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EVALUATION OF SOME GREENHOUSE GASES EMISSIONS FROM LANDFILL MODELS OF MUNICIPAL SOLID WASTE

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Abstract. Major greenhouse gases emissions (GHGs) that cause diseases and global warming evaporate from waste disposal in landfills. For this reason waste management skills in landfills have to be revised, otherwise the magnitude of ozone layer will decrease even more and the global warming consequences will get more obviously on the environmental scale. The resent situation on waste disposal and GHGs from European Union landfills were analyzed in this article. According to survey made in one Lithuanian landfill, the average amount of municipal biodegradable waste is 58%. The research study describes current GHGs emissions quantitative analysis from five laboratory scale municipal solid waste landfill models with different conditions. Conditions in all columns were differed by changing the inlet and outlet flows of air, water/leachate, and probiotics. The object of research is the accumulation of hydrogen sulfide (H_2S) and oxygen (O_2) from municipal solid waste landfill models. After analysis and assessment of emitted GHG's from the municipal solid waste landfill models, the landfill model with the lowest emissions was identified. Suitable landfill model's condition parameters helps to reduce greenhouse gas emissions and shorten landfill aftercare period.

Keywords: hydrogen sulfide, greenhouse emissions, municipal solid waste, biodegradable waste, landfill models.

Introduction

Unsorted or untreated municipal solid waste (MSW) landfills have an influence on forcing air quality rates down to low levels. By the year 2025 European Union has aim to phase out landfilling recyclable (glass, paper, plastics, metals and biodegradable waste) waste in municipal landfills to a maximum 25% landfilling rate. For this reason in 2030 European Union has the aim to increase MSW recycling and re-use to 70%. Low income countries like Lithuania is not an exception. According to country's national greenhouse gas inventory report MSW landfill's surface nowadays mainly releases greenhouse gases like CH_4 CO_2, H_2S and etc. Nevertheless, in such countries around 54% of biodegradable waste are flowing into the landfill. The aim of the research study was to evaluate emissions of oxygen and hydrogen sulfide from five landfill models of municipal solid waste (Pichtel, 2005).

1. Description of MSW

In order to identify influencing emissions from non-hazardous MSW treatment, waste composition has to be analysed. Each waste type can be very specific and contain different quantity of degradable organic carbon and fossil carbon. Generated waste composition very depends on countries and regions. Shortly MSW includes (Sharma et al., 2006): household waste; garden, park waste; commercial/institutional waste.

For the diversity of waste sources, solid waste are called municipal waste (Table 1). Solid waste are generated by households, offices, shops, markets, restaurants, public institutions, industrial plants, water treatment and sewage facilities, construction and demolition sites, and agricultural activities (Sharma et al., 2006). The definition has to be legally strict, because waste has financial implications for business and local authorities. It is also important for national and regional waste management planning and treatment strategy.

Waste generation covers those activities in which materials are identified as no value material and thrown away or gathered together for disposal. It is very important that every identification step would be noticed and waste would be measured individually. Cleaner production studies are one of the main subjects that can help industries to control waste generation (Pichtel, 2005).

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Table 1. MSW generation as a function of source (Pichtel, 2005)

Sources	Typical waste types
Residential (single and multi-family homes)	Food scraps, food packaging, cans, bottles, newspapers, clothing, yard waste
Commercial (office buildings, retail companies, restaurants)	Office paper, yard wastes, paper napkins, yard waste, wood pallets
Institutional (schools, hospitals, prisons)	Office paper, restaurant waste, restroom wastes
Industrial (packaging and administrative; not waste from the process)	Office paper, wood pallets, cafeteria wastes
Municipal (durable, non-durable goods, containers and packaging, food and yard wastes)	Litter, abandoned automobiles, some construction and demolition debris

When waste source and characteristics data a known, it is easier to collect information for reporting and administrative systems. General composition is classified because of definition that is used for landfilling and incineration taxes (Table 2). Classification avoids disagreements between companies and individual consumers. Regulations and policy can be an effective tool for waste classification control in the landfills (Williams, 2005). MSW is important issue, because it comes from a responsibility of public and business sector. Mainly waste management help European countries to classify variety of MSW structure. Although problems of different waste data account between countries may appear. When countries include other type of waste to their general MSW composition management, then statistic data of MSW cannot be compared between countries. For this reason countries have to compliance Waste Framework Directive (European Environment Agency, 2013).

Organic and inorganic wastes have different chemical composition. According to 2014 survey made in one Lithuanian landfill (Figure 1), the average amount of municipal biodegradable waste is 58%. Biodegradable waste is the main environmental threat for its natural production of greenhouse gases like CH_4, CO_2, H_2S. By the year 2025 European Union has an aim to reduce food waste generation by 30% (European Commission, 2014).

Organic wastes can also be called biodegradable waste, where terms means – waste that is capable of undergoing anaerobic or aerobic decomposition, such as food and garden waste, and paper and paperboard (European Commission, 2014).

According to European Environment Agency’s review of achievements in managing European MSW made in 2013, MSW landfilling still has high operational rate in different countries. In a period of 10 years, there are countries that decreased landfilling rate from 10% to 20%.

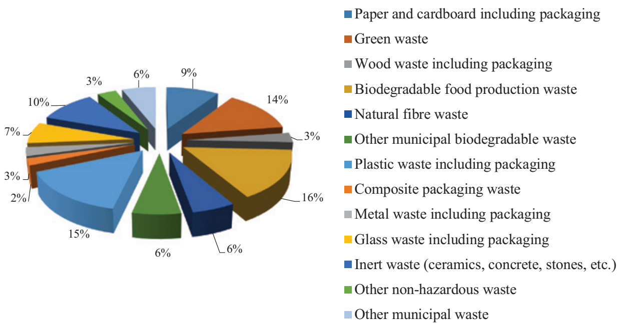

Figure 1. Most common waste fractions and composition found in one of Lithuania’s MSW landfill in 2012 (Lithuania’s national inventory report, 2014)

Table 2. MSW physical composition (Pichtel, 2005; Lithuania’s national inventory report, 2014)

Chemical class	General composition	
Organic	Paper products (A.12)*	Office paper, computer printout, newsprint, wrappings
	Plastics (A.13)	Polyethylene terephthalate, high-density polyethylene, polyvinyl chloride, low – density polypropylene, polypropylene, polystyrene, multi-layer plastics, other plastics including aseptic packaging
	Food (A.07)	Food (putrescible)
	Yard waste (A.03)	Grass clippings, garden trimmings, leaves, wood, branches
	Textiles/rubber (A.08)	Cloth, fabric, carpet, rubber, leather
Inorganic	Glass (A.15)	Clear, amber, green, brown
	Metals (A.16)	Ferrous, aluminium, other non-ferrous (copper, zinc, chromium)
	Dirt (A.06)	Dirt, stones, ash
	Bulky wastes (A.18; A.19)	Furniture, refrigerators, stoves

Note: * – waste code.

However, the major part of European countries landfilled more than a half of municipal solid waste in 2010 (European Environment Agency, 2013).

Clear roles of national and regional government in waste strategy are an important issue. The government has to take the responsibility and take the commitment for environmental, health and safety impacts. Sustainable waste management system has the opportunity to regulate these impacts and can help government and authorities to identify it (Pichtel, 2005). On the other hand, landfill taxes can have an important role in reducing landfilling process (European Environment Agency, 2013).

Size of organic and biomass waste fractions in MSW flow is related to the income rate of a country. Generation of MSW increases evenly with population growth and socio-economic development. The successful waste management have an influence from people living environment, cultural habits and factors, political issues (taxes), urban area development, infrastructure, educational level (Chen & Wu, 2015). If it is low (less then 60 GDP/capita), 65% of biodegradable waste will be generated, if middle (around 110 GDP/capita) then 43% of biodegradable waste and if the income is high (80–270 GDP/capita), countries will generate around 30% (GDP per capita…, 2015). On average, 136 kg per capita are disposed to the landfill. In central Europe (Germany, Austria, Belgium, Netherlands, Denmark), the levels are comparably low with 2–16 kg/capita. Norway (6), France (141) and Poland (186) constitute the middle range.

Organic waste generation in the middle income countries is 22% less than in low income countries, but 13% smaller than in high income countries. The aim of solid waste management strategies is to address the health, environmental, aesthetic, land-use, resource, and economic concerns associated with the improper disposal of waste. These issues are topical concern for nations, municipalities, corporations, and individuals around the world, and the global community at large. In developing countries, the waste produced by growing cities is overwhelming local authorities and national governments alike (Marshall & Farahbakhsh, 2013).

2. Methodology

Five landfill models of MSW were used in the research to improve the decomposition of waste and reduce GHGs. For this reason, the aim is to propose a modern landfill strategy that would reduce GHGs, stabilize waste and shorten landfill maintenance. During the study, five landfill models with different conditions were studied (Table 3). The in-situ treatment processes include anaerobic, aerobic, semi-aerobic and flushing bioreactor technology. For the experiment, MSW that is mechanically-biologically pre-treated (MBP) is taken from JSC "Biodegra".

All of the gases that were generated inside five landfill models were collected into "Teddlar" gas sampler bag and transported to gas monitoring equipment "Drager" every week. This research experiments were done in Vilnius Gediminas technical university's Environment Protection Institute with the help of equipment named "Inca" and "Drager" which showed gasses like H_2S (%) concentration. Columns had different conditions.

3. Analysis and results

Concentrations of released oxygen and hydrogen sulfide were determined during the experiment. Oxygen concentrations were measured in all landfill models surface, but in 3rd, 4th and 5th bottom measures were included. Oxygen injection in the landfills speeds up biodegradation process (Figure 2).

Third landfill column's surface measures showed that here was around 20% of oxygen, during all experimental period. High concentration might be found because of constant air input near the surface. In this case, bottom measurements shows really amount of oxygen inside MSW layers. In general, it started from 0% of concentration, which means that until day 28 oxygen was used by column's waste microorganisms and later it became stable (around 21%).

Forth landfill column's surface oxygen on day 42 was low (9%) because of higher methane concentrations. After this decrease oxygen amount was stable – around 16% of

Table 3. Landfill models conditions

Column	Material	Operating conditions	Landfill models
1st	Waste after MBP	Anaerobic with single input of water and leachate recirculation	Anaerobic with low flushing waste landfill
3nd	Waste after MBP	Anaerobic with single input of water, leachate recirculation and doze of probiotics	Anaerobic with high flushing landfill
3rd	Waste after MBP	Aerobic with high air inflow, single input of water and leachate recirculation	Aerated bioreactor landfill
4th	Waste after MBP	Aerobic with low air inflow, single input of water and leachate recirculation	Semi-aerobic bioreactor landfill
5th	Waste after MBP	Aerobic with low air and single input of water, leachate recirculation and doze of probiotics	Semi-aerobic and flushing bioreactor landfill

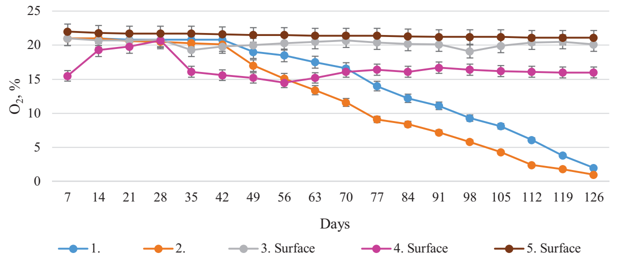

Figure 2. O_2 composition in landfill columns surface: 1) Pre-treated waste anaerobic landfill; 2) Pre-treated anaerobic waste landfill with flushing; 3) Pre-treated waste aerobic landfill 100 l/h; 4) Pre-treated waste aerobic landfill with low air inflow 50 l/4 h/day/5 days per week; 5) Pre-treated waste aerobic landfill with low air inflow 50 l/4 h/day/5 days per week and high flushing

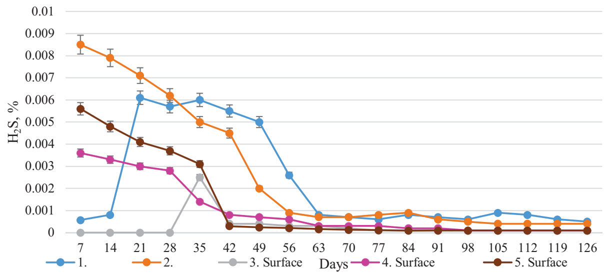

Figure 4. H_2S composition in landfill columns surface: 1) Pre-treated waste anaerobic landfill; 2) Pre-treated anaerobic waste landfill with flushing; 3) Pre-treated waste aerobic landfill 100 l/h; 4) Pre-treated waste aerobic landfill with low air inflow 50 l/4 h/day/5 days per week; 5) Pre-treated waste aerobic landfill with low air inflow 50 l/4 h/day/5 days per week and high flushing

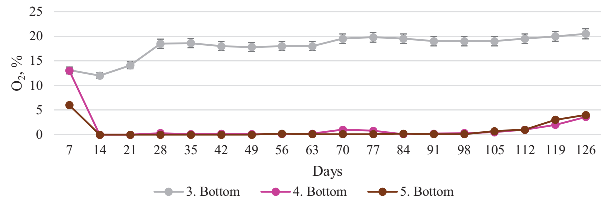

Figure 3. O_2 composition in landfill columns bottom

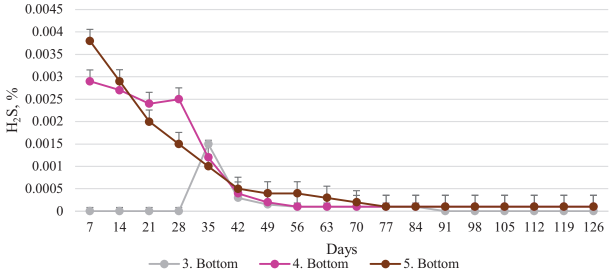

Figure 5. H_2S composition in landfill columns bottom

volume. Oxygen and methane concentrations were stable together in 4th landfill column's surface. Although, only first week showed oxygen parameters in column's bottom (Figure 3).

Later it stayed close to zero and increased only at the end of the experiment. Reproducibility of these measurements are seen in 5th column's bottom values. However, surface oxygen was much lower. It may be effected by methane and carbon dioxide evaporation.

Hydrogen sulfide is one of the main odour contaminants, known for evaporation from the landfills. Figure 4 shows the results of anaerobic 1st and 2nd landfills H_2S contamination to the atmosphere. Sulfur is a component in waste that indicates odour pollution. It is important to mention that biocover has an important value for stopping odour particles from evaporation to the environment.

Over time, in all experimental landfill's hydrogen sulfide concentration decreased during the time. At 1st landfill odour began to evaporate only after two weeks and the volume increased to 0.006% from 0.00057%. The reason of this change is smaller amount of recirculated leachate. H_2S measurements became stable at day 63. Second landfill showed similar results, but the biggest difference is seen at the beginning of experimental time – larger amount of leachate increased hydrogen sulfide concentration suddenly.

Figure 5 shows H_2S concentration in landfill columns bottom. The moment, when concentration reached the highest value is at day 35 (0.0025% in surface and 0.0015% in bottom). Besides this growth, the average of concentration would be close to 0%. However, 3rd landfill is stable from this point of view and has the lowest level to the odour pollution from all.

4th landfill column evaporated odor to day 63 and until then its highest value was 0.0035% on the surface. After that H_2S concentration became stable and was close to 0%.

5th landfill evaporated 0.0056% and 0.0038% of hydrogen sulfide and it became stable and lower at day 42 (0.00029%). The total decrease was lower because of larger amount of leachate and probiotics.

Conclusions

1. The amount of oxygen in anaerobic landfill models was decreasing, however, in the third model, its amount remained constant because it was aerated bioreactor landfill.
2. Analyzing by experiment duration (126 days), the amount of oxygen in anaerobic landfill models (in pre-treated waste anaerobic landfill and pre-treated anaerobic waste landfill with flushing) was decreasing as well.
3. Experimental studies have shown that hydrogen sulfide emissions began to decrease in all landfill models from day 42–65.
4. After evaluating all the results of the research, hydrogen sulfide emissions amount was low during all experimental time (0–0.0085%).
5. Consequently, in order to reduce greenhouse gas emissions, aeration must be increased. To this end, it solves

and reduces the negative impact on the environment 3 landfill model with intensive aeration and 5 landfill model with normal aeration and leachate washing.

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KAI KURIŲ ŠILTNAMIO EFEKTĄ SUKELIANČIŲ TERŠALŲ EMISIJŲ, NAUDOJANT KOMUNALINIŲ ATLIEKŲ SĄVARTYNŲ MODELIUS, VERTINIMAS

K. Mohammadi

Santrauka

Nemažai šiltnamio efektą sukeliančių dujų (ŠESD), sukeliančių ligas ir visuotinį klimato atšilimą, išsiskiria į aplinką netinkamai šalinant komunalines atliekas sąvartynuose. Dėl šios priežasties reikia peržiūrėti atliekų tvarkymą sąvartynuose, nes priešingu atveju ozono sluoksnis dar labiau suplonės bei globalinio klimato atšilimo pasekmės bus dar ryškesnės aplinkos mastu. Šiame straipsnyje analizuojama dabartiniu metu susiklosčiusi situacija dėl netinkamo komunalinių atliekų šalinimo ir ŠESD emisijų iš Europos Sąjungos sąvartynų. Viename Lietuvos sąvartyne, atlikto tyrimo duomenimis, vidutinis komunalinių biologiškai skaidžių atliekų kiekis yra 58 %. Tyrime aprašoma dabartinė ŠESD emisijų kiekybinė analizė iš penkių komunalinių kietųjų atliekų sąvartynų prototipų modelių, juose sudarant skirtingas sąlygas. Tai yra visuose prototipų modeliuose buvo keičiami oro, vandens / filtrato ir probiotikų įleidimo bei išleidimo srautai. Tyrimo objektas buvo vandenilio sulfido (H_2S) ir deguonies (O_2) surinkimas iš skirtingų komunalinių atliekų sąvartynų modelių. Atlikus komunalinių atliekų sąvartynų modelių tyrimus pagal iš jų išmetamų ŠESD sudėtį, buvo nustatytas mažiausią emisiją turintis sąvartyno modelis. Tinkamai parinkti sąvartyno modelio parametrai padeda sumažinti ŠESD emisijas ir sutrumpinti sąvartyno eksploatavimo laikotarpį.

Reikšminiai žodžiai: vandenilio sulfidas, šiltnamio efektą sukeliančių dujų emisijos, komunalinės atliekos, biologiškai skaidžios atliekos, skirtingi sąvartynų modeliai.