Analysis of RMSW Deposited a Decade Ago for Later “Landfill Mining”

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Content

- Background: Hungarian standards for MSW analysis.
- Area of „landfill mining” case study.
- Development of a new sampling protocol for landfill mining case studies.
- Results.
- Conclusion.

Background: Standards for RMSW analysis.

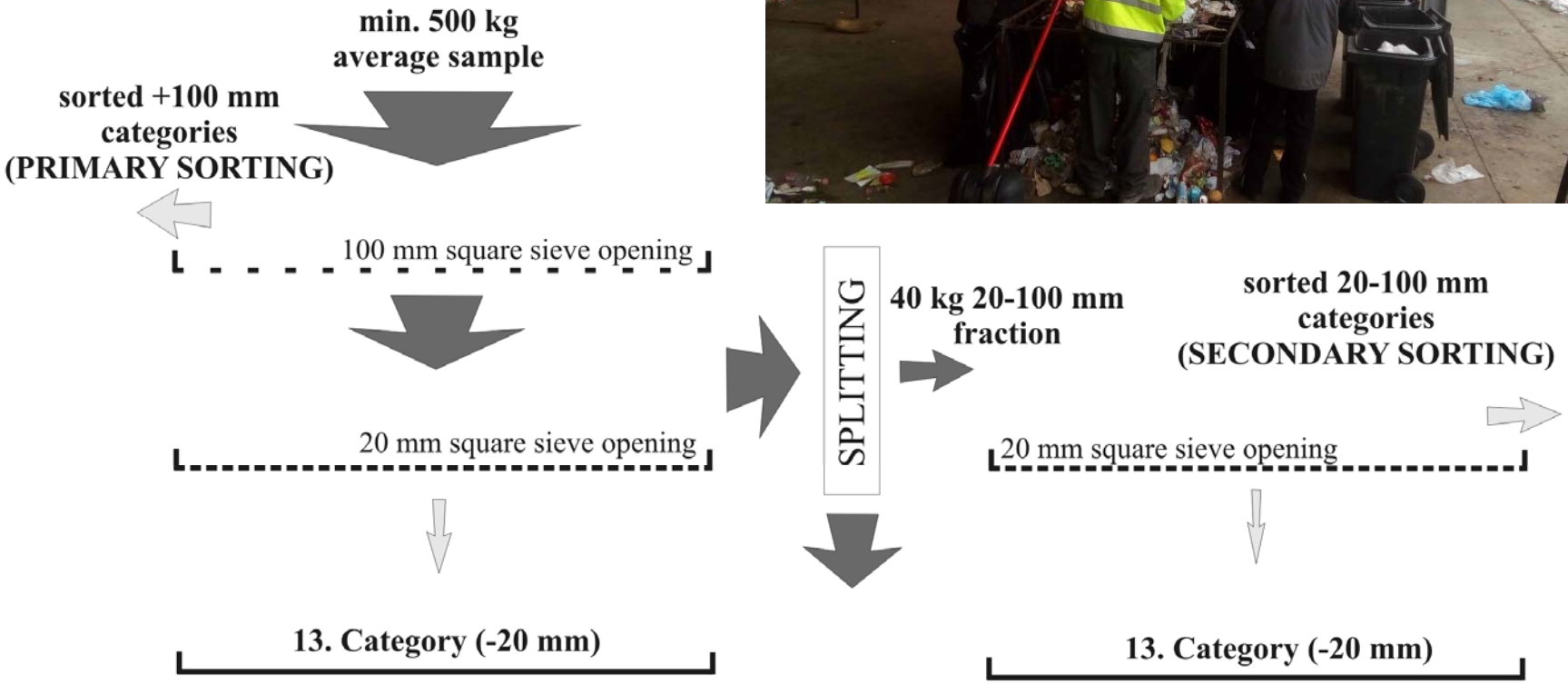
The currently in force **Hungarian Standards MSZ 21420 Parts: 28 and 29 regarding the analysis of municipal solid wastes** were introduced in 2005. Our institute played key role on their developments.

The Hungarian Standards are based on **Gy's sampling theory** (Gy, 1979).

The minimal mass of an average (gross) sample of RMSW is 500 kg comprising ten 50 kg single samples (increments).

Sorted standard material categories are: 1, **Bio** (biologically degradable materials, food residues, plants, etc.); 2, **Paper**; 3, **Cardboard**; 4, **Composite** (two-component packing materials); 5, **Textile**; 6, **Hygienic** (diaper, tampon, tissue paper, etc.); 7, **Plastics**; 8, **Combustible** (other uncategorised combustibles, wood, leather, etc.); 9, **Glass**; 10, **Metals**; 11, **Non-combustible** (other uncategorised non-combustibles or inert, stone, brick, etc.); 12, **Hazardous** (medicine, batteries, etc.), 13, **Fine** (< 20 mm)

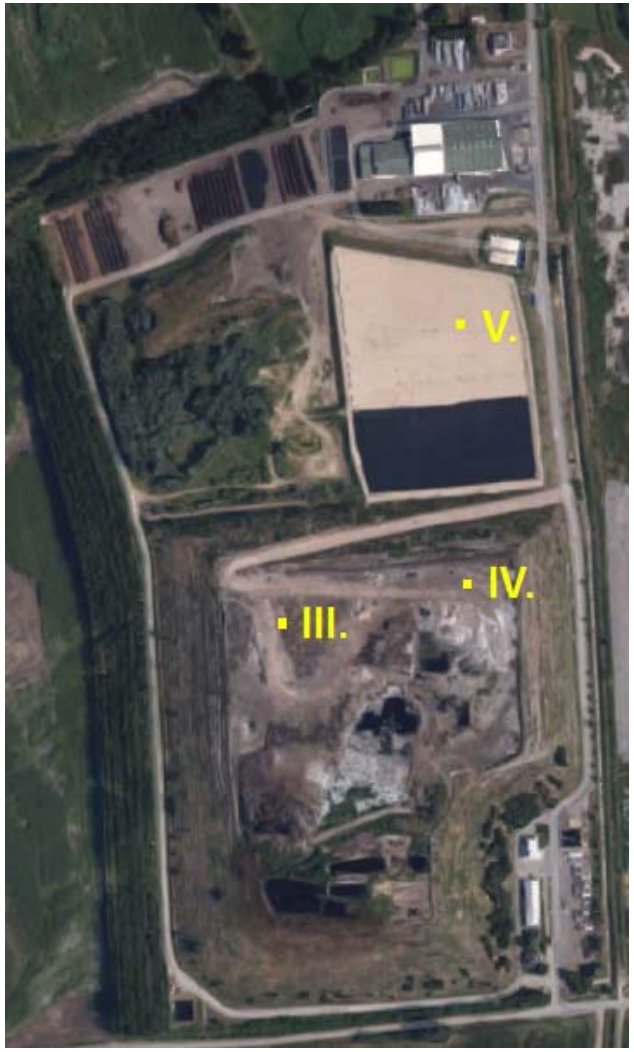
Sample preparation of the 500 kg average sample. Standard method (French MODECOM system).



The area of landfill mining case study.

Table 1. Area and year of opening of landfill sections.

Landfill Section No.	Area [ha]	Start of operation
I.	3.3	1993
II.	3.5	1996
III.	3.3	2004
IV.	3.2	2007
V.	3.2	2014
VI.	3.5	2020



Sampling by drilling. (Diameter of auger is 0.8 m)

Borehole No. V.

Sample from borehole No. IV. bottom

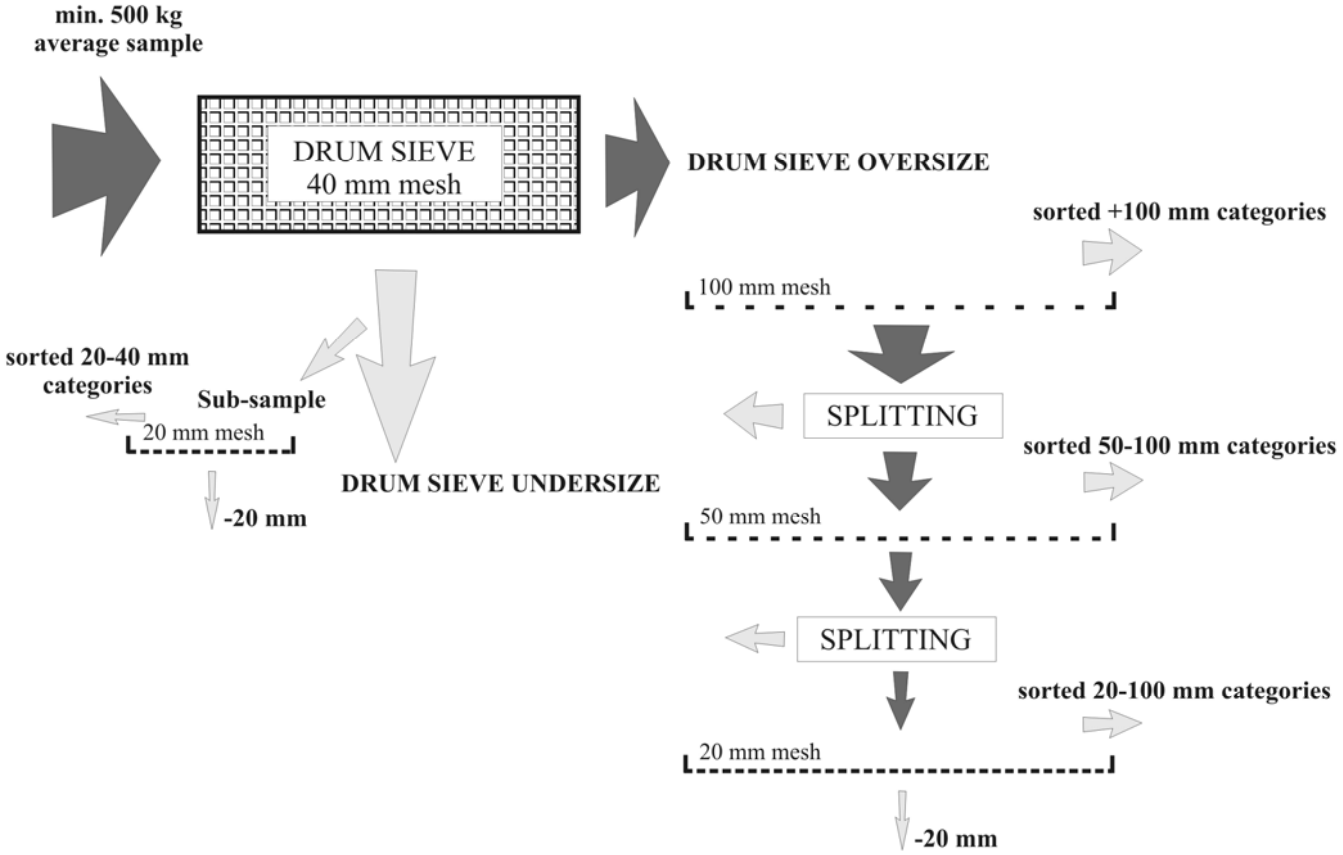
Sample from borehole No. V. bottom

Features of drilled average samples

Name of average sample	Time of landfilling	Depth [m]	Time of sampling
III. Lower	2004. July	10	Feb. 9. 2017.
III. Middle	2005. July	6	Feb. 9. 2017.
III. Upper	2006. July	2	Feb. 9. 2017.
IV. Lower	2008. March	10	Feb. 9. 2017.
IV. Middle	2010. July	6	Feb. 9. 2017.
IV. Upper	2012. September	2	Feb. 9. 2017.
V. Lower	2014. July	7	Feb. 9. 2017.
V. Middle	2015. July	4,5	Feb. 9. 2017.
V. Upper	2016. July	2	Feb. 9. 2017.

The developed average sample preparation protocol for landfill mining.

If the recommendation (500 kg sample mass for 100 mm) of Gy (1979) is accepted, the following sampling nomogram can be applied:



$$m_{AS} = C \cdot X_{95}^{3}$$

C = 500 tons/m^3; X_{95} is the 95 % particle size. According to this sampling nomogram the minimal processed material is **63 kg on the 50 mm sieve and 4 kg on the 20 mm sieve**.

Photos of analysis.

Drum sieve (left) and sorting on the 100 mm mesh sieve frame right).

Results.

Table 2. The wet material composition by mass of the III/M sample.

Wet mass ratio and component content of the size fractions															
SIZE FRACTION / Material category	1 Paper	2 Textile	3 Plastic	4 Combustible	5a Al	5b Fe	5c Cu	5d Stainless steel	6 Inert	7 Bio	8 <20 mm			
> 100 mm	0.57	1.0	7.45	2.77	0	0.21	0.03	0	1.25	0	-	∑	**13.28**	%
50-100 mm	0.095	0.26	3.49	0.42	0	0.25	0	0	1.76	0	-	∑	**6.28**	%
20-50 mm	0.95	0.08	1.97	0.53	0.12	0.08	0.02	0	4.06	0	-	∑	**7.82**	%
<20 mm	-	-	-	-	-	-	-	-	-	-	72.61	∑	**72.61**	%
Total	**1.63**	**1.35**	**12.91**	**3.71**	**0.12**	**0.54**	**0.05**	**0**	**7.08**	**0**	**72.61**	∑	100	%
Distribution of material components in the size fractions														
> 100 mm	35.35	74.39	57.67	74.56	0	39.24	60.51	0	17.66	0	-			
50-100 mm	5.84	19.7	27.03	11.24	0	45.93	0	0	24.93	0	-			
20-50 mm	58.81	5.91	15.29	14.19	100	14.83	39.49	0	57.41	0	-			
<20 mm	-	-	-	-	-	-	-	-	-	0	100			
∑	100	100	100	100	100	100	100	0	100	0	100			

Results.

Table 4. Result of chemical analysis (TOC, DOC, elemental analysis of the **<20 mm fractions**)

Applied equipment's: ELEMENTAR Vario TOC device, Perkin Elmer FIMS 400 Hg-analyser; Perkin Elmer Optima 5300 DV ICP-OES device; UNICAM UV2-200 UV/VIS spectrophotometer.

Sample		III/U <20 mm		IV/M <20 mm		V/M <20 mm			Average	
	Unit	Element. compos.	Dissolution in distilled w.	Element. compos.	Dissolution in distilled w.	Element. compos.	Dissolution in distilled w.	Lower measuring limit	Element. compos.	Dissolution in distilled w.
TOC	*% m/m*	10.4	-	8.13	-	14.6	-	0.01	11.04	-
DOC	*mg/kg (dry based)*	-	411	-	698	-	6980	1	-	2696
Fluoride		-	<1.0	-	<1.0	-	<1.0	1	-	<1.0
Sulphate		-	1030	-	580	-	110	10	-	573
Chloride		-	860	-	1600	-	2130	10	-	1530
Al		10800	-	11300	-	12100	-	1.0	11400	-
As		-	<0.1	-	<0.1	-	<0.1	0.1	-	<0.1
Ba		-	0.5	-	<0.2	-	<0.2	0.2	-	0.2
Co		5.9	-	5.2	-	5.1	-	0.25	5.4	-
Cr		424*	0.1	86.4	0.1	89.3	<0.1	1.0	199.9	0.1
Cu		96.2	0.1	357	0.4	166	0.1	0.5	206.4	0.2
Li		8.5	-	7.7	-	7.3	-	0.2	7.8	-
Mg		3300	-	3510	-	2980	-	2.0	3263	-

older

newer

cerium, lanthanum and neodymium

Table 5. Result of chemical analysis (critical element content of the **<20 mm fractions**)

Applied equipment's: PE NexION 300D ICP-MS 01. EPA Method 6020A:2007

Element	Sample/Unit	III/U <20 mm	IV/M <20 mm	V/M <20 mm	Average
Ag	*mg/kg (d.b)*	1	<1	2	1
Au	*mg/kg (d.b)*	<2	<2	<2	<2
Ce	*mg/kg (d.b)*	59.6	49.3	44.7	51.2
Dy	*mg/kg (d.b)*	2.0	1.7	1.3	1.7
Er	*mg/kg (d.b)*	1.1	1.0	0.8	1.0
Eu	*mg/kg (d.b)*	0.6	0.5	<0.5	0.4
Gd	*mg/kg (d.b)*	2.4	2.0	1.7	2.0
Ho	*mg/kg (d.b)*	<0.5	<0.5	<0.5	<0.5
La	*mg/kg (d.b)*	19.6	16.3	17.1	17.7
Lu	*mg/kg (d.b)*	<0.5	<0.5	<0.5	<0.5
Nd	*mg/kg (d.b)*	16.0	12.4	11.0	13.1

Results.

Table 6. Measured calorific values of **waste-to-energy fractions**

Applied equipment's: e2k Combustion Calorimeter, MSZ EN 15400:2011

	Sample/Unit	Lower measuring limit	III/U Energy fraction	IV/M Energy fraction	V/M Energy fraction	Average
Heat of combustion	*MJ/kg*	0.1	25.2	21.7	21.1	22.7
Calorific value	*MJ/kg (d.b)*	0.1	24.3	20.6	19.7	21.5
Ash content	*% m/m*	0.1	34.1	48.3	24.6	35.7

Results.

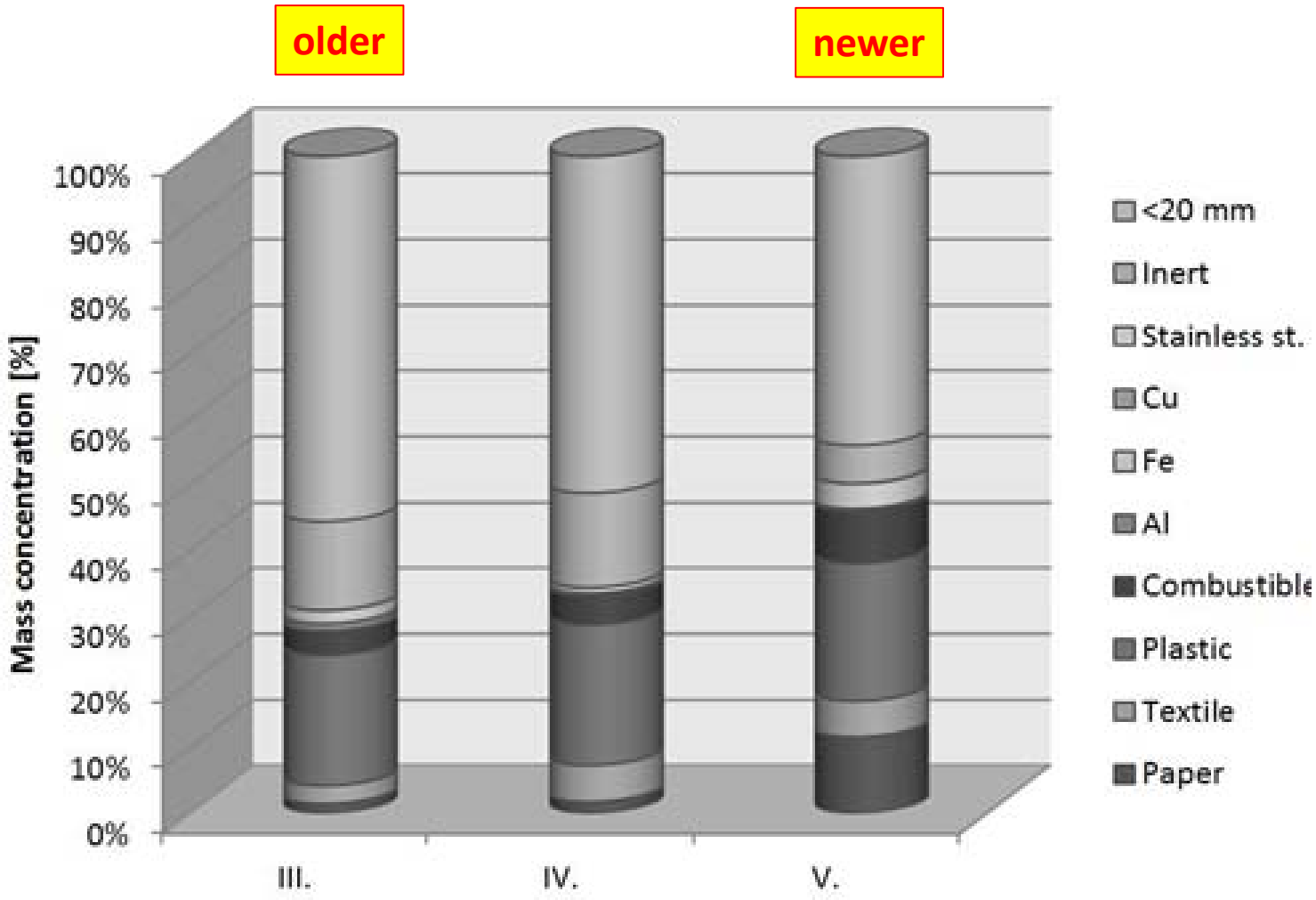


Figure 6. Wet material composition of landfill sections III, IV and V.

Results.

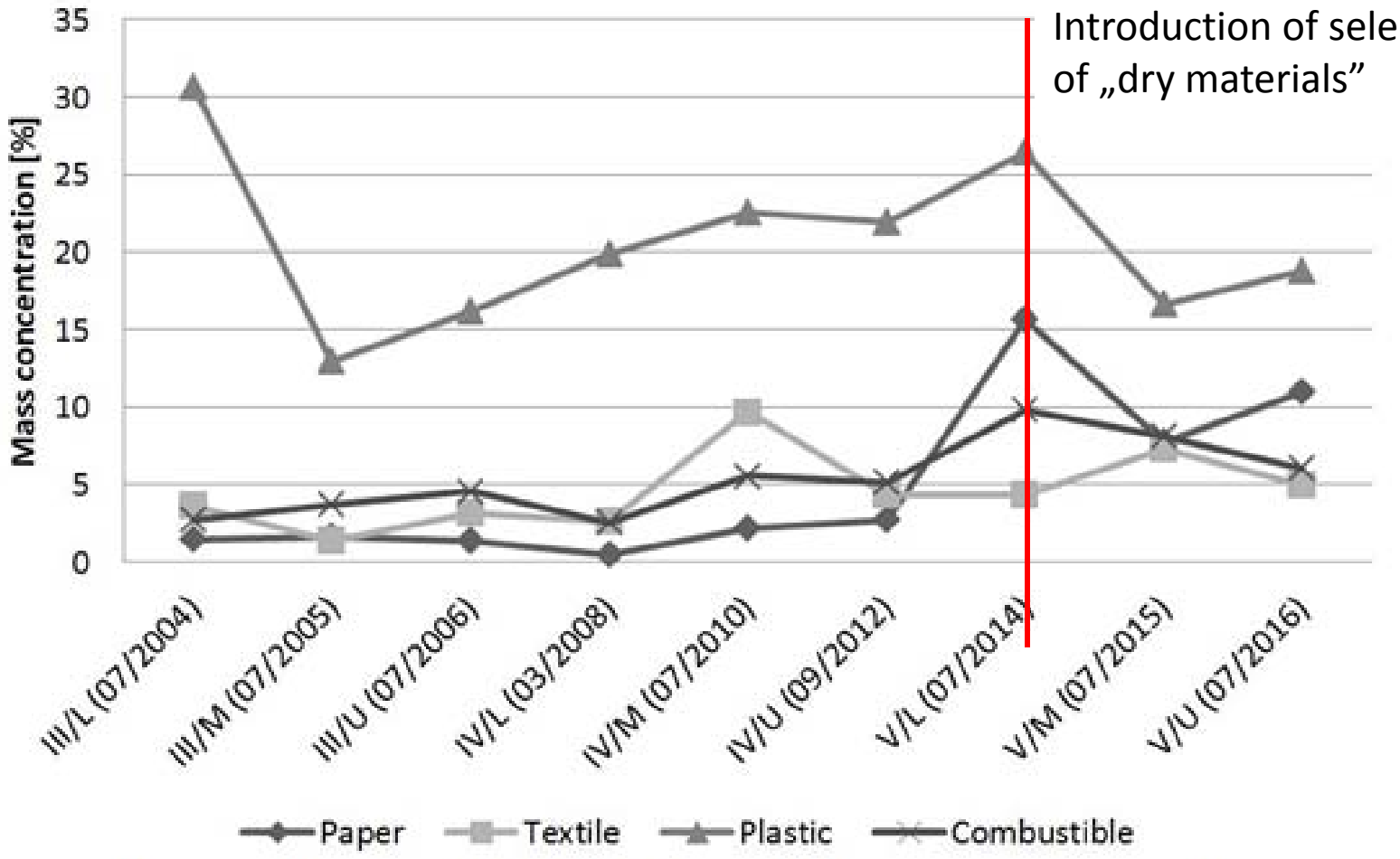


Figure 7. Timescale variation of waste-to-energy components.

Results.

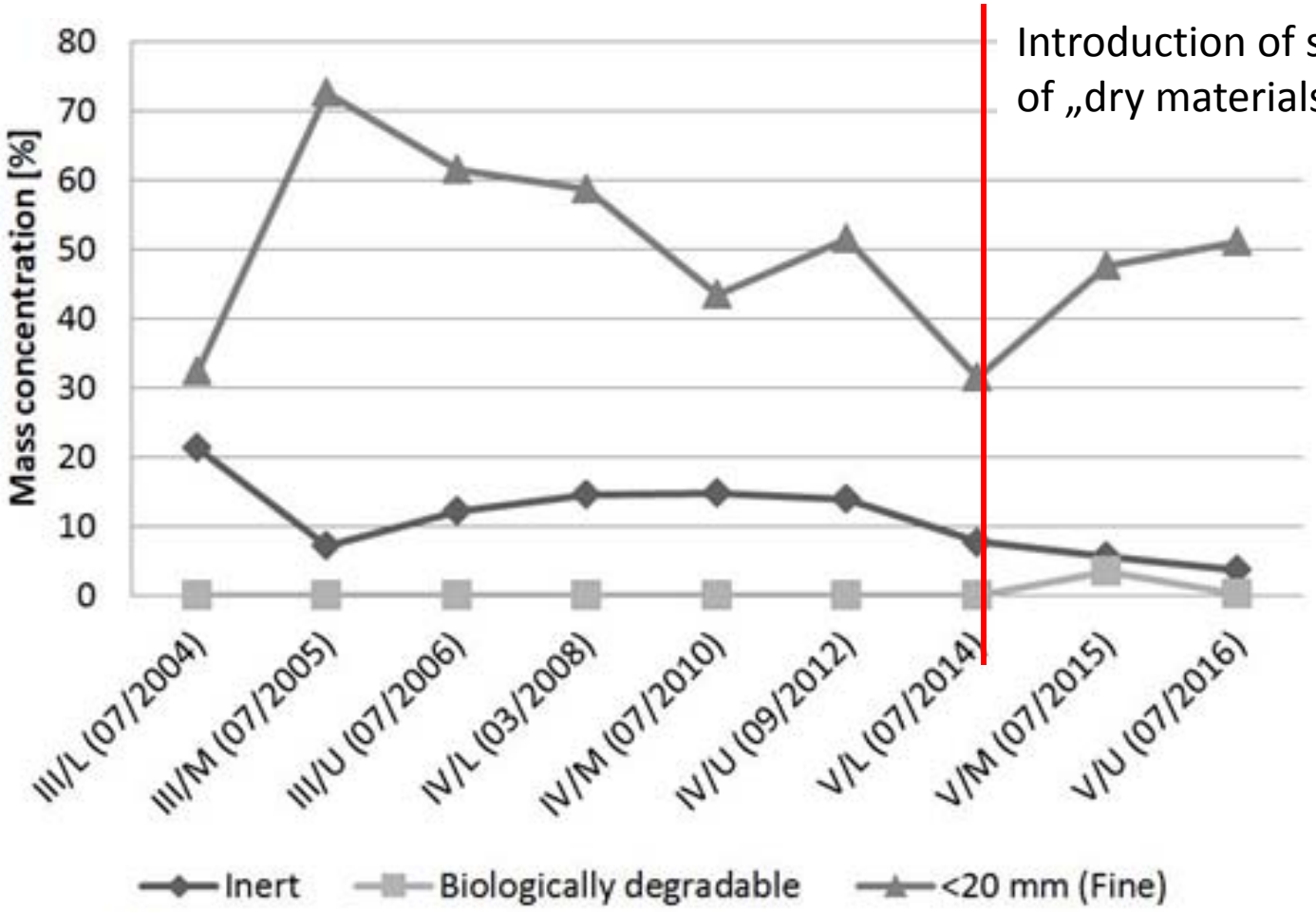


Figure 8. Timescale variation of the residual components.

Results.

Table 8. The calculated total mass of each material component.

Material component	1 Paper	2 Textile	3 Plastic	4 Combustible	5a Al	5b Fe	5c Cu	5d Stainless steel	6 Inert	7 Bio	8 <20 mm
Total wet mass [ktons]	118.3	111.0	500.1	129.2	15.0	53.1	1.0	0.2	272.2	10.2	1213.7
Total dry mass [ktons]	75.0	49.3	344.5	74.1	14.0	47.2	1.0	0.2	237.7	3.4	781.7

- This data can be basis of a cost-benefit analysis for assessing the economic feasibility!
- The economic feasibility of landfill mining can be evaluated by the indicator of **net present value**.

CONCLUSION

Case study on the Debrecen Municipal Solid Waste Landfill showed that the concentration of **plastics** in the stored waste is the highest (regardless of the <20 mm fraction): **20.63 % m/m dry**. The average concentration of the **waste-to-energy components** is **35.42 % m/m dry**, while that of **metals** content is only **2.86 % m/m dry**.

Different tendencies could be observed. The mass concentration of **paper, textile and combustible** did not changed much between 2004 and 2008 and afterwards they increased until 2010. Since 2014 there is a clearly visible decreasing trend for these material categories. The concentration of **plastics** first decreased, then from 2005 increased until 2014, then significantly decreased due to the introduction of the separate waste collection system for the dry materials.

According to results of samplings the estimated wet amount of the fine fraction (<20 mm) was 1,213,700 tons, plastics was 500,000 tons, metals was 69,300 tons and 858,600 tons energetic fraction (paper, textile, plastic and combustible) were landfilled in sections I … V. These results are providing a good basis for later cost-benefit analysis **and process technology design.**

A new sampling and average sample preparation protocol was designed for landfill mining analysis. The carried measurements have proven that the protocol is well suited and flexible for practice.

Thank You for Your attention!

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