JAPAN INTERNATIONAL COOPERATION AGENCY (JICA)

BUDAPEST CAPITAL CITY GOVERNMENT

THE REPUBLIC OF HUNGARY

THE STUDY
ON
THE MUNICIPAL SOLID WASTE MANAGEMENT
IN
BUDAPEST

FINAL REPORT
SUPPORTING REPORT

SEPTEMBER 1993

ENVIRONMENTAL TECHNOLOGIC CONSULTANT CO., LTD.
(ETC)

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CONTENTS

I. Report on the Municipal Solid Waste (MSW) Sampling and Analysis in Budapest Area

- Winter Test Period -

KÖRNYEZETVÉDELMI Kft.
ENVIRONMENTAL PROTECTION Ltd.

Report on the Municipal Solid Waste (MSW) sampling and analysis in Budapest area

Winter test period

(dr. Zoltán Izsáki)
project manager

(dr. János Kálmán)
director

Budapest, 10th March, 1993

1036 Budapest III., Evező u. 4. • Tel.: 168-68-94, 168-62-91 • Fax: 168-68-94

TABLE OF CONTENTS

Participated in preparing this survey:

Person	Company affiliation
Mr. K. Kertész	Environmental Protection Ltd.
Mr. L. Kövári	Environmental Protection Ltd.
Mr. A. Andó	Environmental Protection Ltd.
dr. Zs. Pfeiffer	Municipal Public Services Co. (FKFV)
Mr. Gy. Midrák	Municipal Public Services Co. (FKFV)
dr. Gy. Uzsokiné	Public Health Inspectorate
dr. K. Lakszner	Tech. University of Budapest Dept. of Chemical Technology

1. Introduction

According to signed contract between JICA Study Team and Environmental Protection Ltd. (EP) the EP carried out MSW sampling and analysis in area of Budapest during the winter period.

Environmental Protection Ltd. (EP) has previously performed MSW sampling and analysis during period of June 15-16, 1992 in Budapest area. The data obtained are representing the waste output and composition of summer period. As MSW output and composition are season dependent JICA study team charged EP to perform a second MSW sampling and analysis representing the winter period. The winter sampling was conducted during period of Feb. 1-5. The samples were taken from the zones allocated during the summer test period. The sampling and analytical procedures were in almost all cases identical to those used during summer test period. The modifications in analitycal procedures are indicated in sections of chapter 2.

The survey was conducted according to methodology given by JICA Study Team.

In the course of survey the following tasks were carried out:

- collection of MSW from 12 sampling zones (identical to those used in summer period) during 5 day long period (Monday-Friday) in specialized collection vessels,
- determination of MSW mass and volume output and bulk density from each zone during this period,
- determination of mechanical composition (11 different classes) of collected waste from each zone on Monday and on Thursday (2x12 samples) according to JICA methodology,
- preparation of 10 kg laboratory samples in sealed hard-wall plastic containers from collected waste from each zone on Monday and on Thursday (2x12 samples) according to JICA methodology,
- determination of effective moisture from laboratory samples according to MSZ (Hungarian National Standard) 21976/3-81,
- grinding and homogenization of air-dry laboratory samples and preparation of about 1 kg analytical samples,
- from analytical samples the following determinations were carried out:

> hygroscopic moisture according to MSZ 21976/3-81,

> ash content and combustibles (ignition residue and ignition loss) according to MSZ 21976/5-81,

> elementary composition (carbon, hydrogen, oxygen, nitrogen and sulphur) by automatic elementary analyzer (type:Fisons Carlo-Erba)

> determination of total chlorine content heat of combustion using isothermal bomb-calorimeter (Berthelot-Mahler method)

> calorific value calculated from mechanical composition of each laboratory sample.

The results of this survey were compared to data obtained during the summer test period and data obtained from Analytical Laboratory of Municipal Public Services Enterprise (FKFV) representing the MSW output and waste composition in Budapest area in period of 1987-1991 based on their own survey.

2. Applied methodologies

2.1. Allocation of sampling zones, sampling

The sampling zones were allocated based on JICA methodology during the summer test period. The following parameters were determined:

- in residential areas number of inhabitants and number of households,
- in hotels the number of rooms and number of beds,
- in office and markets the office or shop space,
- in park area the park surface,
- in all sampling zones the collection vessels and collection frequency currently applied by FKFV.

The basic parameters of allocated sampling zones are summarised in Table 1.

Pictures taken at sampling zones are presented in Appendix I.

The actual sampling of MSW from allocated zones were carried out between February 1. - February 5. (Monday - Friday).

MSW was collected by resident in the standardised vessels used by FKFV (see Table 1.). During sampling the waste from collection vessels was transferred to 0.77 m^3 volume covered plastic containers and transported to Municipal Waste Incinerating Facility (HHM).

The volume of collected waste from different zones showed great deviations (from 0.05 m^3 to 5 m^3). For increasing the precision of determinations and obtaining more representative results the following modifications were made on the methodology given by JICA:

- in case the amount of sample obtained after quartering method would be less than 10 kg amount reduction was not performed,

Table 1. Statistical data about allocated sampling zones

Zone code	Adrress	No. of Househ.	No. of Inhabit.	Type of collecting vessels	Collection frequency
	High income area				
A	Bp. XII. Pipiske str. 1-5.	40	90	containers 14 x 120 dm3	two times a week
B	Bp. XII. Pasaréti str. 61-63	36	111	containers 8 x 200 dm3	three times a week
	Middle income area				
C	Bp. VI. Teréz blv. 41	36	101	containers 6 x 220 dm3	every second day
D	Bp. XIV. Ujvidék square 10	6	17	containers 2 x 120 dm3	every second day
	Bp. XIV. Szugló str. 27	6	16	containers 2 x 120 dm3	every second day
	Bp. XIV. Ujvidék square 6	8	20	containers 2 x 120 dm3	every second day
	Bp. XIV. Ujvidék square 16	4	3	containers 2 x 120 dm3	every second day
	Bp. XIV. Ujvidék square 14	2	4	containers 1 x 120 dm3	every second day
	Low Income area				
E	Bp. IV. Váci road 81/b	12	29	containers 4 x 120 dm3	two times a week
	Bp. IV. Váci road 81/c	22	53	containers 5 x 120 dm3	two times a week
F	Bp. X. Kozma u. 15/I-III	36	55	containers 4 x 120 dm3	every second day
	Markets and shops	Surface [m2]	No. of Employees		
M1	Bp. IX. Ferenc blv. 1. Csemege-Meinl Shop No 49.	84	-	containers 1 x 200 dm3	every working day
M2	Bp. XIII. St. István blv. 30. Csemege-Meinl Shop No 20.	300	-	containers 2 x 200 dm3	every working day
	Offices				
O	Bp. Schönherz Z. str. 16 National Crude Oil and Natural Gas Co.	2290	1200	containers 50 x 200 dm3	every second day
	Park area				
P	Bp. V. Erzsébet square	-	-	containers 30 x 20 dm3	-
	Hotels	No. of rooms	No. of beds		
H1	Bp. I. Bem rkp. 11. Hotel Viktória	24	36	containers 2 x 200 dm3	every day
H2	Bp. VI. Teréz blv. 43. Hotel Béke Radisson	246	492	containers 3 x 1100 dm3	every day

- the amount reduction by quartering method was performed proportional to the original mass of collected sample, as a consequence the determination of mechanical composition was carried out on samples amounts of 50 and 150 kg.

2.2 Determination of bulk density

Bulk density was calculated from measured mass and volume of non-compacted waste samples.

The mass was measured by an industrial scale with ± 0.1 kg accuracy.

The volume was determined by filling the samples in standard vessels of uniform volume.

2.3. Determination of mechanical composition

The reduced waste samples were separated into 11 different groups given by JICA (1. paper and cardboard, 2. textiles, 3. plastics, 4. glass, 5. grasses, 6. leather, 7. rubber, 8. metals, 9. kitchen garbage, 10. stones and ceramics, 11. others) with following modifications:

- in group No. 5 were separated all vegetable and green garden waste including grass,
- group 11. (others) included all waste that could not be assigned to previous groups e.g.: complex waste composed of multiple materials, medicines and chemicals, fine grained materials (dust, ash, soil), waste inseparable by hand because of contamination and mixing with other waste during collection and transport.

The mass of each separated fraction was determined by scale (and same precision) as described in section 2.2.

2.4. Determination of effective moisture

Laboratory samples of about 10 kg were prepared on Monday and Thursday from each collection zone (2x12 samples) in sealed hard wall plastic containers with appropriate labeling. The amount of laboratory samples was further reduced by quartering method to about 1 kg. These samples were dried in drying ovens at 105°C for 72 hours then conditioned at ambient air for 48 hours period. The mass of samples before and after drying was determined by laboratory scale with ±50 mg precision.

The effective moisture was calculated from mass reduction during the drying procedure.

2.5. Preparation of analytical samples

From dried and conditioned (air-dry) samples the bulky hard objects (e.g.: metals, stones) were removed manually and the residues were ground first in a laboratory hammer mill

and than pulverised with blade mill. All other determinations were made using these analytical samples.

2.6. Determination of hygroscopic moisture

Portions of analytical samples were dried at 105 °C until the mass steadiness was reached. The mass of samples before and after drying was determined by analytical scale (±0.0001 g precision).

Hygroscopic moisture was determined by making three parallel measurements from each sample. The results given are the averages of parallel measurements.

The total moisture content was calculated from effective and hygroscopic moisture using the following formula:

$$M_T = M_E + M_H * [(100-M_E)/100] \qquad (1)$$

where:
M_T is the total moisture [%]
M_E is the effective moisture [%]
M_H is the hygroscopic moisture [%]

2.7. Determination of ash content

Portion of analytical sample is weighted with analytical precision (0.0001 g) and ignited in laboratory furnace at 600 oC until mass steadiness was reached.

Both the National Standard (MSZ 21976/5) and JICA methodology recommends ignition at 800 oC but according to our experience at this temperature the decomposition of carbonates is substantial. The German methodology is recommending 775 oC as a glowing temperature.

Ash content was calculated from mass loss during the ignition.

Combustible fraction was calculated according to the following formula:

$$C_f = 100 - A - M_H \qquad (2)$$

where:
C_f is the combustible fraction [%],
A is the ash content [%],
M_H is the hygroscopic moisture [%].

2.8. Calculation of heating value

The heating value of waste samples were calculated on basis of mechanical composition and average heating value of constituents. The average heating value of air dry constituents was taken from MSZ 21976/6-86:

Constituent	Heating value
	[kJ/kg]
paper	17585
wood	20034
leaves	16509
leather	20587
rubber	26357
plastics	33424
textile	17798
kitchen garbage	14575
glass, ceramics	150
metals	280
ash, slag, other unidentified	8820

The heating value of garden waste was calculated using the data for leaves.

The heating value was calculated for air dry samples and converted for original condition (raw samples) using the total moisture content.

2.9. Determination of elementary composition (C,H,O,N and S)

The determinations were carried out using an automatic elementary analyzer type Fisons (Carlo-Erba) EA1108. The analytical samples were further pulverised using a micro ball mill and 2-5 mg of homogeneous samples were weighted in. The instrument is pérforming the total analysis automatically and the raw data is processed by PC. The instrument is capable of quantitative determination of carbon, hydrogen, oxygen, nitrogen and sulphur in concentrations above 100 ppm. Detection limit for all five elements is 10 ppm.

The instrument is capable for measuring the heat of combustion and the heating value of samples. But experience from summer test period indicated that because of very small sample amounts the heating value determinations are very unreliable therefore during this test bomb calorimeter was used for measuring the heat of combustion (see later in section 2.10.) Accuracy of measurements using this instrument is:

Measured value	accuracy
100 ppm	± 10 ppm
0,1 %	± 0,001 %
1,00 %	± 0,002 %
10,00 %	± 0,1 %
50,00 %	± 0,3 %
90,00 %	± 0,3 %

2.10. Determination of chloride content and heat of combustion.

The method used is based on isothermal bomb calorimetric method of Berthelot-Mahler. About 750-1000 mg of average samples is weighted in (this amount is considerably higher than the amounts used by Fisons-Carlo Erba elementary analyser). At the bottom of bomb 10 cm^3 of 0.1 mol/l concentration sodium-hydroxide solution was placed and the bomb is pressurised with 3.0 MPa of pure oxygen. The pressurised bomb is placed inside an isothermally sealed casing and after reaching the thermal equilibrium the sample is ignited by electrical impulse. The sample is incinerated with very high velocity and high efficiency in the pressurised oxygen atmosphere. The temperature increase inside the casing is measured with ±0.001 °C precision and the heat of combustion is calculated from the temperature increase.

During the incineration of sample the organically bounded chlorine is converted to hydrochloric acid. The hydrochloric acid is absorbed in the sodium-hydroxide solution after vigorous shaking of bomb. The chloride ion content of solution is determined by electrochemical titration (precision ±0.5 μmol chloride/sample amount)form which the chlorine content can be calculated.

4. Results of sampling and analytical composition

The results of MSW mass and volume output for each sampling day and each zone and weekly averages for zones are summarised in Table 2. The calculated loose bulk densities of MSW for each zone are also indicated in Table 2.

The calculated specific waste outputs for 5 day long periods in each sampling zones are seen in Table 3. The specific waste output is calculated from total waste amount in the given zone and is expressed:

Table 2. MSW mass and volume output and loose bulk density winter test period

	Zone:	A	B	C	D	E	F	H1	H2	H1	M2	O	P	Total
Feb. 01.	mass	82	82	99	86	109	98	51	239	10	17	180	4	1057
	volume	0.7	0.65	0.95	0.6	0.6	0.7	0.3	1.65	0.25	0.2	2.5	0.4	9.5
	density	117.1	126.2	104.2	143.3	181.7	140.0	170.0	144.8	40.0	85.0	72.0	10.0	
Feb. 02.	mass	62	63	81	10	23	9	29	337	24	48	120	3	809
	volume	0.4	0.5	0.77	0.1	0.4	0.3	0.17	3.08	0.7	1.1	2	0.05	9.57
	density	155.0	126.0	105.2	100.0	57.5	30.0	170.6	109.4	34.3	43.6	60.0	60.0	
Feb. 03.	mass	24	22	57	19	46	20	15	264	8	33	155	2	665
	volume	0.3	0.4	0.72	0.2	0.3	0.3	0.2	2.3	0.24	0.7	2.2	0.03	7.89
	density	80.0	55.0	79.2	95.0	153.3	66.7	75.0	114.8	33.3	47.1	70.5	66.7	
Feb. 04.	mass	13	45	47	10	31	24	30	233	14	45	180	2	674
	volume	0.1	0.3	0.7	0.1	0.2	0.7	0.35	2.24	0.26	1.2	2.5	0.03	8.68
	density	130.0	150.0	67.1	100.0	155.0	34.3	85.7	104.0	53.8	37.5	72.0	66.7	
Feb. 05.	mass	32	23	110	29	68	21	21	333	13	43	182	2	877
	volume	0.3	0.4	1.2	0.5	0.5	0.2	0.2	2.31	0.24	1.2	2.5	0.02	9.57
	density	106.7	57.5	91.7	58.0	136.0	105.0	105.0	144.2	54.2	35.8	72.8	100.0	
Total	mass	213	235	394	154	277	172	146	1406	69	186	817	13	
	volume	1.8	2.3	4.3	1.5	2.0	2.2	1.2	11.6	1.7	4.4	11.7	0.5	
Avg.mass		42.6	47.0	78.8	30.8	55.4	34.4	29.2	281.2	13.8	37.2	163.4	2.6	
STD mass		± 28.6	± 25.9	± 26.8	± 31.8	± 34.5	± 36.0	± 13.6	± 50.5	± 6.2	± 12.6	± 26.7	± 0.9	
Avg. volume		0.36	0.45	0.87	0.30	0.40	0.44	0.24	2.32	0.34	0.88	2.34	0.11	
STD volume		± 0.22	± 0.13	± 0.21	± 0.23	± 0.16	± 0.24	± 0.08	± 0.51	± 0.20	± 0.43	± 0.23	± 0.16	
Avg. density		118.3	104.4	90.8	102.7	138.5	78.2	119.7	121.4	40.8	42.3	69.8	24.5	
STD density		± 27.8	± 43.7	± 16.4	± 30.3	± 47.2	± 47.1	± 46.0	± 19.6	± 10.3	± 20.2	± 5.4	± 32.4	

applied units: mass [kg], volume [m3], density [kg/m3]

Avg. = average

STD = standard deviation

Table 3. Specific MSW output winter test period

Zone Code.	Mass output for 5 days [kg]	Avg. output per day [kg]	No. of inhabitants	Specific output [kg/person/day]
A	213	42.6	90	0.47
B	235	47	111	0.42
C	394	78.8	101	0.78
D	154	30.8	60	0.51
E	277	55.4	82	0.68
F	172	34.4	55	0.63
Zone Code.	Mass output for 5 days [kg]	Avg. output per day [kg]	No. of beds	Specific output [kg/bed/day]
H1	146	29.2	36	0.81
H2	1406	281.2	492	0.57
Zone Code.	Mass output for 5 days [kg]	Avg. output per day [kg]	Office space [m2]	Specific output [kg/m2/day]
M1	69	13.8	84	0.16
M2	186	37.2	300	0.12
O	817	163.4	2290	0.07
P	13	2.6		

- for residential zones as kg/person/day,

- for hotels as kg/bed/day,

- for office and market zones as kg/m^2/day (relative to office or shop surface).

Results of mechanical composition and physical-chemical determinations are presented on 12 data sheets in Appendix II (tables A1-A12). Each table contains results of determinations carried out from samples collected on Monday and Thursday from a given sampling zone.

The tables contains following data:

- mechanical composition of raw sample,
- hygroscopic moisture, ash and combustibles content relative to air dry sample,
- total moisture, ash and combustibles content relative to raw sample,
- heating value calculated from mechanical composition relative to air dry and raw sample,
- elementary composition (carbon, hydrogen, oxygen, nitrogen sulphur and chorine) relative to air-dry sample.

The laboratory measurements were performed with analytical accuracy and the data given in the tables are averages of three parallel measurements.

5. Discussion of results

Detailed discussion of following measured results are given:

- bulk density,
- mechanical composition,
- physical properties,
- heating value.

Results from this test (winter period) are compared to the data obtained during summer test period and significant differences are indicated. Data from summer and winter test periods are averaged and compared to data collected by FKFV during past years.

Comparative data have been available for above properties from Analytical Dept. of FKFV. for a 5 year long period (1987-1991).

5.1. General remarks about results

The general remarks about the collected data are similar to those noted in our previous study. The quantity of collected samples varied substantially with the zone and time of collection. This effect was partly compensated by modifying the amount reduction procedure as described in chapter 2.1. As a consequence the differences in waste composition and output have to be handled very carefully. Deviations in waste output and waste composition on different collection days and different locations is rather random than significant therefore the results obtained for zones of identical character were averaged. The mechanical composition was calculated as a weighted average (proportional to the amount of waste in given zone), the physical properties were averaged from original data using plain (arithmetical) average method. The average data for mechanical composition and physical properties of MSW samples for winter test period are summarised in Table 4. Average mechanical composition and physical properties of samples are graphically presented on bar diagrams shown in Figures 1. and 2.

It should be noted that in park area (zone P) there was no maintenance work in the time period of sampling so the collected waste represents the usual public and household waste.

5.2. Bulk density and specific output

The total mass output and bulk density of collected MSW samples for summer and winter test periods and their averaged values are summarised in Table 5.

The observed tendencies in bulk density are similar to data obtained during summer test period, however in some sampling zones substantial differences occurred. This differences are due to relatively low number of samples. It must be mentioned that the bulk density of waste is also influenced by collection frequency (higher frequency means lower bulk density).

The specific MSW output for summer and winter test periods are summarised in Table 6. The correlation between specific outputs in sampling zones for summer an winter test periods seem to be very good.

5.3. Mechanical composition

The mechanical composition and physical properties of MSW samples from

- residential areas (zones A..F)
- hotels (zones H1+H2)
- markets (zones M1+M2)
- office (zone O)
- park area (zone P)

for winter and summer test periods are summarised in Tables 7. and 8., respectively.

Table 4. Averaged mechanical composition and physical properties of MSW winter test period

Mechanical composition [%] (weigthed average)	Zones								
	A+B	C+D	E+F	A....F	H1+H2	M1+M2	O	P	A....P
paper	21.15	25.06	6.36	17.38	14.20	59.88	80.00	25.00	27.09
textile	3.80	8.81	1.23	4.62	2.26	0.00	0.47	0.00	2.99
plastics	12.75	8.44	5.56	8.80	4.89	7.79	3.72	16.67	6.97
glass	2.10	5.94	3.70	3.96	7.21	7.56	1.40	16.67	5.09
grass, greens	0.75	0.00	0.00	0.23	0.98	0.00	0.00	0.00	0.42
lether	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
rubber	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
metals	2.37	6.19	2.41	3.68	1.02	3.14	6.98	13.33	3.22
kitchen garbage	42.44	27.63	42.16	37.29	57.21	14.07	5.12	21.67	37.83
stones, ceramics	1.83	5.63	1.54	3.02	3.44	2.33	0.00	0.00	2.74
other	12.81	12.31	37.04	21.00	8.79	5.23	2.33	6.67	13.63
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Physical properties averaged values	A+B	C+D	E+F	A....F	H1+H2	M1+M2	O	P	A.....P
- moisture** [%]	46.60	43.93	53.10	47.88	44.28	41.07	21.92	58.13	42.65
- ash** [%]	10.08	9.79	7.18	9.02	10.38	6.18	9.69	4.70	7.99
- combustibles** [%]	43.32	44.96	39.73	42.67	45.34	52.75	68.41	37.17	49.27
- total [%]	100.00	98.68	100.00	99.56	100.00	100.00	100.01	100.00	99.91
Bulk density [kg/m3]	111.35	96.75	108.35	105.48	120.55	41.55	69.80	24.50	72.38
Calculated heating value:									
- air-dry waste [kJ/kg]	16053	10825	12650	13176	13285	16190	16370	12680	14340
- row waste [kJ/kg]	8608	7968	5948	7508	7410	9528	12755	5095	8459

** related to raw waste

Figure 1. Mechanical composition of MSW samples, winter period

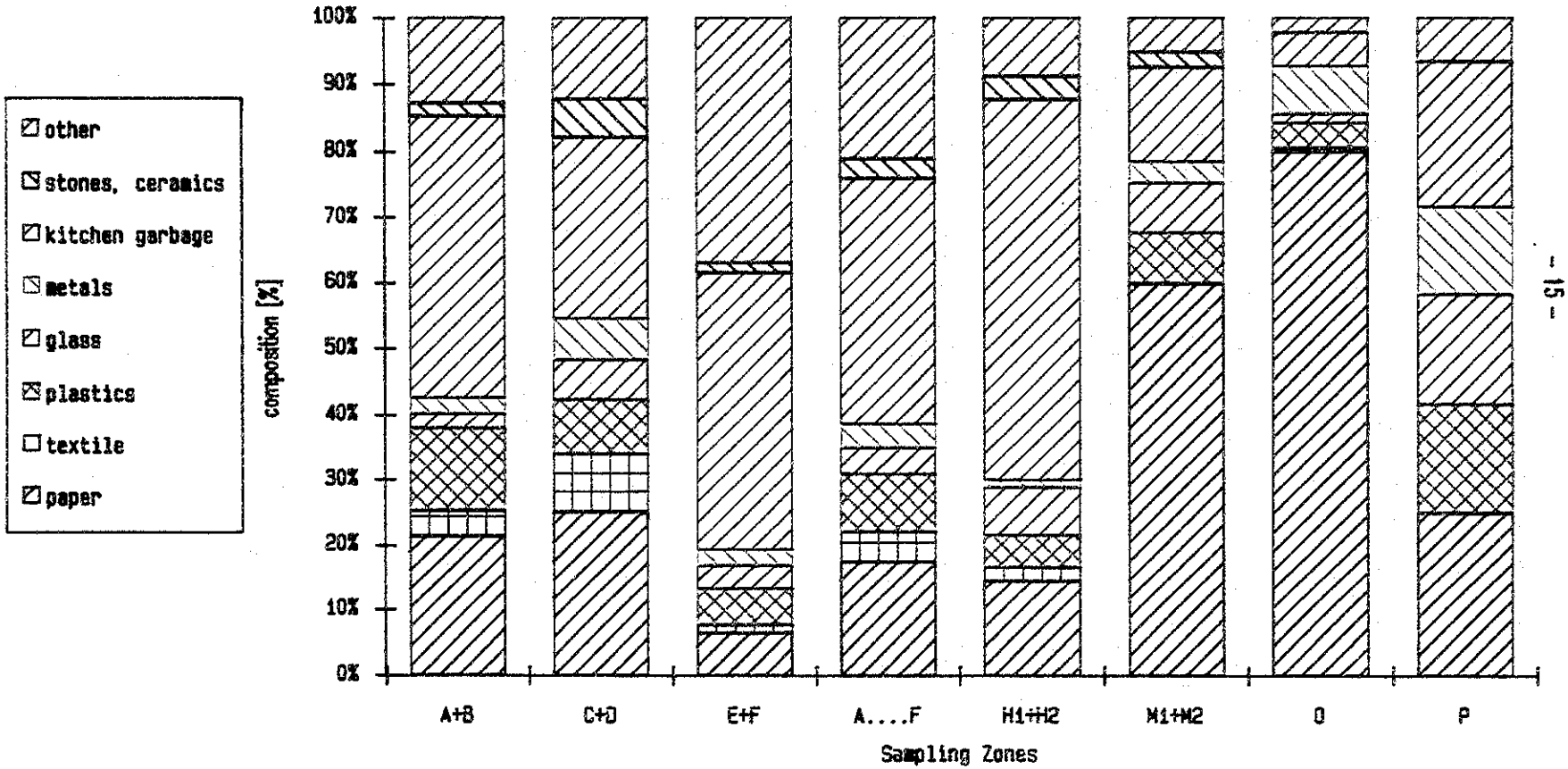


Figure 2. Physical properties of MSW samples, winter perioc

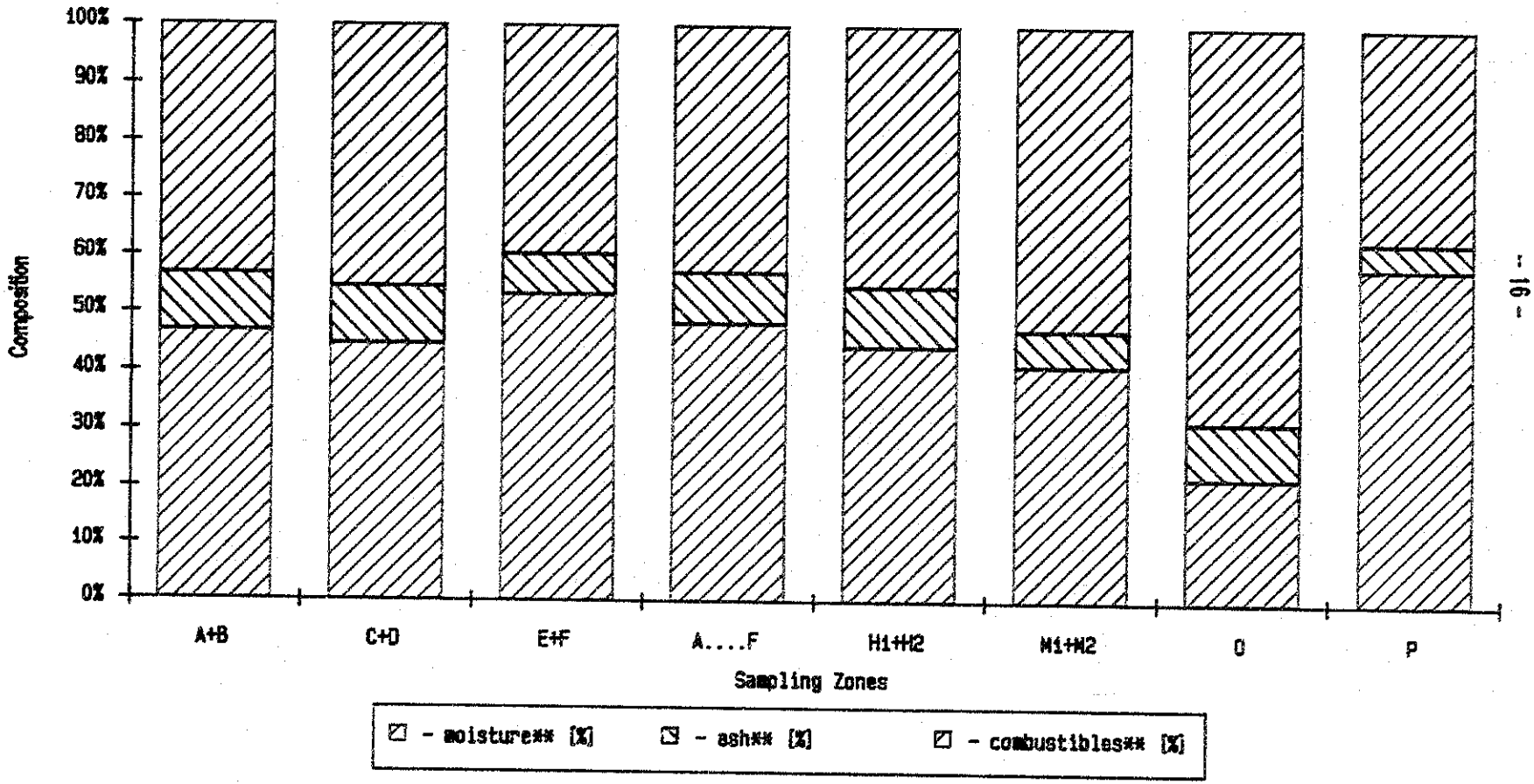


TABLE 5. MSW output and bulk density summer-winter test averages

Zone Code.	Mass output summer test [kg]	Mass output winter test [kg]	Mass output average [kg]	Bulk density summer test [kg/m3]	Bulk density winter test [kg/m3]	Bulk density average [kg/m3]
A	310	213	261.5	175.4	118.3	146.9
B	306	235	270.5	98.3	104.4	101.4
C	344	394	369.0	75.1	90.8	83.0
D	224	154	189.0	141.0	102.7	121.9
E	202	277	239.5	122.2	138.5	130.4
F	238	172	205.0	161.4	78.2	119.8
H1	134	146	140.0	98.5	119.7	109.1
H2	1905.1	1406	1655.6	148.4	121.4	134.9
M1	55.5	69	62.3	51.1	40.8	46.0
M2	212.1	186	199.1	43.5	42.3	42.9
O	824	817	820.5	68.1	69.8	69.0
P	71.5	13	42.3	81.3	24.5	52.9

Table 6. Specific MSW output summer-winter test averages

Zone Code.	Specific output [kg/person/day]		
	summer test	winter test	average
A	0.47	0.69	0.58
B	0.42	0.55	0.49
C	0.78	0.68	0.73
D	0.51	0.75	0.63
E	0.68	0.49	0.58
F	0.63	0.87	0.75
Zone Code.	Specific output [kg/bed/day]		
	summer test	winter test	average
H1	0.81	0.74	0.78
H2	0.57	0.77	0.67
Zone Code.	Specific output [kg/m2/day]		#DIV/0! #DIV/0!
	summer test	winter test	average
M1	0.16	0.13	0.15
M2	0.12	0.14	0.13
O	0.07	0.07	0.07

Table 7. Mechanical composition and physical properties of MSW summer-winter test averages

Mechanical composition [%]	residental zones A..F			hotel zones H1+H2			market zones M1+M2		
(weigthed average)	winter	summer	average	winter	summer	average	winter	summer	average
paper	17.38	15.64	16.51	14.20	16.10	15.15	59.88	42.03	50.96
textile	4.62	9.12	6.87	2.26	0.69	1.48	0.00	0.00	0.00
plastics	8.80	7.52	8.16	4.89	4.92	4.90	7.79	11.59	9.69
glass	3.96	5.81	4.89	7.21	9.69	8.45	7.56	3.04	5.30
grass, greens	0.23	10.09	5.16	0.98	0.09	0.54	0.00	0.00	0.00
lether	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
rubber	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
metals	3.68	2.65	3.17	1.02	1.94	1.48	3.14	15.94	9.54
kitchen garbage	37.29	25.83	31.56	57.21	59.31	58.26	14.07	9.42	11.74
stones, ceramics	3.02	1.54	2.28	3.44	0.67	2.06	2.33	0.00	1.16
other	21.00	21.80	21.40	8.79	6.59	7.69	5.23	17.98	11.61
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Physical properties	residental zones A..F			hotel zones H1+H2			market zones M1+M2		
(plain averages)	winter	summer	average	winter	summer	average	winter	summer	average
- moisture** [%]	47.88	57.87	52.87	44.28	54.69	49.49	41.07	34.73	37.90
- ash** [%]	9.46	13.80	11.63	10.38	6.55	8.46	6.18	5.68	5.93
- combustibles** [%]	42.67	28.33	35.50	45.34	38.76	42.05	52.75	59.59	56.17
- total [%]	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Bulk density [kg/m3]	105.48	128.90	117.19	120.55	123.45	122.00	41.55	47.30	44.43
Calculated heating value:									
- air-dry waste [kJ/kg]	13176	14292	13734	13285	13850	13568	16190	15500	15845
- row waste [kJ/kg]	7508	6228	6868	7410	6585	6998	9528	10830	10179

** related to raw waste

Table 8. Mechanical composition and physical properties of MSW summer-winter test averages

Mechanical composition [%]	offices, zone O			parks, zone P			total of all zones A..P		
(weigthed average)	winter	summer	average	winter	summer	average	winter	summer	average
paper	80.00	46.43	63.22	25.00	14.63	19.82	27.09	20.12	23.61
textile	0.47	1.43	0.95	0.00	17.46	8.73	2.99	4.95	3.97
plastics	3.72	3.57	3.65	16.67	14.63	15.65	6.97	6.73	6.85
glass	1.40	2.14	1.77	16.67	9.76	13.21	5.09	6.83	5.96
grass, greens	0.00	1.43	0.72	0.00	0.00	0.00	0.42	4.79	2.61
lether	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
rubber	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
metals	6.98	0.71	3.84	13.33	5.61	9.47	3.22	3.31	3.27
kitchen garbage	5.12	7.86	6.49	21.67	19.51	20.59	37.83	35.33	36.58
stones, ceramics	0.00	12.14	6.07	0.00	0.00	0.00	2.74	1.88	2.31
other	2.33	24.29	13.31	6.67	18.40	12.53	13.63	16.06	14.85
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Physical properties	offices, zone O			parks, zone P			total of all zones A..P		
(plain averages)	winter	summer	average	winter	summer	average	winter	summer	average
- moisture** [%]	21.92	41.18	31.55	58.13	40.40	49.27	42.65	45.77	44.21
- ash** [%]	9.69	15.27	12.48	4.70	6.06	5.38	7.99	9.47	8.73
- combustibles** [%]	68.40	43.55	55.98	37.17	53.54	45.36	49.27	44.76	47.01
- total [%]	100.00	100.00	100.00	100.00	100.00	100.00	99.91	100.00	99.96
Bulk density [kg/m3]	69.80	68.10	68.95	24.50	81.30	52.90	72.83	89.81	81.32
Calculated heating value:									
- air-dry waste [kJ/kg]	16370	14475	15423	12680		12680	14340	14524	14432
- row waste [kJ/kg]	12755	9575	11165	5095		5095	8459	8925	8692

** related to raw waste

5.3.1. Paper content

Paper is the main constituent of MSW samples from offices (zone O) and markets (zones M1,M2) where the paper content was 80 % and 59.88 %. In these zones the paper quality is homogeneous: in market zone mainly cardboard and packaging paper while in office zone mainly computer printer paper. The seasonal variations in paper content in this sampling zones are minimal. Generally speaking in this sampling zones the overall composition of samples has very small seasonal variation.

The MSW samples from residential areas (A..F) contained in average 17.34 % paper. In high income residence areas the paper content is greater than the average value while in low income areas the paper content is extremely low (6.36 %). In summer test period there were no significant differences between high and low income areas, the significant difference in winter period can be explained by the fact that in low income areas solid fuels are used for household heating. The paper quality in these zones is rather heterogeneous and it is highly contaminated with other waste therefore it is not suitable for recycling.

5.3.2. Textile content

Textile was occurring in all MSW samples except for samples collected in markets (zone M1, M2) and park area (zone P). Textile content showed very big variations in different samples (between 0.4 % and 8.7 %). The big deviation in textile content is due to small amount of samples rather to differences in zones. Due to high deviations the seasonal tendencies can not be observed.

5.3.3. Plastics content

Some characteristic differences can be observed in plastics content of MSW samples from different sampling zones. These differences are similar to those noticed during summer test period. Samples from park area (zone P) had the highest plastics content (16,67 %) and it is composed mainly from bottles. MSW samples from offices (zone O) had lowest plastic content (3.72 %). Proportion of plastics in waste samples from residential areas (zones A..F) is similar to data obtained for summer period (8.79 %) and it is virtually independent from social circumstances in the sampling area.

5.3.4. Glass content

Glass content of waste sample from different sampling zones varied between 1.4 % and 16.67 %. It is very similar to the data for summer test (glass content between 2 and 10 %). The highest glass content during both tests was noticed in park area (zone P) which can be explained by the characteristics in these zones. The glass content of waste samples from residential areas (zones A..F) was between 2-4.5 %. The glass found in collected samples were without exemption glass bottles which can not be returned to manufacturers.

5.3.5. Grass, greens content

The greens content is almost negligible in waste samples from all sampling areas (see remark about park area in section 5.1.). Waste from residential area (zones A..F) contained about 10±3 % greens during summer test period. The lower greens content of waste samples care reflected in lower moisture content, too. In residential areas (zones A..F) the moisture content is lower by 10 % in winter period from summer value.

5.3.6. Metals content

Waste samples from residential areas (zones A..F) contained about 3.68 % metal residues. No deviations due to seasonal variations or social circumstances can be observed.

The extremely high metal content in samples from park area and offices (6.98 5 and 13.3 5) is not characteristic rather incidental and is due to small number of samples.

5.3.7. Kitchen garbage content

Proportion of kitchen garbage was highest (nearly 60 %)in waste from hotel zone and lowest in waste coming from office zone. In waste samples from residential areas (zones A..F) the proportion of kitchen garbage was around 37.04%, and no correlation was found between amount of kitchen garbage in waste and the income of inhabitants. This value seem to be unexplainable high in comparison to the similar data form summer test period (about 26 %) but also in comparison to the long term composition data obtained from FKFV.

5.3.8. Stones and ceramics content

Proportion of stones and ceramics in waste samples was between 1.5 and 3.4 %. These values seems to be realistic in comparison to the long term data from FKFV.

Data from summer test period showed very big variations which are rather incidental than characteristic for the given sampling zone, therefore no comparison can be made.

5.3.9. Rubber and leather content.

Rubber and leather was not found in collected samples. It is probably due to small number of collected samples.

5.3.10. Others content

In samples from different zones a portion of 2.33 % - 37.04 % could not be separated in one of above categories and this residue was classified as "others". Their proportion is strongly influenced by mixing during transportation.

This group consist mainly from ash, slag, soil and other inorganic dust. The constituent mixed inseparable during transportation were also assigned to group "other". The paper and

plastics originating from kitchen waste amounted to about one fifth of the group "other". A similar proportion of group "other" was coming from complex waste made out of multiply materials and hazardous components occurring in municipal waste (medicines, dry batteries, etc.)

5.4. Physical properties

Total moisture of collected samples was between 21.9 and 58.1 % (in average 42.65 %). The moisture content of samples containing high proportion of kitchen garbage is higher then 40 %. The average moisture content of winter sample is lower than moisture content of summer samples, the difference is even more expressed in case of samples from residential areas (zones A..F)

Ash content of waste samples was between 4.45 % and 10.10 %. This values are also lower than corresponding values from summer sampling period.

From calculated heating value it can be concluded that waste from all zones are suitable for incineration. The heating value calculated for row sample (original moisture content) is between 5095 and 12755 kJ/kg. This

5.4. Results obtained by JICA and FKFV methodology

Small number of samples taken during this survey can not satisfy the demands necessary for representative survey. Therefore it was found advisable to compare the results obtained in this survey to those collected by FKFV during longer time period. Analytical department of FKFV has been doing qualitative and quantitative analysis of the municipal solid waste for more than two decades at a rate of more than 150 samples/year.

According to FKFV methodology samples are taken evenly distributed during the whole year from following zones:

- residential area of inner city with old type buildings,
- residential area of modern high-rise block buildings,
- residential area of family houses with gardens.

Mechanical composition and physical properties of MSW according to different methodologies are summarised in Tables 9 and 10. Maximum ±5.47 percent deviation was found in mechanical composition between FKFV data and summer + winter average values from JICA survey (averages from residential zones A..F). Mechanical composition of waste from residential areas according to FKFV and JICA results (in JICA survey average for sampling zones A..F) on pie diagrams in Figures 3. and 4., respectively.

Table 9. Average composition of MSW comparison of JICA test results and FKFV data

Mechanical composition [%] (weigthed average)	results from JICA tests*			FKFV** data	Diff.
	winter	summer	average		
paper	17.38	15.64	16.51	18.72	- 2.21
textile	4.62	9.12	6.87	4.46	+ 2.41
plastics	8.80	7.52	8.16	4.56	+ 3.60
glass	3.96	5.81	4.89	5.00	- 0.11
grass, greens	0.23	10.09	5.16	7.18	- 2.02
lether	0.00	0.00	0.00	0.00	± 0.00
rubber	0.00	0.00	0.00	0.00	± 0.00
metals	3.68	2.65	3.17	5.05	- 1.88
kitchen garbage	37.29	25.83	31.56	28.16	+ 3.40
stones, ceramics	3.02	1.54	2.28	0.00	+ 2.28
other	21.00	21.80	21.40	26.87	- 5.47
Total	100.00	100.00	100.00	100.00	

*Weighted averages for residental zones (A..F)

**Avargeged data for years 1987-1991

Table 10. Average physical properties of MSW comparison of JICA test results and FKFV data

Physical properties (plain averages)	results from JICA tests*			FKFV** data	Diff.
	winter	summer	average		
- moisture*** [%]	47.88	57.87	52.87	36.67	+ 16.20
- ash*** [%]	9.46	13.80	11.63	28.19	- 16.56
- combustibles*** [%]	42.67	28.33	35.50	35.14	+ 0.36
- total [%]	100.00	100.00	100.00	100.00	+ 0.00
Bulk density [kg/m3]	105.48	128.90	117.19	157.0	- 39.81
Calculated heating value:					
- row waste [kJ/kg]	7508	6228	6868	6730	+ 137.75

*Aritmethical averages for residental zones (A..F)

**Avargeged data for years 1987-1991

** related to raw waste

Figure 3. Mechanical composition of samples, winter+summer averages

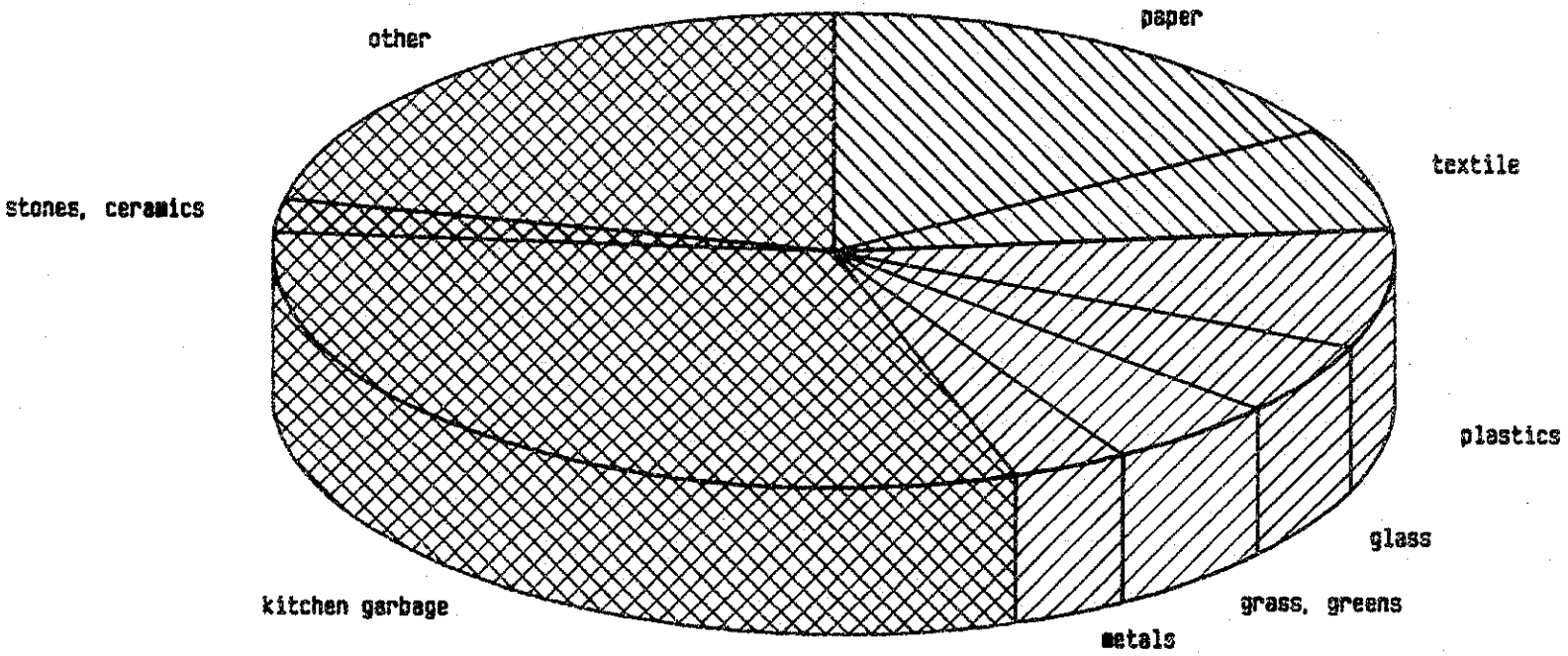
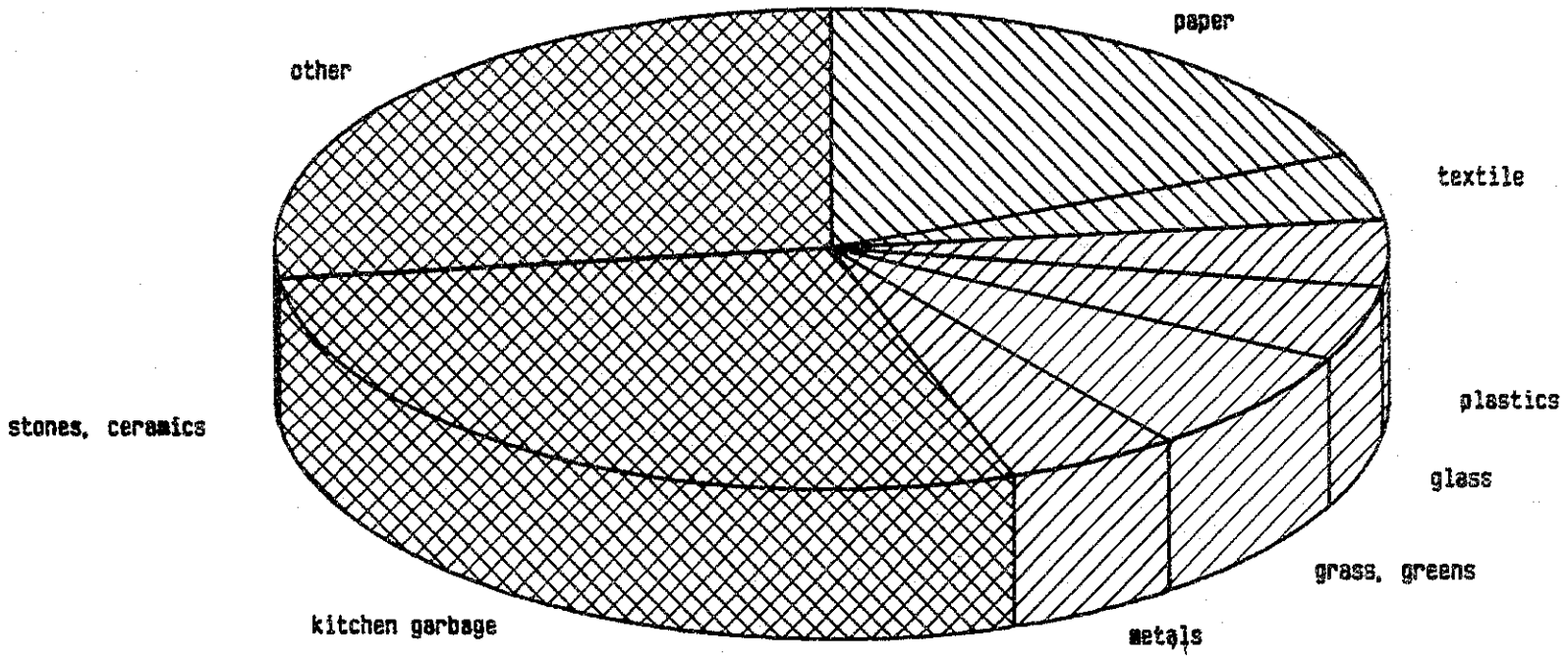
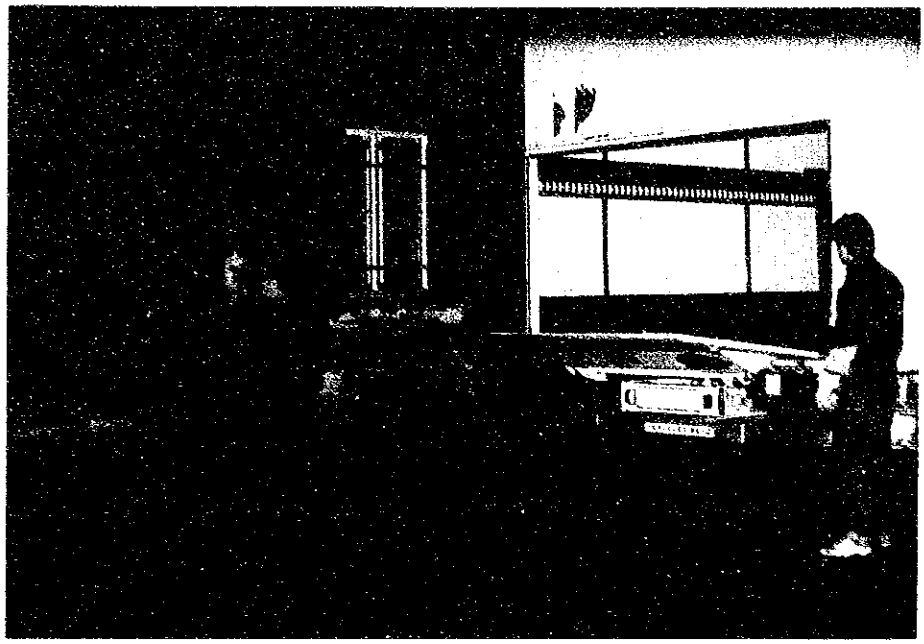


Figure 4. Mechanical composition of samples, FKFV data

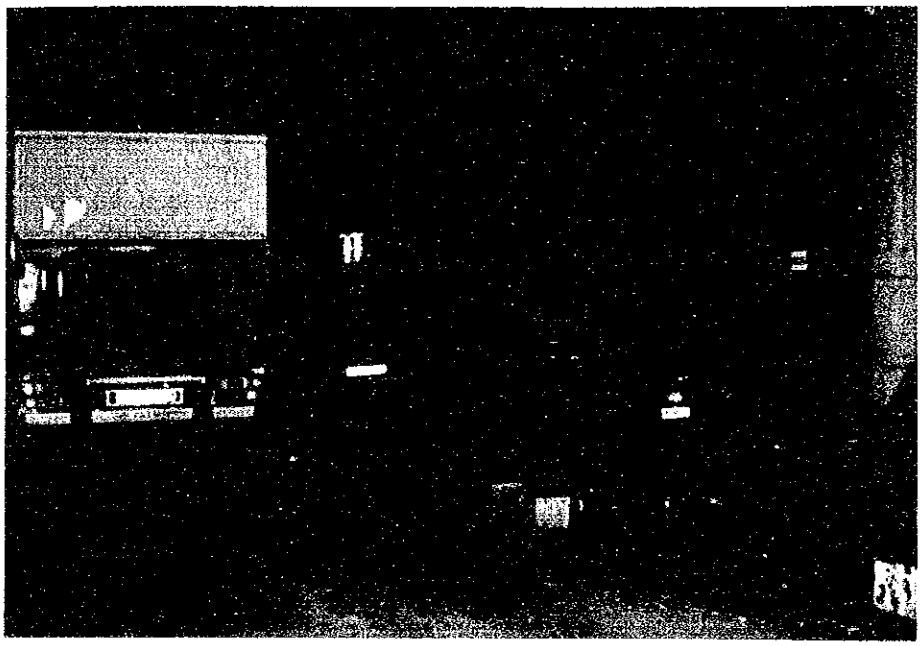


Appendix I.

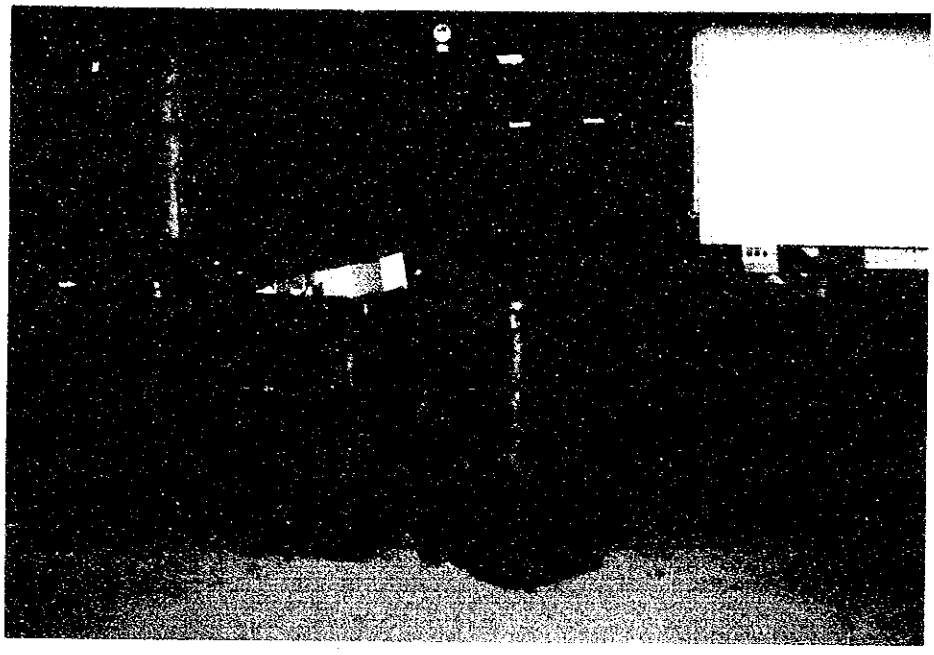
Photos about MSW sampling and analysis in winter test period



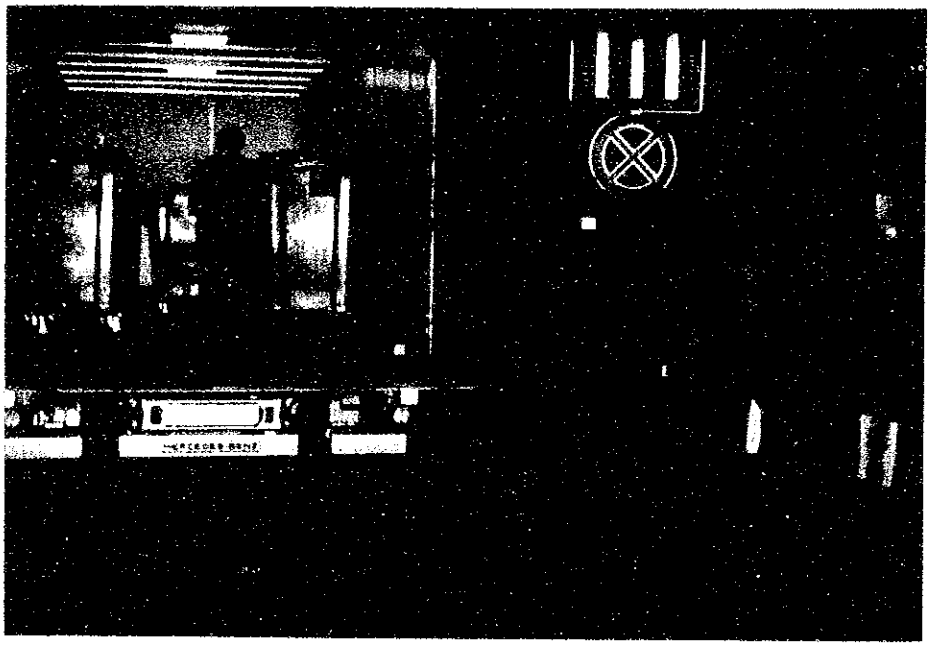
Collection of MSW samples at Hotel Victoria (sapling zone H1)



Collection of MSW samples at Hotel Béke Radisson (sapling zone H2)



Collection of MSW samples at Csemege-Meinl Shop No 20 (sapling zone M2)



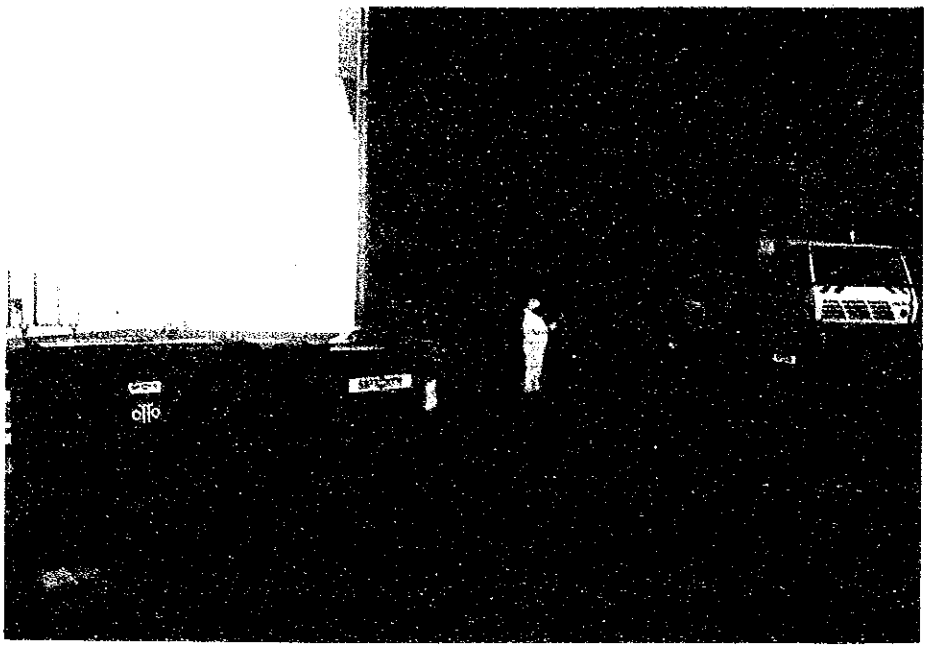
Collection of MSW samples at Csemege-Meinl Shop No 49 (sapling zone M1)

Collection of MSW samples at Budapest, X. Kozma u 15/I-III (low income residental area, sapling zone code F)

Collection of MSW samples at Budapest, XIV. Újvidék tér 6-14 (middle income residental area, sapling zone code D)

Collection of MSW samples in publik park at Budapest, V. Erzsébet tér (zone code P)

Emptying the MSW Samples from 0.77m3 collection containers



Arrival of collection containers to the separation site on the territory of Budapest Waste Incinerator

Emptyinng the 0.77 m^3 collection containers

Preparation of waste for determination of mechanical composition

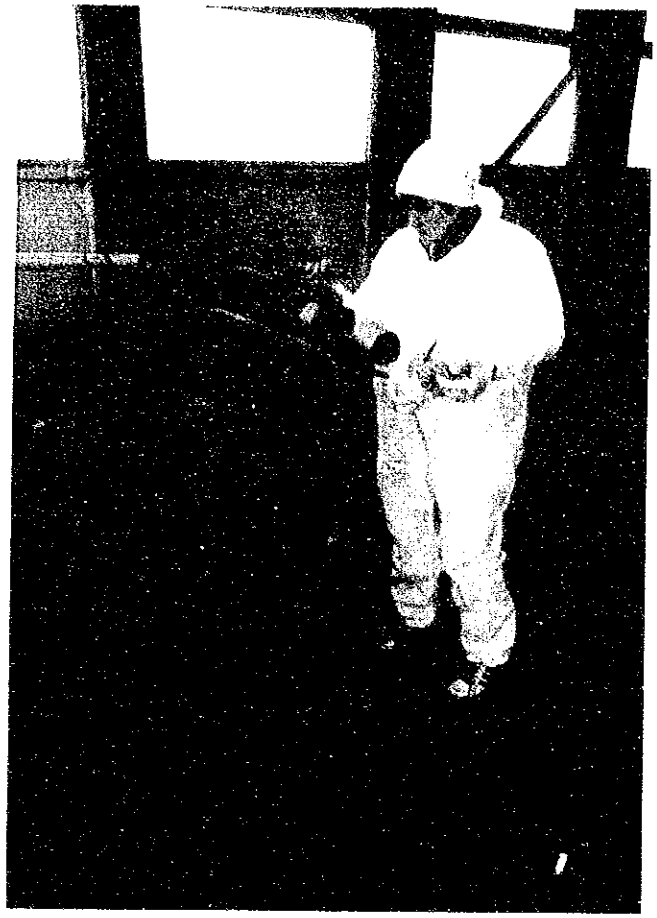
Separation of MSW samples into different classes

MSW sample on separation floor before separation

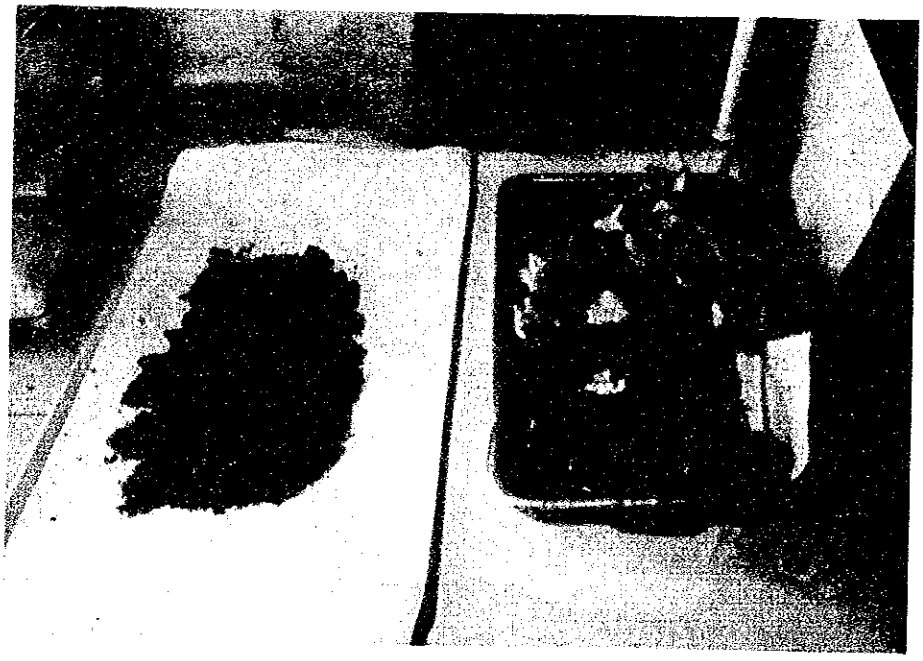
MSW sample on separation floor during separation

An MSW sample before mechanical separation

Weighing of separated fractions



Preparation of laboratory samples



Dried laboratory sample before and after homogenisation

Appendix II.

Data sheets containing the mechanical composition and physical properties of MSW samples

Winter test period

Table A1. Mechanical composition and physical-chemical properties of municipal solid waste

ZONE CODE: A

Mechanical composition	Monday sample		Thursday sample		Average
	[kg]	[%]	[kg]	[%]	[%]
paper	9.00	0.20	3.60	0.28	22.11%
textile	1.50	0.03	-	-	2.63%
plastics	2.00	0.05	0.80	0.06	4.91%
glass	1.00	0.02	-	-	1.75%
grass, greens	0.50	0.01	-	-	0.88%
lether	-	-	-	-	0.00%
rubber	-	-	-	-	0.00%
metals	1.00	0.02	0.40	0.03	2.46%
kitchen garbage	21.50	0.49	7.60	0.58	51.05%
stones, ceramics	2.50	0.06	0.20	0.02	4.74%
other	5.00	0.11	0.40	0.03	9.47%
Total	44.00	100.00%	13.00	100.00%	100.00%

Physical properties		Monday sample	Thursday sample	Average
Effective moisture	[%]	42.41%	62.24%	52.33%
Higroscopic moisture*	[%]	4.71%	5.23%	4.97%
Ash content*	[%]	25.77%	11.62%	18.70%
Combustibles*	[%]	69.52%	83.15%	76.34%
Physical composition:	[%]			
- moisture**	[%]	45.12%	64.21%	54.67%
- ash**	[%]	14.84%	4.39%	9.61%
- combustibles**	[%]	40.04%	31.40%	35.72%

* air-dry waste

** raw waste

Calorific data		Monday sample	Thursday sample	Average
Calculated heating value				
- air-dry waste	[kJ/kg]	14030	15901	14966
- row waste	[kJ/kg]	7699	5690	6695
Measured (air-dry waste)				
- heat of combustion	[kJ/kg]	14120	18000	16060

Chemical composition (air-dry base)		Monday sample	Thursday sample	Average
- nitrogen	[%]	25.30%	3.26%	14.28%
- carbon	[%]	45.33%	45.71%	45.52%
- hydrogen	[%]	7.40%	7.90%	7.65%
- oxygen	[%]	15.50%	15.50%	15.50%
- sulphur	[%]	0.12%	0.02%	0.07%
- chloride	[%]	0.80%	0.87%	0.84%
- total	[%]	94.45%	73.26%	83.86%

Table A2. Mechanical composition and physical-chemical properties of municipal solid waste

ZONE CODE: B

Mechanical composition	Monday sample		Thursday sample		Average
	[kg]	[%]	[kg]	[%]	[%]
paper	10.00	0.23	8.60	0.66	32.63%
textile	3.50	0.08	0.60	0.05	7.19%
plastics	6.00	0.14	10.00	0.77	28.07%
glass	1.50	0.03	0.60	0.05	3.68%
grass, greens	-	-	0.60	0.05	1.05%
lether	-	-	-	-	0.00%
rubber	-	-	-	-	0.00%
metals	1.50	0.03	0.60	0.05	3.68%
kitchen garbage	18.00	0.41	15.50	1.19	58.77%
stones, ceramics	-	-	-	-	0.00%
other	5.00	0.11	8.50	0.65	23.68%
Total	45.50	103.41%	45.00	346.15%	158.77%

Physical properties		Monday sample	Thursday sample	Average
Effective moisture	[%]	33.33%	38.61%	35.97%
Higroscopic moisture*	[%]	4.40%	3.59%	4.00%
Ash content*	[%]	24.47%	7.80%	16.14%
Combustibles*	[%]	71.13%	88.61%	79.87%
Physical composition:	[%]			
- moisture**	[%]	36.26%	40.81%	38.54%
- ash**	[%]	16.31%	4.79%	10.55%
- combustibles**	[%]	47.42%	54.40%	50.91%

* air-dry waste

** raw waste

Calorific data		Monday sample	Thursday sample	Average
Calculated heating value				
- air-dry waste	[kJ/kg]	16380	17900	17140
- row waste	[kJ/kg]	10440	10594	10517
Measured (air-dry waste)				
- heat of combustion	[kJ/kg]	15300	17700	16500

Chemical composition (air-dry base)		Monday sample	Thursday sample	Average
- nitrogen	[%]	1.52%	1.78%	1.65%
- carbon	[%]	48.37%	46.32%	47.35%
- hydrogen	[%]	7.90%	6.60%	7.25%
- oxygen	[%]	21.40%	17.95%	19.68%
- sulphur	[%]	0.01%	0.00%	0.01%
- chlorine	[%]	0.93%	0.35%	0.64%
- total	[%]	80.13%	73.00%	76.57%

Table A3. Mechanical composition and physical-chemical properties of municipal solid waste

ZONE CODE: C					
Mechanical composition	Monday sample		Thursday sample		Average
	[kg]	[%]	[kg]	[%]	[%]
paper	12.00	0.27	18.80	1.45	54.04%
textile	2.50	0.06	4.80	0.37	12.81%
plastics	2.50	0.06	3.20	0.25	10.00%
glass	8.00	0.18	-	-	14.04%
grass, greens	-	-	-	-	0.00%
lether	-	-	-	-	0.00%
rubber	-	-	-	-	0.00%
metals	0.50	0.01	1.60	0.12	3.68%
kitchen garbage	17.00	0.39	15.60	1.20	57.19%
stones, ceramics	3.00	0.07	-	-	5.26%
other	6.50	0.15	3.00	0.23	16.67%
Total	52.00	118.18%	47.00	361.54%	173.68%

Physical properties		Monday sample	Thursday sample	Average
Effective moisture	[%]	55.81%	30.32%	43.07%
Higroscopic moisture*	[%]	5.28%	6.38%	5.83%
Ash content*	[%]	15.15%	3.40%	9.28%
Combustibles*	[%]	76.57%	90.22%	83.40%
Physical composition:	[%]			
- moisture**	[%]	58.14%	34.77%	46.45%
- ash**	[%]	6.69%	2.37%	4.53%
- combustibles**	[%]	33.84%	62.87%	48.35%

* air-dry waste

** raw waste

Calorific data		Monday sample	Thursday sample	Average
Calculated heating value				
- air-dry waste	[kJ/kg]	12420	16540	14480
- row waste	[kJ/kg]	5199	10790	7994
Measured (air-dry waste)				
- heat of combustion	[kJ/kg]	19860	17400	18630

Chemical composition (air-dry base)		Monday sample	Thursday sample	Average
- nitrogen	[%]	4.03%	2.78%	3.41%
- carbon	[%]	56.68%	49.51%	53.10%
- hydrogen	[%]	7.10%	6.90%	7.00%
- oxygen	[%]	13.90%	18.90%	16.40%
- sulphur	[%]	0.02%	0.01%	0.02%
- chlorine	[%]	1.80%	1.10%	1.45%
- total	[%]	83.53%	79.20%	81.37%

Table A4. Mechanical composition and physical-chemical properties of municipal solid waste

ZONE CODE: D

Mechanical composition	Monday sample		Thursday sample		Average
	[kg]	[%]	[kg]	[%]	[%]
paper	7.50	0.17	1.80	0.14	16.32%
textile	6.00	0.14	0.80	0.06	11.93%
plastics	6.00	0.14	1.80	0.14	13.68%
glass	1.50	0.03	-	-	2.63%
grass, greens	-	-	-	-	0.00%
lether	-	-	-	-	0.00%
rubber	-	-	-	-	0.00%
metals	6.00	0.14	1.80	0.14	13.68%
kitchen garbage	9.00	0.20	2.60	0.20	20.35%
stones, ceramics	6.00	0.14	-	-	10.53%
other	9.00	0.20	1.20	0.09	17.89%
Total	51.00	115.91%	10.00	76.92%	107.02%

Physical properties		Monday sample	Thursday sample	Average
Effective moisture	[%]	33.43%	47.02%	40.23%
Higroscopic moisture*	[%]	7.40%	2.62%	5.01%
Ash content*	[%]	8.32%	46.38%	27.35%
Combustibles*	[%]	84.28%	51.00%	67.64%
Physical composition:	[%]			
- moisture**	[%]	38.36%	48.41%	43.38%
- ash**	[%]	5.54%	24.57%	15.06%
- combustibles**	[%]	56.11%	27.02%	41.56%

* air-dry waste

** raw waste

Calorific data		Monday sample	Thursday sample	Average
Calculated heating value				
- air-dry waste	[kJ/kg]	12790	15500	14145
- row waste	[kJ/kg]	7884	7997	7940
Measured (air-dry waste)				
- heat of combustion	[kJ/kg]	14520	10100	12310

Chemical composition (air-dry base)		Monday sample	Thursday sample	Average
- nitrogen	[%]	2.32%	1.12%	1.72%
- carbon	[%]	60.39%	33.52%	46.96%
- hydrogen	[%]	7.90%	3.80%	5.85%
- oxygen	[%]	15.40%	17.00%	16.20%
- sulphur	[%]	0.02%	0.01%	0.02%
- chlorine	[%]	0.10%	0.11%	0.11%
- total	[%]	86.13%	55.56%	70.85%

Table A5. Mechanical composition and physical-chemical properties of municipal solid waste

ZONE CODE: E

Mechanical composition	Monday sample		Thursday sample		Average
	[kg]	[%]	[kg]	[%]	[%]
paper	2.00	0.05	0.50	0.04	4.39%
textile	-	-	1.50	0.12	2.63%
plastics	3.50	0.08	0.50	0.04	7.02%
glass	2.50	0.06	0.80	0.06	5.79%
grass, greens	-	-	-	-	0.00%
lether	-	-	-	-	0.00%
rubber	-	-	-	-	0.00%
metals	1.00	0.02	0.20	0.02	2.11%
kitchen garbage	19.00	0.43	15.00	1.15	59.65%
stones, ceramics	-	-	-	-	0.00%
other	27.00	0.61	12.50	0.96	69.30%
Total	55.00	125.00%	31.00	238.46%	150.88%

Physical properties		Monday sample	Thursday sample	Average
Effective moisture	[%]	46.38%	55.51%	50.95%
Higroscopic moisture*	[%]	8.48%	4.73%	6.61%
Ash content*	[%]	15.63%	10.53%	13.08%
Combustibles*	[%]	75.89%	84.74%	80.32%
Physical composition:	[%]			
- moisture**	[%]	50.93%	57.61%	54.27%
- ash**	[%]	8.38%	4.68%	6.53%
- combustibles**	[%]	40.69%	37.70%	39.20%

* air-dry waste

** raw waste

Calorific data		Monday sample	Thursday sample	Average
Calculated heating value				
- air-dry waste	[kJ/kg]	12270	12300	12285
- row waste	[kJ/kg]	6021	5213	5617
Measured (air-dry waste)				
- heat of combustion	[kJ/kg]	15110	17100	16105

Chemical composition (air-dry base)		Monday sample	Thursday sample	Average
- nitrogen	[%]	2.45%	2.41%	2.43%
- carbon	[%]	57.92%	45.48%	51.70%
- hydrogen	[%]	7.20%	6.90%	7.05%
- oxygen	[%]	18.50%	15.11%	16.81%
- sulphur	[%]	0.06%	0.06%	0.06%
- chlorine	[%]	1.02%	0.44%	0.73%
- total	[%]	87.15%	70.40%	78.78%

Table A6. Mechanical composition and physical-chemical properties of municipal solid waste

ZONE CODE: F

Mechanical composition	Monday sample		Thursday sample		Average
	[kg]	[%]	[kg]	[%]	[%]
paper	4.00	9.09%	3.80	29.23%	13.68%
textile	-	-	0.50	3.85%	0.88%
plastics	3.00	6.82%	2.00	15.38%	8.77%
glass	1.50	3.41%	1.20	9.23%	4.74%
grass, greens	-	-	-	-	0.00%
lether	-	-	-	-	0.00%
rubber	-	-	-	-	0.00%
metals	1.50	3.41%	1.20	9.23%	4.74%
kitchen garbage	25.50	57.95%	8.80	67.69%	60.18%
stones, ceramics	-	-	2.50	19.23%	4.39%
other	16.50	37.50%	4.00	30.77%	35.96%
Total	52.00	118.18%	24.00	184.62%	133.33%

Physical properties		Monday sample	Thursday sample	Average
Effective moisture	[%]	38.85%	60.61%	49.73%
Higroscopic moisture*	[%]	4.67%	3.85%	4.26%
Ash content*	[%]	17.08%	13.22%	15.15%
Combustibles*	[%]	78.25%	82.93%	80.59%
Physical composition:	[%]			
- moisture**	[%]	41.71%	62.13%	51.92%
- ash**	[%]	10.44%	5.21%	7.83%
- combustibles**	[%]	47.85%	32.67%	40.26%

* air-dry waste

** raw waste

Calorific data		Monday sample	Thursday sample	Average
Calculated heating value				
- air-dry waste	[kJ/kg]	13240	12790	13015
- row waste	[kJ/kg]	7718	4844	6281
Measured (air-dry waste)				
- heat of combustion	[kJ/kg]	15000	17500	16250

Chemical composition (air-dry base)		Monday sample	Thursday sample	Average
- nitrogen	[%]	4.31%	2.83%	3.57%
- carbon	[%]	48.21%	44.61%	46.41%
- hydrogen	[%]	7.40%	6.60%	7.00%
- oxygen	[%]	13.90%	16.01%	14.96%
- sulphur	[%]	0.03%	0.06%	0.05%
- chlorine	[%]	0.75%	1.05%	0.90%
- total	[%]	74.60%	71.16%	72.88%

Table A7. Mechanical composition and physical-chemical properties of municipal solid waste

ZONE CODE: H1					
Mechanical composition	Monday sample		Thursday sample		Average
	(kg)	[%]	(kg)	[%]	[%]
paper	8.00	18.18%	2.80	21.54%	18.95%
textile	1.00	2.27%	5.40	41.54%	11.23%
plastics	2.50	5.68%	3.40	26.15%	10.35%
glass	4.00	9.09%	7.50	57.69%	20.18%
grass, greens	-	-	-	-	0.00%
lether	-	-	-	-	0.00%
rubber	-	-	-	-	0.00%
metals	1.00	2.27%	0.60	4.62%	2.81%
kitchen garbage	15.50	35.23%	7.50	57.69%	40.35%
stones, ceramics	10.50	23.86%	-	-	18.42%
other	8.50	19.32%	2.80	21.54%	19.82%
Total	51.00	115.91%	30.00	230.77%	142.11%

Physical properties		Monday sample	Thursday sample	Average
Effective moisture	[%]	35.71%	57.14%	46.43%
Higroscopic moisture*	[%]	4.33%	5.98%	5.16%
Ash content*	[%]	34.26%	4.86%	19.56%
Combustibles*	[%]	61.41%	89.16%	75.29%
Physical composition:	[%]			
- moisture**	[%]	38.49%	59.70%	49.10%
- ash**	[%]	22.03%	2.08%	12.05%
- combustibles**	[%]	39.48%	38.21%	38.85%

* air-dry waste

** raw waste

Calorific data		Monday sample	Thursday sample	Average
Calculated heating value				
- air-dry waste	[kJ/kg]	10780	13140	11960
- row waste	[kJ/kg]	6630	5295	5963
Measured (air-dry waste)				
- heat of combustion	[kJ/kg]	16400	17350	16875

Chemical composition (air-dry base)		Monday sample	Thursday sample	Average
- nitrogen	[%]	2.42%	2.32%	2.37%
- carbon	[%]	40.87%	43.05%	41.96%
- hydrogen	[%]	6.70%	6.90%	6.80%
- oxygen	[%]	13.30%	17.81%	15.56%
- sulphur	[%]	0.01%	0.00%	0.01%
- chlorine	[%]	0.50%	1.15%	0.83%
- total	[%]	63.80%	71.23%	67.52%

Table A8. Mechanical composition and physical-chemical properties of municipal solid waste

ZONE CODE: H2					
Mechanical composition	Monday sample		Thursday sample		Average
	[kg]	[%]	[kg]	[%]	[%]
paper	24.00	54.55%	8.50	65.38%	57.02%
textile	0.50	1.14%	-	-	0.88%
plastics	2.00	4.55%	7.00	53.85%	15.79%
glass	5.00	11.36%	5.50	42.31%	18.42%
grass, greens	-	-	3.00	23.08%	5.26%
lether	-	-	-	-	0.00%
rubber	-	-	-	-	0.00%
metals	0.50	1.14%	1.00	7.69%	2.63%
kitchen garbage	78.50	178.41%	73.00	561.54%	265.79%
stones, ceramics	-	-	-	-	0.00%
other	6.50	14.77%	9.00	69.23%	27.19%
Total	117.00	265.91%	107.00	823.08%	392.98%

Physical properties		Monday sample	Thursday sample	Average
Effective moisture	[%]	62.22%	11.10%	36.66%
Higroscopic moisture*	[%]	5.18%	4.11%	4.65%
Ash content*	[%]	6.64%	16.74%	11.69%
Combustibles*	[%]	88.18%	79.15%	83.67%
Physical composition:	[%]			
- moisture**	[%]	64.18%	14.75%	39.47%
- ash**	[%]	2.51%	14.88%	8.70%
- combustibles**	[%]	33.31%	70.36%	51.84%

* air-dry waste

** raw waste

Calorific data		Monday sample	Thursday sample	Average
Calculated heating value				
- air-dry waste	[kJ/kg]	14530	14690	14610
- row waste	[kJ/kg]	5205	12523	8864
Measured (air-dry waste)				
- heat of combustion	[kJ/kg]	19900	14450	17175

Chemical composition (air-dry base)		Monday sample	Thursday sample	Average
- nitrogen	[%]	2.52%	0.42%	1.47%
- carbon	[%]	49.14%	39.51%	44.33%
- hydrogen	[%]	7.90%	5.50%	6.70%
- oxygen	[%]	15.20%	22.90%	19.05%
- sulphur	[%]	0.00%	0.00%	0.00%
- chlorine	[%]	0.70%	0.20%	0.45%
- total	[%]	75.46%	68.53%	72.00%

Table A9. Mechanical composition and physical-chemical properties of municipal solid waste

ZONE CODE: M1					
Mechanical composition	Monday sample		Thursday sample		Average
	[kg]	[%]	[kg]	[%]	[%]
paper	5.00	11.36%	7.00	53.85%	21.05%
textile	-	-	-	-	0.00%
plastics	1.00	2.27%	2.00	15.38%	5.26%
glass	-	-	0.50	3.85%	0.88%
grass, greens	-	-	-	-	0.00%
lether	-	-	-	-	0.00%
rubber	-	-	-	-	0.00%
metals	1.00	2.27%	1.00	7.69%	3.51%
kitchen garbage	1.50	3.41%	3.00	23.08%	7.89%
stones, ceramics	-	-	-	-	0.00%
other	1.50	3.41%	0.50	3.85%	3.51%
Total	10.00	22.73%	14.00	107.69%	42.11%

Physical properties		Monday sample	Thursday sample	Average
Effective moisture	[%]	11.11%	62.56%	36.84%
Higroscopic moisture*	[%]	4.72%	4.59%	4.66%
Ash content*	[%]	8.68%	11.48%	10.08%
Combustibles*	[%]	86.60%	83.93%	85.27%
Physical composition:	[%]			
- moisture**	[%]	15.31%	64.28%	39.79%
- ash**	[%]	7.72%	4.30%	6.01%
- combustibles**	[%]	76.98%	31.42%	54.20%

* air-dry waste

** raw waste

Calorific data		Monday sample	Thursday sample	Average
Calculated heating value				
- air-dry waste	[kJ/kg]	16800	17030	16915
- row waste	[kJ/kg]	14229	6083	10156
Measured (air-dry waste)				
- heat of combustion	[kJ/kg]	15660	15300	15480

Chemical composition (air-dry base)		Monday sample	Thursday sample	Average
- nitrogen	[%]	0.57%	2.71%	1.64%
- carbon	[%]	40.17%	44.42%	42.30%
- hydrogen	[%]	5.50%	6.60%	6.05%
- oxygen	[%]	21.80%	15.20%	18.50%
- sulphur	[%]	0.03%	0.00%	0.02%
- chlorine	[%]	0.40%	0.67%	0.54%
- total	[%]	68.47%	69.60%	69.04%

Table A10. Mechanical composition and physical-chemical properties of municipal solid waste

ZONE CODE: M2					
Mechanical composition	Monday sample		Thursday sample		Average
	[kg]	[%]	[kg]	[%]	[%]
paper	6.00	13.64%	33.50	257.69%	69.30%
textile	-	-	-	-	0.00%
plastics	2.50	5.68%	1.20	9.23%	6.49%
glass	2.50	5.68%	3.50	26.92%	10.53%
grass, greens	-	-	-	-	0.00%
lether	-	-	-	-	0.00%
rubber	-	-	-	-	0.00%
metals	0.50	1.14%	0.20	1.54%	1.23%
kitchen garbage	5.00	11.36%	2.60	20.00%	13.33%
stones, ceramics	-	-	2.00	15.38%	3.51%
other	0.50	1.14%	2.00	15.38%	4.39%
Total	17.00	38.64%	45.00	346.15%	108.77%

Physical properties		Monday sample	Thursday sample	Average
Effective moisture	[%]	44.44%	30.12%	37.28%
Higroscopic moisture*	[%]	11.10%	5.66%	8.38%
Ash content*	[%]	17.66%	4.14%	10.90%
Combustibles*	[%]	71.24%	90.20%	80.72%
Physical composition:	[%]			
- moisture**	[%]	50.61%	34.08%	42.34%
- ash**	[%]	9.81%	2.89%	6.35%
- combustibles**	[%]	39.58%	63.03%	51.31%

* air-dry waste

** raw waste

Calorific data		Monday sample	Thursday sample	Average
Calculated heating value				
- air-dry waste	[kJ/kg]	15700	15230	15465
- row waste	[kJ/kg]	7755	10040	8898
Measured (air-dry waste)				
- heat of combustion	[kJ/kg]	14140	15900	15020

Chemical composition (air-dry base)		Monday sample	Thursday sample	Average
- nitrogen	[%]	1.77%	0.55%	1.16%
- carbon	[%]	40.16%	42.91%	41.54%
- hydrogen	[%]	6.40%	6.40%	6.40%
- oxygen	[%]	17.50%	22.50%	20.00%
- sulphur	[%]	0.02%	0.00%	0.01%
- chlorine	[%]	0.73%	0.59%	0.66%
- total	[%]	66.58%	72.95%	69.77%

Table A11. Mechanical composition and physical-chemical properties of municipal solid waste

ZONE CODE: O

Mechanical composition	Monday sample		Thursday sample		Average
	[kg]	[%]	[kg]	[%]	[%]
paper	51.00	115.91%	35.00	269.23%	150.88%
textile	-	-	0.50	3.85%	0.88%
plastics	1.50	3.41%	2.50	19.23%	7.02%
glass	0.50	1.14%	1.00	7.69%	2.63%
grass, greens	-	-	-	-	0.00%
lether	-	-	-	-	0.00%
rubber	-	-	-	-	0.00%
metals	-	-	7.50	57.69%	13.16%
kitchen garbage	0.50	1.14%	5.00	38.46%	9.65%
stones, ceramics	-	-	-	-	0.00%
other	-	-	2.50	19.23%	4.39%
Total	53.50	121.59%	54.00	415.38%	188.60%

Physical properties		Monday sample	Thursday sample	Average
Effective moisture	[%]	20.30%	16.56%	18.43%
Higroscopic moisture*	[%]	4.26%	4.28%	4.27%
Ash content*	[%]	9.47%	14.17%	11.82%
Combustibles*	[%]	86.27%	81.55%	83.91%
Physical composition:	[%]			
- moisture**	[%]	23.70%	20.13%	21.91%
- ash**	[%]	7.55%	11.82%	9.69%
- combustibles**	[%]	68.76%	68.05%	68.40%

* air-dry waste

** raw waste

Calorific data		Monday sample	Thursday sample	Average
Calculated heating value				
- air-dry waste	[kJ/kg]	17840	14900	16370
- row waste	[kJ/kg]	13613	11900	12757
Measured (air-dry waste)				
- heat of combustion	[kJ/kg]	19700	14030	16865

Chemical composition (air-dry base)		Monday sample	Thursday sample	Average
- nitrogen	[%]	0.27%	0.59%	0.43%
- carbon	[%]	43.81%	41.21%	42.51%
- hydrogen	[%]	6.20%	5.90%	6.05%
- oxygen	[%]	22.90%	21.30%	22.10%
- sulphur	[%]	0.02%	0.00%	0.01%
- chlorine	[%]	0.59%	0.34%	0.47%
- total	[%]	73.79%	69.34%	71.57%

Table A12. Mechanical composition and physical-chemical properties of municipal solid waste

ZONE CODE: P					
Mechanical composition	Monday sample		Thursday sample		Average
	[kg]	[%]	[kg]	[%]	[%]
paper	1.00	2.27%	0.50	3.85%	2.63%
textile	-	-	-	-	0.00%
plastics	0.50	1.14%	0.50	3.85%	1.75%
glass	1.00	2.27%	-	-	1.75%
grass, greens	-	-	-	-	0.00%
lether	-	-	-	-	0.00%
rubber	-	-	-	-	0.00%
metals	0.60	1.36%	0.20	1.54%	1.40%
kitchen garbage	0.50	1.14%	0.80	6.15%	2.28%
stones, ceramics	-	-	-	-	0.00%
other	0.40	0.91%	-	-	0.70%
Total	4.00	9.09%	2.00	15.38%	10.53%

Physical properties		Monday sample	Thursday sample	Average
Effective moisture	[%]	56.60%	55.17%	55.89%
Higroscopic moisture*	[%]	5.42%	4.78%	5.10%
Ash content*	[%]	14.40%	7.03%	10.72%
Combustibles*	[%]	80.18%	88.19%	84.19%
Physical composition:	[%]			
- moisture**	[%]	58.95%	57.31%	58.13%
- ash**	[%]	6.25%	3.15%	4.70%
- combustibles**	[%]	34.80%	39.54%	37.17%

* air-dry waste

** raw waste

Calorific data		Monday sample	Thursday sample	Average
Calculated heating value				
- air-dry waste	[kJ/kg]	11360		11360
- row waste	[kJ/kg]	4663	0	2332
Measured (air-dry waste)				
- heat of combustion	[kJ/kg]	14000	17200	15600

Chemical composition (air-dry base)		Monday sample	Thursday sample	Average
- nitrogen	[%]	1.58%	1.23%	1.41%
- carbon	[%]	41.64%	44.86%	43.25%
- hydrogen	[%]	5.80%	6.50%	6.15%
- oxygen	[%]	21.60%	18.30%	19.95%
- sulphur	[%]	0.01%	0.00%	0.01%
- chlorine	[%]	1.14%	0.74%	0.94%
- total	[%]	71.77%	71.63%	71.70%

II. Report on the Communal Waste Sampling and Analysis in the Municipal Area of Budapest

KÖRNYEZETVÉDELMI Kft.
ENVIRONMENTAL PROTECTION Ltd.

Report on the communal waste sampling and analysis in the municipal area of Budapest

(dr. Zoltán Izsáki)
project manager

(dr. János Kálmán)
director

Budapest, 27th July, 1992

1036 Budapest III., Evező u. 4. • Tel.: 168-68-94, 168-62-91 • Fax: 168-68-94

Participated in preparing this survey:

Person	Company affiliation
Mr. K. Kertész	Environmental Protection Ltd.
Miss. É. Ulmer	Environmental Protection Ltd.
Mr. L. Kővári	Environmental Protection Ltd.
Mr. A. Andó	Environmental Protection Ltd.
dr. Z. Bonnyai	National Environmental Institute
dr. Zs. Pfeiffer	Municipal Public Services Co. (FKFV)
Mr. Gy. Midrák	Municipal Public Services Co. (FKFV)
dr. Gy. Uzsokiné	Public Health Inspectorate
dr. K. Lakszner	Tech. University of Budapest Dept. of Chemical Technology
dr. L. Bezur	Tech. University of Budapest Dept. of Analytical Chemistry

TABLE OF CONTENTS

1. Introduction

According to signed contract between JICA Study Team and Environmental Protection Ltd. (in following EP) the EP carried out municipal waste sampling and analysis in the municipal area of Budapest. The survey was conducted according to methodology given by JICA Study Team.

In the course of survey the following tasks were carried out:

- allocation of 12 sampling zones according to JICA methodology and survey of population in these zones,
- collection of communal waste from these zones during 5 day long period (Monday-Friday) in specialized collection vessels,
- determination of waste mass output and bulk density from each zone during this period,
- determination of mechanical composition (11 different classes) of collected waste from each zone on Monday and on Thursday (2x12 samples) according to JICA methodology,
- preparation of 10 kg laboratory samples in sealed hard-wall plastic containers from collected waste from each zone on Monday and on Thursday (2x12 samples) according to JICA methodology,
- determination of effective moisture from laboratory samples according to MSZ (Hungarian National Standard) 21976/3-81,
- grinding and homogenization of air-dry laboratory samples and preparation of about 1 kg analytical samples,
- from analytical samples the following determinations were carried out:
  - hygroscopic moisture according to MSZ 21976/3-81,
  - ash content and combustibles (ignition residue and ignition loss) according to MSZ 21976/5-81,
  - elementary composition (carbon, hydrogen, oxygen, nitrogen and sulphur) and calorific data (heat of combustion and calorific value) by automatic elementary analyzer (type: Carlo-Erba)
- determination of toxic and alkali metal content from Monday and Thursday weighted average samples by ICP-AES method,
- calorific value calculated from mechanical composition of each laboratory sample.

The applied sampling and analytical procedures (given by JICA) were compared to currently valid Hungarian Standards (MSZ 21976/xx series) and German methodology (Müll und Abfall Handbuch 1990, p:10900-11028).

The results of this survey were compared to data given by Analytical Laboratory of Municipal Public Services Enterprise (FKFV) regarding the communal waste out-

put and waste composition in Budapest area in period of 1987-1991 based on their own survey.

2. Applied methodologies

2.1. Allocation of sampling zones, sampling

The sampling zones were allocated based on JICA methodology. During allocation period the following parameters were determined:

- in residential areas (high, middle and low income) the number of households and number of inhabitants,
- in hotels the number of rooms and number of beds,
- in office and markets the office or shop space,
- in park area the park surface,
- in all sampling zones the collection vessels and collection frequency currently applied by FKFV.

Data about allocated sampling zone are summarised in Table 1.

In **Appendix I.** the photos taken at sampling zones are presented and the zones are indicated on plan of Budapest.

The actual sampling of allocated zones were carried out between June 15. - June 19. (Monday - Friday).

Waste was put by local population in usual collection vessels supplied by FKFV (see Table 1.).

During collection the waste from each zone was transferred from these vessels to 0.77 m^3 labelled plastic containers and transported to Municipal Waste Incinerating Facility (HHM).

The volume of collected waste from different zones showed great deviations (from 0.05 m^3 to 5 m^3). For increasing the precision of determinations and obtaining more representative results the following modifications were made on the methodology given by JICA:

- in case the amount of sample obtained after quartering method would be less than 10 kg amount reduction was not performed,
- the amount reduction by quartering method was performed proportional to the original mass of collected sample from this zone, so determination of mechanical composition was carried out on samples with mass between 10 and 129.5 kg.

Table 1. Statistical data about allocated sampling zones

Zone code	Adrress	No. of Househ.	No. of Inhabit.	Type of collecting vessels	Collection frequency
	High income area				
A	Bp. XII. Pipiske str. 1-5.	40	90	containers 14 x 120 dm3	two times a week
B	Bp. XII. Pasaréti str. 61-63	36	111	containers 8 x 200 dm3	three times a week
	Middle income area				
C	Bp. VI. Teréz blv. 41	36	101	containers 6 x 220 dm3	every second day
D	Bp. XIV. Ujvidék square 10	6	17	containers 2 x 120 dm3	every second day
	Bp. XIV. Szugló str. 27	6	16	containers 2 x 120 dm3	every second day
	Bp. XIV. Ujvidék square 6	8	20	containers 2 x 120 dm3	every second day
	Bp. XIV. Ujvidék square 16	4	3	containers 2 x 120 dm3	every second day
	Bp. XIV. Ujvidék square 14	2	4	containers 1 x 120 dm3	every second day
	Low Income area				
E	Bp. IV. Váci road 81/b	12	29	containers 4 x 120 dm3	two times a week
	Bp. IV. Váci road 81/c	22	53	containers 5 x 120 dm3	two times a week
F	Bp. X. Kozma u. 15/I-III	36	55	containers 4 x 120 dm3	every second day
	Markets and shops	Surface [m2]	No. of Employees		
M1	Bp. IX. Ferenc blv. 1.			containers 1 x 200 dm3	every working day
	Csemege-Meinl Shop No 49.	84	-		
M2	Bp. XIII. St. István blv. 30.			containers 2 x 200 dm3	every working day
	Csemege-Meinl Shop No 20.	300	-		
	Offices				
O	Bp. Schönherz Z. str. 16	2290	1200	containers 50 x 200 dm3	every second day
	National Crude Oil and Natural Gas Co.				
	Park area				
P	Bp. V. Erzsébet square	-	-	containers 30 x 20 dm3	-
	Hotels	No. of rooms	No. of beds		
H1	Bp. I. Bem rkp. 11.	24	36	containers 2 x 200 dm3	every day
	Hotel Viktória				
H2	Bp. VI. Teréz blv. 43.				
	Hotel Béke Radisson	246	492	containers 3 x 1100 dm3	every day

2.2 Determination of bulk density

Bulk density was calculated from measured mass and volume of non-compacted waste samples.

The mass was measured by an industrial scale with 0.5 kg accuracy.

The volume was determined by filling the samples in standard vessels of uniform volume.

2.3. Determination of mechanical composition

The reduced waste samples were separated into 11 different groups given by JICA (1. paper and cardboard, 2. textiles, 3. plastics, 4. glass, 5. grasses, 6. leather, 7. rubber, 8. metals, 9. kitchen garbage, 10. stones and ceramics, 11. others) with following modifications:

- in group No. 5 were separated all vegetable and green garden waste including grass,
- group 11. (others) included all waste that could not be assigned to previous groups e.g.: complex waste composed of multiple materials, medicines and chemicals, fine grained materials (dust, ash, soil), waste inseparable by hand because of contamination and mixing with other waste during collection and transport.

The mass of each separated fraction was determined by scale described in section 2.2.

2.4. Determination of effective moisture

Laboratory samples of about 10 kg were prepared on Monday and Thursday from each collection zone (2x12 samples) in sealed hard wall plastic containers with appropriate labeling. The amount of laboratory samples was further reduced by quartering method to about 1 kg. These samples were dried in drying ovens at 100 ± 5 °C for 72 hours then conditioned at ambient air for 48 hours period. The mass of samples before and after drying was determined by laboratory scale with 50 mg precision.

The effective moisture was calculated from mass reduction during the drying procedure.

2.5. Preparation of analytical samples

From dried and conditioned (air-dry) samples the bulky hard objects (e.g.: metals, stones) were removed manually and the residues were ground first in a laboratory hammer mill and than pulverised with blade mill. All other determinations were made using these analytical samples.

2.6. Determination of hygroscopic moisture

Portions of analytical samples were dried at 105 °C until the mass steadiness was reached. The mass of samples before and after drying was determined by analytical scale (0.0001 g precision).

Hygroscopic moisture was determined by making three parallel measurements from each sample. The results given are the averages of parallel measurements.

The total moisture content was calculated from effective and hygroscopic moisture using the following formula:

$$M_T = M_E + M_H * [(100-M_E)/100] \quad (1)$$

where:

- M_T is the total moisture [%]
- M_E is the effective moisture [%]
- M_H is the hygroscopic moisture [%]

2.7. Determination of ash content

Portion of analytical sample is weighted with analytical precision (0.0001 g) and ignited in laboratory furnace at 600 °C until mass steadiness was reached.

Both the National Standard (MSZ 21976/5) and JICA methodology recommends ignition at 800 °C but according to our experience at this temperature the decomposition of carbonates is substantial. The German methodology is recommending 775 °C as a glowing temperature.

Ash content was calculated from mass loss during the ignition.

Combustible fraction was calculated according to the following formula:

$$Cf = 100 - A - M_H \quad (2)$$

where:

- Cf is the combustible fraction [%],
- A is the ash content [%],
- M_H is the hygroscopic moisture [%].

2.8. Calculation of heating value

The heating value of waste samples were calculated on basis of mechanical composition and average heating value of constituents. The average heating value of air dry constituents was taken from MSZ 21976/6-86:

Constituent	Heating value [kJ/kg]
paper	17585
wood	20034
leaves	16509
leather	20587
rubber	26357
plastics	33424
textile	17798
kitchen garbage	14575
glass, ceramics	150
metals	280
ash, slag, other unidentified	8820

The heating value of garden waste was calculated using the data for leaves.

The heating value was calculated for air dry samples and converted for original condition (raw samples) using the total moisture content.

2.9. Determination of elementary composition and calorific data

The determinations were carried out using an automatic elementary analyzer type Fisons (Carlo-Erba) EA 1 108. The analytical samples were further pulverised using a micro ball mill and 2-5 mg of homogeneous samples were weighted in. The instrument is performing the total analysis automatically and the raw data is processed by PC. The instrument is capable of quantitative determination of carbon, hydrogen, oxygen, nitrogen and sulphur in concentrations above 100 ppm. Detection limit for all five elements is 10 ppm. The instrument is directly measuring the heat of combustion and the heating value is calculated from heat of combustion using the oxygen and hydrogen content of sample. Accuracy of measurements using this instrument is:

Measured value	accuracy
100 ppm	± 10 ppm
0,1 %	± 0,001 %
1,00 %	± 0,002 %
10,00 %	± 0,1 %
50,00 %	± 0,3 %
90,00 %	± 0,3 %

Weighted average sample (proportional to waste output in sampling zones) for Monday and Thursday were prepared from homogeneous samples and elementary composition was determined for these two average samples, too.

2.10. Determination of metal content.

Weighted average samples (proportional to waste output in sampling zones) for Monday and Thursday were prepared from homogeneous samples and 21 metal and semi-metal components including toxic heavy metals were determined from the

average samples. Known amount of homogeneous samples were digested with conc. nitric acid and hydrogen-peroxide under pressure in PTFE bombs at about 180 °C.

The metal components in aliquot portion of digested samples were determined by ICP-AES (Inductively Coupled Plasma Atomic Emission) technique.

4. Results of sampling and analytical composition

The results of waste output for each sampling day and each zone during the survey are summarised in Table 2.

The measured loose bulk densities of waste for each sampling day and each zone during the survey are shown in Table 3.

The calculated specific waste outputs for 5 day long periods in each sampling zone can be seen in Table 4. The specific waste output is calculated from total waste amount in the given zone and is expressed:

- for residential zones as kg/person/day,
- for hotels as kg/bed/day,
- for office and market zones as kg/m^2/day (relative to office or shop surface).

Tables 5-16 contain the results of mechanical composition and physical-chemical determinations. Each table contains results of determinations carried out from samples collected on Monday and Thursday from a given sampling zone.

The tables contains following data:

- mechanical composition of raw sample,
- hygroscopic moisture, ash and combustibles content relative to air dry sample,
- total moisture, ash and combustibles content relative to raw sample,
- heating value calculated from mechanical composition relative to air dry and raw sample,
- elementary composition (carbon, hydrogen, oxygen, nitrogen and sulphur) relative to air-dry sample.

The laboratory measurements were performed with analytical accuracy and the data given in the tables are averages of three parallel measurements.

Results of metal and toxic heavy metal determination are presented in Table 17. The data in table are derived from weighted average samples (proportional to the amount of waste in each sampling zone) for Monday and Thursday samples.

Table 2. Communal waste output from sampling zones during collection period

Date of sampling	Waste output [kg]											
	Zone: A	Zone: B	Zone: C	Zone: D	Zone: E	Zone: F	Zone: H1	Zone: H2	Zone: M1	Zone: M2	Zone: O	Zone: P
92-06-15	98,0	80,0	118,0	116,0	105,0	90,0	40,0	388,5	7,0	15,0	110,0	3,0
92-06-16	35,0	78,0	37,0	24,0	33,0	41,0	32,0	470,0	8,0	47,5	140,0	21,0
92-06-17	101,0	70,0	72,0	29,0	22,0	18,0	30,0	324,5	15,0	45,5	154,0	20,5
92-06-18	38,0	42,0	42,0	30,0	22,0	65,0	14,0	326,0	17,0	57,0	300,0	17,5
92-06-19	38,0	36,0	75,0	25,0	20,0	24,0	18,0	396,0	8,5	47,0	220,0	12,0
Total	310,0	306,0	344,0	224,0	202,0	238,0	134,0	1905,0	55,5	212,0	924,0	74,0

Table 3. Loose bulk density of collected waste from sampling zones

Date of sampling	Loose bulk density [kg/m3]											
	Zone: A	Zone: B	Zone: C	Zone: D	Zone: E	Zone: F	Zone: H1	Zone: H2	Zone: M1	Zone: M2	Zone: O	Zone: P
92-06-15	140,0	95,2	107,3	181,3	138,2	225,0	125,0	168,2	33,3	34,8	43,6	75,0
92-06-16	152,2	101,3	51,4	96,0	110,0	146,4	110,3	151,6	44,4	44,1	55,8	116,7
92-06-17	229,5	70,0	72,0	152,6	73,3	90,0	62,5	169,2	62,5	44,6	53,5	85,4
92-06-18	165,2	105,0	70,0	150,0	146,7	185,7	100,0	125,4	70,8	44,9	111,0	62,5
92-06-19	190,0	120,0	75,0	125,0	142,9	160,0	94,7	127,8	44,7	49,0	76,4	66,7
Average	175,4	98,3	75,1	141,0	122,2	161,4	98,5	148,4	51,1	43,5	68,1	81,3

Table 4. Specific waste output in samplig zones

Zone Code.	Comment	Mass output for 5 days [kg]	Avg. output per day [kg]	No. of inhabitants	Specific output [kg/person/day]
A	High income area	310	62	90	0,69
B	High income area	306	61,2	111	0,55
C	Middle income area	344	68,8	101	0,68
D	Middle income area	224	44,8	60	0,75
E	Low income area	202	40,4	82	0,49
F	Low income area	238	47,6	55	0,87
				No. of beds	Specific output [kg/bed/day]
H1	Hotel Viktoria	134	26,8	36	0,74
H2	Hotel Béke	1905,1	381,02	492	0,77
				Office space [m2]	Specific output [kg/m2/day]
M1	Market 1	55,5	11,1	84	0,13
M2	Market 2	212,1	42,42	300	0,14
O	Office building	824	164,8	2290	0,07
P	Park area	71,5	14,3		

Table 5. **Mechanical conposition and physical-chemical properties of waste**

Zone code: A

Mechanical composition	Monday sample		Thursday sample		Average
	[kg]	[%]	[kg]	[%]	[%]
paper	10,00	20,41	4,00	10,53	16,09
textile	7,00	14,29	4,00	10,53	12,64
plastics	5,00	10,20	1,50	3,95	7,47
glass	1,00	2,04	1,00	2,63	2,30
grass, greens	5,50	11,22	4,00	10,53	10,92
lether	0,00	0,00	0,00	0,00	0,00
rubber	0,00	0,00	0,00	0,00	0,00
metals	1,00	2,04	0,80	2,11	2,07
kitchen garbage	12,00	24,49	12,00	31,58	27,59
stones, ceramics	0,00	0,00	0,00	0,00	0,00
other	7,50	15,31	10,70	28,16	20,92
Total	49,00	100,00	38,00	100,00	100,00

Physical properties	Monday sample	Thursday sample	Average
Effective moisture [%]	55,71	62,89	59,30
Higroscopic moisture* [%]	5,14	3,66	4,40
Ash content* [%]	18,96	23,83	21,40
Combustibles* [%]	75,90	72,51	74,21
Physical composition:			
- moisture** [%]	57,99	64,25	61,12
- ash** [%]	7,97	8,00	7,99
- combustibles** [%]	34,04	27,75	30,90

* air-dry waste

** raw waste

Calorific data	Monday sample	Thursday sample	Average
Calculated heating value			
- air-dry waste [kJ/kg]	16320	13870	15095
- row waste [kJ/kg]	7230	5150	6190
Measured (air-dry waste)			
- heat of combustion [kJ/kg]	21500	19800	20650
- heating value [kJ/kg]	20200	18700	19450

Chemical composition (air-dry base)	Monday sample	Thursday sample	Average
- nitrogen [%]	2,4945	1,9901	2,2423
- carbon [%]	37,8669	35,4903	36,6786
- hydrogen [%]	5,8969	5,3457	5,6213
- sulphur [%]	0,1869	0,0153	0,1011
- oxygen [%]	36,5895	35,7725	36,1810
- total [%]	83,0347	78,6139	

Table 6. Mechanical conposition and physical-chemical properties of waste

Zone code: B

Mechanical composition	Monday sample		Thursday sample		Average
	[kg]	[%]	[kg]	[%]	[%]
paper	5,00	15,38	11,00	26,19	21,48
textile	2,00	6,15	1,50	3,57	4,70
plastics	3,00	9,23	1,75	4,17	6,38
glass	3,00	9,23	4,00	9,52	9,40
grass, greens	0,50	1,54	1,50	3,57	2,68
lether	0,00	0,00	0,00	0,00	0,00
rubber	0,00	0,00	0,00	0,00	0,00
metals	1,00	3,08	1,00	2,38	2,68
kitchen garbage	13,00	40,00	13,00	30,95	34,90
stones, ceramics	0,00	0,00	0,00	0,00	0,00
other	5,00	15,38	8,25	19,64	17,79
Total	32,50	100,00	42,00	100,00	100,00

Physical properties	Monday sample	Thursday sample	Average
Effective moisture [%]	56,50	54,17	55,34
Higroscopic moisture* [%]	5,75	2,56	4,16
Ash content* [%]	15,30	60,86	38,08
Combustibles* [%]	78,95	36,58	57,77
Physical composition:			
- moisture** [%]	59,00	55,34	57,17
- ash** [%]	6,27	27,18	16,73
- combustibles** [%]	34,73	17,48	26,10

* air-dry waste

** raw waste

Calorific data	Monday sample	Thursday sample	Average
Calculated heating value			
- air-dry waste [kJ/kg]	14350	13490	13920
- row waste [kJ/kg]	6240	6180	6210
Measured (air-dry waste)			
- heat of combustion [kJ/kg]	23200	12400	17800
- heating value [kJ/kg]	21900	11800	16850

Chemical composition (air-dry base)	Monday sample	Thursday sample	Average
- nitrogen [%]	2,2651	0,9045	1,5848
- carbon [%]	40,9971	23,2914	32,1443
- hydrogen [%]	6,3853	3,0995	4,7424
- sulphur [%]	0,0029	0,2012	0,1021
- oxygen [%]	38,5020	23,0674	30,7847
- total [%]	88,1524	50,5640	

Table 7. Mechanical conposition and physical-chemical properties of waste

Zone code: C

Mechanical composition	Monday sample		Thursday sample		Average
	[kg]	[%]	[kg]	[%]	[%]
paper	6,00	14,63	5,50	24,55	18,14
textile	4,50	10,98	1,00	4,46	8,68
plastics	3,00	7,32	3,00	13,39	9,46
glass	5,50	13,41	0,20	0,89	8,99
grass, greens	1,50	3,66	0,10	0,45	2,52
lether	0,00	0,00	0,00	0,00	0,00
rubber	0,00	0,00	0,00	0,00	0,00
metals	0,50	1,22	0,10	0,45	0,95
kitchen garbage	9,00	21,95	5,00	22,32	22,08
stones, ceramics	1,00	2,44	3,00	13,39	6,31
other	10,00	24,39	4,50	20,09	22,87
Total	41,00	100,00	22,40	100,00	100,00

Physical properties	Monday sample	Thursday sample	Average
Effective moisture [%]	52,03	61,90	56,97
Higroscopic moisture* [%]	4,48	3,84	4,16
Ash content* [%]	29,10	24,56	26,83
Combustibles* [%]	66,42	71,60	69,01
Physical composition:			
· moisture** [%]	54,18	63,36	58,77
· ash** [%]	13,33	8,45	10,89
· combustibles** [%]	32,49	28,19	30,34

* air-dry waste

** raw waste

Calorific data	Monday sample	Thursday sample	Average
Calculated heating value			
· air-dry waste [kJ/kg]	12950	14700	13825
· row waste [kJ/kg]	6210	5600	5905
Measured (air-dry waste)			
· heat of combustion [kJ/kg]	20400	19400	19900
· heating value [kJ/kg]	19200	18300	18750

Chemical composition (air-dry base)	Monday sample	Thursday sample	Average
· nitrogen [%]	1,9156	1,4945	1,7051
· carbon [%]	36,0221	35,5532	35,7877
· hydrogen [%]	5,5700	5,0283	5,2992
· sulphur [%]	0,8918	0,0025	0,4472
· oxygen [%]	31,3417	34,2994	32,8206
· total [%]	75,7412	76,3779	

Table 8. Mechanical conposition and physical-chemical properties of waste

Zone code: D

Mechanical composition	Monday sample		Thursday sample		Average
	[kg]	[%]	[kg]	[%]	[%]
paper	6,00	10,34	3,00	10,91	10,53
textile	2,00	3,45	1,00	3,64	3,51
plastics	5,00	8,62	1,50	5,45	7,60
glass	3,00	5,17	1,50	5,45	5,26
grass, greens	13,00	22,41	1,00	3,64	16,37
lether	0,00	0,00	0,00	0,00	0,00
rubber	0,00	0,00	0,00	0,00	0,00
metals	3,00	5,17	0,50	1,82	4,09
kitchen garbage	11,00	18,97	5,00	18,18	18,71
stones, ceramics	2,50	4,31	0,00	0,00	2,92
other	12,50	21,55	14,00	50,91	30,99
Total	58,00	100,00	27,50	100,00	100,00

Physical properties	Monday sample	Thursday sample	Average
Effective moisture [%]	62,23	37,58	49,91
Higroscopic moisture* [%]	5,88	2,24	4,06
Ash content* [%]	21,11	40,72	30,92
Combustibles* [%]	73,01	57,04	65,03
Physical composition:			
- moisture** [%]	64,45	38,98	51,71
- ash** [%]	7,50	24,85	16,18
- combustibles** [%]	28,05	36,17	32,11

* air-dry waste

** raw waste

Calorific data	Monday sample	Thursday sample	Average
Calculated heating value			
- air-dry waste [kJ/kg]	13700	12140	12920
- row waste [kJ/kg]	5180	7580	6380
Measured (air-dry waste)			
- heat of combustion [kJ/kg]	22900	14200	18550
- heating value [kJ/kg]	21600	13400	17500

Chemical composition (air-dry base)	Monday sample	Thursday sample	Average
- nitrogen [%]	2,2551	1,5161	1,8856
- carbon [%]	41,2405	26,3070	33,7738
- hydrogen [%]	6,1069	3,6092	4,8581
- sulphur [%]	0,0042	0,0904	0,0473
- oxygen [%]	33,9007	28,0096	30,9552
- total [%]	83,5074	59,5323	

Table 9. Mechanical conposition and physical-chemical properties of waste

Zone code: E

Mechanical composition	Monday sample		Thursday sample		Average
	[kg]	[%]	[kg]	[%]	[%]
paper	7,50	27,99	1,00	5,95	19,50
textile	5,50	20,52	7,00	41,67	28,67
plastics	2,00	7,46	1,00	5,95	6,88
glass	0,50	1,87	0,30	1,79	1,83
grass, greens	1,80	6,72	0,20	1,19	4,59
lether	0,00	0,00	0,00	0,00	0,00
rubber	0,00	0,00	0,00	0,00	0,00
metals	1,00	3,73	0,80	4,76	4,13
kitchen garbage	3,50	13,06	2,00	11,90	12,61
stones, ceramics	0,00	0,00	0,00	0,00	0,00
other	5,00	18,66	4,50	26,79	21,79
Total	26,80	100,00	16,80	100,00	100,00

Physical properties	Monday sample	Thursday sample	Average
Effective moisture [%]	67,86	40,81	54,34
Higroscopic moisture* [%]	4,85	2,03	3,44
Ash content* [%]	18,48	49,73	34,11
Combustibles* [%]	76,67	48,24	62,46
Physical composition:			
- moisture** [%]	69,42	42,01	55,72
- ash** [%]	5,65	27,97	16,81
- combustibles** [%]	24,93	30,02	27,47

* air-dry waste

** raw waste

Calorific data	Monday sample	Thursday sample	Average
Calculated heating value			
- air-dry waste [kJ/kg]	15740	14760	15250
- row waste [kJ/kg]	5060	8740	6900
Measured (air-dry waste)			
- heat of combustion [kJ/kg]	23000	15400	19200
- heating value [kJ/kg]	21700	14500	18100

Chemical composition (air-dry base)	Monday sample	Thursday sample	Average
- nitrogen [%]	2,1573	2,3090	2,2332
- carbon [%]	41,3455	28,1349	34,7402
- hydrogen [%]	6,1202	3,9860	5,0531
- sulphur [%]	0,0065	0,2136	0,1101
- oxygen [%]	34,3218	26,5335	30,4277
- total [%]	83,9513	61,1770	

Table 10. Mechanical conposition and physical-chemical properties of waste

Zone code: F

Mechanical composition	Monday sample		Thursday sample		Average
	[kg]	[%]	[kg]	[%]	[%]
paper	5,00	16,13	2,00	5,41	10,29
textile	1,50	4,84	1,50	4,05	4,41
plastics	2,50	8,06	2,50	6,76	7,35
glass	0,50	1,61	4,00	10,81	6,62
grass, greens	0,50	1,61	13,00	35,14	19,85
lether	0,00	0,00	0,00	0,00	0,00
rubber	0,00	0,00	0,00	0,00	0,00
metals	0,50	1,61	1,00	2,70	2,21
kitchen garbage	15,50	50,00	8,00	21,62	34,56
stones, ceramics	0,00	0,00	0,00	0,00	0,00
other	5,00	16,13	5,00	13,51	14,71
Total	31,00	100,00	37,00	100,00	100,00

Physical properties	Monday sample	Thursday sample	Average
Effective moisture [%]	60,94	60,53	60,74
Higroscopic moisture* [%]	6,98	3,17	5,08
Ash content* [%]	29,86	45,95	37,91
Combustibles* [%]	63,16	50,88	57,02
Physical composition:			
- moisture** [%]	63,67	61,78	62,72
- ash** [%]	10,85	17,56	14,21
- combustibles** [%]	25,48	20,66	23,07

* air-dry waste

** raw waste

Calorific data	Monday sample	Thursday sample	Average
Calculated heating value			
- air-dry waste [kJ/kg]	15380	14100	14740
- row waste [kJ/kg]	6000	5570	5785
Measured (air-dry waste)			
- heat of combustion [kJ/kg]	16600	13500	15050
- heating value [kJ/kg]	15600	12700	14150

Chemical composition (air-dry base)	Monday sample	Thursday sample	Average
- nitrogen [%]	2,3693	1,3913	1,8803
- carbon [%]	29,3891	24,7406	27,0649
- hydrogen [%]	4,5072	3,4698	3,9885
- sulphur [%]	0,2217	0,0024	0,1121
- oxygen [%]	28,4601	21,1724	24,8163
- total [%]	64,9474	50,7765	

Table 11. Mechanical composition and physical-chemical properties of waste

Zone code: H1

Mechanical composition	Monday sample		Thursday sample		Average
	[kg]	[%]	[kg]	[%]	[%]
paper	13,50	33,75	3,50	25,00	31,48
textile	0,30	0,75	0,00	0,00	0,56
plastics	4,50	11,25	1,50	10,71	11,11
glass	7,00	17,50	2,00	14,29	16,67
grass, greens	0,30	0,75	0,00	0,00	0,56
lether	0,00	0,00	0,00	0,00	0,00
rubber	0,00	0,00	0,00	0,00	0,00
metals	0,50	1,25	0,50	3,57	1,85
kitchen garbage	8,50	21,25	3,50	25,00	22,22
stones, ceramics	0,00	0,00	0,25	1,79	0,46
other	5,40	13,50	2,75	19,64	15,09
Total	40,00	100,00	14,00	100,00	100,00

Physical properties	Monday sample	Thursday sample	Average
Effective moisture [%]	44,00	44,54	44,27
Higroscopic moisture* [%]	6,23	3,60	4,92
Ash content* [%]	6,46	26,82	16,64
Combustibles* [%]	87,31	69,58	78,45
Physical composition:			
- moisture** [%]	47,49	46,54	47,01
- ash** [%]	3,39	14,34	8,87
- combustibles** [%]	49,12	39,12	44,12

* air-dry waste

** raw waste

Calorific data	Monday sample	Thursday sample	Average
Calculated heating value			
- air-dry waste [kJ/kg]	14270	13390	13830
- row waste [kJ/kg]	7990	7420	7705
Measured (air-dry waste)			
- heat of combustion [kJ/kg]	27100	18200	22650
- heating value [kJ/kg]	25600	17100	21350

Chemical composition (air-dry base)	Monday sample	Thursday sample	Average
- nitrogen [%]	2,0802	3,6761	2,8782
- carbon [%]	48,5275	32,7643	40,6459
- hydrogen [%]	7,2865	4,8148	6,0507
- sulphur [%]	0,0467	0,2253	0,1360
- oxygen [%]	36,8852	30,1858	33,5355
- total [%]	94,8261	71,6663	