste materials can be distinguished by their specific spectral pattern and a PCA. Various parameters such as respiration activity and total organic carbon (TOC) contents are reflected by the mass spectra of combustion gases and by the DSC-profiles. This correlation enables parameter prediction by means of a partial least squares regression (PLS-R) that was performed for respiration activity and the TOC content. Based on thermograms and discriminant analysis (PLS-DA) differentiation of MSWI bottom ash before and after carbonation was carried out to evaluate the effect of accelerated CO_2 uptake.

Influence of Air Injection on the Stabilization of Landfill Adopting the Aerobic-anaerobic Method

Takayuki Shimaoka (1), Gangzhen Jiao (2) and Teppei Komiya (3)

(1) Kyushu University, Japan (shimaoka@doc.kyushu-u.ac.jp)
(2) Kyushu University, Japan (jiao@doc.kyushu-u.ac.jp),
(3) Kyushu University, Japan (t-komiya@doc.kyushu-u.ac.jp)

In order to enhance the stabilization of solid waste landifll, it is important that landfilled solid waste is kept in aerobic atmosphere, where the decomposition of organic matter is accelerated. However, the anaerobic type landfills are generally adopted in the most of the developing countries because of restrictions due to economical and technological powers. As one of problems on landfill in developing countries, the generation of leachate which shows high concentrations of organic matter and nitrogen for a long period causes environmental pollution. Landfills under anaerobic condition are also one of the main sources of greenhouse gases (GHG) emission The amount of methane gas emission from landfills is estimated approximately at 3 to 4 % of the artificial GHG emission (IPCC2006). Thus, in a viewpoint of prevention of global warming, it is desirable that the aerobic decomposition of landfilled solid waste is advanced and GHG emission from a landfill is reduced

Based on the nitrification under aerobic condition process and the denitrification under anaerobic condition process in sewage treatment, the air is injected into solid waste layer at the appropriate stabilization phase and depth to make the aerobic atmosphere in solid waste layer, then it is expected to enhance the decomposition of nitrogen. In the decomposition of organic carbon, it can be expected that the aerobic decomposition brings the restrain of emission of methane gas, which shows twenty one times higher global warming coefficient than carbon dioxide, and that the earlier stabilization of landfilled solid waste because the aerobic decomposition is faster than the anaerobic decomposition in decomposition rate.

In this study, the aerobic-anaerobic method is described as a new method to control a landfill, and the objective of this study is to make clear the optimum conditions of the air injection including (1) flow rate of air injection, (2) air injection position (depth), (3) phase of solid waste stabilization and (4) duration time of air injection which enable the improvement of leachate quality, the restrain of methane gas generation and the enhancement of landfilled solid waste stabilization .

Photo 1 Large lysimeters for experiment

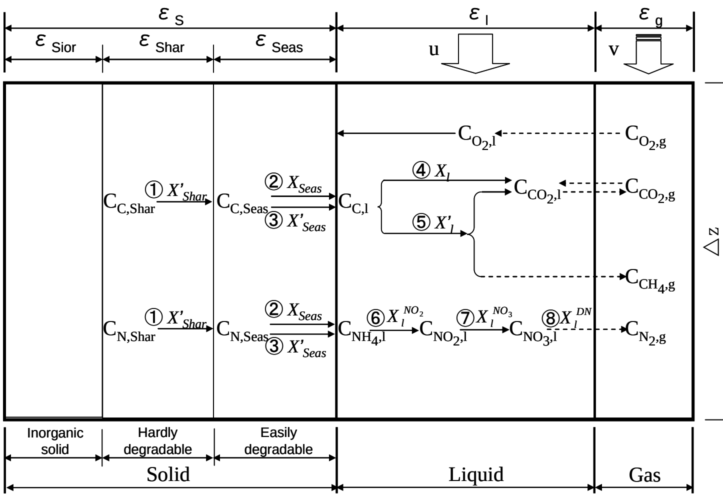


Fig.1 Schematic diagram of landfill model

The experiment using large lysimeters showed in Photo1 was carried out, and the influence of air injection conditions on the leachate quality, the landfill gas generation amount and the solid waste stabilization was examined. Solid waste layer is modelled as Fig.1. The one-dimensional landfill model, where water movement, solute transport, bacteria activity, gas generation and movement and heat generation and transport were considered, was constructed. Coefficients in the model were obtained from the experimental results and the influence of air injection conditions such as air injection position and duration time of air injection on the leachate quality, the landfill gas generation and the stabilization of landfilled solid waste was studied through numerical simulation.

As examples of the numerical simulation results, the profiles of dissolved oxygen concentration in liquid phase, organic carbon and nitrogen concentration in solid phase after the one year of air injection which were different in the air injection position(depth) are showed in Fig.2, Fig.3 and Fig.4, respectively. It is seen that, at the depth of air injection, (1) the dissolved oxygen concentration in liquid phase is higher, (2) the decomposition of organic carbon in solid phase is advanced and (3) the decomposition of nitrogen in solid phase is slower than at other places in any cases.

Fig.5, Fig.6 and Fig.7 show the average concentration of dissolved oxygen in permeating water, the decomposition amounts of organic carbon and the nitrogen in landfilled solid waste, respectively. It is seen that the average concentration of dissolved oxygen is highest, the organic carbon in landfilled solid waste is the most decomposed and the nitrogen in landfilled solid waste is the least decomposed in the case of the middle depth of air injection. In this simulation, air injection is kept at all times. The result shows the disadvantage of continuation of air injection in nitrogen removal and implies the importance of conversion between aerobic and anaerobic atmospheres by air injection with appropriate phase of solid waste stabilization.

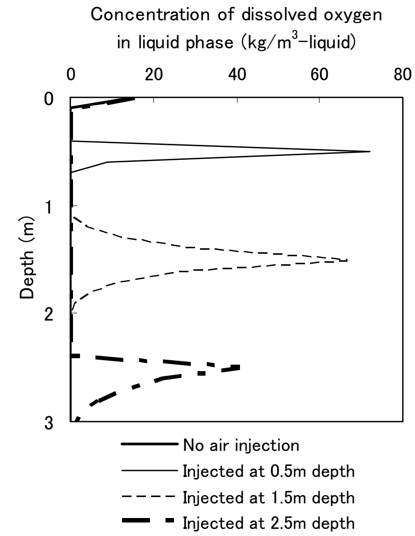


Fig.2 Concentration of dissolved oxygen in liquid phase at 1 year after

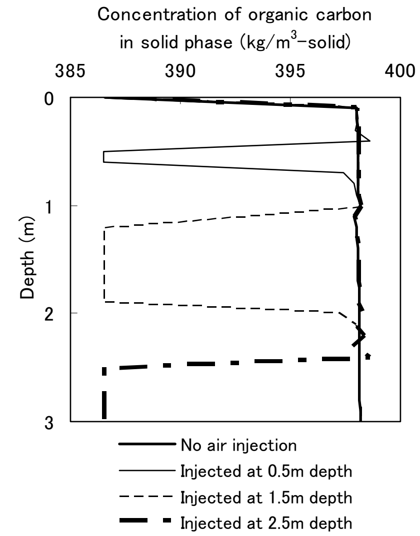


Fig.3 Concentration of organic carbon in solid phase at 1 year after

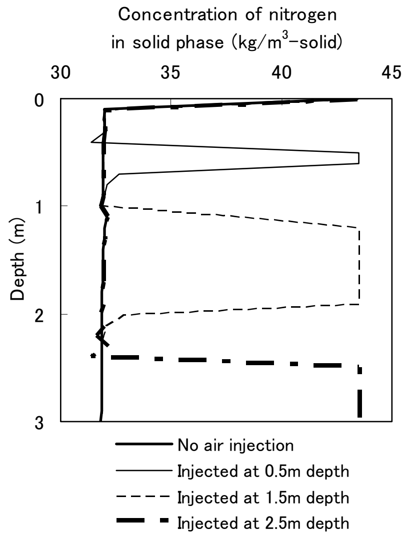


Fig.4 Concentration of nitrogen in solid phase at one year after

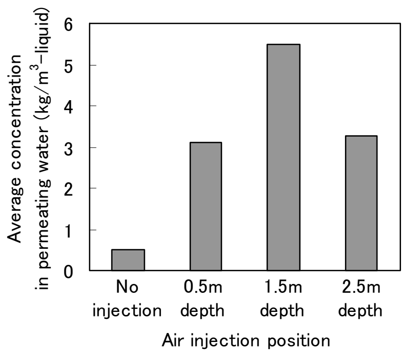


Fig.5 Average concentration of dissolved oxygen in permeating water at 1 year after

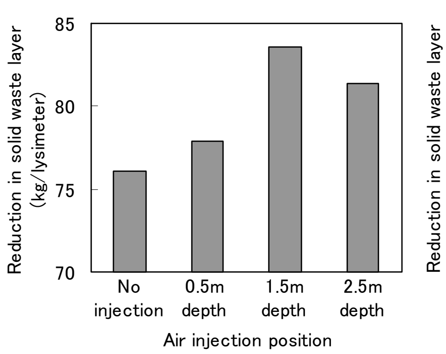


Fig.6 Reduction of organic carbon in solid waste layer during 1 year

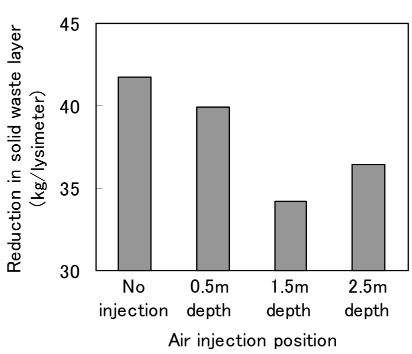


Fig.7 Reduction of nitrogen in solid waste layer during 1 year

Natural attenuation in groundwater around landfills: implications for landfill post-closure

D. Guyonnet (1), D. Hubé (1), L. Gourcy (1), J.-C. Gourry (1)
(1) BRGM, France (d.guyonnet@brgm.fr)

The « Controlled Landfill » technology, which emerged in the seventies but only became truly operational in France in the late eighties with the impetus of environmental regulations, is now shifting as an increasing number of landfill sites reach the post-closure phase. Technology developments typically focus on passive attenuation technologies for the treatment of residual emissions. One example is the use of methane oxidation covers for the passive treatment of residual GHG emissions. From an operator's viewpoint, if a landfill is no longer a source of financial income, it is highly desirable that it should rapidly cease to be a source of cost. Therefore during the post-closure phase, landfill operators are particularly keen about convincing environmental inspectors that landfills no longer pose a threat to health or the environment. The demonstration of such absence of risk relies typically on data collected from environmental monitoring networks and also on modelling of possible future evolutions of environmental concentrations. Models for groundwater contaminant transport generally include conservative assumptions, due to the inherent complexity of mechanisms affecting the fate of contaminants in groundwater near landfills. Therefore it may be necessary, in a context of post-closure risk assessments for decommissioning old landfills, to demonstrate, by field data, that attenuation mechanisms are at work in the subsurface. One difficulty that is typically encountered in France is related to the fact that groundwater monitoring systems around landfills are usually insufficiently detailed to provide conclusive evidence of natural attenuation mechanisms. This is particularly the case when such monitoring systems have been designed in reference to the minimal requirements of the Landfill Directive (99/31/EC) which include (Annex III) "… *at least one measuring point in the groundwater inflow region and two in the outflow region*." Data collected from a monitoring system designed according to such minimal requirements will be unlikely to convince environmental authorities of the reality of the absence of risk. In particular, 3 monitoring points may define a plane, but in the vast majority of landfill situations, the groundwater table is much more complex than a plane, due for example to groundwater mounding in the landfill or to aquifer heterogeneity. Therefore flow directions are rarely uni-directional and a minimal-specification monitoring system may well "miss" contaminant fluxes. In this paper we present data on groundwater quality in the vicinity of an old landfill located in a complex aquifer system. While isotopic data suggest an influence of the landfill leachate on the groundwater in the vicinity of the landfill, chemical pollutant analyses do not show a noticeable influence, which could be indicative of natural attenuation mechanisms in the area between the landfill and the groundwater monitoring points. However, the complexity of the groundwater system in this area is such that it cannot be excluded that a pollutant flux is being missed. In practical situations, there is inevitably a balance between the number of monitoring points that is economically feasible, and the level of uncertainty that can be accepted with respect to "missing" a contaminant flux. Such a balance, which will vary largely according to specific context, is not yet clearly identified.

Session F - Landfill Stability and Aftercare II

Sustainable emission reduction at closed landfills based on natural biochemical processes.

Final results of a full scale bioreactor project at the Vlagheide landfill (NL)

W.J. van Vossen (1) and Theo Folmer (2)

(1) Royal Haskoning, The Netherlands (w.vanvossen@royalhaskoning.com)
(2) Urban District of 's-Hertogenbosch, The Netherlands,

Introduction

The Urban District of 's-Hertogenbosch (UDH) owns the closed landfill Vlagheide in Schijndel (NL). The Vlagheide landfill must meet the requirements of the EU-Directive 1999/31/EC of 26 April 1999 on the landfilling of waste. The Vlagheide landfill encounters the two following situations:

1. An older part without a bottom liner, but almost totally sealed by a top liner. The quality of groundwater has been affected due to leaching of contaminants from the waste body. Abstraction of groundwater takes place to prevent further migration of pollution in the groundwater.
2. A newer part provided with a bottom liner, but not yet with a top liner. UDH is obliged to apply a top liner as soon as technically possible, to isolate the landfill from its environment. Also a groundwater monitoring system is installed to monitor the landfill's environment and to detect possible leakages.

In both situations, the operational aftercare measures are expensive and everlasting. The waste itself remains an everlasting source of pollution and therefore a burden to next generations.

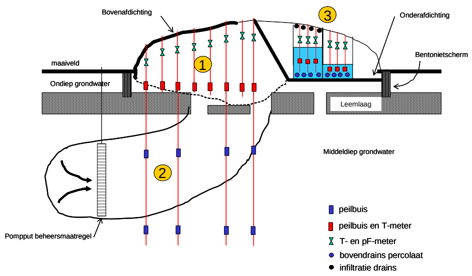
Vision and strategy

New technological developments in natural biochemical processes occurring in landfilled waste make it possible to consider a landfill as a dynamic bio- and physico-chemical reactor instead of a static landfill body. These natural processes, called "Natural Attenuation", are able to reduce/eliminate all types of contaminants in the landfilled waste. Natural Attenuation (NA) is a generic term for all natural self-cleaning processes in both landfill body and downstream groundwater, consisting of microbiological decay, chemical precipitation and sorption of contaminants to organic material and silt particles.

When the conditions are optimized for NA to occur and the landfill is monitored and steered accordingly, the landfilled waste might become harmless within 20-30 years. Royal Haskoning already succeeded to demonstrate this principle at 80 former landfills in the Netherlands.

However, the aftercare measures as prescribed by the Dutch legislation do not support the measures necessary for NA to become fully operational. In fact, they are counter-productive from this point of view. Due to this legislation the self-cleaning ability of nature in landfills has never been demonstrated on a full-scale situation in the Netherlands. Royal Haskoning has developed the as a new strategy for NA-monitoring in the waste body as well in the downstream groundwater plume at existing landfills. The SANA-model can be applied in the operational phase as well as in the after care phase of a landfill. The full scale demonstration project demonstrates this new strategy, which might lead to sustainable emission reduction.

Full scale demonstration project at Vlagheide landfill



The demonstration project at the Vlagheide landfill started in 2005 and will end in 2010. The landfill measures 40 ha and 6 million m³ of waste has been stored in the period 1969-2003. At the landfill 3 zones are distinguished (see figure). Zone 1 (22 ha) without protection measures to soil and groundwater, but is almost totally provided with a top-liner. Zone 2 is the leachate plume underneath the landfill as a result of the absence of a bottom liner. Zone 3 (18 ha) is provided with a bottom-liner, but has no top-liner yet. Zone 3 is divided into 8 waste compartments.

Objectives demonstration project

The general objective of this demonstration project is to implement and demonstrate the new approach for sustainable emission reduction. With this project, the effectiveness of optimizing the natural biochemical processes in both landfilled waste and the downstream polluted groundwater is demonstrated. The main objectives of the project are:

- mapping the current NA-processes in and outside the landfill body (biogas, leachate, groundwater, waste);
- picturing the critical factors and key performance indicators, which influence the (progress of) NA;
- design and execution of pilot-tests (incl. enhanced infiltration) in order to optimize these NA- processes;
- development of a fully operational concept for sustainable aftercare at landfills based on NA.

Research program

To demonstrate the effectiveness of NA in the Vlagheide landfill, an extensive number of measurements have been carried out during the project over a period of 5 years (2005-2010). Therefore measuring equipment like piezometers and drainpipes, including enhanced infiltration in zone 3, has been installed (see figure above). Changes in the biochemical composition of the waste will reveal the occurrence and status of NA-processes. To demonstrate the influence of different circumstances on NA and the effectiveness of the NA-strategy, measurements in these different zones have been compared during the project. During initial NA-measurement, data have been collected on the conditions of landfill gas and leachate in all zones.

Results and future perspectives

The results of this demonstration project will be translated into a fully operational concept for sustainable, based on natural biochemical processes, called the SANA[1]-model. The advantages of the SANA-model are:

- a sustainable emission reduction of contaminants to groundwater and of biogas to the air compartment.
- a shift from everlasting aftercare to ending aftercare without risk of future groundwater contamination.
- redevelopment of these landfill sites in an earlier stage;
- a substantial cost reduction with respect to the aftercare phase, compared to traditional aftercare measures.

Finally the results will contribute to the development of criteria for sustainable emission reduction, by which the competent authority might decide to less stringent aftercare or even to discharge from aftercare.

Aftercare measures are most often prescribed by national legislation and permits. The project results may influence this legislation in such a way that NA becomes an important part of prescribed aftercare measures. Besides, aftercare measures which are counterproductive to natural biochemical processes may be excluded.

---

[1] SANA stands for **S**ustainable **A**ftercare based on **N**atural **A**ttenuation

Investigation of polycyclic aromatic hydrocarbons (PAHs) content in several incineration residues and simple estimation of their fate in landfill

*Masahiro Sato (1), Yasumasa Tojo (1), Takayuki Matsuo (1), and Toshihiko Matsuto (1)

*(1) Graduate School of engineering, Hokkaido University, Japan (sato-m@eng.hokudai.ac.jp)

For sustainable landfill, to ensure long-term safety is essential. For this objective landfill should be operated and managed without any environmental pollution caused by release of hazardous compounds. However, knowledge about long-term behavior of some hazardous compounds still seems to be not sufficient.
In this study, Polycyclic aromatic hydrocarbons (PAHs) are focused on because some of them are designated as the carcinogenic and genotoxic. PAHs are considered to be generated from incomplete combustion. So, it is easily assumed that combustion by-product such as incineration residue contains much PAHs. Especially, in Japan, large quantity of incineration residue is currently disposed of into landfill (4.5 million tons) so that their fates have important implications. Thus, overall objectives of this study were set to elucidate the amount of them delivered by waste, behavior (partition and transportation) of them in landfill, and also their biodegradation. In this report, parts of the results obtained up to now are presented. Namely, content of PAHs in several bottom ashes and calculated results regarding the long-term fate of PAHs by simple numerical calculation are provided.

Samples were obtained at five incineration facilities. PAHs were extracted basically by Soxhlet extraction with acetone and hexane (1:1, v/v) for 6 hours. Extracts were concentrated and purified and then analyzed by GC-MS. The content of US-EPA 16 PAHs, 1-metylnaphthalene, and perylene were quantified. Numbers of detected PAHs were ranged from 5 to 18 kinds depending upon the sample. This is because sample matrix significantly affected extraction efficiency. Sum of their content varied from 26.7 mg/g to 841.2 mg/g and major components in bottom ash were naphthalene, phenanthrene, and fluoranthene. However, it was revealed that there are several issues regarding extraction procedure. Surrogate recovery ratios of some PAHs were lower than 50% and also their RSDs (relative standard deviation) were over 50% due to inappropriateness of sample amount, time for extraction, and extraction solvent. Further investigation must be necessary to improve their recovery.

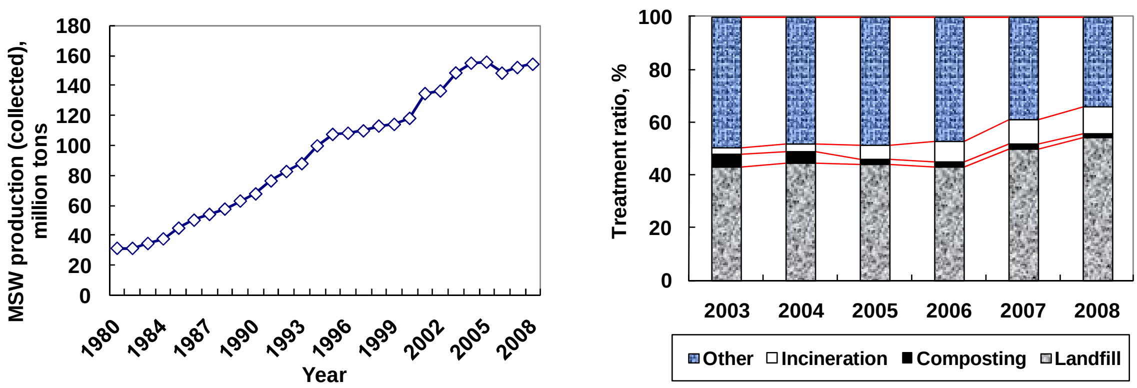
Based on the content of PAHs obtained by analyses, simple calculations estimating the long-term fate of PAHs were carried out. Box model under unsaturated steady flow condition was created. Distribution of PAHs among solid, liquid and gas phase and also their biodegradation were taken into account. As for parameters such as Henry's constant, distribution coefficients (Koc), and biodegradation rate, data presented in past study on soil and sediments were utilized.
As a result of simple calculation, these PAHs were estimated to remain in landfill layer longer than 30 years when no biodegradation was assumed because of high solid-liquid partition coefficient, i.e., PAHs were hardly removed from landfill with leachate or landfill gas for a long time. On the other hand, when biodegradation was assumed, PAHs in solid phase could be removed readily. In aerobic condition, naphthalen and phenanthlene were almost completely biodegraded within 1 year and it took 7 years for fluoranthen to disappear. In anaerobic condition, it took one year for most of the naphthalene to diminish. Phenanthlene and fluoranthene needed 21 and 31 years each to degrade.

Biostabilization of municipal solid waste with high water content and putrescible waste prior to landfill

Pin-Jing He*, Hua Zhang, Li-Ming Shao, and Fan Lü

State Key Laboratory of Pollution Control and Resources Reuse, Key Laboratory of Yangtze River Water Environment, College of Environmental Science and Engineering, Tongji University, Shanghai 200092, P.R. China (solidwate@tongji.edu.cn)

With the development of social economy, sprawling urban area, population growth and improving living standards, the production of municipal solid waste (MSW) has progressively increased in China. During the last 25 years, the amount of collected MSW increased by 350%, with an annual ratio of 6.2% (Figure1) (National Bureau of Statistics of China, 1982-2009). As a result, MSW management is of an increasing concern. Before 1990, the treatment ratio of MSW was less than 2%, after that, numerous treatment and disposal facilities have been established to deal with the collected MSW. The ratio of MSW treated by landfill and incineration increased from to 43.1% and 2.5% in 2003 to 50.6% and 10.2% in 2008 respectively, while that by composting decreased from 4.8% to 1.1%, due to the poor quality of mixed waste compost (Figure1). Landfill is used as the most prevalent disposal method for MSW in China.



(a) (b)

Figure 1 Production and treatment of MSW in China

MSW in China is of characterized by high water content and high proportion of putrescible food waste. For example, 50%-70% of water content and 50%-65% of food waste composition in MSW have been observed in Shanghai (Zhang, 2008). Landfilling of such kind of MSW can not only produce a large amount of high concentrated leachate, but also result in acid tomb in landfill layer which would inhibit organics degradation and methanogenesis startup. Furthermore, the high water content would greatly deteriorate the sorting efficiency of MSW or even invalidate the sorting operation, thus adversely influencing the recovery of valuable matters.

Biostabilization can greatly reduce moisture and degradable organic matter content in MSW, which is considered to be an effective pretreatment prior to landfill (Norbu et al., 2005). In this study, the optimal parameters for biostabilization were investigated. One aerobic (the process was operated at an air-inflow rate of 0.056 m3 per kg wet wastes per hour for 16 d with a ventilation interval of 7 min run/23 min stop and the fed wastes were manually turned every 2 days) and two combined (4-d hydrolytic stage with non-forced aeration followed by 12-d aerobic stage with a ventilation interval of 7 min run/23 min stop; 4-d hydrolytic stage with a ventilation interval of 10 min run/230 min stop followed by 12-d aerobic stage with a ventilation interval of 7 min run/23 min stop) bio-drying processes were set up to study the quantitative relationships of sorting efficiency with organics degradation and water removal during bio-drying. The environmental and economic impacts of the combined "biostabilization + sanitary landfill" processes were evaluated and compared with those of sanitary landfill alone. The results indicated that, bio-drying could enhance the sorting efficiency of MSW up to 71% from the initial 34%, and the efficiency was negatively correlated with water content and positively related with organics degradation rate. By contrast with sanitary landfill alone, the combined "biostabilization + sanitary landfill" processes could not only substantially save land, minimize landfill pollutions regarding leachate generation and methane emission, but also reduce the total cost. Therefore, the combined MSW biostabilization followed by landfill process was suggested as an environmentally friendly technology for substituting the sanitary landfill of raw MSW.

Key words: Biostabilization; landfill; pretreatment; municipal solid waste; high water content

References:

National Bureau of Statistics of China, 1982-2009. China Statistical Yearbook 1982-2009. Beijing: China Statistics Press.

Norbu, T., Visvanathan, C., Basnayake, B., 2005. Pretreatment of municipal solid waste prior to landfilling. Waste Management 25, 997–1003.

Zhang, D.Q., He, P.J., Jin, T.F., Shao, L.M., 2008. Bio-drying of municipal solid waste with high water content by aeration procedures regulation and inoculation. Bioresource Technology 99, 8796-8802.

The fate of nitrogen relating to in-situ aeration of landfills

Marion Huber-Humer (1), Pia Paola Huber (2) andOliver Gamperling (3)

Institute of Waste Management, BOKU - University of Natural Resources and Applied Life Sciences, Vienna, Austria
(1) marion.huber-humer@boku.ac.at (2) pia.huber@boku.ac.at (3) oliver.gamperling@boku.ac.at

As nitrogen is responsible for the long aftercare time of landfills, we investigated the fate of organic and inorganic nitrogen compounds of different waste materials during in-situ aeration in landfill simulation reactors (LSR). NH_4-N in the leachate can be significantly reduced via in-situ aeration and the leached NO_3-N can not compensate the reduction of NH_4-N. Even at high aeration rates there are anaerobic zones where NO_3-N is denitrified to gaseous N_2. One problem that may occur is the emission of nitrous oxide (N_2O), which is an intermediate product of denitrification. N_2O is a potent greenhouse gas with a global warming potential (GWP_{100}) of 298, and is released especially when oxygen disturbs the decomposition via the enzyme N_2O-reductase.

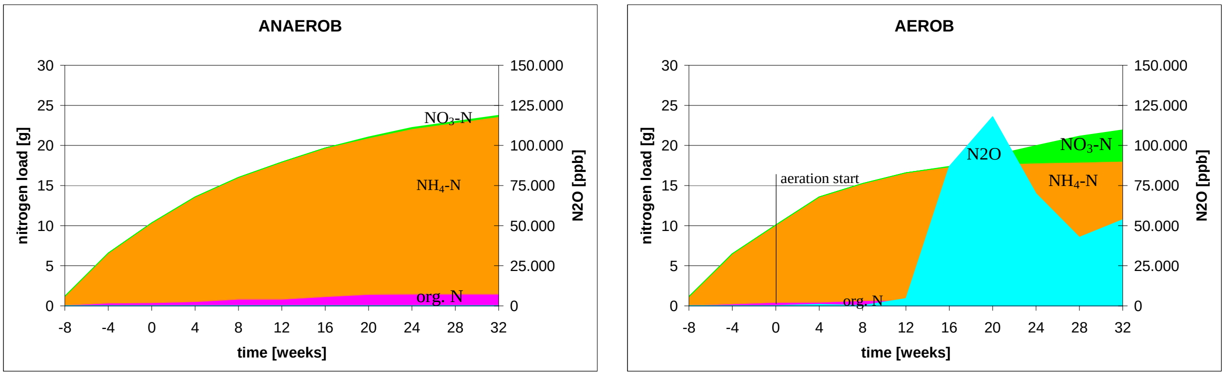


Fig. 1. Development of nitrogen compounds of anaerobic and in-situ aerated LSR.

Figure 1 shows the leached nitrogen compounds of waste material from a municipal solid waste landfill. In this case, nitrogen was mainly leached in form of NO3-N after about 12 weeks of aeration. A main part of the reduced NH_4-N was just transformed into NO_3-N. As the organic nitrogen in the aerated LSR is similar to the anaerobic LSR, there is only a small difference of the overall leached total nitrogen (organic and inorganic nitrogen) between the anaerobic and aerated variants.

Another point shown in Figure 1 is the release of N_2O via the exhaust air. When NO_3-N–release in the leachate started, the N_2O-concentration multiplied. In this case the N_2O-concentration was over 250-fold higher than ambient air and accounts therefore to the CO_2-equivalents in the exhaust air.

ISSUE 1: In-situ aeration is a promising way to get rid of NH_4-N in the leachate. But is it also a suitable method to reduce the high nitrogen pool in municipal solid waste landfills?

ISSUE 2: In-situ aeration enhances the carbon discharge via CO_2 and decreases the reactivity of waste material. It reduces the high methane emissions and thus the emitted CO_2-equivalents. Nevertheless, if N_2O-emissions occur, they may reduce the success of in-situ aeration with respect to CO_2-equivalent reduction. A main question is therefore: How can N_2O-emissions be minimised and which role do they effectively play in contributing to CO_2-equivalents compared to anaerobic landfill degradation?

Long-term performance of landfill covers: Results of lysimeter test fields in Bavaria (Germany)

W. U. Henken-Mellies (1) and A. Schweizer (2)

(1) Geotechnical Institute, LGA Bautechnik GmbH, Nuremberg, Germany (wolf-ulrich.henken-mellies@de.tuv.com),
(2) Bavarian Environment Agency, Augsburg, Germany (andreas.schweizer@lfu.bayern.de)

Solid waste landfills have to be provided with a final cover after complete filling, in order to minimize the ingress of precipitation and the generation of leachate. Until recently it was taken for granted that landfills would perform as ideal, ever-lasting repositories, if only the barrier systems were built according to regulations. It was thought that compacted clay barriers would maintain their sealing properties over "geologic" time spans in the same way as clayey geologic formations do (e.g. as aquiclude).
In recent years there is increasing evidence that the components of landfill cover systems have a limited service life. Landfill covers are dominated by unsaturated hydraulic conditions in a similar way as the upper few meters of the pedosphere. They are exposed to seasonally changing weather conditions and to progressively changing conditions due to vegetation and root growth. Under the influence of these factors the properties of landfill covers may change considerably with time.

In order to study these effects large scale lysimeter test fields for long-term measurements of water balance and in-situ-properties of landfill cover systems have been implemented at several landfills in Germany. For the research work reported here, which was conducted on behalf of the Bavarian Environment Agency, large scale lysimeter test fields (520 m²) were constructed on the landfill of Aurach, Bavaria. Three different cover systems were examined:

(1) Simple soil cover consisting of a 1.5 m thick layer of loamy sand – simulating a typical cover of abandoned old landfills,
(2) Cover system with a geosynthetic clay liner (GCL) topped by a drainage geocomposite and 1.0 m of cover soil,
(3) Cover system according to the EU landfill directive, consisting of a compacted clay barrier, a drainage layer and a soil cover with a thickness of 2.0 m (in test-field 3a) and 1.5 m (in test-field 3b).

The lysimeter test-fields are equipped with tipping buckets to measure the relevant water fluxes (surface runoff, drainage flow and percolation through the respective sealing layer). FDR-probes and tensiometers were installed to take in-situ measurements of soil water content and matric suction. The measurements were conducted over a period of 4 to 10 years and are still ongoing.

Results of the precipitation and flow measurements show distinct seasonal differences which are typical for middle-European conditions: During summer evapotranspiration (ET) exceeds rainfall; soil water is extracted by ET, reducing soil water content even in depths of > 1 m. During winter season precipitation is higher than ET; the soil water reservoir is replenished, further precipitation percolates down into deeper layers.
In lysimeter (1) with the soil cover of loamy sand, a high amount of seepage into the landfill body inevitably occurrs during winter season. Seepage is in the same order of magnitude as the annual groundwater recharge in the region.
The 3-layer-systems of lysimeter (2) and (3) show a better sealing effect: Most of the water which percolates through the top soil is diverted into the drainage layer and does not percolate through the mineral barrier layer. The long-term effectivity of the mineral barrier layer depends on the ability of the top soil layer to protect it from critical loss of soil water / critical increase of matric suction. The 1.0 m soil layer was not able to prevent deterioration of the GCL, resulting in an increase of percolation from 1% to >5% of precipitation after 10 years of testing. In test field 3 only 2 – 3% of precipitation percolated through the mineral sealing layer. In dry summers there is even a loss in soil water content at the base of the 2.0 m thick soil cover.

The results of this study demonstrate the importance of considering the long-term aspect when assessing the effectiveness of landfill covers: The hydraulic conductivity at the time of construction gives only an initial (minimum) value. Hydraulic conductivity of the compacted clay layer or of the geosynthetic clay liner may increase substantially, if there is no long-lasting protection against desiccation (e.g. by a thick soil cover or by a geomembrane). This has to be taken into account in landfill cover design.

The cover system of a landfill is only one element of landfill aftercare. The emission potential of the waste and the capability of the subsoil and the aquifer for natural attenuation have to be taken into account as well. For an integral approach all three elements and their variability with time have to be considered.

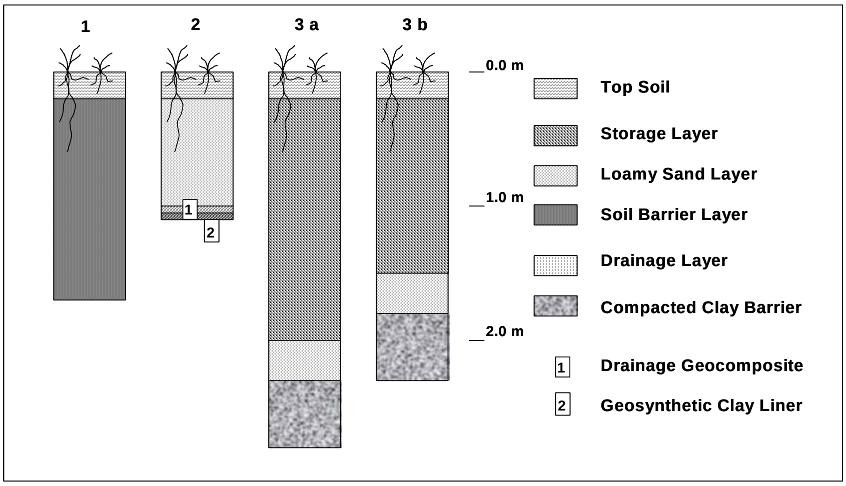
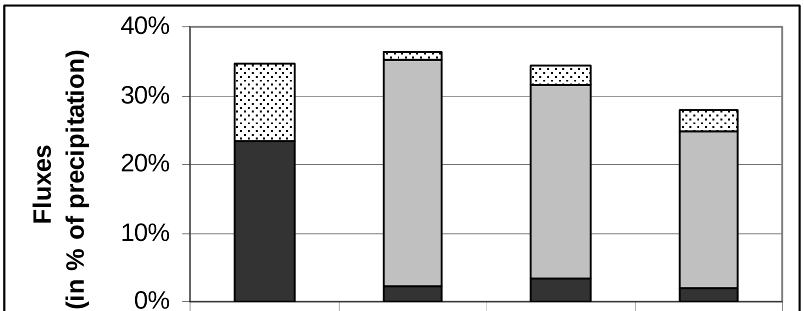


Figure 1: Profiles of the lysimeter test fields.



	Lysimeter 1 (1997-2001)	Lysimeter 2 (1998 - 2008)	Lysimeter 3a (2002 - 2008)	Lysimeter 3b (2002 - 2008)
Surface Runoff	11,3%	1,0%	2,8%	3,3%
Drainage Flow		33,0%	28,2%	22,8%
Percolation	23,3%	2,2%	3,5%	1,9%

Figure 2: Water balance of the lysimeter test fields: Fluxes in percent of precipitation.

Session G - Landfills – Resource and Hazard

Landfills, complexity and biogas risk assessment

A. Mavropoulos (1) and D. Kaliampakos (2)

(1) ISWA STC Chair, CEO EPEM SA, Greece (amavrop@epem.gr), (2) NTUA, Professor Dept. of Mining Engineering and Metallurgy, Greece

The purpose of this paper is to introduce the context of complexity in landfills as a conceptual framework for biogas risk assessment procedures.

Traditionally, landfills are considered as engineering systems with complicated interactions but predictable behaviour. This approach has resulted in a thorough understanding and high scientific progress of landfills' macro-behaviour. A lot of applied models do already exist for biogas emissions and movement, for leachate generation, for settlement approach etc. Yet, biogas accidents, landfill slides, landfill fires and leachate leakages still happen and can not be predicted or excluded with a high degree of certainty. The paper suggests that there is an endogenous non-predictability to landfills' accidents and sudden events, which is created by the iterative process of building a landfill and the emerging complexity that characterizes it.

The daily interaction of different kind of waste, moisture variation, daily cover quality and human activity is the driving force for developing a complex system and not just a complicated one. This distinction means that although landfills are composed from a lot of well known and understood parts, their interaction is not always understood, causes and results are not easily linked and below the apparent stable and emerging order of macro-behaviour, pockets of uncertainty do exist and create the playground for landfill accidents.

Therefore, landfills may be considered as Complex Adaptive Systems (CAS), because they follow all the pre-conditions and characteristics of a CAS, namely:

- They are complex, self-similar collection of interacting daily cells, human activities and climate conditions.
- All components are acting in parallel, constantly acting and reacting to what the other agents are doing. The overall behaviour of the system is the result of a huge number of interactions made every moment.
- Landfills behave /evolve according to three key principles:
    - Order is emergent as opposed to predetermined
    - The system's history is irreversible, and
    - The system's future is often unpredictable

The previous characteristics are discussed and explained especially regarding the biogas issues.

Following this framework of analysis, biogas accidents are discussed as emerging events through the interaction of three main parameters:

- The lack of spatial uniformity
- The micro behaviour
- The variations of barometric pressure

These parameters are further analysed and a more systematic approach is made, in order to include them in an appropriate risk assessment procedure.

Finally the conceptual framework for a new biogas risk assessment model is presented. Its main characteristics and advantages are highlighted, as well as its limitations and difficulties and further research steps are proposed.

Persistent Organic Pollutants and Landfills – Past Experiences and Future Challenges

R. Weber (1) A. Watson (2) and M. Forter (3)

(1) POPs Environmental Consulting, Germany (roland.weber10@web.de), (2) Public Interest Consultants UK (alanwatson@p-i-c.org
(3) Hazardous Landfills Expert, Switzerland (martin.forter@sunrise.ch)

The landfilling of persistent hazardous compounds with a tendency to migrate, such as PCBs, is a major challenge. Historic dumping and landfilling in badly engineered and unsuitably located sites has resulted in widespread contamination from the landfilling of PCB contaminated wastes (e.g. condensers, transformers, sealings etc.). Countries are now discovering that entire river systems are being contaminated by these old dumps and that extremely expensive remediation work is now required.

PCBs are now listed together with similar problematic persistent organic pollutants (POPs) addressed by the global Stockholm Convention (UNEP 2001). Other key examples of chlorinated POPs contamination of landfill site include PCDD/PCDF, HCB and HCH. Experiences in both, developed and developing countries, has demonstrated association between POPs in landfill site and impacts on humans living in the vicinity.

In 1990 the UNEP Governing Council called for "*elimination, phaseout, or reduction with the aim of elimination of substances that are toxic, persistent and bioaccumulative*" and this was echoed in 1992 by the Paris Commission yet there remain many other persistent toxic substances (PTS) fulfilling these criteria, or those of POPs, but which are not (yet) regulated by International Conventions. Most are addressed, if at all, only by national regulations. There are now relatively and stringent standards for levels of food contamination (increasingly recognised as being associated with leakage from stockpiles, landfills and dumps); some standards for land remediation but few limits have yet been established for the disposal to landfills or for emissions to air and water.

More recently other (halogenated) chemicals exhibiting the characteristics of POPs have emerged. Brominated aromatic compounds (e.g. Polybrominated diphenylethers (PBDEs) and other brominated flame retardants) widely used as flame retardants (for electronics; textiles, furniture; upholstery; insulation foam etc.) are an important example. As products containing these chemicals reach the end of their life these hazardous compounds are increasingly entering the waste recycling and disposal sectors and often end-up in landfills.

In May 2009 the first fluorinated POP – Perfluorooctane sulfonic acid, its salts and perfluorooctane sulfonyl fluoride were added to the Stockholm Convention. PFOS and other fluorinated surfactants and related compounds have been produced in bulk for several decades and are also increasingly entering waste streams in a wide range of products. Fluorinated organics have even higher persistence than chlorinated and brominated POPs and have been described as "eternal chemicals".

Whilst historical uses (and releases) of POPs such as PCBs or pesticides were often linked to industrial applications circumstances have now changed so that a large proportion of POPs in current use are found in households and in domestic wastes (e.g. flame retarded textiles, carpets, electronics, mattresses, furniture, plastic, fluorinated surfactant impregnated paper, textiles, carpets etc.) and consequently the quantity of POPs in municipal waste streams is increasing. In most countries a large proportion of these wastes are disposed to landfills. In developing countries and those with economies in transition almost all this waste is landfilled.

Because of their persistence and relative mobility these compounds will persist in landfills for many decades and probably centuries. Over these extended time frames landfill engineering systems, including basal and capping liners, gas and leachate collection systems will inevitably degrade and loose their abilities to contain contamination. Furthermore in the next century involved consideration has to be given to the impacts of climate change and increased flooding on the integrity of the containment systems and the consequences of future leakage. It is therefore inevitable that landfilled POPs will leach into the environment via escaping leachate, ground or surface water as well as escaping to atmosphere by volatilisation (Figure 1). Due to their bio-accumulating properties these compounds will then build up in the food chain with exposure to animals, possibly impacting upon biodiversity, and finally to humans thus causing health impacts for current and future generations (Figure 1).

This study aims to provide an overview of past experiences (mistakes!); the current challenges; and future risks associated with dumpsites and landfills containing chlorinated POPs and considers the evidence that the problems associated with brominated and fluorinated POPs in landfills might ultimately follow the same path – albeit delayed for decades by the essentially temporary containment offered by modern engineered landfill sites. An objective of the study is therefore to review the sustainability of current approaches to the disposal and treatment of wastes containing new POPs classes like brominated flame retardants or fluorinated surfactants.

The case of landfilling POPs demonstrates the importance of considering that the time dimension of containment systems and necessity of ensuring that geological issues are taken fully into account along with adequate aftercare provisions to ensure protection of human health and the environment. In the case of landfill this would require aftercare being extended to decades or centuries and therefore burden future generations revealing the non-sustainability of such practices.

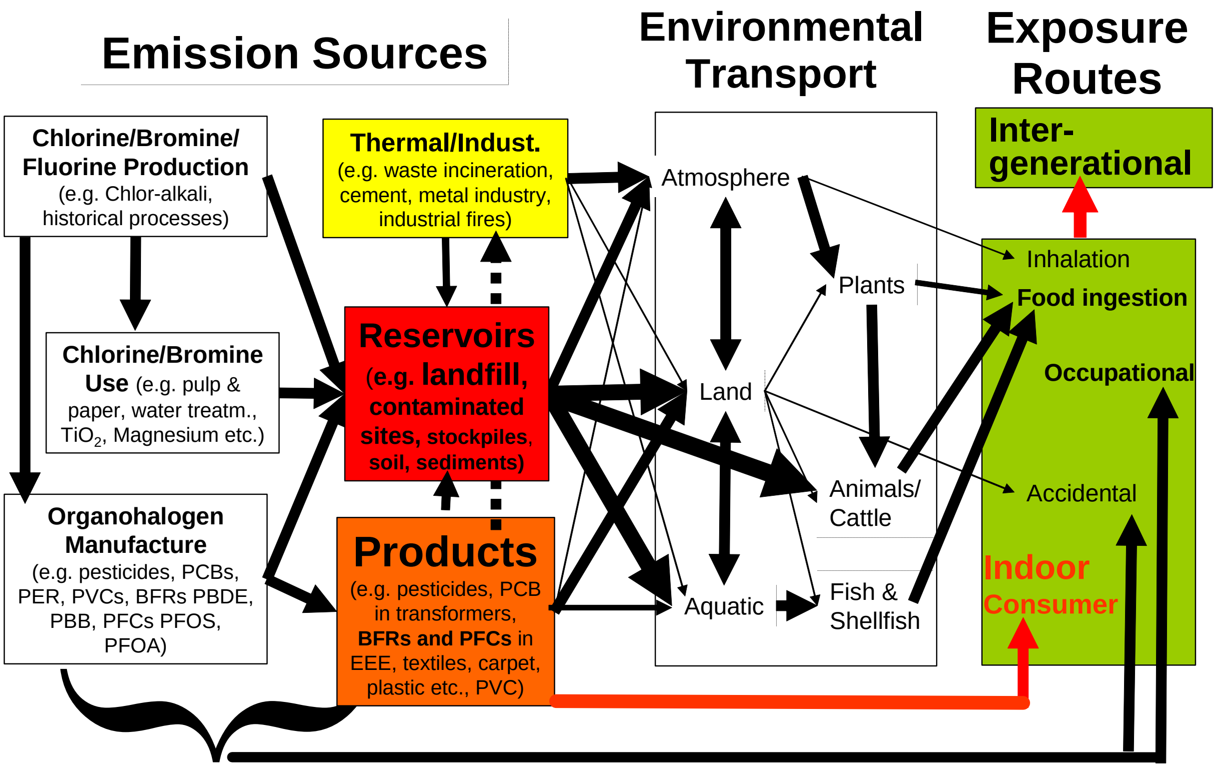


Figure 1: Substance Flow of POPs/PTS and human exposure and the important role of landfills, stockpiles and contaminated soil and sediments (for the POPs life cycle).

Developing a concept for mining of old landfill sites

Hoai Nam Tran [1,*], Klaus Fricke [1], Kai Münnich [1], Tobias Bahr [1], Jan Bauer [1]

(1) Technical University of Braunschweig, Leichtweiß-Institute, Department of Waste and Resource Management, Beethovenstr. 51a, 38106 Braunschweig, Germany.

* Corresponding author, E-mail address: h.tran@tu-bs.de

1. Current problem

Landfill mining is defined as the process of excavating old landfill sites and reprocessing their contents. The purpose of landfill mining is to remove the waste in order to remediate a site, to recover valuable resources from the excavated material, to reduce aftercare costs, to retrieve space for continued disposal or any combination of these purposes.

For the last half century landfill has been a cheap and simple way for many countries to dispose of their unwanted materials. In the meantime, many countries have to face with the fact that their landfill sites are reaching capacity, and more important, environmental and safety concerns become emerging problems. Furthermore, the interest in landfill mining is increasing for new economical reasons.

One of the main reasons for landfill mining in the future is that on one hand, there will be a shortage of resources, and on the other hand, landfill sites contain materials which can be recycled, composted or incinerated for the generation of energy.

Regarding to this issue, Germany is not an exception. The current situation is obvious that the shortage of raw materials supply for energy feedstocks, metals and industrial minerals is to be expected. Meanwhile, important raw materials, such as copper or phosphorus have a limited amount from natural resources. There are possible urban sources, including old household waste landfills (metals, plastics, wood), residues from metallurgical processes (rare metals), sewage sludge (phosphorus) and construction waste (iron, copper, aluminum, wood, minerals).

The experiences so far show that the excavation of old landfill sites is basically feasible. However, there is a lack of reliable data in nearly all subject areas that are crucial for decision-makers.

2. Preliminary work

The authors have theoretically built a four-step procedure for landfill mining process.

* Stabilisation: Landfill sites are aerated by pumping air inside the waste body in order to change the conditions inside the landfill from anaerobic to aerobic. This will accelerate microbiological degradation processes in order to stabilize the waste and to reduce odors.

* Excavation: As the landfill becomes stabilized, the waste will be excavated by opening the landfill and then removed and/or relocated.

* Separation and treatment: This step involves loosening and separation processes in which defined waste fractions are retrieved. Chemical definition is done in order to make decision on utilization or choice of specific treatment techniques. Material-flow specific treatment depends on type of waste. They can be recycled, biologically treated, incinerated, or decontaminated.

* Landfill: The remaining residues and sludge are deposited on new areas.

3. Objectives of the project

The primary objective of the project is to develop the concept for mining regarding different types of landfills. Firstly, reliable data and information relating to landfill mining operations are collected. From this, it is possible to assess both advantages and disadvantages relating to landfill mining in terms of technical aspects (waste contents, possible hazards and negative impacts on the surrounding environments and the public…), sociological aspects (acceptance or protest from the public…) and economic ones (benefits and costs).

Then, based on those data and also on fully validated data which might be achieved by additional analyses and measurements such as landfill age, waste composition, geophysical, geotechnical and hydraulic parameters of the surrounding areas…, an analysis of Strengths, Weaknesses, Opportunities and Threats (SWOT) is implemented. This SWOT analysis is the basis for the development of concepts for landfill mining and safety standards for different landfill types.

In this work a multi-variable marginal cost model is developed. Based on this model, it is possible to identify economical key data for which landfill mining is equal or beneficial compared to conventional options under economical aspects.

Experiences of landfill mining projects in Bavaria under consideration of the German law (TASi)

Hölzle, I.

Institute of Resource and Energy Technology, Technical University of Munich, Germany (DE), ingo.hoelzle@wzw.tum.de

The Technical Guidelines for the Disposal of Municipal Solid Waste (TASi) banned with June 1, 2005 the dumping of waste that has not been preprocessed. Compared to landfill remediation projects before, the guideline (TASi) obliged to separate and to recycle the excavated materials. In 2006 the Bavarian Soil Protection Act (BayBodSchG) and Waste Management Law (BayAbfG) were changed to support communities to remediate their landfills between 2006 and 2010. Therefore a fund with 50 mio. Euro was established and the PPP Company for remediation in Bavaria Ltd. "Gesellschaft zur Altlastensanierung in Bayern mbH (GAB mbH) was entrusted to administrate the fund and to consult the communities. By means of this fund, several landfills, filled mostly with municipal solid waste (MSW), were excavated recently. The reasons for excavation were groundwater and surface water protection, as well as instability.
In the following sections, the experiences of the recent Bavarian case studies are analysed and evaluated on the basis of publications, site visits and own expert interviews. Main topics are the composition and amount of the excavated materials, the experiences of separation and sorting methods, the possibilities of recycling of the recovered materials and remediation costs.
The landfills of Schwarzach, Tiefenbach, Scheffau, Marquartstein, Wunsiedel and Grosswallstadt were excavated between 2008 and 2010. The considered landfill sites were used from the local communities to dump municipal solid waste (MSW) until mid of the 1970s. These were all small dumps up to 20,000 cubic metre. The communities obliged the waste management companies to document all material flows and waste disposal verification for the remediation.
In case of the excavation of the landfill site of Tiefenbach in Swabia, the recovered materials composed mostly of mineral constituents and a small proportion of metals, plastics and wood (see Fig. 1). The other remediated landfills didn't vary too much at this point.

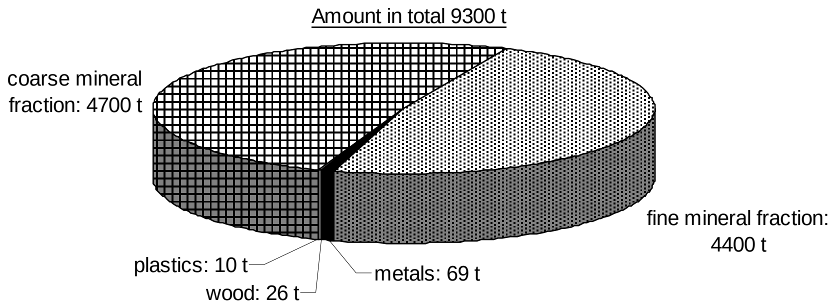


Fig. 1: Composition of the excavated material of the landfill site at Tiefenbach in Swabia (modified from Danzer et al. 2008)

For separation and sorting in all case studies mobile drum, crusher, stone traps, star vibrating and riddle screens were used as well as air and magnetic separators. In the case of Marquartstein even a budget was allocated to test different separation methods. In a first step, the excavator operators separated already at the landfill site larger objects, like tyres, steal, scrap vehicle etc. After transportation of the excavated materials to local processing plants, every company used different techniques (e.g. Fig. 2). The waste management companies tried to separate metals, a lightweight fraction (plastics, wood, textiles etc.), a fine mineral fraction including heavy metals and harmful substances as well as a coarse mineral fraction. The homogeneity and adhesion of the waste caused problems for all sorting machines, in particular for drum screens. Dry screening machines with grizzly fingers were very successful for the first separation step.

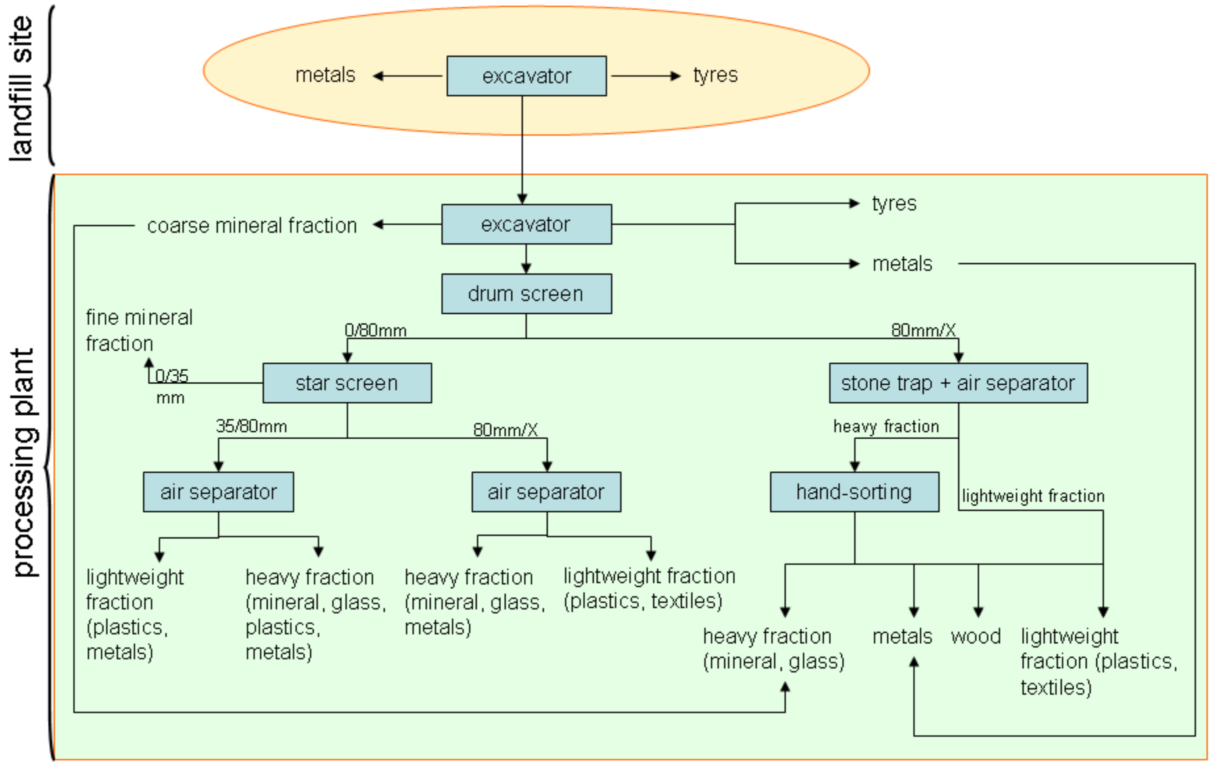


Fig. 2: Separation processes for the excavated material of a studied landfill site in Bavaria/Germany

The lightweight fraction was combusted in an incineration plant, the metals were recycled, the fine and coarse mineral fraction were used in landfill sites with high technical standards and in some cases the coarse mineral fraction was crashed and used for road construction.
The costs of the remediation varied, according to the Company for remediation in Bavaria Ltd. (GAB mbH), between 750,000 Euro at Schwarzach (7,098 t), 1,120,000 Euro at Tiefenbach (9,300 t), 1 500,000 Euro at Pitztalsgrund (25,000 t) and more than 3 mio. Euro at Marquartstein (approx. 35,000 t). The costs of the excavated landfills varied between 220 –680 Euro/m³ respectively 25 –80 Euro/m² (Hauck et al. 2008).
The next steps of the projects will be a detailed material flow analysis and carbon dioxide emissions. The results will be presented at the conference.

List of references

Danzer, J.; Keilhauer; M.; 2008: "Dig and treat" - erste Ergebnisse einer neuen "Sanierungstechnologie" am Beispiel der ehem. Hausmülldeponie Tiefenbach bei Oberstdorf. 5. Bodenschutztage Marktredwitz 2008 (Oktober 2008), Bayerisches Landesamt für Umwelt.

Hauck, T.; Rühl, S.; 2008: Untersuchung, Bewertung und Sanierung von Altdeponien – aus der Praxis des bayerischen Unterstützungsfonds zur Finanzierung der Erkundung und Sanierung gemeindeeigener Hausmülldeponien. In: Henken-Mellies, U. (Hrsg.), 19. Nürnberger Deponieseminar - 2008 - Weiterbetrieb von Deponien sowie Stilllegung, Abdichtung und Nachsorge von Deponien, 238 S.

Session H - Landfilling in Transition and Developing Economies I

Challenges and Issues in Sustainable Landfilling in a transitory country-Malaysia

Agamuthu P.* and Fauziah S.H.

Institute of Biological Sciences, Faculty of Science, University of Malaya, 50603 Kuala Lumpur, Malaysia
Email: agamuthu@um.edu.my; fauziahsh@um.edu.my

Landfilling has become an essential need for waste management regardless of the pre-treatments prior to waste disposal. Malaysia with daily generation of more than 30,000 tonnes of municipal solid waste (MSW), disposes approximately 95% of MSW directly into landfills. This fact alone necessitates sustainable landfills as to avoid adverse impacts to human and the environment. However, the concept of sustainable landfilling is too intricate for developing countries to achieve. This is due to the fact that there are numerous obstacles to sustainable landfilling in the country. The aim of this paper is to elucidate the challenges and issues faced by waste managers in making landfills in Malaysia sustainable.

Various factors influence the management of a landfill. Among others is human factor which include attitude and public participation. In more environmentally-concerned nations, positive attitude leads to high public participation in matters concerning the environment. Although Malaysia is a country with rapid economic development, the concern and awareness among the public are not parallel and their participation towards sustainable waste management that promotes sustainable landfilling such as 3Rs is severely lacking. Currently, recycling was only at 5%. As a result, the volume of MSW disposed off into landfills increased at 3% per year rather than decrease. In addition to that, illegal dumping has become a serious matter to be tackled by waste managers. Consequently, landfill space is exhausted earlier than anticipated and is no-longer sustainable. Also, the NIMBY syndrome is very immense that siting of landfill on appropriate site and constructing pre-treatment facilities such as compactor and transfer stations were sturdily opposed by the public and non-governmental agencies.

From the economic point, the challenges arise from lack of funding and the increase in the price of land. As a result, most waste managers normally aimed for "just enough" to comply with the regulations instead of "self-sustained landfills". In Malaysia, landfills are seen as a mere burden and not as a commodity. The absence of gas harvesting system resulted with landfill not being able to generate any revenues other than from the tipping fee. Aside from that, the subsidies on electricity tariff deprived the market potential of landfill gas conversion to power. Therefore, investment on landfills generally is at the minimum as it is considered un-economical once it is closed. To make matter worse, the National Policy discourages financial institutions such as banks to invest in waste management projects. Therefore, waste managers with small capital are impeded from improving their disposal sites.

Institutional factor also hampers the practice of sustainable landfilling in the country. Lack of proper waste management policy hinders the implementation of an integrated waste management system in Malaysia. As a result, 3Rs is not mandatory and waste separation is totally absent. Indiscriminate disposal of the unseparated MSW into landfill is highly un-sustainable in terms of retrieval of resources, environmental pollution and landfill life-span. In addition, waste management is highly political and due to the lack of political will in improving current waste management system, no effort was taken by most waste managers to improve the current state of the landfills. As a result, 90% disposal sites in Malaysia remains as non-sanitary landfills which lack pollution prevention features such as bottom lining, leachate treatment and gas collection system. As most developing countries, Malaysian landfills too contribute greenhouse gases that lead to global warming.

Even though there are huge obstacles to be dealt with in moving towards sustainable landfilling in Malaysia, changes in the waste management sector has enlightened its possibility. The passing of Solid Waste Management and Public Cleansing Bill 2007 paves a new way towards improved waste management system in the country. Consequently, with the issues solved and challenges tackled or at least minimized, landfills in Malaysia can be managed effectively at a more sustainable approach in the near future, hopefully.

The New Waste Law : Challenging Opportunity for Future Landfill Operation in Indonesia.

Christia Meidiana (1), Thomas Gamse (1)

(1),(2) Graz University of Technology,
Institute for Thermal Process Engineering and Environmental Engineering, Graz, Austria
meidiana@student.tugraz.at1), thomas.gamse@tugraz.at2)

Municipal solid waste management has been starting to evolve in Indonesia by the enactment of The new Waste Law No. 18/2008 in May 2008. This could be a challenge for the Government to improve the waste management due to the raising involvement on issues related to global environment such as trans-boundary pollution, global warming, climate change and MDG-2015. Nonetheless, the implementation of the new Waste Law requires efforts to attain the national waste management targets. In 2006, only 56% of the population was provided by Municipal Solid Waste Management (MSWM) facilities showing that the Level of Service (LoS) of MSWM in Indonesia was still low (MoE, 2008). The Waste Law No. 18/2008 was enacted by the Government of Indonesia (GoI) last year. The enactment of this law gives the local governments the authority to administer the waste management wider on the one hand, but requires them to improve the current waste management practices on the other hand. Under the Waste Law, the local governments are authorized to decide the policy in waste management, to administer the waste management in regional and urban scale, and to determine the sites for transfer stations and final disposals according to the national waste policy. However; they are obliged to implement some measures i.e., determining the waste reduce targets, facilitating the environmentally sound technology of waste treatment. There will be some implications if the local governments want to apply fully the Waste Law. The Waste Law No. 18/2008 articles 44 is challenging since the local governments are demanded to plan and to close the final disposal methods with open dumping system at the latest one year and five years respectively after the Waste Law No. 18/2008 was enacted. Thereafter, the future final disposal method has to be environmentally friendly. Some factors such as legal aspect, institutional aspect, economical aspect, involvement of stakeholders, and waste characteristic can influence the choice of appropriate waste treatment technology. In legal aspect, there is lack of policy or law regulating waste management. There was no national waste policy until 2007 describing the concepts, aims and measures in waste management. Generally, there were significant changes in waste composition during last two decades (1989 to 2007), but there were no developments in policies. Furthermore, though the wider role of local government as prominent players in waste management because of decentralization in 1999, the LoS (LoS) of waste management is still low. In 2006, only 56% of the population was provided by waste management service. Decentralization had impact also on financial aspect. Before the decentralization, the local governments had received solid waste program financed by the state budget and some financial assistances from ADB Loan, IBRD Loan, and JICA. After the decentralization, solid waste program is mostly financed through local financial source like waste collection fee, waste retribution, and local government budget. However, the amount of the contribution was low (about 2% of the total local budget) and could not fulfill the budget demand on waste management since the collection rate of the retribution amounted only 40 - 50 % of the expected revenue. In national level, GoI provided less than 1% of the national budget for urban waste management service (UNEP, 2004). Some measures were applied to improve the stakeholders' involvement in waste management such as revenue-raising and revenue-providing instruments, or non-revenue instruments for private sector and community initiative and retribution for public sector. There was no direct involvement of private sector in municipal waste management system such as waste collection, treatment or disposal (MoE, 2008). The separation system did not done in community level. Waste delivered to the landfill was mixed-waste. Furthermore, the increasing amount of waste generation becomes a problem. Based on the country paper 1987, it was estimated that the solid waste generation was 0.4 kg/capita/day in 1989 (UNDP, 1987). In 2006, this amount was 1.12 kg/capita/day with the high percentage of organic waste (62%) for household waste prevalence in waste source (43,4%) contributing to

45.4% moisture content . The waste generation increased more than twice as much during two decades. Due to low LoS, only 69% of total waste generation was transported to landfill by the local government. The rest would be composted (7.15%), burned (4.8%), buried (9.6%) and disposed to the river (2.9%) by the community (MoE, 2008). The waste delivered to the landfill would be dumped without any treatments such as separation, dismantling or compacting. Therefore, many landfills impacted the surroundings adversely through uncontrolled leachate and methane emission. In addition, many of them were close to the end-year-period., There were 179 final disposal sites in Indonesia owned (93%) or rent (7%) and operated by the government in 2006 and 60% of them was closed to the end-year-period (less than 5 years), but 53% of the total local governments had not decided the new final disposal site (MoE, 2008). This will be a critical situation for the local governments if they want to meet The Waste Law No. 18/2008, especially Article 44. The choice of sanitary landfill or other appropriate method should be compromise of all above aspects. The question will be 'is the end-pipe-approach the best solution for the municipal waste treatment for such inferior condition'?

Municipal Solid Waste Landfills in Jordan, Current and Prospective Future

Mohammad Aljaradin (1), Kenneth M. Persson (1)

(1) E-mail: Mohammad.aljarain@tvrl.lth.se , (2) Kenneth_M.persson@tvrl.lth.se
(1), (2) Technical Institute of Technology, Lund University; Box 118, SE 221 00 Lund

Jordan has seen a large increase in population during the past five decades as a result of high population growth rate and forced migrations, among this increase the cultural development has improved the standard of living and changing consumer habits in the community, resulting an increase in the volume of Municipal solid waste (MSW).World Bank visibility study (2004) showed that the rate of production of solid waste in Jordan was estimated annually of about 1.46 million ton, and is expected to reach 2.5 million ton by year 2015 with a generation of 0.9/kg/capita/ day which is relatively high.

This increasing in the amounts of MSW is not accompanied with the proper management practice in landfilling resources, which poses negative effects on the human health and environment . throughout the country there is 24 landfills handling Municipal solid waste; one of the landfills is designed probably and the others doesn't have the simplest needed requirement. Generally Jordan has many environmental problems due to lack of resources and the absence of the suitable legislations.

In this work we discussed the general issues of the current situation of landfills, a recent literature on landfills has been reviewed, and a data on the total amount of generation, future production and the composition are presented. The review of the legislation indicates there is a need for a new developed regulation to deals with landfills in a clear framework. Also the main obstacles which stand against developing this sector to sustainable levels in the coming future are identified. Suggestions and recommendations that should be taken in consideration for developing landfills are presented also. Hopefully this work which if funded by the European Union, Erasmus Munds project, will contribute to improving the success of MSW projects and practices in Jordan.

Chennai open dumps, from environmental health to climate change – a case study

Pooja Singh (1) and R. Nagendran (1)*

(1) Centre for Environmental Studies, Anna University Chennai, India (pooja_singhind@yahoo.co.in, rnagendran@gmail.com)

Landfills have been the safest way of organised waste disposal. There are no proper scientifically engineered landfills in India. Mostly the waste is dumped into low-lying areas. More common scenario is a dumpsite which has no leachate or gas collection system leave alone a proper leachate treatment plant or way of putting the collected landfill gas to use. When they are in the form of open dump they do more harm than benefit. This not only causes environmental issues like percolation of toxic leachate to the groundwater, scavenging, unaesthetic issues, open burning but also global concern of greenhouse gas emission leading to human and environmental health issues. This demands establishment of systems in place to deal with these problems. With the carbon market becoming popular the capturing to the gases can earn some carbon credits hence providing another benefit of landfill gas capturing.

Municipal solid waste constitutes a dominant portion of the kind of waste that is generated in Asia. Same is the case in India where recycling is still not a common practice on household level. Chennai, a metropolis and capital of an Indian state Tamil Nadu, turning into a commercial hub has brought a stream of crowd migrating to the city thus increasing the population especially that of youngsters. The change in lifestyle has left the tradition of reusing bags, bottles etc., and the high income does not oblige people to reduce their consumption hence increasing the waste quantity. The residential waste takes up 68% of the total waste. Municipal solid waste has become one of the most prominent sources of greenhouse gases emission and VOCs. It contributes mainly to the carbondioxide and methane emission because of the degradation of the waste matter, along with the release of chlorofluorocarbons due to their volatilization directly from the waste. These emissions contribute to global warming on a substantial level.
The rise in temperature gives a rise in vector borne diseases as the vectors get an environment to comfortably proliferate. The diseases carried by mosquitoes, flies like malaria, dengue, and cholera etc., increase. These vectors find the open dumps highly habitable. The degenerating waste and toxic leachate make them even more dangerous.

The paper will present a review of the present condition of the landfills in India and the measures that are being employed to reduce the issues pertaining to them. The review will be based on the reports on the landfills and the research papers on their condition from a scientific point of view. Specifically the concentration will be on Kodungaiyur and Perungudi dumpsites which are the only two dumpsites in Chennai of altogether 600acres in size. They support the daily waste generation of 3,700 tonnes according to Asian Urban Information Center of Kobe *(*AUICK) 2006 workshop report. The emission flux have been reported to be ranged from 1.0 to 23.5 mg CH_4 m^{-2} h^{-1}, 6 to 460 μg N_2O m^{-2} h^{-1} and 39 to 906 mg CO_2 m^2 h^{-1} at Kodungaiyur and 0.9 to 433 mg CH_4 m^{-2} h^{-1}, 2.7 to 1200 μg N_2O m^{-2} h^{-1} and 12.3 to 964.4 mg CO_2 m^{-2} h^{-1} at Perungudi. The problems faced by the residents in the vicinity of the dumpsites will also be identified.

We wish to make an oral presentation under the "Sustainable landfilling" session.

Sustainable landfilling through CDM waste composting in developing countries in Africa

R. Couth(1) and C. Trois (2)

(1) SLR Consulting Ltd, United Kingdom (bcouth@slrconsulting.com)

(2) University of kwaZulu-Natal, School of Civil Engineering, Surveying and Construction, Durban, South Africa (troisc@ukzn.ac.za)

The objective of this paper is to demonstrate a solution for the delivery of sustainable landfilling in developing countries in Africa through the Clean Development Mechanism (CDM). This paper is part of a larger project initiated by University of kwaZulu-Natal to assess and reduce to greenhouse gas (GHG) emissions from waste management in Africa and promoting "zero waste" to landfill.

Statistical information shows that greenhouse gas emissions (GHG) from human activity are causing climate change. Temperatures have increased by 1°C across central Africa between 1970 and 2004, and 2°C across northern and southern Africa. In order to control global warming the annual GHG emissions ceiling for the world is considered to be 2.256tCO_2 per capita (14.5GtCO_2). This is less than half of the actual 2004 emissions of 4.56tCO_2 per capita (29GtCO_2). However the mean for sub-Saharan countries in 2004 was 1.02tCO_2 per capita. Indicators show that 6.8% of the GHG emissions for Africa are from waste, greater than the average of 4.2% for Non-Annex 1 developing countries. Methane emissions from landfills are a significant contributory factor. As the African population becomes more urbanised, and as waste continues to be dumped, initiatives aiming at improving waste management practices will become an increasingly important factor in controlling GHG emissions.

The Rio Earth Summit in 1992 led to the establishment of the United Nations Framework Convention on Climate Change (UNFCCC). Under the UNFCCC Kyoto Protocol adopted in 1997, Annex 1 industrialized nations agreed to legally binding reductions in GHG emissions of an average of 6 to 8% below 1990 levels between the years 2008-2012. The Clean Development Mechanism (CDM) is one of three mechanisms to reduce anthropogenic emissions under the Kyoto Protocol, and allows Annex 1 countries to purchase Certified Emission Reductions (CERs) from developing countries. The rules for CDM projects to receive CERs are complex and time consuming. Project activities must be hosted by non-Annex I countries; developed by public or private entities authorised by the relevant host country; validated by a designated operational entity (DOE); registered by the CDM Executive Board; and once commissioned and operational, verified and certified by a DOE as resulting in real, additional, measurable and verifiable reductions in GHG emissions.

The majority of CDM Category 13 waste projects have been related to landfill gas combustion, however their viability is questionable in sub-Saharan Africa as the majority of landfills are uncontrolled dumps. The most practical and economic way to manage waste in the majority of urban communities across Africa is to source-separate waste at collection points to remove dry recyclable; compost the biogenic carbon waste in windrows using the stabilised compost as a substitute fertilizer; and then landfill the fossil carbon waste. If biogenic waste is removed, mainly fossil carbon and inert waste will be landfilled, and the landfill may not require landfill gas extraction.

In this context the first Mechanical Biological Waste Treatment pilot project was set up in Durban, South Africa to assess the applicability of windrow composting in local landfills. Five full-scale passively aerated windrows were built to treat municipal solid waste and garden refuse. A consistent 50-70% reduction of in the carbon content of the treated waste was observed after 4 months of composting.

Separated waste collection, followed by open windrow composting and anaerobic digestion of the organic residues and food waste were selected as the most appropriate, low energy, cost effective technology for South Africa and other emerging countries. The feasibility of these methods was compared with a cost-benefit analysis of a landfill-gas to energy CDM project also implemented at the same Durban landfills. The potential for GHG emission reductions from landfill gas extraction systems in Africa were estimated to range around 3 million/tonnes/year. The findings of this research prove that this may be almost doubled by waste pre-treatment. At an income of €10/CER, this represents an income of around €13 million/year per territory, justifying the introduction of waste composting in the CDM process.

Session I - Landfilling in Transition and Developing Economies II

From landfill to 3R, pathway in developed as well in developing country

Vujić Goran *, Batinić Bojan, Stanisavljević Nemanja, Ubavin Dejan

Department of Environment Engineering, Faculty of Technical Sciencies, Unversity of Novi Sad, Serbia *contact person: goranvujic@uns.ac.rs

Eight years after the democratic changes, Serbia is a true example of a transitional country. Legal and economic system is characterized by a radical and comprehensive reform, human rights are at a high level, making the democratic system in Serbia similar to real systems in the developed western countries. After major changes, improvement, and reform are also spread to system of waste management, including the utilities sector.

With 3527 willd landfills, which only 4 have sanitary conditions, with 2057 million tons of waste generated per year, which 43% is organic waste, with 80% of the territory where collecting waste is organized, and the GDP of € 4000 capita, Serbia is in its strategy identified 29 regional landfills, 4 incinerators, and several MBT plants. Recycling is a favorite of the media, the Ministry for Environmental Protection emphasizes the application of recycling, while the Ministry of Economy encourages companies which have recycling programs.

In the Netherlands, the number of landfills was determined by the number of municipalities, however, after a regional approach to problem solving, as well as waste separation iniciatives, environment management act, landfill ban and tax, and the EU landfill directive, number of landfill sites from 450 go to 11. In almost same time number of plants and waste volume insinirate incrise from 2.2 Mtonne to 4.9 Mtonnes. The aforementioned scenario in the field of waste management in the Netherlands was occurred in the period from 1980 to 2000. What is indicative, is the fact, that the beginnings of scenarios in most western countries irresistibly reminiscent of the situation in this area with which Serbia now faces. Over capacity in a number of facilities for waste treatment in the world, implementation of recycling, reuse and reduce, are the basic scenarios that are inevitably expected Serbia, also. Researching and analyzing the experiences from other countries, as well as the implementation of proper policies, can help Serbia to avoid certain mistakes and unnecessary investments related to waste management sector.

At the time of development of the whole society, especially the economy, legal system and culture, landfills are safe solution to fulfill two main goals of solid waste management, that include protection of human health and protection of the environment (+conservation of resources?). Further investment depends on the degree of economy development, but also the ability of relevant institutions and decision makers to recognize the importance of investment in the field of waste management. Introduction of advanced technologies and achieving 3R model is possible to achieve with bypass some traditional steps of development of SWM, but in the case of the slow development of economy and society, landfills are the optimal solution that will fulfil two main goals of SWM. In other words, landfilling is a sustainable solution for many years if there are slow development of economy or negative even, and landfills are the solution that in a relatively short time and with less than investment for other treatment facility can be adopted into a modern system of waste management.

Keywords: developing country, waste management, landfills, 3R

What You Sow Today, You Will Reap Tomorrow The Future of Landfilling in Croatia

I. Stanic

VERBUND-Umwelttechnik GmbH, Austria (Ira.Stanic@verbund.at)

In Croatia waste material is predominantly landfilled, while very little is recycled or recovered. Today, the time has come for the country to close old landfills and set up a new sustainable waste management system based on the goal of environmental and human protection. In this process, Croatia orients itself on EU's directives which it has transposed into its own legislation. In the upcoming years, the waste management system will be reorganised and new landfills will be constructed, according to principles of sanitary landfilling and waste recycling. Thus, Croatia, just like many Central and Eastern European countries, finds itself at a crucial point where it will define its waste management system of tomorrow.

However, what can Croatia realistically afford? Looking at the country's present and foreseeable economic development and analysing considerations and steps undertaken by Croatia in the last years, it can be argued that the sanitary landfilling system that is being introduced is the only financially feasible option. In fact, since the country is planning to introduce state of the art technology, the investment is so high that it is posing a big obstacle to faster progress in the implementation of the Landfill Directive. Therefore, the financial means planned for investment in the next decade are the determining factor of the future waste management system.

As the economically most advanced EU countries are already thinking of the next step in the evolution of waste management – final storage landfills – a further question arises: have Croatia's environmental policy-makers considered final storage in their recently set-up plans for the waste management system or have they dismissed that option altogether for the time being? What is the country's long-term goal? Is there any at present? In order to determine the answers, the legislative framework and the national waste management strategy need to be looked at. The analysis shows that sanitary landfilling is the only option considered as a foundation of the country's waste management system.

A Croatia without landfilling is not a thinkable scenario for the next 50 or even 100 years, since the entire system of WM is built around landfilling and changes can only happen in the long run. Several future developments are possible, but one stands out as probable: Croatia will set up new large sanitary landfills with waste recycling for the next 50 or more years, as planned, and build waste-to-energy plants in the largest towns. Final storage landfills can be expected after this period, when the new landfills reach the end of their operational lives and a new system needs to be set up again. Considering the overall goal of sustainable, environmentally-friendly waste management, it would certainly be advisable for the government of Croatia to take these points into greater consideration already today. Since the new waste management system has not yet been shaped and construction of new sanitary landfills is only about to start, the course can still be set today for the anticipated needs of tomorrow.

Procedure supporting creation of landfill concepts in low and middle income countries

G. Hädrich, W. Bidlingmaier, E. Kraft

Department of Waste Management, Faculty of Civil Engineering, Bauhaus-Universität Weimar, Thüringen, Germany (gunnar.haedrich@uni-weimar.de)

Deposit of municipal solid waste is until present time most common used disposal form. In low and middle income countries, more than 50 % of municipal solid waste is not disposed of in an environmental friendly way. This leads to significant environmental pollution. But economical conditions and options limit rapid improving of that situation in that countries. Therefore, waste management concepts according to German or European standards can not be implemented currently under these circumstances. In contrast to the above mentioned situation, series of regulations and technical concepts for environmental friendly disposal have been developed and implemented in Germany. An assessment algorithm has been created based on the fact, that waste is deposit on dumps and therefore uncontrolled in the environment in many countries. By means of the scheme it will be shown which protective potential is realisable by which economical and technical/ engineering effort. Derived from that, it should be possible to decide where available technical and financial resources are used most effective.

The algorithm has been developed on the principle of the multibarrier idea as pursued amongst others in Germany. Two aspects have been in front of the scheme development. It should be independent and/or uncoupled from any location to point out its generality. Furthermore it should be mainly a tool for low and middle income countries. Hence, modifications have been taken place regarding underlying terms in general regulations. The assessment algorithm focuses on barriers and its associated components as well, which do not fulfil the proof of equality as required amongst others in German regulations. In that context, the scheme has to be seen as a catalogue including several different possibilities to each barrier. These possibilities have a specific protective potential as well as economical and technical effort without to meet the above mention proof of equality. The scheme is concentrating on the parts pre-treatment (extensive mechanical-biological processes), landfill bottom liner, emplacement technique/landfill body, surface cover/liner, emission treatment (considering gas- and leachate path). Specifications describing the situation in respective application area can serve as input data.

Suitable and different modifiable value benefit analyses as well as cost-effectiveness analysis form the methodical base of assessment procedure. Classification of relevant criteria and associated parameters to describe the protective potential has been carried out for each barrier. That allows a clear separation and evaluation of barrier components and its variants. The main focus lays on the biological degradable organic carbon, because its leads to the main emissions of a landfill via gas and leachate path. Main part of the economical and technical effort geared on the cumulated energy demand, on part for use. Based on it the specific process chain divided in reasonable steps are displayed for each barrier reflecting necessary work steps and techniques. Thus an estimated energy demand for operation can be displayed and it shows the engineering complexity necessary to implement a specific barrier and/or landfill concept. Where applicable the individual barriers are divided into the hierarchical levels: essential components of each barrier, different variants and construction types. In the bottom level, single elements have been considered and proved with data and/or values according to criteria and associated parameters. The protective potential - also definable as effectiveness - of considered barriers describes the emission contribution that is retained and not released in the environment. That is displayed as a normalised factor between 0 and 1 on an ordinal scale. The factor is determined by comparing released emissions of chosen barrier and reference scenario. The factor itself gives information about the potential of emission reduction, whereas the factor multiplied with an emission amount gives information of real amount of retained pollutants. Each single barrier and/or its components are being analysed regarding its protective potential starting from bottom hierarchical level. In contrast to that, there is no weighting between two issues protective potential and economical/ technical effort. Here, former is leading objective of consideration. The underlying raw data rest upon state of the scientific and technical knowledge. Therewith, evaluation bases on measurable values, if procurable.

By using the assessment scheme it will be possible to create respective define stepped and appropriate landfill concepts, that considers the economical and technical situation in the target regions of low and middle income countries. In this manner adapted landfill concepts can be generated considering local condition. The assessment algorithm will serve as a decision tool for decision makers and professionals within the activity field of landfilling and waste management.

Proposed actions for landfill improvements in economically developing countries

Cecilia. B. Öman (1)* and Dinesh Raj Manandhar (2)

(1) Royal Institute of Technology (KTH), Department of Land and Water Resources Engineering, Sweden (cecilia.oman@gmail.com),
(2) Kathmandu University, Department of Environmental Science and Engineering, Nepal (mrdinesh@ku.edu.np)
*Presenting author

Introduction

Economically developing countries are suffering from serious problems with managing waste as waste volumes continue to rise, and new hazardous waste materials are introduced, rendering traditional well functioning waste management procedures redundant. This is a result of rapid increase in population, increased consumption, unplanned urbanisation, industrialisation, and political conflicts. Despite a number of improvements at the national and municipal level, the procedures need further strengthening. The objective with this paper was to analyse the prevailing situation and propose appropriate actions.

Present situation

Most of the existing solid waste landfill sites in economically developing countries are practicing either open dumping or controlled dumping. Most of the landfills have not come under the sanitary landfill classification as they often lack facilities to collect and/or treat the leachate, as well as, infrastructure to exploit the landfill gas. Concerning the sanitary landfills which do exist in developing countries, many or possibly most of them, employ stabilization ponds as the main treatment method for leachate. In addition to the limited treatment potential of stabilization ponds, and the lack of resources to manage them properly, heavy rainfall during monsoon seasons yield huge amounts of leachate, and the capacity of the ponds are then often insufficient. The reason for not fully implementing proper sanitary landfill concepts stems obviously from financial constraints. Thus, implementation of a more economically feasible landfill design is crucial for economically developing countries, and interim soultions should also be considered.

Proposed actions

In this paper six actions are proposed; i) composting and fermentation of organic matter, and co-composting of house-hold organic matter with ecological sanitation, ii) strengthening of the informal sector, iii) improved leachate treatment, iv) collection of landfill gas with financing through CDM projects, v) reduced risks with hazardous waste, vi) improved international technology and knowledge transfer.

It is proposed that waste recovery is strengthened, by composting or fermentation of larger fractions of organic waste. It is often favourable to re-introduce appropriate and safe traditional procedures. In addition, introduction or strengthening of ecological sanitation is proposed and should be combined with household waste composting.

The informal sector through community-based organizations, non-governmental organisations (NGOs) and the private sector also offers solutions towards reuse and recycling of waste material and should be strengthened. At most landfills in the economically developing world, individuals try to make a living by engaging in landfill scavenging. Scavenging provides potential in sustaining livelihoods among those who cannot secure employment in the formal urban market. Thus, scavenging tends to be useful although it may be hazardous to the informal entrepreneurs. In addition various items collected for recycling constitute an important source of raw materials for industries in developing countries. Improved waste recycling should integrate the informal sector, building on their practices and experience, while working to improve efficiency and the living and working conditions of those involved.

There are options for economically feasible leachate treatment designs, such as constructed wetlands where land is available

Clean Development Mechanism (CDM) has potential to deliver benefits to developing countries in the areas of economic growth through the collection of landfill gas with financing through CDM projects. CDM was one of the key achievements of the Kyoto Protocol and was established with the dual purpose of assisting economically developing countries in achieving sustainable development while at the same time assisting industrial countries in achieving compliance with their quantified green house gas emission commitments.
Minimisation and substitution of materials and procedures generating hazardous waste is to be addressed or strengthened. Also treatment methods for hazardous fractions generated within the country must be improved; such as the management of batteries, obsolete pesticides and pesticide containers, hazardous health care waste and industrial waste. Thirdly, uncontrolled import of hazardous waste from industrialised countries should attract greater international concern and contaminated sites from such activities should be remedied. Industries and governments of industrialized nations are increasingly exporting hazardous waste to economically developing countries. Initiatives have been established to control or at least reduce international shipment of hazardous waste, and its effects; OECD Initiatives, Basel Convention, EU/ACP initiative, and the ECOWAS resolution, but uncontrolled and illegal activities are still taking place.
Overall, there is a need for improved transfer of technology and knowledge. Technology transfer must carefully take into consideration the significant variations in waste composition between industrialised and economically developing countries. Knowledge transfer can only be sustainable if building on mutual ownership and equal partnership. In actual practice equal partnership is frequently far from the reality in collaboration projects between economically developing and industrialised countries.

Monitoring and evaluation

Actions and institutional aspects must be monitored and evaluated to secure efficient use of the resources available. The Outcome Mapping method is one useful tool for this.

Session J - Landfilling in Transition and Developing Economies III

Waste management options for reducing landfilling in Cali, Colombia

W. Castano Tejada (1), L.F Marmolejo (2), A. Stringfellow (1), and W. Powrie(1).

(1) School of Civil Engineering and the Environment, University of Southampton, UK (wct1p07@soton.ac.uk)
(2) Universidad del Valle, Cali, Colombia (lfmarmolejo@hotmail.com)

In Colombia, waste management infrastructure is currently being developed, recycling is principally carried out by "hand pickers" and old landfills are filling up rapidly. The city of Cali is located 300 kilometres southwest of Bogota, and has a population of two million people. Cali is facing a crisis in waste disposal because the old landfill is filling up, resulting in the transport of waste materials to a new landfill located 12 km away; this has implications for energy use because of the fuel needed to transport waste to the new landfill. The quantity of household waste recovered from the city as recyclables is rapidly increasing, suggesting that there is potential to reduce the amount of material going to landfill, and extend the life of the existing and new landfills if the correct waste management infrastructure is put in place. In 2005, public health legislation banned hand pickers from landfills with the result that there are increasing numbers of street 'finders' who collect materials from households and streets. Families are driven by the resource value of household waste from which they remove saleable items to provide a daily income. Organic waste from markets was previously recovered by hand picking at the landfill but only a small percentage was composted at the landfill. More recently, windrow or aerated compost operations have been developed in response to increasing regulation and minimum requirements for compost quality have to be met.

The choice of waste management options in Cali is currently driven by regulation (which is currently based on environmental, socioeconomic and public health issues (e.g. PGIRS)), by technological advances, and financial considerations, both at commercial and domestic scales. In order to develop waste management in the city in a sustainable way, it is necessary to evaluate different methods for recovery of useful resources and assess the energy use (and therefore potential for greenhouse gas emission) associated with collection, separation and processing of these materials and final disposal of the residual waste. An investigation was carried out to assess the potential for reduction of the amount of waste going to landfill by the recovery of recyclables using highly engineered technologies such as mechanical biological treatment (MBT) and mechanical heat treatment (MHT) which are commonly used in developed countries, but not currently practiced in Cali. These mechanised waste management practices were compared to the traditional methods such as hand picking of recyclables from households and landfills, and transport of the residual waste to landfill, in terms of energy efficiency, mass recovery and rate of processing. Characterisation of household waste from the city showed that there is a high proportion of organic material which has the potential to be used as a soil conditioner in the rural outskirts of the city. Screening of the waste to remove contaminants such as metals, plastics and glass by hand picking has a low external energy input, and provides financial support for the operatives. Mechanised technologies such as MBT or MHT have a higher energy input and recover recyclables with high purity; they also have the potential to produce a range of biomass products either for use as soil conditioner (with additional processing) or as fuel. The paper describes a preliminary appraisal of the relative benefits of different waste management options in Cali, which will improve sustainability and reduce the amount of waste disposed of to landfill.

Landfills in Malaysia: Past, Present and Future

Fauziah S.H.* and Agamuthu P.

Institute of Biological Sciences, Faculty of Science, University of Malaya, 50603 Kuala Lumpur, Malaysia
Email: fauziahsh@um.edu.my ; agamuthu@um.edu.my

Annual generation of municipal solid waste (MSW) in Malaysia has exceeded 10.95 million tonnes that there is an urgent need of an efficient waste management system. The absence of an integrated waste management resulted with more than 10.40 million tonnes of MSW being disposed off into landfills annually. This highlights the importance of landfills in MSW management in Malaysia. The immense dependency necessitate that landfills are managed effectively and in a sustainable manner in order to reduce environmental impacts. However, sustainable landfilling technology is yet to be achieved. This paper deliberates the scenarios of landfilling in Malaysia. Past and present statuses are thoroughly discussed while future prospects will be scrutinized.

Among the main issues of concern is achieving sustainable management of landfills in the country. During the 1970s, daily MSW generated by each Malaysians was below 0.5 kg. The solid waste management program in Malaysia was quite primitive and only involved local authorities. Waste collection service was only confined to urban areas while the rural community disposed the waste by burying of burning. Disposal sites then were mere open-dumping grounds. The sizes were small to cater small community and were scattered through out the country.

In the 80s population expansion resulted with the development of areas for commercials, industrial and housing activities. As a result, efficient waste management system was necessary to avert risk to human. This led to the siting of landfills far from residential areas and away from urban centres. A national program was developed to manage municipal and industrial wastes more systematically. However, not much improvement was recorded that waste management was still identified as one of the contributors towards environmental degradation in the country, particularly river pollution of leachate.

Early 1990s saw more development in the waste management system. This begun with the privatization of waste management in Malaysia, and the establishment of the first sanitary and secure landfills. The former was to cater the disposal of MSW from Kuala Lumpur and its outskirt while the latter was for the treatment and disposal of the nation's hazardous waste. To accommodate the needs to dispose medical waste, medical waste incinerators were constructed in 1994.

A more systematic waste management was gradually in place by end of 1990s. However, with the rapid development of the nation, urban population increase and improvement in the standard of living, resulted with an average daily per capita generation of 1.2 kg in 2007 and 1.7 kg in 2009. In fact the 3% MSW increase per annum alarms most waste managers. The absence of an integrated waste management resulted with landfills being pre-maturely closed. An incident when leachate contaminated drinking water in the Klang valley became the eye-opener that the government was forced to reduce the number of disposal sites particularly open-dumps in the country from 230 in 1990, to 130 in 2007. As a result, more sanitary landfills are being built and new non-sanitary landfills are totally forbidden. Existing non-sanitary landfills are to be upgraded to Level 4 landfills or to cease operation. This will enhance a better management and monitoring of landfills in the country.

In terms of policy and regulations, the early 1980s saw the implementation of the Action plan on Beautiful and Clean (ABC) Malaysia. This indicated the first launching of recycling campaign in the country. Recycling in the country increased to approximately 3%. However, the plan was a failure that recycling rate in 1990s was stagnant. No improvement was observed that intensive recycling campaign was re-launched in late 1990s. As a result, recycling increased to 5% and again become stagnant. The flow of events had eventually led to the passing of the Solid Waste Management Bill 2007. Even though the bill is yet to be implemented, the government has taken the big steps to improve waste management system further. Future waste management in Malaysia seems somewhat brighter with a clear waste management policy in place. Therefore it is hoped that waste management and landfilling can be more sustainable in the near future.

Solid Waste Landfilling Operations in Developing Countries: The Case of Turkey

Başak Mesci (1), N. Gamze Turan (2), Osman Nuri Ergun (3)

(1) Ondokuz Mayıs University, Engineering Faculty, Dept. of Material Science and Engineering, 55139 Kurupelit, Samsun, Turkey; Tel: +90 362 3121919/1565; Fax: +90 362 4576094; (basakm@omu.edu.tr)
(2) Ondokuz Mayıs University, Engineering Faculty, Dept. of Environmental Engineering, 55139 Kurupelit, Samsun, Turkey; Tel: +90 362 3121919/1329; Fax: +90 362 4576094; (gturan@omu.edu.tr)
(3) Ondokuz Mayıs University, Engineering Faculty, Dept. of Environmental Engineering, 55139 Kurupelit, Samsun, Turkey; Tel: +90 362 3121919/1010; Fax: +90 362 4576094;(onergun@omu.edu.tr)

Improper management of solid waste has serious environmental and health consequences. Such practices contribute to widespread environmental pollution as well as the spread of diseases. Health deterioration, accidents, flood occurrences, and environmental pressures are just a few of the negative effects. Other environmental effects include pollution of surface and subsurface waters, unpleasant odours, pest infestations, and gas explosions. The hazards associated with inappropriate solid waste disposal and the associated environmental health impacts should therefore be of utmost concern to waste management experts.

In developing countries and developing areas with mixed economies, the problem of upgrading practices for the disposal of solid wastes is far more difficult than in developed countries. In most developing countries, municipal authorities lack the resources and trained staff to provide their rapidly growing populations with the necessary facilities and services for solid waste management to support an adequate quality of life. Within the framework of sustainable development, developing countries today face the challenge of balancing economic growth with environmental progress.

In Turkey, an economically developing country, industrialization and increased standards of living have contributed to an increasing amount of solid waste and its consequent disposal problems. Turkey's traditional method of disposing of solid waste has been to dump it at open sites – of which there are over 2000 – or at sea. According to the Turkish State Statistical Institute's 2004 database, there are 16 sanitary Landfills, five composting plants (three of which are being actively operated), and three incineration plants in Turkey. In 2004 25,013,521 ton of MSW were collected, whereas 7,002,000, 351,000, and 8000 ton were disposed of in sanitary landfills, composted, and incinerated, respectively. A total of 17,661,254 ton of waste was disposed of without any control.

In Turkey, as in many developing countries, in the short term, the best policy might be to leave disposal methods without any controls, and use the resources available to upgrade them with environmental protection systems. In the long term, the construction of new sanitary landfill areas, composting, and incineration facilities could be planned. Public participation and awareness are also important issues in achieving the goals of the suggested management system, but it is difficult and takes a long time to make people aware of the importance and of the principles of the proposed management system and to effect their participation.

In this study, solid waste landfilling operations in Turkey as a developing country are investigated. This paper, adopting a problem-based approach, also identifies practical alternatives, solutions and opportunities for sustainable landfilling.

Study and implementation of appropriate technologies for municipal solid waste landfilling in Somaliland

V. Di Bella*, M. Vaccari and C. Collivignarelli

CeTAmb – Research centre on appropriate technologies for environment management in Developing Countries
Department of Civil Engineering, Architecture, Land and Environment, Faculty of Engineering, University of Brescia, via Branze 43, 25123 Brescia, Italy, Tel.: +39 030 3711302, Fax: +39 030 3711312, E-mail address: cetamb@ing.unibs.it
*Presenting author, E-mail address: veronica.dibella@ing.unibs.it , Tel.: +39 030 3715421

CeTAmb has been carrying on a study for the improvement of collection, recycling and disposal of municipal solid waste (MSW) in Northern Somalia since 2005. The study was initially performed in collaboration with UNA Consortium within "Somalia Urban Development Programme (SUDP)" and since October 2008 with CESVI NGO in the "Support to improved service delivery in Somali cities (SISDISC)" project.
The present paper illustrates current systems for waste disposal in Somaliland (Northern region of the former Somalia) and strategies identified for their improvement. Also some case studies are going to be analyzed in detail.
Surveys carried out with the close collaboration of local administrators and technicians have shown that all the phases of MSW management have to face severe lacks. In the whole Somaliland, collected wastes (corresponding to less than 50% of totally produced wastes) are usually transported to open dumpsites, where they are just discharged on the soil and burnt. Open dumpsites are not provided with proper environmental pollution control and monitoring systems and their location was chosen giving little or no consideration to environmental impacts. Moreover, no sanitary practices such as the compaction of wastes or the application of a daily coverage are usually performed.
The techniques to develop away from open dumping towards sanitary landfills can be adapted to suit local conditions, material and technologies. On this base, the shifting of some Somali dumpsites to sanitary landfills, like for Boroma city, or the building of simplified sanitary landfills, as for Sheikh town, were carried out. The commonly accepted definitions of sanitary landfilling require the isolation of wastes from the environment until rendered them innocuous through biological, chemical and physical degradation processes in the landfill. This technique uses engineering principles to confine the waste to as small an area as possible, covering it daily with layers of earth and compacting it to reduce its volume. In addition, it anticipates the problems that could be caused by the liquids and gases produced by the decomposition of organic matter. In particular, in arid climates, such as in the Northern Somali context, where monthly rainfall is always lower than potential evapo-traspiration, only sporadic leachate is generated; so, simplified systems for leachate collection were studied. All the interventions were widely discussed with local stakeholders, trying to individuate solutions appropriate for the specific context and characterized by sustainability from technical, economical and social point of view.
For example, in Boroma, actions necessary for the shifting of the already existing open dumpsite to a sanitary landfill were identified on the basis of both topographical and hydrogeological studies. The regularization of the dumpsite bed, the construction of embankments and simplified systems for leachate collection were firstly designed and secondly carried out (see Figure 1). Moreover, the building of a warehouse was performed, in order to guarantee the control of the upgraded site.
In Sheikh, a new area was identified (after some problems) by local authorities for the construction of a sanitary landfill. Indeed, no places for wastes disposal of had been previously chosen by the municipality. The shaping of natural ground slopes and the building of embankments and systems for sporadic leachate collection were successfully performed (see Figure 2), whereas the construction of neither a warehouse nor a proper access road has been completed at the moment of writing.
At the end, on the job trainings aiming at describing correct practices for the manual operation of these sanitary landfills were also worked out. They were delivered to local technicians and operators after the conclusions of works.

Figure 1: View of the upgraded landfill in Boroma

Figure 2: View of the new landfill in Sheikh

Poster Session A – Landfilling Strategies and Concepts

Precise controlled sequencing batch bioreactor landfill: an exploration of municipal solid waste harmless disposal and landfill gas resources in China

Sang Shuxun, Zhou Xiaozhi, Cao Liwen, Ji Xiaoyan

School of Resources and Geoscience, China University of Mining and Technology, China (sangshux@gmail.com)

Sanitary landfill is the most important approach of municipal solid waste (MSW) disposal nowadays and for quite a long period in China, which is determined by the low level of economic development and MSW classification. It is the key to MSW reduce rapidly, harmless disposal and landfill gas (LFG) resources that landfill structure optimization and landfill operation innovation. At present, kitchen waste, fruit, vegetable and other perishable components decrease year by year in MSW, and the MSW shows the characteristics of high water content and high organic matter content in China. MSW composition changes increase the hidden danger of secondary pollution to landfill surrounding environment; however, it also provides a basis and precondition for LFG mass development and utilization. Therefore, changing the traditional extensive operation and management model according to the composition changing features and rapid degradation characteristics of MSW, and achieving the precise control of perishable MSW whole degradation process, which is an effective measure to MSW harmless disposal and LFG resources in China. Compared the relative merits of several bioreactor landfill modes, such as semi-anaerobic bioreactor landfill, anaerobic bioreactor landfill, self-recirculation anaerobic bioreactor landfill and two-phase anaerobic bioreactor landfill, the authors explored a precise controlled anaerobic sequencing batch bioreactor landfill (PCASBRL) mode based on the principle of anaerobic sequencing batch bioreactor landfill (ASBRL), and initially constructed the structure and operational mode of PCASBRL, as shown in Figure 1.

Each landfill area still takes the traditional modular landfill mode in PCASBRL, but the bottom landfill units have independent leachate collection way, in other words, the leachate of bottom landfill units is collected in different collection pools. After PCASBRL in operation, landfill work is operated in the bottom unit 1-1 firstly, and LFG collection equipment is installed at the same time. When the unit 1-1 reaches to a certain height, landfill worker should operate interim cover on it immediately, and starts the LFG collection and utilization system. At the same time, landfill operations should be continued in unit 1-2 which is adjacent to the unit 1-1. As time goes on, the last unit 4-4 will be used at the bottom of the landfill area.

In the process of PCASBRL operation, leachate is pumped and self recirculated from the top of unit regularly, and leachate recirculation frequency is determined by the degradation rate of filled MSW. The combination recirculation method of Vertical well and horizontal well can be applied to interim covered unit, and direct recirculation method is suitable to operating landfill unit.

Monitoring the generation and evolution process of leachate and LFG in each landfill unit continuously, and it can be used to determine the spacing interval of landfill operations again on the lower landfill unit. When the monitored LFG production rate decreases rapidly, and organic pollution concentrations are low in leachate, these indicate that the landfill unit have a relatively stable situation. At this time, the interim cover should be removed firstly, and a new landfill unit should be formed on the lower landfill unit. For example, landfill unit 2-1 is established on unit 1-1, and their leachate is gathered in the same leachate collection pool. In the unit 1-2 operating process, landfill worker can gradually extend the length of LFG drainage wells to collect LFG resources produced in unit 1-1 and 2-1.

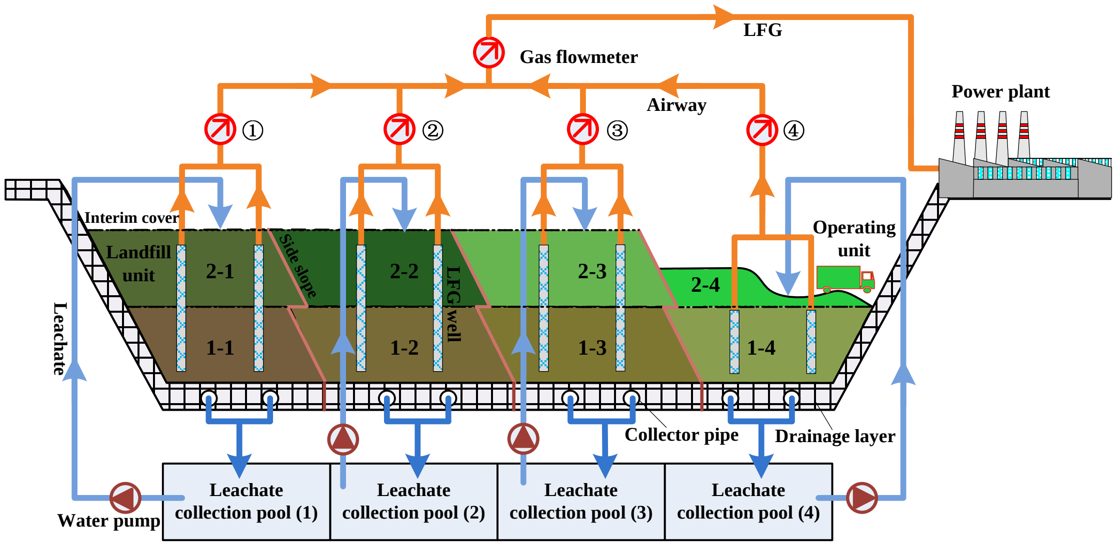


Fig. 1 PCASBRL structure and operational mode

Theoretical analysis and simulation studies all show that PCASBRL can promote the rapid formation of appropriate biogeochemical environment for microbial metabolism based on the adjusting, carrying and scouring action of mixed leachate self-recirculation, and it also can promote the synergy of methanogens and non-methanogens, improve the degradation rate and degradation degree of filled MSW. Moreover, PCASBRL also have a stable LFG production rate, improved cumulative LFG production and CH_4 content, which are favourable to LFG development and utilization.

Keywords: precise controlled anaerobic sequencing batch bioreactor, landfill, municipal solid waste, harmless disposal, landfill gas resources

Environmental cost of landfill

Heijo Scharff

Afvalzorg Deponie BV, Assendelft, Netherlands, h.scharff@afvalzorg.nl

European waste legislation has embraced the polluter pays principle. The waste legislation attempts to prescribe the most important environmental protection measures. This approach safeguards that environmental protection is to a very large extent incorporated in the minimum standards of operation of the waste management facility and consequently also in the gate fee. Some aspects are however not covered. In the Thematic Strategy on the Prevention and Recycling of Waste the European Commission envisages an important role for the use of economic instruments, such as landfill taxes. Taxation is a financial instrument to compensate for costs that are not represented in the gate fee. By imposing the tax the alternative treatment option with a lower impact, but higher costs, becomes more attractive. Landfill is mainly regarded undesired because of the emissions of uncontrolled landfill. The Thematic Strategy also promotes application of Life Cycle Thinking. Consistent application of environmental tax should mean that improved landfill with lower impact is taxed less. In reality environmental tax is not applied uniformly to all human activities and often it is seen as a means to fill the National Treasury: the connection with impact is lost. In order to determine the correct level of taxation a calculation of the net social costs can be made. This includes all private and external environ-mental costs and benefits. Private and environmental costs of waste management are given by various authors (Table 1).

Table 1: Overview of private, environmental and social costs of landfill and incineration.

Source	1	2	2a	3a	4a	5	1	2b	3b	4b	5
Management option	CLF	ULF	CLF	CLF	CLF	CLF	MSWI	MSWI	MSWI	MSWI	MSWI
Private costs	25 - 85			36,00	36,00		75-105		79,00	101,00	
Environmental costs:											
- Disamenity costs					3,50			7,50		9,09	
- Emissions to air		8,19	5,03	5,84	4,21			50,85	17,26	0,11	
- Emissions to water		1,52	0,00	0,00	0,52			0,00	0,00		
- Health effects					0,70					7,09	
- Land use		10,01	10,01	17,88	0,00				0,00		
- Materials & agriculture										0,13	
- Solid waste				2,63					28,69	0,11	
- Transport related					1,25					1,67	
Environmental benefits:											
- Energy function			-4,03	-4,21	-1,14			-20,98	-22,55	-7,63	
- Materials function									-5,76		
Environmental costs		19,72	11,01	22,14	9,04	10-13		37,37	17,64	10,57	4-21
Social costs				58,14	45,04				96,64	111,57	

1 Hogg (2001)
2 COWI (2000); a with gas recovery; b 25% energy efficiency
3 Dijkgraaf & Volleberg (2003) € 34 / tonne CO_2 equivalent; a 77% gas recovery; b 22% energy efficiency
4 Bartelings et al. (2005) € 5-80 (10) / tonne CO_2 equivalent; a 40% gas recovery; b 22% energy efficiency
5 Rabl (2007) € 19 / tonne CO_2 equivalent
CLF = controlled landfill, ULF = uncontrolled landfill, MSWI = municipal solid waste incineration

Landfill tax in the EU-27 and Norway varies between € 0 – 88 / tonne. When applied it is mostly between € 20 – 50 per tonne. Environmental costs suggest "reasonable" landfill tax would be € 9 – 22 per tonne MSW. The difference in impact (Figures 1 and 2) suggests for "low organic" and bioreactor landfills € 3 – 7 per tonne waste would be reasonable. It can only be concluded that landfill tax throughout Europe is not based on "true" environmental cost. It is arbitrary and does not serve the protection of human health and the environment correctly.

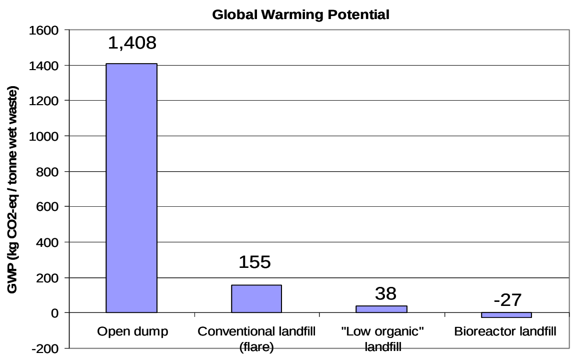


Figure 1: GWP of landfill

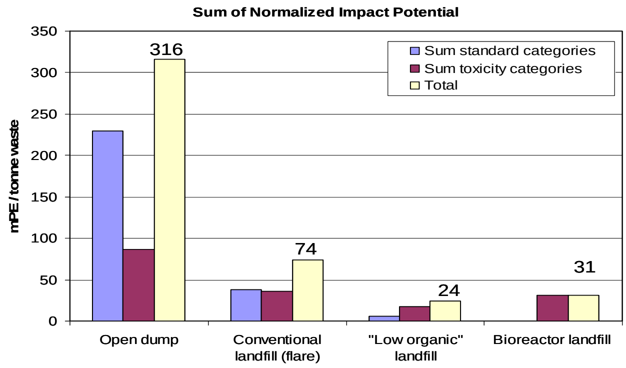


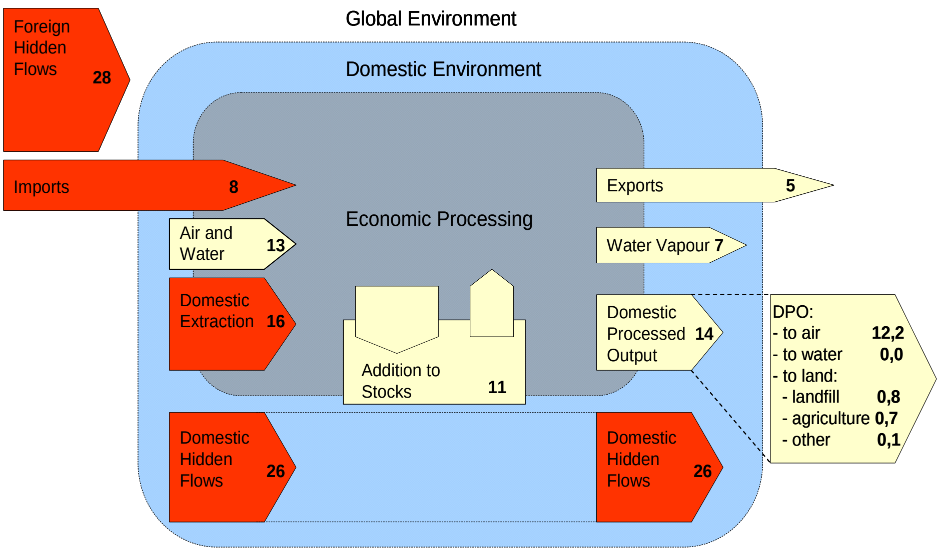
Figure 2: Total impact of landfill

Considering that operational costs for landfill are € 40 to 50 per tonne of waste and that environmental costs are € 10 to 20 per tonne of waste, the total social costs are € 50 to 70 per tonne of waste.The total social costs compensate for any remaining environmental and social damage. So comparing total social costs for different options means that similar impact is compared. Energy yields are also considered. In other words based on total social costs there can be no preference for an option other than based on money. According to different authors the operational costs for incineration are € 80 to 100 per tonne of waste and the environmental costs are € 10 to 30 per tonne of waste. The total social costs for incineration are € 90 to 130 per tonne of waste. Waste incineration is € 40 to 60 per tonne of waste more expensive to society at compensated impact. The impact does not seem to differ that much anyway and landfill can further be improved by adopting "low organic" and bioreactor landfill approaches. In 2005 110 out of 250 million tonnes of MSW (or 45%) were landfilled in the EU-27. EEA predicts 340 million tonnes MSW generation in 2020. Assuming that the additional 90 million tonnes plus the 110 million tonnes of MSW landfilled in 2005 would be landfilled in 2020 instead of treated otherwise, an annual saving of 8 to 12 billion euro without any difference in environmental impact could be realised. Consistent application of Life Cycle Thinking might require that we reconsider if improved landfill, such as the bioreactor landfill or the "low organic" landfill should really be at the bottom of the waste hierarchy.

The need for landfill in a sustainable society

Heijo Scharff
Afvalzorg Deponie BV, Assendelft, Netherlands, h.scharff@afvalzorg.nl

The atmosphere, the soil or the groundwater do not care where contamination comes from. A kilogram of lead is always a kilogram of lead, a kilogram of carbon dioxide equivalent is always a kilogram of carbon dioxide equivalent. An indication of material flows for the European citizen in tonnes per capita and year based on data of the World Resources Institute is given below. It is not accurate, but the order of magnitude tells enough.



The 'developed' EU level of consumption requires processing of 77 tonnes of material per capita and year. Landfill of municipal and industrial waste is 0.8 tonnes per capita and year (only 1%) and belongs to the Domestic Processed Output (DPO). The majority of DPO is 12.2 tonnes carbon dioxide emission per capita and year. Hidden Flows represent 70% of the 77 tonnes per year. Hidden flows mainly consist of overburden soil, bedrock, mining waste and dredging sludge. The 54 tonnes of material per capita and year are also disposed on land and not harmless. Heavy metal and organic contaminant leaching may occur and sulphide can result in acid mine drainage. The 'management' of these materials is not called landfill, but very often in its true nature it is close to the 'open dump' situation that the waste management industry is abandoning or already has abandoned. Mining activities today occur to a large extent in developing countries. It is important to control hidden resource flows not only to protect the environment in industrialised countries, but as much to prevent serious environmental degradation in developing countries.

Prevention, re-use and recycling should be favoured over disposal. Materials should not be landfilled, if an alternative use is available that is practically, economically and environmentally more sensible. The intentions of for instance the European Landfill Directive to improve the environmental impact of landfill should be supported. Financial instruments, such as for instance landfill tax, to compensate for environmental impact and to promote prevention, re-use and recycling should also be supported. But no matter how much prevention, re-use and recycling a society manages to realise, there will always be a role for landfill in a waste management system. Most of all to dispose of materials that for some reason cannot be prevented, re-used or recycled. There are some types of waste for which landfill is the best waste management option. It is important to remember that it is still allowed to produce and use products with components that harm the environment. Many of these components cannot be destructed. Certain mineral compounds, salts and heavy metals should (depending on the environment) not be returned to the environment. Many recycling and re-use activities do redistribute undesired compounds into the environment. For some compounds a final sink is required. In many cases landfills constitute the best final sink option that is available. For such materials landfill is not the least desired waste management option. Moreover, treatment of waste results in residues for which there is very often no other option available than landfill. Landfill can also be a 'safety net' for other waste management operations. This means that landfill is a valuable and essential element of an integrated waste management system and should be recognised as such. A society striving for sustainable development consequently needs sustainable methods for landfill.

In-situ aeration – a promising strategy to shorten landfill aftercare?

O. Gamperling (1)*, A. Budischowsky (2), P.-P. Huber (3), and M. Huber-Humer (4)

(1) Institute of Waste Management, BOKU - University of Natural Resources and Applied Life Sciences, Vienna - Austria (oliver.gamperling@boku.ac.at) – * presenting the paper
(2) NUA – Abfallwirtschaft GmbH, Traiskirchen - Austria (Andreas.Budischowsky@nua.at)
(3) Institute of Waste Management, BOKU - University of Natural Resources and Applied Life Sciences, Vienna - Austria (pia.huber@boku.ac.at)
(4) Institute of Waste Management, BOKU - University of Natural Resources and Applied Life Sciences, Vienna - Austria (marion.huber-humer@boku.ac.at)

The current emission potential of old municipal solid waste (MSW) landfills is mainly influenced by the degradation state of organic matter. Based on the current state of knowledge the period of landfill aftercare is estimated to last some decades up to several centuries.
In-situ landfill aeration is a promising tool to shorten this aftercare-period. Due to air supply the shift from anaerobic to aerobic conditions is induced and the current as well as the residual emission potential are influenced in a positive way. Accelerated organic matter transformation and mineralisation cause environmentally relevant emissions to decline. Reduction of substantial gaseous emissions (especially the greenhouse relevant gas methane) is paralleled by decreasing concentrations of organic leachate compounds (BOD, COD, DOC) and inorganic mineralisation products.

The paper – aimed for oral presentation – will be divided into 2 main parts.

First, the fundamental processes of landfill in-situ aeration will be introduced. Its potential will be discussed based on own experience gained from laboratory experiments. Different materials – regarding less reactive, older landfill material, younger, more reactive landfill material and already deposited mechanically-biologically treated (MBT) material – will be in the focus and additionally compared to international research results.

The second part will focus on the practical application of landfill in-situ aeration.
In Austria the first aeration plant to stabilise an abandoned landfill in-situ was put into operation in spring 2008. The initial situation of this specific landfill site and the results from solid waste characterisation before implementing the in-situ aeration process will be presented as well as the experience gained from operation in-between spring 2008 and autumn 2010. At this time the second solid waste sampling campaign will be finished as well and the impact of aeration over 2.5 years will be presented.
For success control the in-situ stabilisation project is accompanied by a comprehensive monitoring program, not only focussing on the solid waste material, but also on changes in leachate quality and gas composition. Beside the conventional chemical parameters (TOC, TN and eluat-parameters like COD, BOD, NH_4-N, …) the solid waste material is characterised applying Fourier Transform-Infrared (FT-IR) spectroscopy. Additionally settling behaviour, surface emissions (using FID-measurements) as well as gas composition and temperature at several sampling points are observed regularly.

By now the first in-situ stabilisation projects are completed successfully, e.g. in Germany. Compared to the very expensive methods of landfill-clearing (and the adjacent ex-situ treatment of the excavated material) the method of in-situ aeration is a promising low-cost treatment method to reduce aftercare-phase significantly – not only suitable for old MSW dump sites, but also for sanitary MSW landfills – that are already low in reactivity, with small gas production (not feasible fur energetically use any longer) – and more reactive landfill sites, as well.

The position of sustainable landfilling in the European hierarchy of waste management.

W.J. van Vossen (1)

(1) Royal Haskoning, The Netherlands (w.vanvossen@royalhaskoning.com)

Introduction and objectives

What is the long term strategy of our waste management? What is the definition of sustainable waste management?. How do we manage our waste now, do we manage our waste in right way at this moment and how can we improve it? With these kinds of questions in mind, Royal Haskoning started a Delphi internet-discussion on the topic „The future of sustainable waste management“, of which sustainable landfilling also is a part. Sustainable waste management is defined as the approach of waste management by which no negative environmental effects remain for the next generation.

The main objective of starting this discussion is the collection of creative ideas and solutions and translate and transform them into a manifesto regarding sustainable waste management.

The Delphi-method

De Delphi-discussion method is a so-called interactive survey. It is the right method to discuss a certain issue with a limited number of participants. The method is frequently used in order to paint a picture of future scientific, technical, policy and social developments, in this case within the field of sustainable waste management. The name of this method refers to the Delphi-oracle.

The Delphi-method requires that participation in the internet discussion takes place on the basis of anonymity. The anonymity especially aims to break through conflicts of interest, which block creative-thinking in case of face-to-face methods such as brainstorm sessions of conferences. The anonymity might eliminate the pressure on confirmation (group thinking). It is our experience that this method functions very inspiring.

Background information

Within the framework this internet discussion we distinguish about three waste management sectors being recycling, incineration and landfilling and their mutual interaction. Within these three sectors many technical developments have been occurred. Within each sector certain technical, economical and social developments can be pointed out such as improved waste separation techniques, higher energetic efficiency at incineration and sustainable landfilling concepts.

A good reason to reconsider the priority order in waste prevention and management legislation and policy (prevention → preparing for re-use → recycling → incineration with/without energy recovery → landfilling) of the waste hierarchy as stated in the European Directive 2008/98/EC of 19 November 2008.

Participants

43 participants are engaged in the internet discussion, composed out of a representative mix of the three sectors recycling, incineration and landfilling and originating from competent authorities, industry and science.

The process

A special internet site „the future of sustainable waste management“ has been lounged at the end of September 2009. At this site the topic will be discussed by putting forward a proposition. This will be done in several rounds. Participants give their view and reactions to a proposition, in the course of which they should use their creativity as much as possible and have been asked to see beyond existing dogma's and rooted prejudices. From all reactions a synthesis will be made, from which a new proposition is extracted for the next round, and so on. The discussion will continue as long as interesting propositions can be deduced form the reactions on the previous proposition. The discussion will last for a maximum time-period of 6 months. This means that the discussion will be ended not later than the end of March 2010.

Results

So far two rounds have been finished, which means that participants reacted to the following two propositions:

1. In order to realize a real revolution in favour of sustainable waste management, an amendment of the present waste hierarchy is absolutely necessary.
2. Incineration of waste is a wasting of raw material. The authorities should financially promote recycling, financed by taxation on incineration.

The reactions so far show very interesting results, which can shortly be summarized as follows: the waste hierarchy should be reprioritized by means of a proper Life Cycle Analysis (LCA) of all waste processing methods or even by prioritizing processing techniques for each waste product, based upon criteria of durability still to be developed including weighing factors. The present incineration techniques have a relative low energetic efficiency, which is the reason that recycling by means of proper separation and reprocessing techniques might be a better solution. In case of taxation on incineration, it should be implemented in all European countries in order to create a level playing field.

The proposition in the running third round is: „Sustainable landfilling which leads optimal recuperation of biogas and sustainable emission reduction to admissible levels, is better than incineration with low energetic efficiency“.

Conclusions and future perspectives

After ending the discussion at the end of March 2010, all reactions will be translated into a manifesto with creative ideas and opinions, which might contribute to sustainable waste management. All participants are asked to terminate their anonymity and to sign the manifesto. Then the manifesto will be published and presented at a symposium to which all participants and all players in the field of waste management will be invited. The manifesto will be handed over to a prominent representative of the European Community or the Dutch Ministry of Environment (with reservation).
This might the start of a reconsideration of the present waste hierarchy and the position of sustainable landfilling in it.

Anyway this manifesto also might be of interest for the Vienna Conference not only for presentation, but also as a contribution to a fundamental discussion of the position of sustainable landfilling within the European waste hierarchy.

Sinks as Constraints for Urban Development

Paul H. Brunner & Ulrich Kral

Vienna University of Technology, Insitute for Water Quality, Resources and Waste Management.
A-1040 Vienna, Karlsplatz 13/226

Modern cities have a high metabolic rate, requiring large amounts of resources which are used on one hand to build up the urban structure (buildings and networks) and on the other hand to power and feed the "urban metabolism". In parallel to the supply of materials, cities also have to dispose of materials such as waste water, off-gases, solid wastes, products of corrosion and weathering of surfaces and others. The main goals of this project are (1) to test by a comprehensive approach the hypothesis if the flows of materials leaving a city are overloading available sinks such as water, air, soil, underground storages now or within the next few centuries, and (2) in case there is a sink limitation to give first indications how to cope with these limits. It is a distinctive characteristic of this project to take a long term point of view, taking into account the building up of urban material stocks as well as the constant deterioration, renewal and disposal of this stock in the future.

In order to reach the main objective, the following five steps will be performed: (1) the terms "sinks" and "final sinks" will be defined in a rigid, scientific, and utilitarian manner in view of accommodating emissions from the metabolism of cities; (2) the relevant sinks are substance specifically identified for cities in general, and more particularly for the two case study cities Taipei and Vienna; (3) based on MFA methodology, flows and stocks of the urban metabolism to sinks are determined for Taipei and Vienna for selected indicator substances; (4) the impact of these selected flows on the sinks is assessed for short and long time periods according to existing and new assessment methods such as risk assessment and anthropogenic-geogenic reference methods; (5) the results are used to derive conclusions regarding decision support for designers of urban systems, for urban planners, and for environmental engineers who are responsible for securing metabolic processes in cities while maintaining environmental quality in the city and its disposal-Hinterland.

To take advantage of specific scientific strengths, the project will be performed in close cooperation with the group of Prof. Hwong-Wen MA, a long-term partner from National Taiwan University NTU. Methodological issues such as sink definition and assessment methods for flows to sinks are elaborated in close contact to ensure compatibility of results. Both partners use similar methodologies to assess flows and stocks of (the same) materials in Vienna and Taipei. NTU and VUT use different approaches to evaluate sink capacity: While the Taiwanese side uses risk assessment techniques, the Austrian group uses the anthropogenic-geogenic reference method.

The project will answer the question if the development of cities might be limited by the availability of sinks. Besides this main result, new definitions and methods to investigate into and evaluate the sink issue will become available. New results about the flows and stocks of selected substances in the two cities will serve urban planners as well as environmental engineers and designers in the two cities and elsewhere. The collaboration of the two research groups will enhance the research cooperation between Taiwan and Austria, and will serve to build up and widen capacity in the field of urban metabolism and industrial ecology.

Poster Session B – Understanding the Landfill Body

Experimental complex to investigate the biogas emission from municipal solid waste landfills (MSW).

M.P. Fedorov, V.V. Korablev, V.I. Maslikov, A.N. Chusov
Saint Petersburg State Polytechnical University, Russia (expert1@gpu.neva.ru)

Municipal solid waste (MSW) landfills for a long time of their operation and after closure present a danger to the environment due to emissions of pollutants. Therefore, it is very important to have information on the condition of sites and their impact on the environment.

Full-scale experiments allow us to estimate only the current condition of the landfill, but does not allow to forecast its condition in the coming years. During the laboratory experiments, simulating the processes of waste decomposition in bioreactors, it is possible to obtain the necessary information about the processes occurring in the sites. Creating optimal conditions in bioreactors, we can accelerate the waste decomposition in dozens or more times, and several months of the laboratory unit's work to observe the processes occurring under natural conditions for many decades of years.

We have developed an automated training and research laboratory complex “Bioreactor”, designed to simulate and investigate various stages of MSW biodegradation process, taking place in landfills and dumps, in an accelerated time scale. The physical and chemical composition of recycled municipal solid waste, emission of leachate, biogas, and the compounds they contain are the measured parameters. This is one of the first complexes in Russia meeting the relevant international requirements for the equipment and methodology of research. The results of experiments on study the decomposition processes of waste disposed in landfills of St. Petersburg, Almaty, Ashgabat, obtained during the implementation of international projects are presented.

Sustainable landfilling in practice

Marianne Mohr (1, presenting author) and Jan Thrane (2)

(1) Odense Waste Management Company, Denmark (mm@odenserenovation.dk), (2) Odense Waste Management Company, Denmark (jt@odenserenovation.dk)

Sustainability as a concept was first introduced in the Brundtland report in 1987 with the definition: "Meet the needs of the present without comprising the ability of future generations to meet there own needs". In this definition no further directions where given on how sustainability might be used in practice. So sustainability stood as a very open and wide concept to be interpreted.

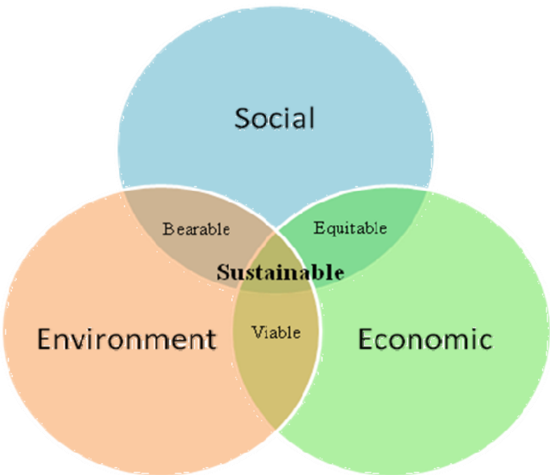


Figure 1: Composition of sustainability

As shown above sustainability may be obtained if the tree equally important aspects are fulfilled. Not only the environmental aspect but also the social and the economic aspects need to be considered.
This triple nature of sustainability means e.g. that developed and developing countries should not necessarily consider sustainability in the same perspective. Sustainability must be seen in a broad context when it is carried out in practise.

Within the context of landfilling, sustainability has often been interpreted as a landfill which after a certain time frame (often set to one generation or 30 years) should have no remaining significant effects on the environment. The aim has been that each generation should take care of their own problems. In principle a sustainable landfill should be planned, designed, operated, and closed down so there would be no (or little) future limitations on land use, no use of electricity or man power to run measuring systems, no gas flaring and similar.

Operating a landfill it is very important to attempt to translate the objectives and definitions of sustainable landfilling into questions and proceed with measurable actions. In all the phases of the landfill cycle it is important to determine and specify the criteria for sustainable landfilling. For example it must be determined what significant effects on the environment could be, where does this criteria of significance apply (where is the point of compliance), what is the corresponding emission from the landfill etc.

The paper will give practical examples of how a municipal owned waste management company attempts to implement sustainable landfilling. Further, there will be given examples of topics where the sustainability may be disputed in spite of good intentions.

Prediction of hydraulic conductivity of MSW from particle size distribution

John Sandoval, John Barker, Andrew Hudson, Richard Beaven

School of Civil Engineering and the Environment, University of Southampton, SO17 1BJ, UK (jjs1x07@soton.ac.ukl)

Introduction and background

Management solutions often adopted at existing landfill sites include the recirculation of leachate in order to enhance biodegradation process, increase landfill gas production and potentially reduce post-closure care periods. Assessment of any such management solution requires an understanding of the movement, amount and quality of the contaminants. In this context, an accurate determination of the hydraulic conductivity (*K*) of municipal solid waste (MSW) materials under different conditions of stress and degree of saturation is essential (Powrie & Beaven, 1999).

As for soils, methods using particle size distribution (PSD) information can be applied to estimate *K* for MSW systems. Common semi-empirical expressions used such as the Kozeny-Carman equation are based on conceptual models considering the pore structure and particle geometry. Employment of such equations requires determination of porosity values and either a representative particle diameter, d_m [L], or the specific surface area, *S* [L^2/L^3], for the system as in the version of the Kozeny-Carman expression:

$$K = C_{K-C} \frac{\gamma_w}{\mu_w} \frac{1}{S^2} \frac{n^3}{(1-n)^2} \qquad \textbf{(1)}$$

Here μ_w and γ_w are the dynamic viscosity and specific weight of the permeant, respectively; $C_{K\text{-}C}$ is the Kozeny-Carman constant, related to the shape and tortuosity of the conduits, which is found to be in the range 3 – 6 for different packing types (Coulson & Richardson, 1968).

Methodology

Hydraulic conductivity data has been reported by Beaven (2000), Powrie *et al.*(2008) and Velkushanova *et al.* (2009) for different waste types including excavated aged MSW (AG1), pulverised household refuse (PV1) and fresh shredded MSW (SW1). The *K* values were obtained using a large-scale compression cell located at Pitsea, Essex in the UK (2 m ID and a typical sample height of 2 to 2.5 m) covering a wide range of overburden pressure conditions. In this work the various results of hydraulic characterisation and particle size distribution (PSD) obtained for these samples, together with new results obtained in a laboratory cell (0.48 m ID, 0.90 m high) are used to evaluate the applicability of the Kozeny-Carman equation for predicting the hydraulic conductivity of landfilled MSW.

Example results and discussion

PSD data obtained for some of the samples evaluated is shown in Figure 1. For those samples with a less detailed PSD characterisation, fitted curves obtained using a lognormal PSD are also plotted.

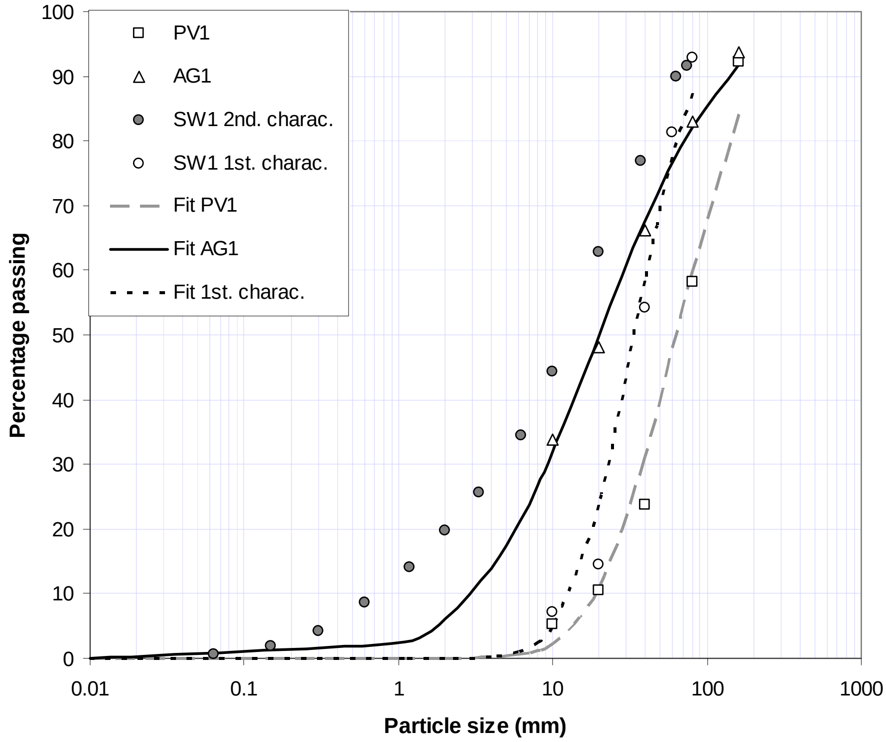


Figure 1. PSD data and fitted curves for MSW samples.

Using this information, values of the geometric parameters related to the permeability of the waste, *S* and d_m, were calculated according to various methods reported in the literature for MSW and other materials (Felske *et al.*, 2001; Carrier, 2003; Chapuis & Aubertin, 2003). Using these values along with the drainable porosity data obtained from hydraulic conductivity tests on the samples, *K* values were calculated using equation (1) or similar relationships. Predicted and measured *K* values for the experiments at the Pitsea cell and the laboratory unit are illustrated in Figure 2.

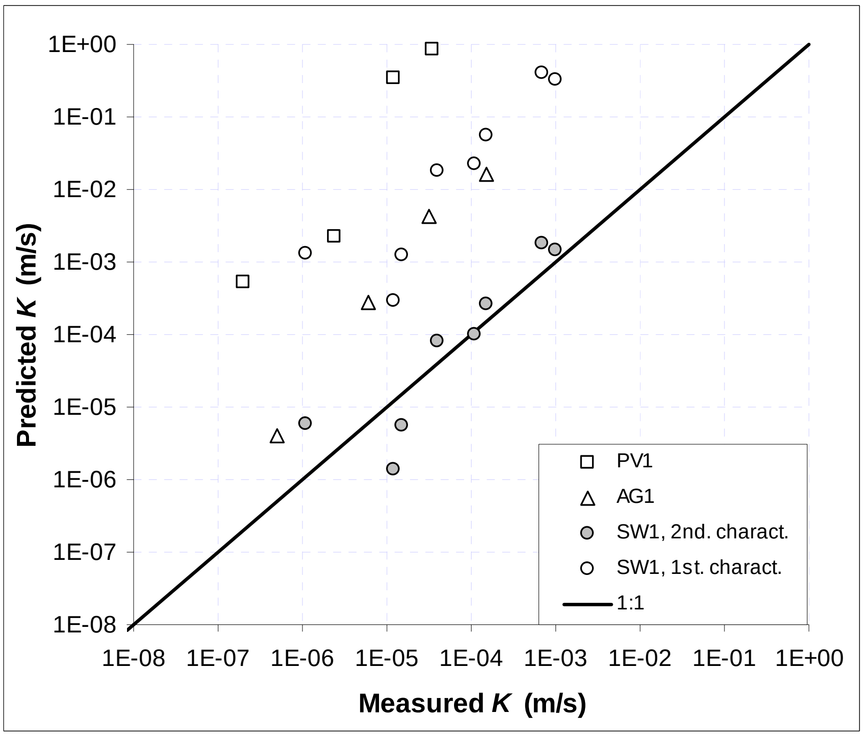


Figure 2. Measured versus predicted hydraulic conductivity values for MSW

The results yielded a relatively good prediction of *K* based in the Kozeny-Carman equation for the sample with more detailed PSD characterisations (i.e. SW1 second characterisation). In that case differences between predicted and measured values were within one order of magnitude over up to five orders of magnitude of variability in *K*. In contrast, estimations based on scarce PSD data yielded very poor predictions. Variability in the predictions is also due to the common difficulties found in estimating representative values of geometric parameters for highly heterogeneous materials like MSW landfilled. Further work has been undertaken to investigate approaches where estimation of those parameters are explored by fitting PSD experimental data to various probability distributions. Also, the variability of specific surface area with porosity has been investigated.

The results indicate that the Kozeny-Carman equation and similar relationships may prove useful in estimating the hydraulic conductivities of semi-compressible MSW material subjected to different stresses, provided good quality waste characterisation and porosity data are available. In particular, it appears necessary to determine the low end of the PSD accurately.

References

Beaven, R. P. (2000). The hydrogeological and geotechnical properties of household waste in relation to sustainable landfilling. *Department of Civil Engineering.* London, Queen Mary and Westfield College, University of London. PhD: p.388.

Carrier, W. D. (2003). Technical note: goodbye Hazen hello, Kozeny-Carman. *Journal of Geotechnical and Geoenvironmental Engineering* 129(11): p.1054-1056.

Chapuis, R. P. & Aubertin, M. (2003). Predicting the coefficient of permeability of soils using the Kozeny-Carman equation. Montreal, Department CGM, École Polytechnique de Montréal: p.1-31.

Coulson, J. M. & Richardson, J. F. (1968). *Chemical engineering 2nd. Ed.*, Pergamon, Oxford.

Felske, C., Kraft, E., Zeiss, C. & Bidlingmaier, W. (2001). Geometric characterisation of residential waste with special consideration to the fluid flow behaviour in landfills. *Proceedings Sardinia 2001, Eight International Waste Management and Landfill Symposium*, S. Margherita di Pula, Cagliari, Italy.

Powrie, W., Beaven, R. P. & Hudson, A. P. (2008). The Influence of landfill gas on the hydraulic conductivity of Waste. V. K. Milind, N. A. Akram & R. R. Krishna, ASCE. 309: p.33.

Velkushanova, C., Caicedo, D., Richards, D. & Powrie, W. (2009). A detailed characterisation of an MBT waste. *Proceedings Sardinia 2009, Twelfth International Waste Management and Landfill Symposium*, S. Margherita di Pula, Cagliari, Italy.

Analysis of landfill gas temperatures and components in new passive gas extraction wells of a closed landfill

Hideki YOSHIDA (1)

(1) Department of Civil Engineering & Architecture, Muroran Institute of Technology, Muroran, Hokkaido, Japan
(email: gomigomi@mmm.muroran-it.ac.jp)

Many closed landfills may last the high potential for emissions of leachate and landfill gas (LFG) to the environment. Aftercare or completion of the aftercare phase of those landfills are discussed in Japan. Passive LFG extraction wells may contribute to releasing LFG from the landfill and inducing the air inside the landfill body naturally though it will need more long time for remediation than forced aeration.
A closed landfill in Hokkaido has been studied to examine LFG temperatures and compositions in new passive gas extraction wells. This landfill accepted municipal waste for more than 20 years and closed in 2003. Ninety new passive LFG extraction wells have been installed for stabilization of this landfill since the completion of landfilling. If those wells work effectively, how will the stabilization of this landfill be accelerated? LFG temperature and composition are important indices for stabilization. Those indices have been observed for five years in this landfill and discussed in this paper. Then gas transport model is proposed to describe transport phenomena of LFG and the air around the wells. Such model includes multi component diffusion and Darcy flow. Numerical simulation of gas flow in the wells is carried out with finite element method.

Firstly the temperature profiles and LFG concentrations in new ninety passive LFG extraction wells of the landfill are discussed. The maximum temperatures in several wells exceed 50 degrees Celsius and such significant temperature rise may confirm active aerobic biodegradation in the landfill. Furthermore, methane concentration is very small in those wells because aerobic biodegradation may reduce methane gas emission successfully. On the other hand, low temperature and high concentration of methane have been observed in other wells since those wells were installed. Anaerobic biodegradation is dominant in those wells. Active methane gas generation may prevent the air diffusion into the landfill body, however, it is difficult to discuss such phenomena only by observed data in the landfill.

Secondarily simulations of gas flow around passive LFG extraction wells are examined by numerical models. Such models include Maxwell-Stefan equation for diffusion and Darcy law for gas flow through porous media. Two-dimensional profiles of gas components are simulated. Maxwell-Stefan equation describes the diffusion of the air into the landfill body through the wells and the landfill surface. The air easily diffuses into the landfill body from the surface of the landfill or through the wells if LFG flow is small. Once methane generation gets large, LFG flow purges the air from the landfill body. So aerobic biodegradation may depend on such LFG flow from the landfill body to the air.

Finally this paper attempts to explain the role of a passive LFG extraction well in a closed landfill for landfill stabilization quantitatively and qualitatively.

Applications of TDR in Bioreactor Landfill Monitoring

Raymond S. Li (1) and Loretta Y. Li (2)

(1) CH2M HILL Canada Ltd. (Raymond.Li@ch2m.com)

(2) Department of Civil Engineering. University of British Columbia, Canada. (lli@civil.ubc.ca)

Corresponding author and presenting author: Loretta Y. Li

Bioreactor landfill is considered as the new generation of waste treatment landfill, able to accelerate the decomposition of organic wastes and resulting in more rapid stabilization of municipal solid waste (MSW), increased rate of settlement and saving of footprint area relative to conventional landfills. However, the success of operating bioreactor landfills depends on maintaining an optimum distribution of moisture.

Since the introduction in the late 1990's for measuring in-situ volumetric water content of MSW, time-domain reflectometry (TDR) has been accepted as one technique among others for both laboratory and field testing. Advantages of TDR include its relatively simple operation, its non-destructive capability, and its ability to be automated and multiplexed compared with neutron probe or gravimetric techniques. Despite its potential applications and benefits for landfill monitoring, TDR has not been widely used in monitoring bioreactor landfills due to its high cost.

The objective of this paper is to explore various potential applications of TDR for landfill monitoring. It will be shown that there are multiple applications of TDR including: (1) in-situ waste moisture measurement; (2) leachate head measurement; (3) liner leak detection; (4) preferential pathway detection of clay capping; and (5) detection of contaminant migration. One TDR can replace all other equipment that would be required for each of the above functions, with the overall result that TDR can provide substantial cost savings for purchase and installation of monitoring instruments, as well as significantly reducing the complexity of operating an array of different instruments.

Characteristics of Municipal Solid Waste using Electrical Resistivity Imaging

Hossain, M.S.(1), Kemler, V. (2) , Dugger, D. (3), and Shihada, H. (4)

(1) Assistant Professor, Department of Civil Engineering, The University of Texas at Arlington, 417 Yates Street, NH 404, TX 76019, e-mail: hossain@uta.edu

(2) Director of Solid Waste, The City of Denton, 1527 S. Mayhill Road, Denton, TX 76208, e-mail: vance.kemler@cityofdenton.com

(3) Landfill Manager, The City of Denton, 1527 S. Mayhill Road, Denton, TX 76208, e-mail: David.Dugger@cityofdenton.com

(4) Graduate Research Assistant, Department of Civil Engineering, The University of Texas at Arlington, 417 Yates Street, NH 404, TX 76019, e-mail: huda.shihada@mavs.uta.edu

Enhanced leachate recirculation (ELR) landfills are designed and operated for rapid waste stabilization, waste decomposition and increased rate of gas generation. The fundamental process improvement involved in the operation of landfills as ELR landfills is the addition of water and/or the recirculation of leachate into the landfill's waste mass. Electrical Resistivity Imaging (ERI) has been successfully used in the field to monitor the performance of the leachate recirculation system. However, the characteristics of Municipal Solid Waste (MSW) using resistivity imaging (RI) are not well documented. The objective of this paper is to characterize MSW with depth or placement in a landfill and with decomposition using ERI in the laboratory. Solid waste samples were collected from the City of Denton Landfill (Texas, USA) using a 3ft diameter bucket auger from a depth up to 65 ft from the landfill final surface. Initially, physical and chemical composition (mainly Volatile Organic Content, VOC) were determined for the collected samples. Then the resistivity of MSW samples were determined using a resistivity meter, SuperSting R8, and a resistivity test box. A co-relation between MSW characteristics and resistivity were developed. The study will help professional community linking MSW characteristics with resistivity imaging.

Assessment of microbial function in waste landfills using DNA microarray

Tomonori Ishigaki (1), Masaki Hamada (1), Aki Ishida (1), Yasushi Kobayashi (1), Hiromi Sawamura (2), Daisuke Inoue (2) and Kazunari Sei (2)

(1) Department of Environmental Solution Technology, Faculty of Science and Engineering, Ryukoku University, Shiga, Japan, (ishigaki@rins.ryukoku.ac.jp)
(2) Division of Sustainable Energy and Environmental Engineering, Graduate School of Engineering, Osaka University, Osaka, Japan

Waste landfills that contain several hazardous substances could be a potential pollution source of environments. Landfill management has been basically decided by physical and chemical parameters from the emission of landfills to prevent the environmental pollution. On the other hand, microbial community must be also considered to be good indicator of the landfill condition, because (1) microbiological reaction plays important role for the waste stabilization and (2) microbial community will be affected and/or changed by the environmental condition. Multi function of microorganisms, such as transformation of chemicals, tolerance against heavy metals and antibiotics, assimilation of carbon, nitrogen and sulfur compounds, should be the essential information on the landfill stabilization. This study aimed to design and develop a DNA microarray that is able to evaluate the multi bacterial function in landfills. The compounds that were frequently detected from waste landfill leachate or landfill gas were selected as follows; aliphatic hydrocarbons, aromatic hydrocarbons, volatile organics, phenolic compounds, polymers, antibiotics, heavy metals, and carbon, nitrogen and sulfuric compounds. The gene coding the enzyme that relates the degradation, tolerance, and element cycle of these compounds were objected to evaluate for the microarray analysis. Specific oligonucleotide probes were designed from common sequences of target DNA and were mounted on the microarray. Microarray analysis for DNA extracted from landfill leachate exhibited reliable and reproducible results to detect the bacterial function in landfills. Results of assessment the bacterial potential to reduce the environmental impact from landfill were shown.

Keywords: Waste landfill, microorganism, biodegradation, DNA microarray, hazarodous compound

Poster Session C+D - Modeling & Monitoring of Landfill Emissions I+II

Estimation of methane emission by a municipal landfill: the case of Palermo

G. Di Bella (1), D. Di Trapani (2)* and G. Viviani (3)

(1) Dipartimento di Ingegneria Idraulica ed Applicazioni Ambientali, Università degli Studi di Palermo, Viale delle Scienze 90146, Palermo, Italia (dibella@idra.unipa.it), (2) Dipartimento di Ingegneria Idraulica ed Applicazioni Ambientali, Università degli Studi di Palermo, Viale delle Scienze 90146, Palermo, Italia (ditrapani@idra.unipa.it), (3) Dipartimento di Ingegneria Idraulica ed Applicazioni Ambientali, Università degli Studi di Palermo, Viale delle Scienze 90146, Palermo, Italia (gviv@idra.unipa.it)

* Corresponding author. Tel +39 0916657755; fax: +39 0916657749

Methane (CH_4) emissions from municipal solid waste (MSW) landfills represent one of the most important anthropogenic source of greenhouse-gases (Baird 1995; Aronica et al., 2009). Indeed, CH_4 more effectively absorbs the infrared radiations than CO_2 (its global warming potential is 21 times more effective than that of CO_2), and it is one of the most rapidly increasing greenhouse-gases in the atmosphere. It's well-known that municipal solid waste contains a certain amount of biodegradable organic matter, and, inside the buried wastes, microbial anaerobic degradation of this organic fraction results in the production of the so called landfill gas (LFG), which basically is a mixture of methane and carbon dioxide (Raco et al. 2006), whose main component is typically represented by CH_4. In order to minimise its negative effects on the environment, LFG recovery is a suitable tool to effectively control CH_4 emissions from landfill sites. Bearing in mind such consideration, the quantification of CH_4 emissions represents a good way to evaluate the effectiveness of biogas recovering system in reducing biogas emission to the atmosphere. However, up to now few measurements of landfill CH_4 emissions have been reported, due to the heterogeneity of waste composition and temporarily landfill surface covering which give as a result high spatial variability of the LFG emission from the landfill surface. In the technical literature various methodologies are described to measure methane emissions from landfills: in particular, LFG emissions can be indirectly evaluated starting from a mass balance equation and taking into account biogas formation, recovering and oxidation (Morcet et al., 2003), as well as on a different approach based on direct LFG emission measurement from landfill surface (Capaccioni et al., 2006). In the present study, both methodologies have been applied to the case study of Palermo (IT) landfill (Bellolampo). The main aim of the study was to compare CH_4 production/emission based on direct measurements with the accumulation chamber method (EA, 2007), with the estimate of methane production/emission calculated by means of mass balance equations based on the Erhig (1991) and Landgem (US-EPA, 2001) biogas production models. In particular, direct measurements of CH_4 fluxes from the landfill surface have been used to obtain the total diffuse methane flux from the investigated area; indeed, through the use of statistic and geostatistic methodologies, Inverse Distance Weighting (IDW) (Tobler, 1970) and Ordinary Kriging (OK) (Matheron, 1965), contoured methane flux maps have been realized. The obtained results showed a good agreement between the two methodologies, even if the balance models gave a little bit higher production values. This result can be explained considering that a large number of uncertainties surely affects (and usually overestimates) the prediction curves, such as landfill history, waste composition, nutrient level, moisture content (Cossu et al., 1996). Contoured flux maps represent a reliable tool to locate areas with abnormal emissions in order to optimize the gas recovering system efficiency and, in addition, the analysis of flux map can be used to define the correlation between the local CH_4 emissions and the specific features of landfill management. Finally, direct measurements could be a good tool to calibrate/validate balance production models, in order to obtain a more reliable methane production estimates.
In Figure 1, flux maps obtained with IDW (a) and OK (b) methodology are represented.

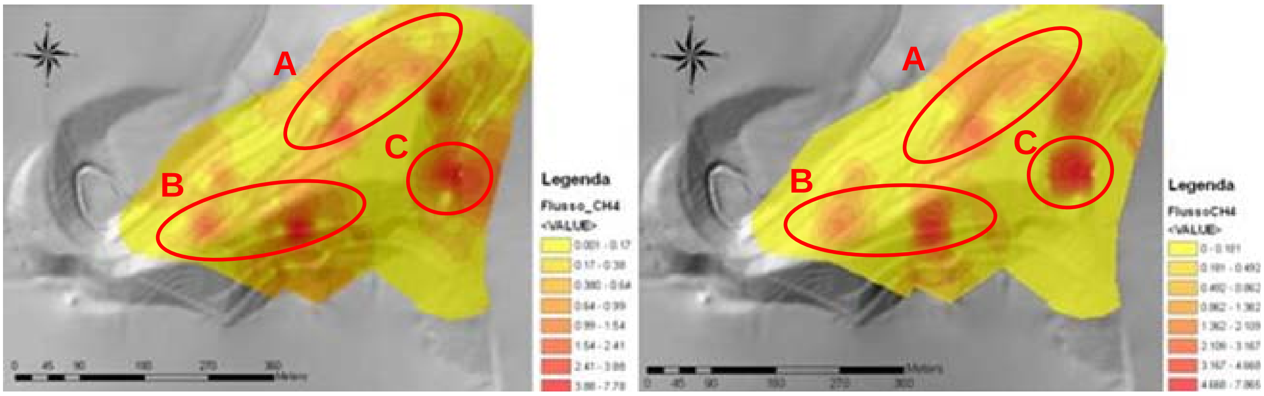


Figure 1. Contoured flux map for the investigated area with IDW (a) and OK (b) respectively.

References

- Aronica S., Bonanno A., Piazza V., Pignato L., Trapani S. (2009). Estimation of biogas produced by the landfill of Palermo, applying a Gaussian model. Waste Management 29 , pp,233–239
- Baird C. (1995) Environmental Chemistry. W.H. Freeman and Company, New York, pp. 484
- Capaccioni B., Didero M., Lucci P., Pirillo M., Scartoni P., Tatano F. (2005) Camera di accumulo portatile per il monitoraggio di emissioni di biogas da discarica: risultati sperimentali ed elaborazioni preliminari a scala provinciale, RS Rifiuti Solidi, Vol. XIX, n. 2, 96-110.
- Cossu, R., Andreottola, G. and Muntoni, A. (1996). Modelling Landfill Gas Production in Landfilling of waste: biogas. T. H. Christenses, R. Cossu, R. Stegmann, E&FN Spon, Chapman&Hall, 237-268.
- Environment Agency, (2007). Guidance on monitoring landfill gas surface emissions. Environment Agency, Bristol. Available from: <http://www.environment-agency.gov.uk/static/documents/Business/lftgn07_surface_936575.pdf>, UK.
- Ehrig H.J., (1991). Prediction of gas production from laboratory scale tests. Proceeding Sardinia 91, Third International Landfill Symposium 1, Cagliari, Italy, pp. 87–114.
- Matheron, G. (1965). Les variables Regionaliseés et leur estimation, Masson Paris, 305 (in French).
- Morcet M., Aran C., Bogner J., Chanton J., Spokas K., Hebe I. (2003). Methane mass balance : a review of field results from three french landfill case studies. Proceedings Sardinia 2003, Ninth International Waste Management and Landfill Symposium Cagliari, Italy.
- Raco B., Cioni R., Guidi M.,. Scozzari A, Lelli M., Lippo G. (2006). Monitoraggio del flusso di biogas diffuso dal suolo da discariche rsu: il caso di legoli, peccioli (PI).RS Rifiuti Solidi, Vol. XZ, n. 2, 120-136.
- Tobler, W. (1970). A computer movie simulating urban growth in the Detroit region. Economic Geography 46, 234-240.
- US Environmental Protection Agency, USEPA, (2001). Landfill Volume III. Available from: <http://www.epa. gov/ttn/chief/eiip /techreport/volume03/iii15_apr2001.pdf>, USA.

Utilizing Natural Zeolite for Zinc (II) Removal in Simulated Landfill Conditions

E. Beril Gümüşel (1), N. Gamze Turan (2)

(1) Ondokuz Mayıs University, Natural Science Institute, Dept. of Environmental Engineering, 55139 Samsun, Turkey; Tel: +90 362 3121919/1221; Fax: +90 362 4576035; (berilgum83@yahoo.com)
(2) Ondokuz Mayıs University, Engineering Faculty, Dept. of Environmental Engineering, 55139 Samsun, Turkey; Tel: +90 362 3121919/1329; Fax: +90 362 4576094; (gturan@omu.edu.tr)

Sanitary landfill is the most common method of disposal of solid waste all over the world. As well as municipal solid waste, commercial and industrial wastes, which may contain hazardous substances are also received by landfills in many countries. One of the problems arising from this form of waste disposal is the generation of leachate. The composition of the leachate depends on the type of waste being disposed of, landfill design, local rainfall, etc. Landfill leachate is the most complicated and costly wastewater to treat due to its high content of organic and inorganic pollutants. Heavy metal is one of the most common groups of contaminants in landfill leachate. Heavy metals may constitute an environmental problem, if the leachate migrates into surface water or groundwater, or a treatment issue where the leachate is collected and treated prior to discharge.

Heavy metals contamination exists in waste stream from many industries such as metal plating, mining, tanneries, painting, car radiator manufacturing, as well as agricultural sources where fertilizers and fungicidal spray intensively used. Zn^{2+} is among the most common heavy metal in these industries. Zn^{2+} is in the list of priority pollutants proposed by Environmental Protection Agency gives rise to serious poisoning cases. The main symptoms of zinc poisoning are dehydration, electrolyte imbalance, stomachache, nausea, dizziness and incoordination in muscles.

Many researchers have shown interest in the removal of heavy metals in leachate by adsorption on solid surfaces to improve efficiency, economy and effectiveness of productivity. Compacted clay soils, especially bentonitic clays, are preferred, because of its fine particle size and consequent micropores and high surface charges; it possesses low hydraulic conductivity and a high adsorption capacity. However, compacted clays can have problems with shrinkage and/or desiccation cracking especially those containing an appreciable amount of bentonite. Many studies have shown that compacted clays undergo large changes in physicochemical properties when exposed to shrink–swell and/or freeze–thaw cycling.
Zeolites are crystalline, hydrated aluminosilicate of alkali and alkaline earth cations possessing an infinite, open three-dimensional structure. The microporous crystalline structure of zeolites is able to adsorb species that have diameters that fit through surface entry channels, while larger species are excluded, giving rise to molecular sieving properties that are exploited in a wide range of commercial applications. Natural zeolites have particularly effective removal of lead, cadmium, thorium, lead, zinc, manganese and ammonium from effluents. It has also found application in removal and purification of cesium and strontium radioisotopes. Natural zeolites nowadays are mostly used in catalysis, in air enrichment, as filters in paper and rubber industry, in soil beneficiation, as animal feed supplements, and in water and wastewater treatment.

This paper presents a study of the removal of Zn^{2+} present in the leachate from an inorganic industrial waste landfill using natural zeolite as a liner material. The results indicated that natural zeolite showed excellent adsorptive characteristics for the removal of Zn^{2+} ions from leachate and could be used as very good liner materials due to its high uptake capacity and the abundance in availability.

Removal of Copper (II) Ions from Leachate of Industrial Waste Landfill by Hazelnut Shells

N. Gamze Turan (1), Başak Mesci (2), Osman Nuri Ergun (3)

(1) Ondokuz Mayıs University, Engineering Faculty, Dept. of Environmental Engineering, 55139 Kurupelit, Samsun, Turkey; Tel: +90 362 3121919/1329; Fax: +90 362 4576094; (gturan@omu.edu.tr)
(2) Ondokuz Mayıs University, Engineering Faculty, Dept. of Material Science and Engineering, 55139 Kurupelit, Samsun, Turkey; Tel: +90 362 3121919/1565; Fax: +90 362 4576094; (basakm@omu.edu.tr)
(3) Ondokuz Mayıs University, Engineering Faculty, Dept. of Environmental Engineering, 55139 Kurupelit, Samsun, Turkey; Tel: +90 362 3121919/1010; Fax: +90 362 4576094;(onergun@omu.edu.tr)

Industrial waste landfills have the potential to contaminate subsurface groundwater supplies through migration of leachates down to the water table and into groundwater aquifers, despite the use of compacted low permeability clay or polyethene liners. Leachates may be removed from the base of the mass for immediate treatment or disposal or may be recycled within the waste mass to accelerate decay and defer treatment and disposal costs.

Many industries such as metal finishing, electroplating, plastics, pigments, and mining contain hazardous substances such as heavy metals. Heavy metals can be treated from leachate by using various physicochemical methods icluding adsorption, ion exchange, precipitation, phytoextraction, ultrafiltration, reverse osmosis, and electrodialysis. Among them, adsorption receives considerable interest with the high efficiency in heavy metal removal.

The most respective and widely used adsorbent material in the adsorption processes is activated carbon. Even though it has a high adsorption capacity, surface area and has a microporous structure; it is restricted to use due to its relatively high price; high operation costs, and problems with regeneration for the industrial scale applications. This led to a search directed to developing the low-cost and locally available adsorbent materials with the maximum adsorption capacity. These kinds of adsorbents, which are biological-based materials such as saw dust, wheat shell, cacao shell, banana pith, soybean, rice husk.

The aim of the study is to investigate the removal of Cu^{2+} present in the leachate from an inorganic industrial waste landfill using hazelnut shells as a biosorbent. In the present paper, the kinetics of adsorption of Cu^{2+} on hazelnut shells has been studied using different models and the effect of temperature for the adsorption of Cu^{2+} onto hazelnut shells has also been investigated. Thermodynamics of adsorption process has also been studied and the change in Gibbs free energy and the enthalpy, and the entropy of adsorption have been estimated for the biosorbent used.

Diffusion coefficient of a protective layer for a long-term repository vessel of recovered mercury evaluated based on a mercury transportation-intake model

F. Takahashi (1)*, T. Takatori (2), and T. Shimaoka (3)

(1) Faculty of Urban and Environmental Engineering, Graduate School of Engineering, Kyushu University, Japan (f-takahashi@doc.kyushu-u.ac.jp), (2) Dept. of Urban and Environmental Engineering, Graduate School of Engineering, Kyushu University, Japan (takatori@doc.kyushu-u.ac.jp), (3) Faculty of Urban and Environmental Engineering, Graduate School of Engineering, Kyushu University, Japan (shimaoka@doc.kyushu-u.ac.jp)

International efforts to decrease mercury usage have been conducted more and more owing to adverse effects of mercury to human health and the environment. A lot of mercury, which has been used in municipal and industrial applications now, must be recovered and be disposed finally in the near future. When we consider long-term underground reposition of recovered mercury, a protective layer of a repository vessel should be concerned for environmentally safe storage because the corrosion on the inside and the outside of the vessel should occur by mercury-amalgam formation and groundwater, respectively. Although the protective layer must have certain level of diffusion coefficient for long-term safe reposition, it has been still unknown. In this study, mercury diffusion coefficient of the protective layer was evaluated based on a mercury transportation-intake model for long-term safe reposition.
This model included the leaching of inorganic mercury (mercury sufide, HgS) from a protective layer to groundwater, chemical/biological conversion to methylmercury/inorganic mercury, sorption and desorption during the transportation to a lake or a gulf, hydraulic diffusion in a lake (or a gulf), methylmercury bioaccumulation, and mercury intake via fish foods (see Figure 1). In this model, it was assumed that mercury sulfide was already contacted with a protective layer owing to the corrosion of the repository vessel. All parameters excluding sorption/desorption used in this model were geometrical averages of reported data. The other parameters were obtained by equilibrium adsorption tests and adsorption breakthrough experiments. Calculated mercury intake via fish foods was compared with provisional tolerable weekly intake (PTWI) reported by WHO (1.6 μg/kg-weight/week) for the risk assessment. Repository period that expected mercury intake was less than PTWI were used as an indicator for sensitivity analysis for this model.
Sensitivity analysis indicated that methylation/demethylation rate coefficient for the sediment, distribution constant of methylmercury between water and sediment, and bioaccumulation factor were significant. Because most parameters were reported to have greatly wide range and depend strongly on local surrounding conditions, these significant parameters should be concerned for the risk assessment of mercury repository. Environmental risk was calculated to be larger with the increase of methlyation rate coefficient and bioaccumulation, and the decrease of demethlyation rate coefficient and distribution constant. If negligible risk

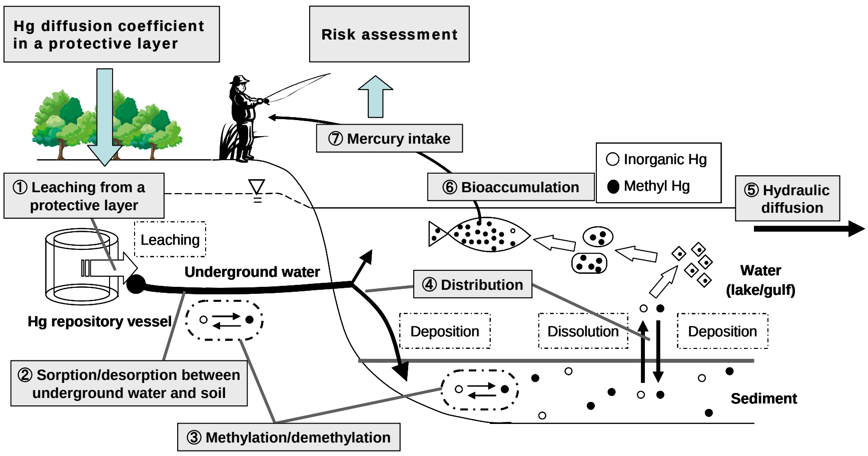


Figure 1. Schematic illustration of the mercury transportation-intake model

is requested during more than 10,000 years repository, model calculation suggested the protective layer should have less than 7.7×10^{-15} m^2/s of mercury diffusion coefficient and more than 15 cm of thickness (see Figure 2 and 3). This means that cement and bentonite materials might be insufficient as a protective layer of mercury repository vessel.

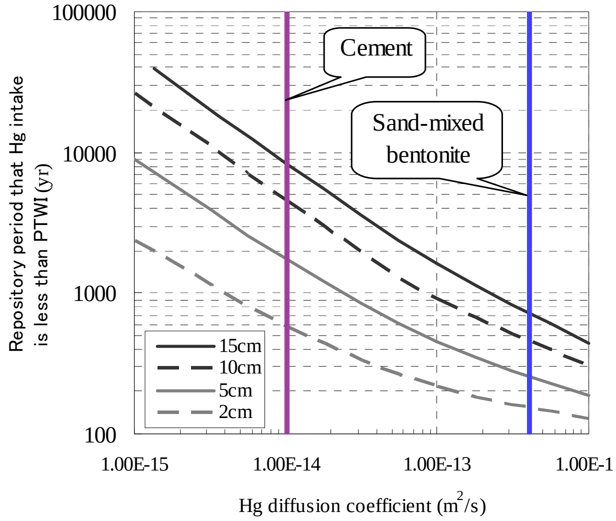


Figure 2. Comparison of Hg diffusion coefficient with repository period that Hg intake is less than PTWI

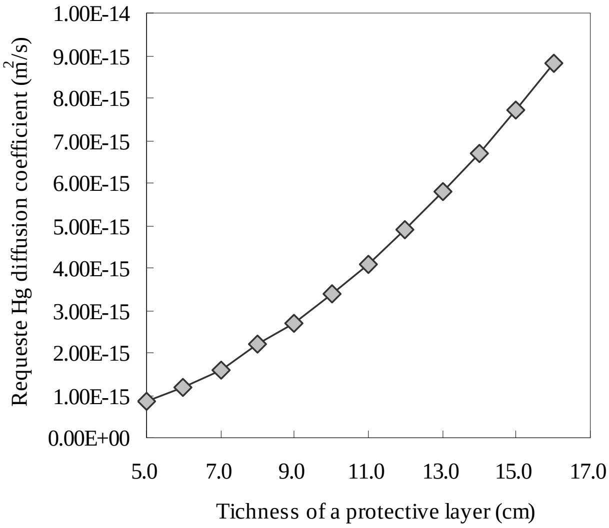


Figure 3. Comparison of thickness of a protective layer with Hg diffusion coefficient that enables negligible risk during 10000-year repository

Leaching Characteristics of pollutant from Shredded Residue by Balky and Incombustible Waste

K. Miyawaki (1) and K. Osato (1)

(1) Department of Environmental Systems, Meisei University, Japan (miyawaki@es.meisei-u.ac.jp)

The lack of landfill space is remarkable in Japan. Moreover, the mostly whole quantity of combustible waste is incinerated. And, 60% of the landfilled waste of Japan is an incinerator ash (residue). Moreover, incombustible waste and the bulky waste are crushed. The incombustible shredded residue accounts for 15% or more of the landfilled waste. Recently, melted processing of waste and the cement raw material making of the incineration ash are done to advance recycling. The amount of reclamation of the incineration ash decreases gradually. The future, there is a possibility that the ratio of the incombustible shredded residue increases. Figure 1 shows present processing flow in Japan.

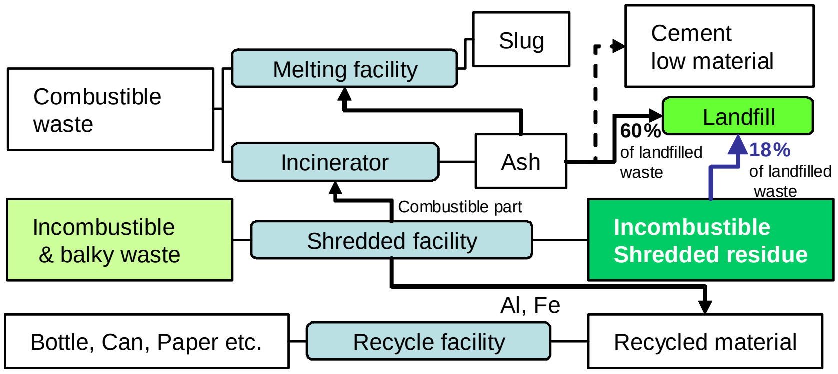


Fig.1 Ordinary Waste Manegement Flow in Japan

However, the research example concerning the environmental burden of the incombustible shredded residue is fewer than other wastes.
In this research, to examine the leaching characteristic when it landfilled from the incombustible shredded residue, various characteristic tests (leaching test etc.) were executed.

In the experiment, incombustible shredded residue of the city (population: 100,000) in suburb area Tokyo collected from the bulky and incombustible waste processing facilities was used. Sieve classification of samples was done. A physical composition was investigated by 4.75mm or more particle size. Moreover, various characteristic tests were executed according to the particle size by 4.75mm or less.

Figure 2 shows the physical composition example. It has been understood that there are a lot of plastic. Moreover, the metal and the printed wiring board, etc. are variously included.

Official method leaching test in Japan (JLT46), the pH dependency test, the content test, and the column test, etc. were executed as various characteristic tests. Official method leaching test(JLT46) is an examination to confirm environmental quality standards for soil. Pure water 300mL was added to the sample 30g (L/S=10), it shook for 6 hours, and it filtered with 0.45um membrane filter. The metals of filtered sample were measured. The pH dependency test was added pure water about 300mL to the sample 30g, set the pH to 4, 6, 8, 10, and 12, stirred for 24 hours, and filtered with 0.45um membrane filter. The metals of filtered sample were measured.

A part of the result is introduced. Figure 3 shows the result of Pb and Cd by pH dependency test. It is confirmed that lead and cadmium leaching quantity increases in acid condition (pH4) though it is general as the leaching characteristic of the metal. Moreover, leaching on alkali condition (pH12) was confirmed about Pb. It is confirmed that leaching quantity is different depending on the particle size. This reason was thought about increase of surface area with the particle size decrease or the possibility of the different composition with the particle size after crushing process.

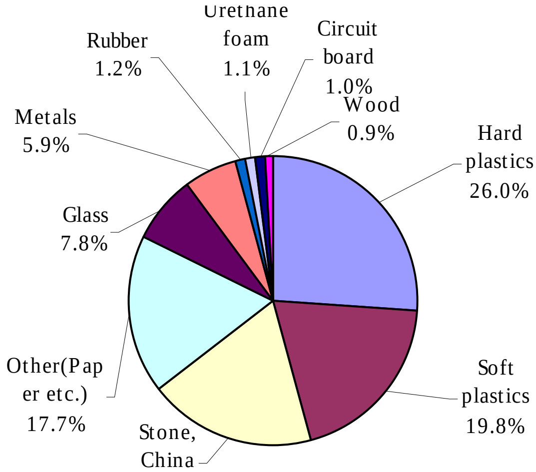


Fig.2 Compornent of Incombustible Shredded Residue

It can be said that the environmental burden of incombustible shredded residue landfilling is not large.However, there is a possibility that heavy metal leaching happen in landfill with depending on kinds of mixed waste and the landfilling condition.

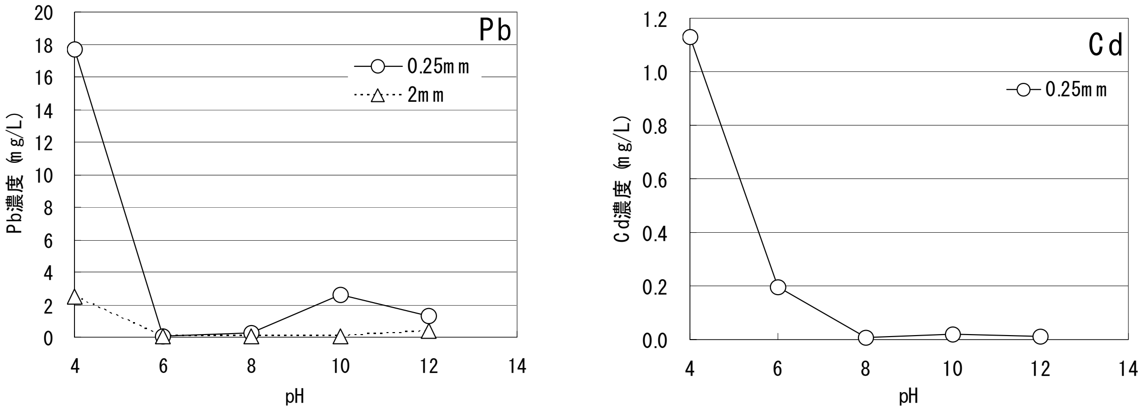


Fig.3 Heavy Metal leaching by pH Dependent Test of Incombustible Shredded Residue

Effects of saline solutions on MSWI bottom ash – results from field experiments with different experimental setup

D. Sager (1) and S. Heuss-Aßbichler (2)

(1) Institute for Sustainable Waste Management and Technology, University of Leoben, Austria (daniela.sager@unileoben.ac.atl), (2) Department of Earth and Environmental Sciences, Ludwig-Maximilians-University Munich, Germany (soraya@min.unimuenchen.de)

Under real landfill conditions composition of the percolating leachate may vary from natural rain water composition to saline pore solution due to landfill leachate recirculation. Hence one aim of this study is to investigate the effect of leachants with different salt contents on solid phase and leachate development of municipal solid waste incineration (MSWI) bottom ash. During disposal the material undergoes different compaction rates causing a change of permeability within the landfill. A further aim of this study is to determine the effect of experimental setup by means of heterogeneous permeability along the vertical transport profile.

Four test bodies with MSWI bottom ash were accomplished and exposed to natural precipitation. The total test duration was 102 weeks. Each test body had its own separated base. Experiment one (TB 1) had no combined surface with the other bodies and serves as reference. The setup was homogeneous without any layering. The other three bodies had a combined surface. They were characterized by changing permeability along the vertical transport profile. At half height a layer, consisting of MSWI bottom ash with 0 – 4 mm grain size fraction (fine grained ash, FGA), was placed and afterwards technically compacted to 15 cm thickness. Experiment two (TB 2) was exposed to natural precipitation only, comparable to TB 1. The other two bodies were irrigated additionally with saline solutions after 22 weeks of test duration: Experiment three (TB 3) with landfill leachate (LL) and experiment four (TB 4) with reverse osmosis concentrate (RO). The amount was each 50 litres a week. Amongst other parameters following Cl- and Cu-concentrations were supplied: 3,9 g/L (Cl) and 0,2 mg/L (Cu) to TB 3 and 11,8 g/L (Cl) and 0,25 mg/L (Cu) to TB 4. The leachate was collected continuously. Three sampling campaigns of solid samples were conducted: after 22 weeks (D 1), 48 weeks (D 2) and 102 weeks (D 3). Concerning the reference body (TB 1) four samples were taken along the vertical transport profile. Within the test bodies TB 2 – TB 4 additionally the fine-grained bottom ash layer (FGA) was sampled to examine the effect of permeability change.

Water content of solid samples was always higher than that of fresh material (Figure 1A). After 102 weeks the water content of solid samples increased from top to the base in case of a homogeneous setup. In case of the other experiments the highest water content was determined above the FGA-layer. This indicates very clearly the impounding effect due to permeability change. Electrical conductivity of the eluates was always lower than that of fresh material (Figure 1B). In case of experiment TB 1 the conductivity increased from the top to the base. Placing a FGA-layer caused a slight increase of conductivity immediately above this layer. Beneath the conductivity was always lower compared to reference test body (TB 1). This effect was even observed in case of irrigation with RO concentrate. Investigations concerning contaminant transport along the vertical profile showed also differences between reference experiment and experiments with layering. As an example of heavy metals the Cu eluate concentrations are presented (Figure 1C). The Cu concentrations of the reference TB 1 decrease from the top to the middle of the profile. At the bottom a slightly higher value was measured. Note, in case of TB 2 – TB 4 Cu concentrations are always lower within and beneath FGA-layer.

The leachate pH values fluctuate over the entire test duration (Figure 2A). Irrigation with landfill leachate (LL) or reverse osmosis (RO) had no noticeable influence on leachate pH-values. Concerning electrical conductivity in all cases maximum values were measured after more than 120 days (Figure 2B). Over the entire test duration the lowest values were detected for the reference TB 1. The FGA-layer caused in all three cases higher leachate conductivity. In general highest values were observed for TB 4. Concerning parameter Cu in general a decrease of the concentrations was determined (Figure 2C). In tendency after a period of 250 days the leachate from test bodies with FGA-layer had higher Cu-concentrations, especially experiment four. Note the increase of Cu concentration after about 550 days which was most pronounced for the reference TB 1.

A main conclusion is that water retention capacity was enhanced due to permeability change. The higher salt content of the leachant amplifies this effect. Furthermore the layer causes a noticeable decrease of salt content within the samples. The lowest values were obtained within the FGA- layer. Accordingly the salt concentration in the leachate was much higher indicating that salts are mobilized in a higher amount. In this context leachate load calculations were accomplished to estimate amount of salt and pollutant release or retention.

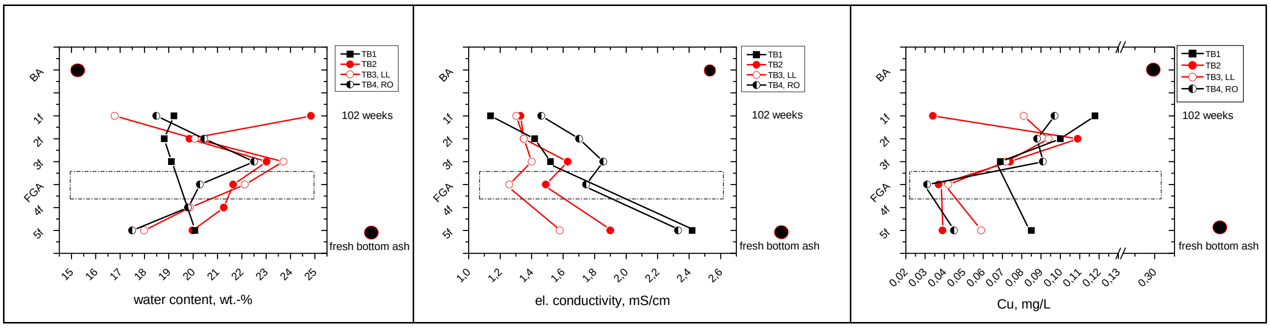


Figure 1 (A-C) Results from solid phase analyses: water content (left), el. conductivity (middle) and Cu eluate concentration (right) along a vertical transport profile from sampling campaign D3, FGA (fine grained bottom ash layer)

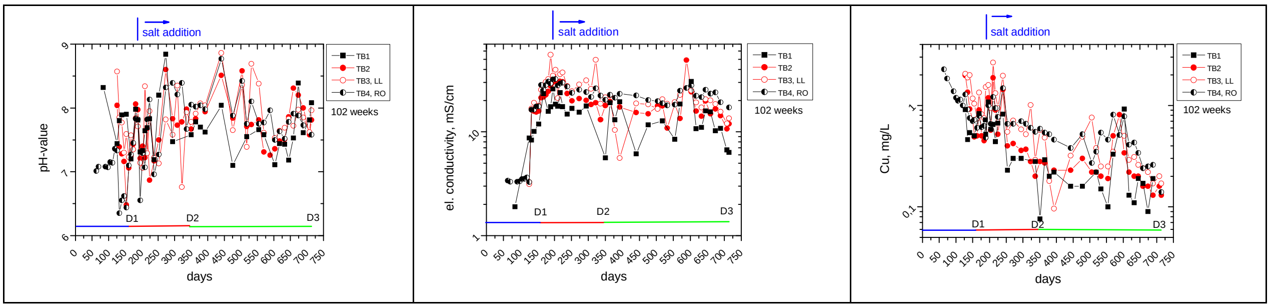


Figure 2 (A-C) Results from leachate development: pH-value (left), el. conductivity (middle) and Cu leachate concentration (right) over a test duration of 102 weeks, D1 – D3 time of sampling campaigns

Monitoring specific organic compounds in landfill leachates

Cecilia B. Öman (1)* and Christian Junestedt (2)

(1) Royal Institute of Technology (KTH), Department of Land and Water Resources Engineering, Sweden
(2) IVL Swedish Environmental Research Institute Ltd., Sweden (christian.junestedt@ivl.se)
*Presenting author

Introduction

Landfill leachates contain a large number of compounds, some of which can be expected to create a threat to health and nature if released into the natural environment. The objective of the study was to discuss the importance of addressing hazardous organic compounds in landfill risk assessment and leachate treatment studies, and to develop on previous proposed methods for monitoring emissions of such compounds. Heavy metals, ammonia, chloride and microorganisms, which may also constitute negative environmental effects, are not addressed here.

Risk assessment

The method for assessing the risks builds on; i) principle of caution, ii) hazardous compounds detected in leachate, iii) available treatment methods, iv) expected attenuation in the natural environment.
i) The internationally accepted Principle of Cautiousness, the OECD Polluter Pays Principle, PPP and the Swedish Environmental law (1998:808) states that as soon as there are reasons to assume that an activity can harm human health or the natural environment, measures of caution have to be taken. The regulations states further that lack of scientific evidence that harm can be caused, should never be used as a reason for not acting when a possible risk is perceived. Still the demands on action must be reasonable.
ii) Extensive amounts of specific organic compounds have been identified in leachates and in leachate plumes. For example, Holm, Rugge and others (1995) found 13 pharmaceutical organic compounds; Paxéus(2000) identified 200 organic compounds; Baun, Ledin and others (2004) found 55 organic compounds and 10 degradation products; Eganhouse, Cozzarelli and others (2005) found 70 VOCs; and Öman and Junestedt (2008) identified 90 organic compounds. Even though the quantified levels often were low, at the μg/l levels, toxicity tests have shown that leachates are hazardous (Castillo and Barceló 2001; Baun, Ledin et al. 2004; Abdulhussain, Guo et al. 2009).
iii) The use of membrane technologies have shown to be an indispensable means of achieving quality standards for direct discharge of leachate into the surface water (Trebouet, Schlumpf et al. 2001; Abdulhussain, Guo et al. 2009), but the high cost per unit volume is a major drawback. In addition, as the hazardous compounds are not known it is not possile to actually evaluate the treatment efficiency.
iv) It has been argued that the release of leachate into the natural environment will not be a threat due to natural attenuation. Christensen, Kjeldesn and others (2001) propose that the effects of the leachate on the groundwater is limited to an area of less than 1000 m from the landfill, which was supported by findings of Kjelsen and Barlaz (2002) and of Eganhouse, Cozzarelli and others (2005). On the other hand, for example Nielsen, Bjarnsdóttir and others (1995) and Nielsen, Albertsen and others (1995) found that several organic compounds were not at all or only slightly degraded in anaerobic landfill leachate pollution plumes.
In conclusion, the authors refer to the principle of cautiousness, the amount of hazardous compounds found, the high costs for leachate treatment combined with lack of data on actual treatment efficiency and lack of proof for sufficient natural attenuation, and thus emphasises on the importance of addressing the risk with specific organic compounds. Still without putting too high demands on required actions.

Addressing risks

Due to limitations in sampling and chemical analytical capacity, it will not be possible to monitor each hazardous organic compound present in the leachates. Instead the method presented here for addressing the risks is monitoring the hazardous compounds with carefully selected and representative tracers. A few compounds are proposed to be selected to represent combination of biological, chemical and physical character. This can be done by using a method proposed by Öman (2001) where the summing up the score values, indicates the expected presence of a compound in the leachate phase(Table 1).

Table 1. Ranking expected fate of organic compounds inside a landfill (Öman 2001).

Ranking	Sorption	Evaporation		Microbial transformation	
Score	Log K_{ow}	H, Pa*m³/mole	Description	Rate 1/2	Description
0	< 1	<0.1	Not volatile	>10 years	Persistent
1	1-2	0.1-100		100 days – 10 years	Medium degradability
2	2-3	100-1000		1 – 100 days	Good – medium degradability
3	>3	>1000	Volatile	< 1 day	Good degradability

The method does not take into account landfill related factors such as waste composition and the stage reached in the decomposition process, even though this has been found to be important (Allen, Braithwaite et al. 1997; Calace, Liberatorib et al. 2001; Kjeldsen, Barlaz et al. 2002). Thus, compounds selected should be representative also for the type of landfill studied. In addition, it has been found that lagphases and the redox conditions affect the leachate composition (Nielsen, Bjarnadóttir et al. 1995; Nielsen, Albrechtsen et al. 1995; Röling, van Breukelen et al. 2001), and therefore these two parameters must be considered while evaluating results.

Conclusion

It is thus concluded that specific hazardous organic compounds should be monitored when addressing risks with landfill leachate and assessing leachate treatment methods. The compounds are preferably monitored through a few tracer compounds that are carefully selected to be representative for different groups of compounds and different types of landfills.

References

Abdulhussain, A. A., J. Guo, et al. (2009). "Review on Landfill Leachate Treatments " American Journal of Applied Sciences **6**(4): 672-684.

Allen, M. R., A. Braithwaite, et al. (1997). "Trace Organic Compounds in Landfill Gas at Seven U.K. Waste Disposal Sites." Environ. Sci. Technol. **31**(4): 1054-1061.

Baun, A., A. Ledin, et al. (2004). "Xenobiotic organic compounds in leachates from ten Danish MSW landfills-chemical analysis and toxicity tests." Water Research **38**(18): 3845-3858.

Calace, N., A. Liberatorib, et al. (2001). "Characteristics of different molecular weight fractions of organic matter in landfill leachate and their role in soil sorption of heavy metals." Environmental Pollution **113**(3): 331-339.

Castillo, M. and D. Barceló (2001). "Characterisation of organic pollutants in textile wastewaters and landfill leachate by using toxicity-based fractionation methods followed by liquid and gas chromatography coupled to mass spectrometric detection." Analytica Chimica Acta **426**(2): 253-264.

Christensen, T. H., P. Kjeldsen, et al. (2001). "Biogeochemistry of landfill leachate plumes." Applied Geochemistry **16**(7-8): 659-718.

Eganhouse, R. P., I. M. Cozzarelli, et al. (2005). "Natural Attenuation of Volatile Organic Compounds (VOCs) in the Leachate Plume of a Municipal Landfill: Using Alkylbenzenes as Process Probes." Ground Water **39**(2): 192 - 202.

Holm, J. V., K. Rugge, et al. (1995). "Occurrence and distribution of pharmaceutical organic compounds in the groundwater downgradient of a landfill." Environmental Science &Technology **29**(5): 1415-1420.

Kjeldsen, P., M. A. Barlaz, et al. (2002). "Present and Long-Term Composition of MSW Landfill Leachate: A Review " Critical Reviews in Environmental Science and Technology **32**(4): 297-336.

Nielsen, P.-H., H. Bjarnadóttir, et al. (1995). "In situ and laboratory studies on the fate of specific organic compounds in an anaerobic landfill leachate plume, 2. Fate of aromatic and chlorinated aliphatic compounds." Journal of Contaminant Hydrology **20**(1-2): 51-66.

Nielsen, P. H., H.-J. Albrechtsen, et al. (1995). "In situ and laboratory studies on the fate of specific organic compounds in an anaerobic landfill leachate plume, 1. Experimental conditions and fate of phenolic compounds." Journal of Contaminant Hydrology **20**(1-2): 27-50.

Öman, C. (2001). "Comparison between the predicted fate of organic compounds in landfills and the actual emissions." Environ Sci Technol **35**(1): 232-9.

Öman, C. B. and C. Junestedt (2008). "Chemical characterization of landfill leachates – 400 parametersand compounds." Waste Management **28**: 1876-1891.

Paxéus, N. (2000). "Organic compounds in municipal landfill leachates " Water Science & Technology **42**(7-8): 323-333.

Röling, W. F. M., B. M. van Breukelen, et al. (2001). "Relationships between Microbial Community Structure and Hydrochemistry in a Landfill Leachate-Polluted Aquifer." Appl. Environ. Microbiology **67**(10): 4619-4629.

Trebouet, D., J. P. Schlumpf, et al. (2001). "Stabilized landfill leachate treatment by combined physicochemical–nanofiltration processes " Water Research **35**(12): 2935-2942.

Application of multistage Kinetic model to anaerobic degradation of soluble substrate in high strength leachate

E. Safari (1) and M. Jalili Ghazizade (2)

(1) Ph.D. Environmental Engineering, Associate Research Director, Department of Civil Engineering, Queen's University, Kingston, Ontario, Canada; (edwin.safari@ce.queensu.ca)
(2) Ph.D. Student of Environmental Engineering, Graduate Faculty of Environment, University of Tehran, Tehran, Iran (Corresponding Author); (mjalili@ut.ac.ir)

Landfill has been the most economical and environmentally acceptable method for the disposal of solid waste throughout the world. Up to 95% of solid waste generated in Iran is currently disposed in landfills. The high organic fraction of Municipal Solid Waste (MSW) with about seventy percent (by weight) of moisture content leads to generation of high strength leachate even in areas of scarce atmospheric precipitation typical of many cities in Iran. In this study biological treatment of such high strength leachates was addressed in terms of the governing kinetic model. The combination of landfill and compost plant leachate was characterized in terms of pH, BOD_5, COD, Ammonium, chloride and heavy metals. As a first attempt, anaerobic degradation of soluble Chemical Oxygen Demand (COD) of fresh leachate samples from the landfill and the associated compost plant were fitted to single stage first and second order kinetic models as well as multistage models. The initial COD concentrations were about 66,000 to 77,000 mg/l. The extent of anaerobic biodegradability of high strength leachate was determined through this lab scale experiment to be more than 95% in terms of soluble COD removal. The best fit was achieved using the first order multistage kinetic model. Table 1 shows Summary of kinetic models fitted to soluble COD degradation in two reactors. The rate constants of hydrolysis, acidogenesis and methanogenesis were found to be reasonably different.

Table 1: Summary of kinetic models fitted to soluble COD degradation in Reactor 2 and Reactor 4

Reactor/Model	Simple First Order		Simple Second Order		Multistage First Order			
	R^2	k (d^{-1})	R^2	k (l/mg.d)	R^2	k1 (d^{-1})	k2 (d^{-1})	k3 (d^{-1})
Reactor 2 (Filtered NTL)	0.947	0.052	0.815	15E-7	0.987	0.0993	0.209	0.1636
Reactor 4 (Filtered FL)	0.832	0.022	0.702	45E-8	0.950	0.0691	0.0802	0.0825

The rate limiting stage was recognized to be hydrolysis in this specific experiment. This study can open room for further analysis of applying multistage approach to anaerobic processes, which would improve the design of units corresponding to the main stages.

Keywords: Landfill, High Strength Leachate, Anaerobic, Multistage Kinetic Model.

A New Modelling Approach for Determining the Fate of Organic Carbon in Municipal Solid Waste Landfills

Edi Munawar (1,2), Johann Fellner (1), and Paul H. Brunner (1)

[1]Institute for Water Quality, Resources and Waste Management, Vienna University of Technology, Vienna, Austria

[2]Chemical Engineering Department, Syiah Kuala University, Banda Aceh, Indonesia

(e.munawar@iwa.tuwien.ac.at and edi.munawar@unsyiah.ac.id; j.fellner@iwa.tuwien.ac.at; paul.h.brunner@iwa.tuwien.ac.at)

The probably most important directive concerning the management of Municipal Solid Waste (MSW) within the European Union is the Council Directive on the Landfill of Waste 1999/31/EC, released by the European Parliament on April 26, 1999. This directive requests member states of the European Union (EU) to reduce the percentage of biodegradable municipal solid waste going to landfills to 35% (referred to the total amount of biodegradable matter produced in 1995) until the end of 2016. In addition, the landfill directive also requires member states to cover old existing landfills in order to prevent the contamination of surface and ground waters by leachate and to control the amount of water entering the landfill body by precipitation. Although controlling rainwater entering into the landfill body may prevent contamination of surface and groundwater due to low leachate flow rates, this method also reduces the degradation rate of organic matter in the landfill body, which again leads to extended post-closure periods. Of course this fact does not comply with the overall goals of waste management, which among others is prohibited to export of emissions in time. However, there is still no reliable method that allows predicting the fate of organic carbon in the landfills, which is beside nitrogen the determining factor for the termination of the aftercare. The present study is aimed at developing a model for simulating the fate of organic carbon in landfills. This model should help to decide which approach should be followed after covering the landfill, both in terms of economic and technological aspects. The proposed model will be approached by combining the concepts of modified Fixed-Bed Bioreactors (FBR's) and counter-current gas-liquid absorption, where the reaction occurs begin between the solid reactant in fixed-bed state and the fluid reactant flowing downward by gravity then followed by liquid-liquid and gas-liquid reactions. The gas absorption by liquid occurs due to intimate contact their movement through interstice of solid waste. Since, the biodegradation of organic matter in the landfill is determined by population and growth rate of microorganisms, the reaction rate of solid-liquid is assumed to follow the Contois equation, while liquid-liquid and gas-liquid reactions are assumed to follow the Monod equation. The heterogeneous character of waste going to the landfills, in particular regarding the differences in degradability, is accounted by dividing the degradation rate of organic carbon into three categories: easily, slowly, and hardly degradable. Since the presence and flow of water play an important role in the degradation rate of organic matter, differences in the water content are also accounted for by the model. Information about the distribution of water in landfills will be obtained by using the methodology proposed by Fellner (2004). Finally, the model will be calibrated with the available data from landfills and landfill simulation experiments.

Poster Session E+F - Landfill Stability and Aftercare I issions I+II

Closure, Aftercare and Afteruse of Landfills

W. Terhorst / O. Niemeyer / R. Küsters-Cattelaens

WMT Waste Management Technology & Service GmbH, Germany (info@w-m-t.biz)

Closure of Landfills

Precondition: With the start of the landfill operation a reserve study was made. In this study the financial resources which are needed for the closure and the aftercare measures where listed. This study has to be revised during the closure and aftercare period because there is a cash outflow during this time.

Objectives: The main objective is the prevention of emerging contaminants to protect groundwater, soil and air. Further objectives are the integration of the landfill in the surrounding landscape and to enable the possibility of a use of the landfill after the closing. Measures: After stopping the operation on the landfill the surface of the open face has to be restored. Systems to collect leachate and landfill gas have to be installed. The landfill gas will be utilised or correctly disposed. Leachate will be treated on the site or also lead to a correct disposal. The surface water would be collected and lead to a water recipient. Furthermore monitoring points were installed to control groundwater, surface water and to study the settling of the landfill surface.

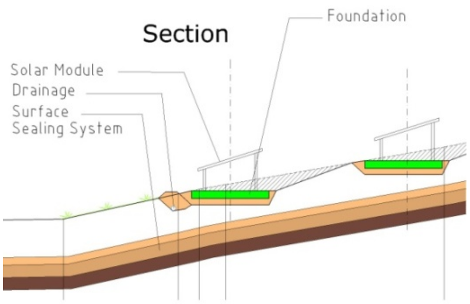
Landfill Aftercare

In Germany the period of the aftercare is fixed with 30 years in minimum.
However, this period ends not until there are no emerging contaminants at all, which can pollute water, ground or air.

Items of Aftercare:

- Leachate Managing System (collecting, treatment, disposal and monitoring).
- Landfill Gas Managing System (extracting, transporting, energy recovering or correct disposal, monitoring, e.g. regular flame ionisation measuring (FID) on the surface to check the efficiency of the extracting system).
- Surface Water Managing System (regular cleaning of the collecting system, pipes and shafts, inspection of retention and restriction structures, monitoring).
- Structural Monitoring und Maintenance (e.g. leachate shafts; inspection chambers; extracting systems, pipes and shafts of the gas collecting system), maintenance and repair of the facility, roads and fences.
- Process Measuring and Control Technology for the Leachate Managing System (leachate pumps, dosing systems, measurements), the Landfill Gas Managing System (remote maintenance of the gas utilisation plant and the gas flare) and for the lighting and security system.
- Monitoring of the groundwater with wells (minimum requirement: one monitoring well in the upstream and two monitoring wells in the downstream)
- Monitoring of the settlement at the landfill surface (yearly terrestrial survey of fixed measurement points; interpretation of the results of the survey)
- Maintenance of vegetation (regular care of grasslands, grazing or mowing, cleaning and thinning of the planting)

Landfill Afteruse

- Agricultural Use
  Because of the dynamic characteristics of the landfill surface, the minor thickness of the restoration layer, the disturbed water balance and the installed technical elements (gas extraction units, shafts, etc.) an agricultural use during the aftercare period is as a rule not possible.
- Biotope(s)
  
  Mainly landfills were designed as biotopes when the restoration phase is finished. Because of the fact that the landfills are generally completely fenced, no unauthorized persons can enter this area and the development of biotopes on the landfill surface can take place undisturbed. An indication for that is the high diversity of species, the number of individuals per area of each species in comparison with other locations without a surrounding fence. From these protected landfill areas fauna and flora can spread into bordering regions and can effect an ecological valorisation of a bigger area.
- Location for Plants of Renewable Energies
  

  The installation of photovoltaic plants is possible and already realised on several landfills. If the basic conditions of the location (sunshine duration, exposition and inclination of the area, grid connection, foundation of the modules, etc.) are fulfilled.
  The installation of wind power plants can be realised if defined requirements (possible foundation depth, minimum distance to settlements and roads, grid connection) were fulfilled. After the amortisation of these plants the remaining revenue can cover a part of the annual aftercare costs.
- Recreation Areas
  Directly after the closure of a part of a landfill (as realised in Neuss, Germany) there was a building of an indoor skiing hall on this closed area. This skiing-hall is operated all-the-year. The installations and technical elements of the leachate and landfill gas management systems were modified before.
  
  The founding of the hall was possible on the existing restoration layer with a thickness of 1.20 m. To ensure that the foundation of the Skiing-Hall has no negative influence on the surface sealing of the landfill, WMT Waste Management Technology & Service GmbH installed and operated a monitoring system to control the settlings of the elements of the foundation.
  The incomes of the leasehold fort he facility area can cover a part of the annual aftercare costs. The conditions for the installation of these recreation areas are urban areas within spitting distance, an excellent traffic connection and a possibility for a good grid connection.

Benefits of prior versus posterior waste humidification in bioreactor landfills

G. Bellenfant (1), J.-F. Bulteau (2) and D. Guyonnet (1)

(1) BRGM, France (g.bellenfant@brgm.fr), (2) IKOS Environnement, France (jean-francois.bulteau@ikos.fr)

The bioreactor landfill, which was developed in the United States in the nineteen seventies, relies on the recirculation of leachate into the waste body in order to promote the degradation of organic matter. The overall objective is typically to reach a final waste quality within a time frame that is compatible with the expected lifetimes of the waste containment barriers. The full-scale application of this landfill management concept has been challenged in particular by the difficulty to ensure homogeneous distribution of humidity in the waste, due primarily to waste heterogeneity. An alternative method is to humidify the waste with leachate, prior to landfilling (with or without leachate recirculation following landfilling). This alternative is privileged by IKOS Environnement, on two landfill sites located in the North of France. Data relative to landfill gas collection illustrate the rapid generation of landfill gas compared to traditional sites. Such rapid gas generation implies that the landfill cell must be covered with an impervious cover as soon as possible. If this is performed within a year or so, drastic reductions in GHG emissions can be achieved compared to classical landfills. Similarly leachate quality and quantity data are analysed in order to highlight the performance of this process. This paper presents landfill gas data and leachate quality data collected from the landfill which enables to appreciate the enhancement of gas generation kinetics and the evolution of leachate composition. The particular landfill management concept (patented) developed at these two sites includes the excavation of waste following the degradation phase, with mechanical separation of several waste phases in view of their recycling and reuse on site or offsite.

Leachate leakage from landfills in the long run: an environmental and economic evaluation

Bayer S (1), Mazeas L., Mery J., Touze-Foltz N. (2)

(1) FührungsAkademie für Bundeswehr (FüAk), Germany (stefanbayer@bundeswehr.org)

(2) French institute for agricultural and environmental engineering research (Cemagref), France (jacques.mery@cemagref.fr)

All the studies on the externalities of landfills underline the specific difficulties to evaluate the environmental cost of leachate leakage. This is due to several kinds of uncertainty, from the durability of liners on a secular timescale to the value society puts on groundwater quality and on its own future through the discounting procedure used for cost-benefit analyses. Then, while these studies propose external costs in the range 0€/t to 2€/t, opponents to landfill projects often argue on the potential pollution of the underlying groundwater for refusing such installations, which could mean that such low cost figures do not represent at all the real social value of this environmental risk.

We first present as a matter of fact the composition of leachate from eight French municipal solid waste landfills, focusing on organic micro-pollutants some of which had not been previously encountered or looked at, like polychlorinated biphenyl and polybrominated diphenyl ethers. Some problematic pollutants are present in leachate, like bisphenol A which is found in not unsignificant concentrations.

The potential concentrations in the groundwater are then to be quantified. Using a numerical model of transfer through current landfill liners including diffusion processes of organic contaminants in synthetic and mineral materials the order of magnitude of concentrations in the groundwater is quantified. It is generally below the health limits for the two compounds for which calculations where performed : benzene and dichloromethane.

Last, we propose a socio-economic interpretation on the environmental risks linked to the quality of barriers, including:

- intergenerational equity considerations through an original discounting procedure (generation-adjusted discounting) ,

- spatial equity through the territorial consequences of the potential application of the current French guide on the design on landfill liners based on the concept of equivalent level of protection.

The cost of using high quality liners in landfills may be then better justified, leading to more sustainable ways of design and locate often locally unwanted landfills.

Poster Session G - Landfills – Resource and Hazard

Implementation of Interaction Matrix Method in Solid Waste Landfill Engineering

Milorad Jovanovski (1), Katerina Donevska (2), Igor Peshevski (3)

(1) University Sts.Cyril and Methodius, Faculty of Civil Engineering, jovanovski@gf.ukim.edu.mk,
(2) University Sts.Cyril and Methodius, Faculty of Civil Engineering, donevska@gf.ukim.edu.mk,
(3) igorrgf@hotmail.com

One of the main steps in rational and efficient designing of solid waste landfills is to define in detail geological, hydrogeological and geotechnical conditions of the natural environment. They can be limiting factors in site selection for solid waste landfills, and have a primary role in design of the landfill slopes, prediction of the settlements, possible infiltration of the leachate, pollution of the groundwater's etc. On the other side, artificially created elements of the solid waste landfills, such as occupied area with landfill body and surroundings facilities, landfill volume, height and other constructional elements, are factors that produce additional influences and changes in the elements of the natural environment.

In order to find a way to incorporate mutual influences of the natural environment and elements of the solid waste landfill, here, we will introduce the use of Interaction Matrix Method (IMM) in solid waste landfill engineering. This comes from the fact that geological, hydrogeological and geotechnical parameters can affect one another in processes of mechanical and hydrogeological interactions with the elements of solid waste landfills.

The methodology is based on the principles developed in Rock Engineering Systems (RES) firstly introduced by Hudson [1] and in the Hydrogeological Engineering Systems introduced by the authors [2].

The IMM is an approach which aims to identify the parameters relevant to a problem, and their possible interactions. The whole concept providing overall coherency in approaching engineering problems in Solid Waste Landfills, where the need to study the interactions has always been present. In fact, the interaction matrix method can be shortly explained as an intelligent method for solving of complex problems, using appropriate conceptual, mathematical, numerical or mechanical models.

The first step in analyses shall be preparing of conceptual matrices, that latter serves as a basis for defining of analytical solutions and defining of monitoring system (Fig.1).

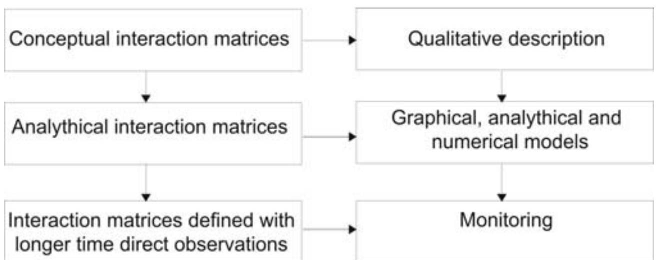


Fig. 1 Main steps in defining of IMM methodology starting from conceptual, analytical to matrices defined with direct observations during exploitation phase

The relevant 'state variables' must be chosen in a first place and they are placed along the leading diagonal of the interaction matrix. When resolving some problems, these variables have to be more conceptual in nature. An example of conceptual matrix consisted of four elements in a leading diagonal, applicable to the solid waste landfills is presented on Fig. 2. These factors are involved mutually, in 12 basic kinds of interaction, illustrated in a conceptual way presented in Table 1.

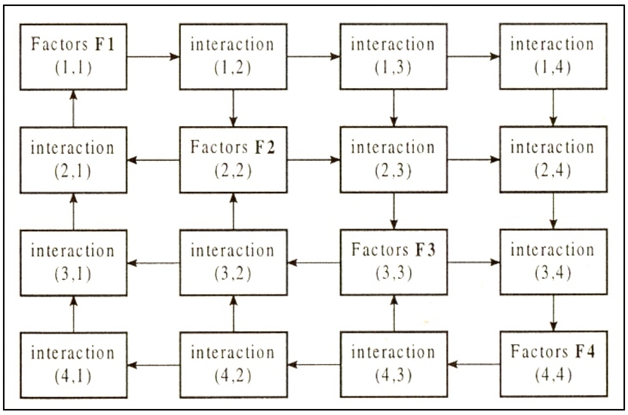


Fig. 2 Conceptual matrix of interaction between four basic factors which have influence on the interactions for Solid Waste Landfills: F1-Group of factors related to geological, tectonical and seismic characteristic of the geological environment; F2-Physical and mechanical properties of the foundation media for the landfill; F3-Groundwater condition; F4- Artificial created element of the Solid Waste Landfill.

Table 1 Illustration of mutual interactions between elements of the natural environments and elements of Solid Waste landfill

Interaction 1,2	Geological, lithological and tectonical composition has a direct influence on the physical and mechanical parameters of the foundation media.
Interaction 1,3	Geological, lithological and tectonical composition influences the filtration properties, groundwater movement velocity and so on.
Interaction 1,4	Geological parameters are the base for site selection and designing of the Solid Waste Landfill Elements.
Interaction 2,1	Physical and mechanical properties of the foundation media influences degree of compaction of sediments, opening of the joints and cracks in the field if unstable conditions are created and so on.
Interaction 2,3	Physical and mechanical properties of the foundation media influences the groundwater condition, pore water pressure, decreasing of the filtration in higher stressed zones and so on.
Interaction 2,4	Physical and mechanical properties of the foundation media are the basis for slope stability analyses and settlement calculations
Interaction 3,1	Groundwater condition influences the decreasing of the strength properties of sediments, increasing of porosity as a result of underground erosion and so on.
Interaction 3,2	Groundwater condition influences the decreasing of the total stress (concept of effective stresses).
Interaction 3,4	Water pressures, inflow of ground waters at a zone for landfill excavations, chemical interaction and has an influence for choosing of safety measures for protection.
Interaction 4,1	Solid Waste landfill elements influences the groundwater condition through changes in velocity movement's, possibility of creating critical hydraulic gradients, appearance of underground erosion and pollution of groundwater's and so on.
Interaction 4,2	Solid Waste Landfill elements influence the changes in situ stress, stress concentration and so on, which can lead to the changes in a physical and mechanical properties in a process of consolidation
Interaction 4,3	Solid Waste landfill elements influence the geological condition through compaction of the foundation basement, stability conditions of the geological environment etc.

Defined interactions in a qualitative manner are a good basis for complex analytical and numerical analyses, where the interactions can be defined with all necessary outputs (safety factors of landfill slopes, stress-strain conditions, stability of the surrounding geological media, groundwater pollution etc).

Keywords: Groundwater, natural environment, hydrogeology, interaction matrix method, solid waste landfill.

References:

1. Hudson, J. A.: Comprehensive Rock Engineering, 1992.
2. Jovanovski, M., Popovska C., Donevska, K., Peshevski I., Interaction Matrix Method in Hydrogeological Analyses at Coal Mines, 11th Symposium, WMHE, Ohrid, 2009.

Technological solutions providing for a clean reclamation of MSW landfills.

M.P. Fedorov, V.V. Korablev, V.I. Maslikov, A.N. Chusov (1), A.B. Weisberg (2) A.M. Gonopolsky (3)

(1) Saint Petersburg State Polytechnical University, Russia
(2) (OOO Mekhanobr, Russia), (3) (MSUIE, Russia)
(2,3) (E-mail: expert1@gpu.neva.ru)

The problem of municipal solid waste (MSW) disposal in Russia continues to be quite acute. More than 90% of 50 million tons MSW annually generated in Russia are disposed in dumps and landfills, whose area is over 40 thousand hectares of land.

Moreover, 1.000 ha of land is additionally expropriated per year for MSW landfilling. At present, about 1300 MSW landfills in Russia are under operation, of which only about 8% meet the health and environmental requirements . This creates a real danger for the environment and population. It is necessary to notice a great difference between the operated landfills by the set of parameters (capacity, area, etc.), as well as the difference in their condition. Creation of relatively cheap integrated environmentally friendly technology is actual, which allows at the lowest cost and with use of modern materials and equipment to ensure environmental safety operation, reclamation and return of territories of the landfills in the economic and recreational activities in accordance with environmental requirements.

We have developed technological solutions providing for the return of territories occupied by MSW landfills to reuse for economic and recreational purposes:

- a reliable multi-layer composite coating with the use of local cheap materials;
- technological lines and equipment for production of multilayer composite coating MSW landfills;
- suppression technology of methane generation to accelerate the process of mineralization of waste and transfer them to an inert state;
- integrated technology for improving gas production from MSW landfills by joint disposal of MSW and compost from waste treatment plants;
- technology of biogas purification in a wide range of components of its composition;
- power plant operating on landfill biogas;
- experimental- industrial technology of leachate deep cleaning including the reagent and electrochemical treatment;
- technological regulations for reclamation of MSW landfills.

In comparison with analogues the proposed technologies are cheaper while ensuring high reliability, allow the use of reused materials and are environmentally safe.

Identification of unsanitary landfills using GPS and determination of minimum factors for the risk assessment

Vujić Goran, Ubavin Dejan*, Milovanović Dušan, Stanisavljević Nemanja, Batinić Bojan

Department of Environment Engineering, Faculty of Technical Sciences', University of Novi Sad, Serbia *contact person: dejanubavin@uns.ac.rs

Decades of bad waste management practice and poor legislation in the field of waste management made a lot of damage to the environment in the Republic of Serbia. One of the most obvious implications of bad practice in the past is large number of small, unsanitary landfills, which are not suitable for waste disposal. Absence of almost all appropriate landfilling measures, such as covering of landfill, leachate and landfill gas collection, separation of hazardous from nonhazardous waste, raising the height of waste instead of expanding the landfill surface and others, resulted in unnecessary engagement of land and significant pollution caused by unsanitary landfills.

In order to create inventory of all landfills in the Republic of Serbia, research team of the Department of Environmental Engineering, Faculty of Technical Sciences, University of Novi Sad, used a GPS equipment to locate and store positions of all landfills within the project „Identification of landfills in the Republic of Serbia" which was conducted during the 2008. and 2009. and financed by Serbian Ministry of Environment and Spatial Planning. Besides position and location, many other attributes have been collected and obtained for each landfill, such as: area, average depth of waste, entering point to landfill, access road, distance from water bodies and other vulnerable objects, period of landfill exploitation, information about applied landfilling measures and others, for the purpose of environmental risk assessment. For project purpose, landfills are defined as places where waste was disposed for a certain time, regardless of size and amount of waste. More than 3500 landfill were located, including only 180 larger municipal landfills, owned and maintained by municipalities. All other landfills are small, unsanitary landfills placed on inadequate locations, and absolutely unsuitable for waste disposal. Research shown that almost every village, regardless of its size, has at least one unsanitary landfill and that total engagement of land in Serbia by municipal and unsanitary landfills is about 1300 ha. The research also pointed out on absence of applied landfill measures, even on larger municipal landfills. For purpose of processing and presentation of collected data and putting it in usable form for risk assessment, and for other use, several GIS based software tools were used. One of the most important project goals was to create landfill inventory which will be used in various projects, as a starting point for future planning. In accordance with that, collected data about landfills have already been used within several projects regarding remediation and closure of landfills, and for waste management planning projects in Serbia.

Keywords: waste management, landfill, location

Utilizing unusable space: Solar (Photovoltaic) installations on working landfills

A. Bodenhagen

Solar Integrated Technologies GmbH, Robert-Koch-Str. 50, 55129 Mainz
e-mail: abodenhagen@solarintegrated.eu

Energy supply is one of the major contributors in terms of CO2 generation and therefore heavily linked to the actual discussion about climate change. The extension of the use of regenerative energy sources like the sun is the way to stop the emissions from the electricity generation sector and to preserve the environment as well as the limited resources.

Energy from the sun can be produced through so called solar or photovoltaic systems. To realize systems with high power output installations on free areas unconnected to buildings are the best way. These are known as ground mounted systems. Adequate areas have are old airports, former military areas and renatured landfills.

After closure landfills are covered with a temporary cover until the final settlements are over and the gas emissions and leachate amounts are reduced to a minimum. There are few regulation for the temporary cover, prevalently soil covers are utilized. Because the soil cannot be made convection tight climate damaging landfill gas can emit, water can infiltrate the landfill and lead to continuous leachate emergence. The temporary cover is usually installed for 15 to 25 years. This period is called renaturing, after which the land is returned to the municipality. During this time the area cannot be used for any alternative purpose.
Photovoltaic systems are an attractive afteruse for the big surface areas of closed landfills that are in the renaturing process. The utilization enables an area recycling as well as climate saving power generation.
For different types of landfills (in size, shape, slope or orientation landfill) there are various approaches for covering the landfill with a watertight solar cover to turn it into a sustainable power plant. The Malagrotta landfill is used as a case study to introduce one of the possible solutions.
Case study
The Malagrotta landfill is Rome's largest landfill and is reaching its maximum capacity soon. Hence the owners as well as the operator increase their efforts on the one hand to recycle waste, particularly plastic and metal. The aim is to become one of the region's major electricity provider. While their projects to increase the exploitation of the landfill gas are already set up, they were also looking for a way to use the renaturing areas of the landfill for clean energy production. This led to the evaluation of photovoltaic systems.
While originally a fixed crystalline installation was considered, such system showed several problems compared to flexible thin film photovoltaic solutions.

If installed directly to the ground the risk of breakage of the modules was very high because of the still moving ground, which could lead to areas being shifted against each other. A substructure on the one hand would not have completely solved this problem and would not allow for a real integration into the landscape. Furthermore, a stiff substructure withstanding shifting within the landfill would have been very expensive and would have compromised on the economical viability of the system.

A flexible photovoltaic solution based on a roofing membrane as offered by Solar Integrated provided advantages in eliminating the need for a costly substructure, as it is able to adapt to the moving ground. Additionally the thin-film modules showed to produce approx.100 kWh/kWp more than crystalline silicon modules due to their better performance at high temperatures.

Figure 1. Malagrotta landfill

To realize the installation the landfill was filled with concrete, separated by splices packed with wooden beams to allow for controlled movement of the area and breakage of the concrete plate. Attaching the flexible PV membrane as is done on a roof inhibits air being able to penetrate from underneath and causing wind-uplift. Additionally this fixation method prevents theft of modules.

As no water coming from a landfill – even rainwater – may leave the landfill area, the concrete plates combined with the watertight roofing membrane serves and additional purpose, which is sealing of the ground and allowing for a controlled discharge of the water. Rainwater can also help to clean the PV system and is recollected at the bottom of the installation.

The Malagrotta landfill PV system consists of a nearly 1 MW PV installation covering a total area of 21.300 m² and produces approx. 1.421.000 kWh per year. It preserves the climate by avoiding an estimated 1257 tons of CO2 emission per year. And as the TPO roofing membrane and the constituent parts of the laminate can be recycled the environmental effect lasts even beyond the systems lifetime.
This project demonstrates that flexible solar systems can provide a solution for large area photovoltaic systems, thereby turning a previously unutilized area into a valuable revenue-generating asset.

Poster Session H - Landfilling in Transition and Developing Economies I

investigation of public's perception on solid waste problem in samsun, Turkey

Feza Geyikçi (1) , N. Gamze Turan(2), Semra Çoruh(3), Başak Mesci(4) & Osman Nuri Ergun(5)

(1) Department of Chemical Engineering, Engineering Faculty, Ondokuz Mayıs University
55139 Samsun, Turkey; Tel: +90 362 3121919/1011; Fax: +90 362 4576094; E-Mail: fezag@omu.edu.tr
(2)Department of Environmental Engineering, Engineering Faculty, Ondokuz Mayıs University
55139 Samsun, Turkey; Tel: +90 362 3121919/1329; Fax: +90 362 4576094; E-Mail: gturan@omu.edu.tr
(3) Department of Environmental Engineering, Engineering Faculty, Ondokuz Mayıs University, 55139 Samsun, Turkey;
Tel: +90 362 3121919/1329; Fax: +90 362 4576094; E-Mail: semcoruh@omu.edu.tr
(4) Department of Material Science and Engineering, Engineering Faculty, Ondokuz Mayıs University, 55139 Samsun, Turkey;
Tel: +90 362 3121919/1329; Fax: +90 362 4576094; E-Mail: semcoruh@omu.edu.tr
(5) Department of Environmental Engineering, Engineering Faculty, Ondokuz Mayıs University, 55139 Samsun, Turkey;
Tel: +90 362 3121919/1329; Fax: +90 362 4576094; E-Mail: onergun@omu.edu.tr

The progression of modern civilization and associated continuous increase in population worldwide contribute significantly to the increase in the quantity and variety of waste generated. The ever-increasing consumption of resources results in huge amounts of solid wastes from industrial and domestic activities, which pose significant threats to human health. Continuing advancement in science and technology is also, contributing significantly to the increasing volume and toxicity of waste generated.

In Turkey, as an economically developing country in which 68 million people are living with quite different socioeconomic and demographic features and dietary habits, industrialization, and standards of living have contributed to an increasing amount of solid waste and its consequent disposal problems. In developing countries, the problems of attempting to bring the municipal solid waste under control may appear almost insuperable. The works in the direction of more efficient collection and transportation and environmentally acceptable waste disposal continue in Turkey. Although strict regulations relating to a solid waste management, primitive disposal methods such as open dumping and discharge into the surface water have been applied in various parts of Turkey. The responsible authorities for solid waste management in Turkey are the Ministries of Environment, Industry and Trade, Interior Affairs, Public Works and Settlement; municipalities; the chambers of trade and industry; and the Turkish Statistical Institute. Turkish Statistical Institute has been collecting data on waste by applying annual surveys to industrial establishments and municipalities. The amount of solid waste collected in 2004 was 25 014 000 tonnes/year whereas, the amount of solid waste disposed to sanitary landfill, composted and incinerated were 7 002 000, 351 000 and 8000 tonnes /year, respectively. These figures clearly show that 17 653 000 tonnes/year of waste was disposed without any control.

Samsun is a city in northern Turkey, on the coast of the Black Sea, with a population of 725,111 as of 2007. It is the capital city of Samsun Province and an important port. Based on case studies in Samsun, it identifies three themes behind this opposition: threats to quality of life, potentially harmful economic impacts, and frustration over representational issues in the process involved in selecting the proposed solid waste facility.

These concerns mirror much of the literature on public opposition to landfill and other facilities which pose similar to the environment and public health.

A growing literature suggest that citizen interests and concerns do not correspond to the technological world view of "environmental professional" that is reflected in how public participation is structured. Similar problems have been encountered by risk communicators, who find that citizens often do not respond "appropriately" to risk messages. Public participation in solid waste management is mandated by the local governments. Sustainable development is of great significance in solid waste management of Turkey, which is under coupled pressures of poverty reduction; environmental investigation of public's perception towards sustainable development.

The aim of the study is to present an overview of public's perception on solid waste management in Samsun, Turkey. The legally established municipal responsibility and management structure in Turkey is also presented.

Practical experience of a Pioneer in CEE-Countries

Mag. Sabine Kitz (1) and DI Erich Padaurek (2)

.A.S.A. International Environmental Services GmbH, Austria (sabine.kitz@asa.at)

.A.S.A. is an international waste management group with business activities in 9 Countries in Central and Eastern Europe (Austria, Czech Republic, Slovakia, Poland, Hungary, Lithuania, Romania, Bulgaria and Serbia). .A.S.A. Group has more than 4.300 employees, thereof only 600 are employed in Austria and the majority in CEE. The annual turnover of .A.S.A. Group exceeds 300 Mill €, whereof nearly 70% were achieved outside of Austria. .A.S.A. is covering all kind of waste management activities and services, starting with collection & transport, treatment and disposal of waste. Currently .A.S.A. is operating 23 waste management centres/ landfills in 7 European Countries, all in accordance with the Environmental Standards of the European Union.

.A.S.A. is a pioneer in realization of landfill projects in CEE-Countries. When entering into a new Country, especially in the Balkan region (for example Serbia, Macedonia or Bosnia), the situation of the local waste management system is in most cases unsatisfactory for everybody:

- Most of the existing landfills for disposal of waste don't correspond to any environmental standard. They are wild and illegal, neither equipped with bottom sealing foil, nor with a system for leachate water collection and treatment. They are heavily polluting the underground as well as water and air.
- The landfills are not operated in a proper way, they are burning and stinking, there is no separate collection of waste existing.
- In most cases all kind of hazardous and toxic waste from industry and hospitals as well as dead animal-bodies are disposed at those landfills.
- Nevertheless in many cases people pay reasonable tariffs for a bad waste service.

Facing such a situation, an environmental safe landfill is always the first and affordable step for a city/ municipality/ region to improve its waste management system in order to stop the pollution of the environment. Further measures for improvement of the existing waste management system are cost-intensive and have to be paid by the population at the end. All other state of the art treatment technologies used in Western European Countries as incineration or mechanical biological treatment are very often not applicable for such Countries, as they have to start from zero level to modernize and adjust their system to the strict environmental standards of EU.

Measures for the improvement of the waste management system have to be implemented in a step-by-step procedure (.A.S.A.-sandwich-approach) accompanied by measures for raising the environmental awareness of the population (e.g. training in kindergartens and schools).

Examples for .A.S.A.-references of first EU-conform landfills in CEE-Countries:

1 Waste Management Centre Dablice (Czech Republic), established 1991 but until today the waste management solution for the City of Prague.
2 Waste Management Centre in Arad (Romania), established 2003. This project was awarded with the Austrian ÖGUT-Umweltpreis 2006.
3 Waste Management Centre Kikinda (Serbia), established in 2008. First landfill in Serbia corresponding to the environmental standards of the EU.

According to the experience of .A.S.A. during the last 20 years in developing and realizing landfill projects in CEE-Countries, there is still a huge need for sanitary landfills especially in the Balkan region. Many Countries in Europe (but of course also outside of Europe) didn't implement an efficient and environmental-friendly waste management system until now. Those Countries must find a solution for their problems, a solution protecting the environment, affordable for the population and convincing the local decision makers. Our generation has a huge responsibility towards the next generations by handing over a sound and clean environment to our children and their descendants. According to our experience as pioneer in CEE-Countries an environmental safe landfill will remain the most important first step in this part of Europe for the next 20 years.

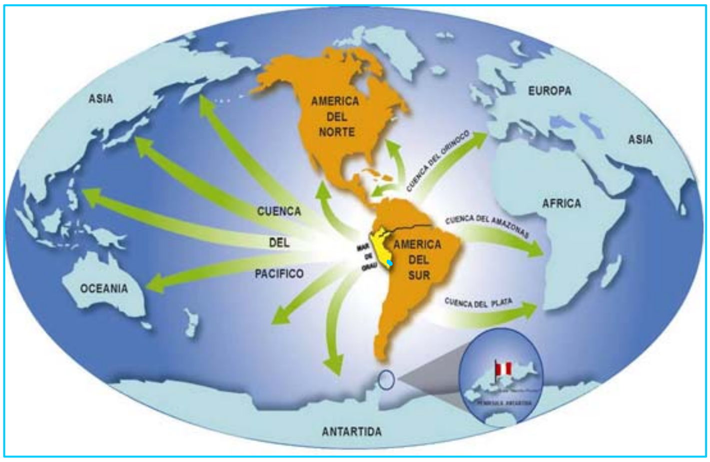
The peruvian sea and the necessity of a sustainable disposal of waste

Gladys Carrion (1). Jorge Gutierrez.(2)

(1) Universidad Nacional Agraria la Molina. Lima, Peru, gcc@lamolina.edu.pe

(2) Marina Guerra del Peru, UNALM, Lima, Peru

The Peruvian sea is one of the richest in diversity of flora and fauna in the world due to its high content of nutrients. Physical and chemical factors like appropriate sunlight (photosynthesis process), temperature, dynamic ocean currents, salinity, water density (buoyancy of plancton) favour its richness (Fig. 1). However the rising marine pollution has been reducing its richness significantly in the last decades.



The main sources of marine pollution come from land and sea. Land contamination is generated by domestic waste, industrial waste, petroleum hydrocarbons and chlorine hydrocarbons, which are poured directly into the sea without any treatment or insufficient primary treatment.

Figure 1. Peruvian sea

Large charges of pollution comes from industrial residues like chemical industries (38%), food and drinks industries (32%), fisheries and mining. Lima and Callao cities receive 93% of discharges of polluted water.
In 2000 there was made an inventory of solid waste dumped in the sea (Rada internal of the Marina de Guerra del Peru) reporting about 1968 m3 of solid waste from January to December.

Another important pollution source takes place in Chimbote Bay.
Figure 2 and Table 1 show an estimated report of oily contamination from national and foreigners ships (far-reaching foreign vessels).

Table 1. Generation of oily waste from ships at Chimbote Bay

Ship No.	Characteristics	Waste Hydrocarbons gal/year/ship	Waste Hydrocarbons gal/crossing/ship	Waste Hydrocarbons gal/year
300	foreign ships		5000	1.500.000
400	medium-sized	330		132
60	medium-sized	3600		216
100	handmade	3900		390
Total				**2.238.000**

Figure 2. Oily contamination

A proposal for a sustainable disposal of waste from boats that arrive to Peruvian ports must include the items shown in **Figures 3** and **4**:

a) Presence of a boat transporting piles of waste from the ship towards a transfer plant.

b) Transfer plant (dry dock) in which different types of waste should be classified and separated.

c) Sanitary landfill where piles of waste should be stored.

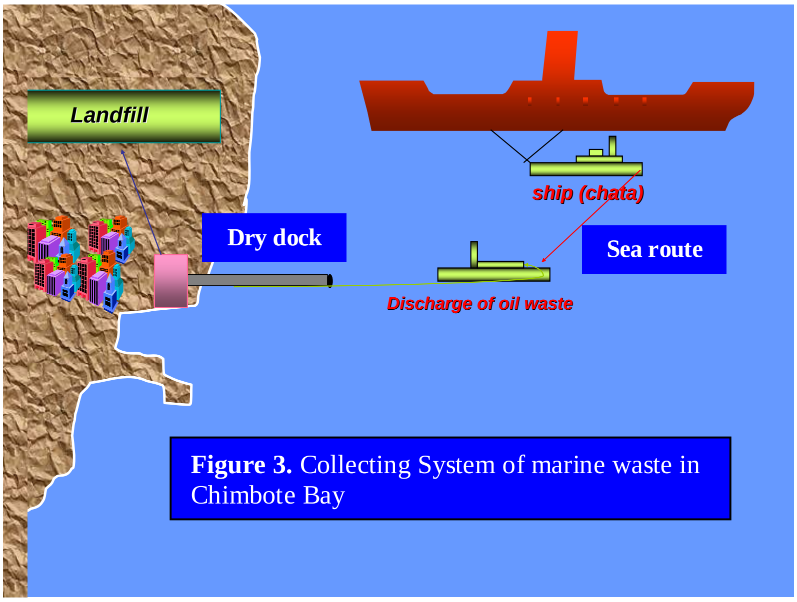


Figure 3. Collecting System of marine waste in Chimbote Bay

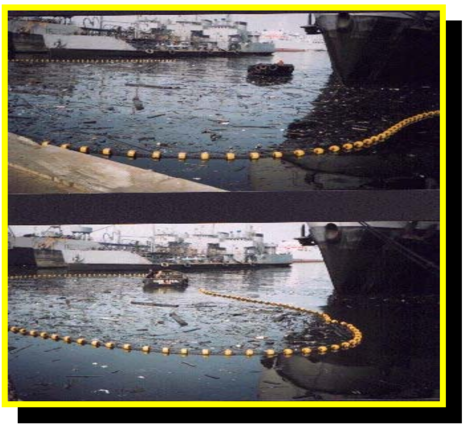


Figure. 4. Clearing the sea

From Sanitary to Sustainable landfilling: Construction and Operational experience of Dhaka City Corporation, Bangladesh

Tariq Bin Yousuf

(1) Dr, Project Director, Landfill Improvement Project, Waste Management Department, Dhaka City Corporation (tby@bangla.net)

Dhaka City Corporation (DCC) inaugurated the first ever sanitary landfill in Bangladesh at Matuail in October 2007. A dump site was transformed into a sanitary landfill. This was a very tough job and DCC succeeded very nicely. Now DCC is doing the tougher and the challenging task; operating the landfill as a sanitary landfill. Matuail Landfill never sleeps! It is operated 24 hours a day in 3 shifts. It receives around 1,200 tons per day, arriving at both daytime and nighttime. Over 350 truck trips arrive to the landfill in one day. The truck enters through the LF gate and proceeds to the weighbridge. A weighbridge operator inputs the truck weight and arrival times into the PC. The truck then proceeds to the waste dumping areas using access roads built on the waste disposal areas. A waste instructor instructs the truck where to unload its waste. Three types of heavy equipments are used in Matuail Landfill; excavator to unload the trucks, tyre dozer to push the waste away from the platform & feed the bull dozers and bull dozers to spread & compact the dumped wastes which are operated 24 hours as required. Now the empty truck descends from the waste disposal area, and goes to the vehicle washing bays where the tires and body are sprayed by water. The truck then leaves the site.
Leachate is generated as rain falls on the disposed wastes and rain water percolates through the waste. Also the moisture in the waste trickles down forming the leachate. Perforated pipes have been laid below the waste layers to collect the leachate into two large ponds. There the leachate pond operator operates blowers and the leachate is aerated and then re-circulated back into the waste layers. No leachate is allowed to leave the site. The landfill is designed as semi-aerobic and perforated gas vent pipes are installed at 50m interval. With the increasing height of the waste piles; the gas vent pipes are vertically extended.
For sanitary landfill operation two types of soil covers are used; daily soil cover and final soil cover. Daily soil cover has to be applied after each day dumping operation and final soil cover to be applied on the places where dumping operation will not be carried further. Environmental monitoring of ground water, surface water, leachate and gases are done at regular interval.

The specific objectives are as follows:

(1) To transform the existing dump site into a sanitary landfill and to reduce the environmental pollution generated from the disposal activities.
(2) To improve the control and operational practice of landfilling through provision of sufficient facilities and equipments
(3) Improve the working conditions at the site including safety
(4) Improve the aesthetics of the landfill site through pleasant landscaping including plantation and turfing.

Methodology:

(1) Design and construction/installation of administrative/operational facilities
(2) Establishment of side slope of waste dump
(3) Installation of leachate collection and landfill gas vent system
(4) Construction of boundary storm water drainage system
(5) Establishment of semi-aerobic system of solid waste stabilization
(6) Excavation of old wastes for use as cover materials

Results:

a) Waste management system and operational conditions of the landfill have tremendously improved due to the construction of control building, weighbridges, car wash pool, water supply and sanitation facilities, working road and platform, lighting facilities for night time operation and installation of monitoring and recording facilities.
b) Environmental conditions have been greatly improved due to the construction of leachate collection, gas venting system and surface drainage.
c) Leachate accumulation and drainage congestion have been eliminated.
d) Odour, fire hazard and fly breeding have been reduced.
e) Quality of surface water around the landfill site has significantly improved.
f) Aesthetic condition of the site has been drastically improved due to the waste slope reformation (1:3), landscaping, grass turfing and plantation.
g) The service life of the existing dump site has been greatly extended by the proposed multi-stage landfill system (total height 20 m). This type of land-saving project is very much needed as land is extremely scare and costly in and around Dhaka City.

Significance:

a) Optimum utilization of existing landfill site in order to avoid difficulties in finding new site for landfill.
b) Low cost technologies and locally available materials are to be used for development of the landfill facilities for ensuring sustainability of the development works.
c) Consultation with the field level officials and workers to include their reasonable ideas and suggestions in planning, design and operation of landfill facilities.
d) Expert guidance by local consultants and close supervision by engineers are essential to solve the peculiar local problems and challenges confronted during implementation of the project.
e) Consultation with the local people to accommodate their pragmatic views into the project.
f) A dedicated Landfill Management Unit is essential for smooth operation of the landfill. Regular training of the landfill staff to enhance their skill is essential for proper management of the landfill site.
g) Daily operational records/reporting system and routine monitoring of environmental parameters (leachate, gas, surface and ground water) is key to maintain the landfill standard.

<u>Key words:</u> Dump site rehabilitation, semi-aerobic landfill, leachate and gas management, Matuail landfill, Clean Dhaka Master Plan

The Role of Landfill within Urban Solid Waste Management in Rapidly Growing Cities: The Case Study

Nükhet Günbeyaz (1), N. Gamze Turan (2)

(1) Ondokuz Mayıs University, Engineering Faculty, Dept. of Geodesy and Photogrammetry Engineering, 55139 Samsun, Turkey; Tel: +90 362 3121919/1078; Fax: +90 362 4576094; (nukhetg@omu.edu.tr)
(2) Ondokuz Mayıs University, Engineering Faculty, Dept. of Environmental Engineering, 55139 Samsun, Turkey; Tel: +90 362 3121919/1329; Fax: +90 362 4576094; (gturan@omu.edu.tr)

Increased urbanization is a global problem and a form of environmental change that impacts directly on the day-to-day lives of people. Most people are not aware that the overwhelming majority of the urban growth in the world today (over 95%) is taking place in developing countries, also referred to as less developed countries. Since 1950 the population living in developing world cities has increased fifteen fold. Nearly half the world's population now lives in urban settlements. Cities play a vital role in the social fabric of countries and in national and regional economies worldwide. Cities offer the lure of better employment, education, health care, and culture; and they contribute disproportionately to national economies.

National income and level of human development are strongly and positively correlated with level of urbanization. However, rapid and unplanned urban growth is often associated with poverty, environmental degradation and population demands that outstrip service capacity. Substandard housing on marginal land, crowding, increasing levels of air pollution, water pollution and over usage, inadequate sanitation services, motor vehicle traffic are all associated with rapid growth of urban centers. Solid waste management is one of the other important problems in rapidly growing cities.

Open dumping is the most common method of disposal of solid waste all over the rapidly growing cities and this cause a potential pollution problem for environment and human health. As well as municipal solid waste, commercial, industrial and medical wastes, which may contain hazardous substances, such as heavy metals, organic solvents, radioactive wastes etc. are also received by dumping areas in these cities.

Turkey is a developing country in which 68 million people are living with quite different socioeconomic and demographic features and dietary habits. One of the major challenges for Turkey is planning for population growth. Turkey has been affected by urbanization like other developing countries. Currently, over 45% of Turkey population lives in urban areas and the annual population growth rate are around 2.4% $year^{-1}$in urban areas compared around 1.7% $year^{-1}$in non-urban areas. Cities with already inadequate infrastructure facilities have to face congested population problems coupled with illegal settlements due to migration from the small settlement units to the large metropolises.

Samsun is the 14th largest province of Turkey with 1,209,137 in habitants, according to the 2000 census. Of theese population, 635,254 in habitans live in the urban areas. Samsun has experienced and unusual urbanization, due to recent in-migration from the rural areas. Samsun has faced a high urbanization rate of 55, almost half of whom live in poor conditions. Samsun is the largest city in the Black Sea region. Samsun is the most appropriate productive place for the new investments when its geographical, strategic position and infrastructure considered. The city of Samsun has experienced rapid urbanization, which has generated urban problem, especially solid waste management, seeming unsolvable in the current institutional context.

The specific aims of the paper are: (i) to investigate the recent patterns and trends solid waste management in Samsun, Turkey, (ii) to relate solid waste management with urbanization, and (iii) to identify the role of landfill within urban solid waste management. This paper, adopting a problem-based approach, also identifies practical alternatives, solutions and opportunities for sustainable solid waste management.

Requirements for the Closure of Open Dumping Areas-Towards Sustainable Landfilling

Nurdan Aycan (1), N. Gamze Turan (2)

(1) Ondokuz Mayıs University, Natural Science Institute, Dept. of Environmental Engineering, 55139 Samsun, Turkey; Tel: +90 362 3121919/1078; Fax: +90 362 4576094; (nurdan.aycan@oposta.omu.edu.tr)
(2) Ondokuz Mayıs University, Engineering Faculty, Dept. of Environmental Engineering, 55139 Samsun, Turkey; Tel: +90 362 3121919/1329; Fax: +90 362 4576094; (gturan@omu.edu.tr)

The term “open dump” is used to characterize a land disposal site where the indiscriminate deposit of solid waste takes place with either no, or at best very limited measures to control the operation and to protect the surrounding environment. In the past, when waste streams were simple and land constraint was not a challenge, open dumping was used as an inexpensive and often appropriate solution. It served the purpose of keeping waste separated from the populace, hence limiting exposure to disease vectors, as well as odour and other direct effects. However, the introduction of more and more complex products into the waste stream, increasing urbanisation and population growth have all resulted in a huge increase in the impacts of open dumps in many situations.

The most commonly used method of waste management in economically developing countries has been and still is the deposition of waste in open dumps. From today’s point of view the use of open dumps is not in line with the increasing public awareness of environmental issues and the demand for environmental improvement, including the current focus on sustainability and global climate change. Closing, or alternatively upgrading, open dumps is therefore a key issue for many communities, particularly in developing countries. Such upgrading is an essential step in reducing future environmental impacts and impacts on public health, as well as avoiding future costs caused by the ongoing waste disposal mismanagement evident at open dumps.

The concept “sustainability” was introduced in Rio de Janeiro Conference in 1992 and after that has been received world-wide acceptance. According to the World Commission on environment and Development, sustainable development is “development that meets the needs of the present without compromising the ability of future generations to meet their own needs”. Applied to waste disposal policy it means that the waste stabilisation should be achieved within one generation.

The overall objective of this paper is to provide a framework of issues that need to be adressed in progressively reducing open dumping where this is stil practiced, and to find solutions for minimising the environmental impacts of open landfilling areas.

Use in agriculture of sewage sludge from wastewater treatment plant of Puente Piedra, City of Lima, Peru.

J. Francisco (1) and P. Ramos (2)

(1) Faculty of Chemical Engineering, Universidad Nacional del Callao, Perú (email: jennyfra042004@gmail.com), (2) Organización para el Desarrollo Sostenible – ODS, Perú (email: pedroramo@gmail.com)

Different tests were performed at level of greenhouse to determine, with agricultural purposes, the use of the sewage sludge proceeding from wastewater treatment plant of Puente Piedra, City of Lima, Peru. The experimental stage was developed at the Soil Fertility Greenhouse Station of the Faculty of Agronomy of the Universidad Nacional Agraria La Molina (National Agrarian University of La Molina), in Lima, between January 2007 and January 2008.

The present research has the following objectives: i) To determine the characterization of the sewage sludge proceeding from wastewater treatment plant of Puente Piedra, City of Lima, and ii) To formulate the composition of a type of fertilizer using the sewage sludge proceeding from treatment plant.

For the preliminary analysis of the metals Hg, Pb, Cd, Cr and As of the sewage sludge proceeding from the wastewater treatment plant (WWTP), there were applied the means analysis and the standard deviation of the descriptive statistics. It was used in this stage the SAS v.8 statistical package.

In the case of the fertility tests of the sewage sludge, the corn (*Zea mays* L.) was used as indicator plant, for which different agronomic variables were evaluated. The experimental design used was completely randomized design (CRD) and they were evaluated as agronomic variables of the corn: the height, thickness and dry weight of the plant. The agronomic variables were evaluated through the analysis of variance (ANOVA) and the comparison test of Tukey.

The preliminary analysis result of the pH, electrical conductivity (E.C.) and of metals in the sewage sludge, showed values below the allowed ones according to the methods of the standards for the WWTP's sewage sludge use and disposal of the US Environmental Protection Agency (EPA-US), Part 503 Rule; determining an initial characterization suitable for their use.

Two fertilization tests were established. In the Test No. 1, the following doses were reformulated: 0 (pure control), 2, 4, 6, 8 and 10% of dry sewage sludge in the mixture of sewage sludge and sand and a control with inorganic fertilizer or NPK (Nitrate, Phosphorus and Potassium). The most significant results of the morphologic variables evaluated, were achieved by the mixture of dry sewage sludge and sand at very low rates of concentration, 2%, 4% and inclusive 6%.

While, for the Test No. 2, the sewage sludge was composted by garden weeds before its use, in an approximate period of 8 months in an aerobic environment. The doses of application were: 0 (pure control), 25, 50, 75 and 100% of the mixture of composted sewage sludge - sand. The most significant results of the agronomic variables were given in the dose of 100%.

As for heavy metals in the soil before and after the fertilization, the results showed presence in quantities within the established ranges, indicating that there would not be risk of toxicity, except for the chrome in the mixture of composted sewage sludge and sand (Test No. 2), that showed as result slightly higher ranges than the established normal ones.

It was concluded that the composted sewage sludge presents the best conditions to be used as amendment or enhancer for the soil, though it dragged metals in a larger quantity than the dry sewage sludge.

This research is the first one performed in sewage sludges proceeding from an activated sludges domestic wastewater treatment plant in Peru, specifically through the Sequencing Batch Reactor (SBR) system.

Unknowledge, origin of conflicts: Case lindfill of Huancayo City

M. Mucha Torre

La Molina University, Perú, cemtrar@lamolina.edu.pe

Huancayo is a city located in the Peruvian highlands over 3200 meters from the sea in to the Mantaro´s valley, eastern from Lima, with 336 000 inhabitants of population. As a big city, the solid waste generated from the population become in an environmental problem, when a city have not a landfill with appropriate technical specifications, that is the case of this city which for years used the border of the Mantaro river as an provisional landfill.

In Peru the solid waste production for each person per day is 0.75 kg in average. With this information, Huancayo city generate close to 235 TM Solid waste per day which the major part of them are destinated to the provisional landfill and small quantities are burned or located in free land near the homes of the population in rural areas specifically.

The local authorities knew the problematic of the city, they prepared an ambitious project to install a modern landfill for the city of Huancayo and the locations of this infrastructure was selected near the town called San Jeronimo; this village is located within the Mantaro´s Valley northern to Huancayo, and its main economic activity in agriculture.

In September 2008, the population of San Jerónimo protested against the decision to install the landfill in their area, because they did not have appropriate information on the operation of the new landfill, and they said that this landfill would have negative impacts as rodents (rats) that can affect the crops, and it will generate bad odors and toxic gases from human burning waste; and this could pollute surface and groundwater.

Authorities made the mistake of not timely and properly inform environmental studies into the population to get the acceptance of the population to build this landfill, and other mistake was selecting a location within the valley by the authorities, they had to locate the landfill outside the Mantaro´s Valley.

The protest, which lasted more than 10 days, finished in death and injured people, economic loss, roads blocked and finally the construction of the landfill was suspended, hoping to the authorities to take another decision on the new location of the landfill. Meanwhile, Huancayo once again is using the bank of Mantaro River as temporary landfill.

The solution to the problem would be to build the landfill in another area outside of the valley because these events could be repeated in the different towns because nearly the whole valley is an agricultural area.

Landfilling of produced spent pot liner in aluminum industries: proposed method in developing countries

M. Jalili Ghazizade (1) and E. Safari (2)

(1) Ph.D. Student of Environmental Engineering, Graduate Faculty of Environment, University of Tehran, Tehran, Iran; (Corresponding Author), (mjalili@ut.ac.ir)
(2) Ph.D. Environmental Engineering, Associate Research Director, Department of Civil Engineering, Queen's University, Kingston, Ontario, Canada; (edwin.safari@ce.queensu.ca)

As the world's capacity for aluminum production increases, the amount of waste connected with this industry is also increasing. Spent pot liner (SPL) is a one of the most important solid waste generated by the aluminum industry during the manufacture of aluminum metal in electrolytic cells. Initially the electrolytic cell liners comprise of graphite and carbonaceous materials, but after several years of operation, the liner materials deteriorate and must be removed from the cells. Because of the presence of fluoride and cyanide in the SPL, the US Environmental Protection Agency (USEPA) has listed the materials as a hazardous waste. The purpose of this work was to manage produced SPL in Almahdi aluminum plant located at Bandarabbas, Hormozgan, Iran. Approximately 1000 t of SPL wastes are generated annually from activities associated with this plant. In order for an SPL management method to achieve widespread acceptance (especially in developing countries), it needs to have a low cost and simple technology as well as minimum adverse effects on environment.

For this purpose at first the extent of leachable cyanide and fluoride compounds were characterized as well heavy metals (As, V, Cd, Co, Cr, Li, Mn, Ni, Pb and Zn). Laboratory tests showed an average pH values for the SPL inorganic fraction of 10.2. Fluoride and cyanide content of the solid samples when leached at a pH of 5, was 1 and 0.028 mg/l respectively. Also total and leachable measured heavy metal content was a high concentration as compared to effluent discharge standards (based on Iranian National Environmental Regulations). Then according to this characterization and based on Basel convection and EPA definition, SPL classification was carried out.

In second step, different management methods were evaluated based on economic, technical and environmental aspects. These methods can be classified to four categories: Recovery of fluoride, cyanide and carbon from spent pot lining; immobilizing by using cement-based systems for stabilization and solidification of spent pot liner inorganic fraction, incineration; and sanitary landfilling. Results reveal that regarding to readily available facilities (shortage of equipments and skill-labors), sanitary landfill is the best methods for SPL management. Since in a landfill, barrier system is the most important element for preventing leachate leakage to environment, so by using IWEM model a lining system was designed (for installing in bottom of the landfill) in order to minimize adverse effects of toxic compounds on groundwater.

Keywords: Landfill, Spent Pot Liner, Cyanide, Fluoride, Solid Waste.

Landfilling of municipal solid waste in Amasya, Turkey

Hümeyra Özen & Semra Çoruh

Department of Environmental Engineering, Ondokuz Mayıs University, 55139 Samsun, Turkey
e-mails: humeyraozen@gmail.com; semcoruh@omu.edu.tr, fax: +90 0362 457 60 35

In the last two decades, Municipal Solid Waste (MSW) Management became a major concern and is presently one of the main publich subjects under discussion. This is probably due to the considerable increase of MSW production in both absolute and per capita values. In Turkey, an economically developing country, industrialization and increased standards of living have contributed to an increasing amount of solid waste and its consequent disposal problems.

Amasya since the early 2000s, from occurring in population growth and urbanization rates depending on the quantity and diversity of solid waste in terms of increased adverse effects to the nature of a significant environmental problem, the removal of local authorities is one of the most important environmental problem has become. In Amasya City, solid wastes are collected by the Municipal Cleansing Department by a fleet of 14 vehicles, twice a day. Municipal solid waste generated from the Amasya City is disposed on a dumpsite located in Seyh Cui place in 4 km distance of the city centre. The waste disposed at the site is levelled by a dozer and covered by soil. As irregular storage of solid waste, waste management covering all areas, rather than an effective management plan be considered at the level of municipalities solution becomes impossible. The study presents the MSW responsibility and management structure together with the present situation of generation, composition, recycling,and treatment.

Key words: solid waste, composition, landfill

Recovery of areas for MSW disposal

Galiya Armisheva, Vladimir Korotaev, Natalya Slyusar

Institute for Environmental Protection, Perm State Technical University, Russian Federation (slyusar@eco.pstu.ac.ru)

Till now disposal of municipal solid waste is an integral and important part of waste management systems in Russian Federation. Urban areas are surrounded by landfills and dumps. Meanwhile it becomes more and more difficult to find new places for landfills; costs for landfill aftercare are significant; the resource potential of waste disposal areas is not used. Rational use of areas, which are occupied by landfill, becomes a problem that demands urgent solutions. It is extremely necessary to reduce consumption of land resources by reuse of MSW disposal areas recovery. At the moment such experience in Russia is absent.

The purpose of the investigation is to work out the technology of waste disposal areas recovery, which allows increasing landfill life cycle, receiving secondary material resources, saving land resources and providing environmental safety of disposal objects.

To achieve this purpose the following tasks were solved: to analyze the structure and properties of landfill body during different stages of life cycle; to estimate the resource potential of landfill body and the possibility of using of landfill body material; to develop the process flowsheet for recirculation of MSW disposal area.

As a result of investigation, carried out on landfills and dumps of Perm Region (RF) the following data were obtained: landfill body material, being a mix of MSW decomposition products and soil, consists of remains of MSW components and unsorted friable materials with low organic carbon content and high mineralization.

According to physical-mechanical, physical-chemical and microbiological properties landfill body materials and soils from urban area of Perm region are similar. It allows considering landfill body material like a mix of technical soil and ballast fractions. Thus, processes in landfill body lead to foundation of renewable recourse such as technical soil.

The technical soil can be used on landfill and disturbed areas as a recultivation material for soil and landscapes recovery, industrial sites improvement and gardening.

The analysis of changes in weight of biodegradable components in MSW permits to estimate weight loss of biodegradable components. The weight loss accounts for 75 % on the assumption of full biodegradation. The analysis of volume changes for the some landfills and dumps of Perm region made it possible to estimate that the volume of landfill body decreases to 45-61 % for 20 years.

The developed process flowsheet for recirculation of MSW disposal area allows using landfill areas many times and save the territory for the building of new landfills.

organized by

Vienna University of Technology & Helsinki University of Technology, Lahti Center

sponsored by

ww.iwa.tuwien.ac.at/landfill-conference