Politehnica University of Timisoara (UPT)

Proiect European ENK5 – CT – 2002 - 00697, UPSWING, 2003 – 2005, „Implementarea unui incinerator de deşeuri solide la o centrală termo-electrică”

Data of preparation: 28.10.2005

I. Preliminary final report

Reporting period: 01.01.04 - 30.10.05

I.1 Specific objectives in the reporting period

Work package WP1:

Country specific data: Waste characteristics (size, composition, moisture, pollutants)

Non-compulsory Work package 2:

Theoretical aspects of coupling

Task 2.3 Effects of flue gas injection on boiler and combustion

Work package 4:

Emission behaviour

Task 4.3 Potential of a scrubber to remove simultaneously several components

Work package WP5:

Guidebook

Summary of the results acquired for the most promising scenario achieved and the set-up and the operation of an UPSWING Process

I.2 Status of Milestones and Deliverables (quantify the actual progress in %)

M9: Flue gas scrubbing system operable (UPT, 03/2004) Delivered 100 %

I.3 Scientific and technical progress

- Accomplished activities

WP1 Results:

One mainly concentrated versus the following topics:

- Waste characteristics as typical for Romania

C	11,271 % by mass
H	1,551 % by mass
O	9,242 % by mass
N	0,434 % by mass
S	0,048 % by mass

W	57,140 % by mass
A	20,314 % by mass
Hi raw	2983 kJ/kg*

The tests have been concluding that the low calorific value in Romania, for raw probes, is reduced, so difficulties exist for autonomous combustion of municipal waste. Special technologies (co-combustion, pre-drying) are needed.

- Combustion tests to verify input data (concentration values) as typical for flue gases resulting from waste incinerators

Thus one determined that the limits allowed for specific emissions at stack were over the limits. For ex. NOx – 110 mg/m3N, SO2 – 408 mg/m3N, Particles – 691 mg/m3N, Hg - 0.199 mg/m3N, all in reference to 10 % O2,

In fly ash: Zn < 0,05 mg, Fe < 0,1 mg, Mn < 0,05, Pb < 0,2, Cd < 0,05 , all expressed in mg/0,4424 m^3_N flue gas

In Romania not yet municipal incinerators are running. Only cement factories have introduced co-incineration, especially because of the economic benefit of the process.

- Environmental regulations and legislation's.

Romanian legislation HG 128 06-03-2002

For waste incinerators

Total particles	10 mg/m^3
TOC	10 mg/m^3
HCl	10 mg/m^3
HF	1 mg/m^3
SO_2	50 mg/m^3
NO and NO_2, expressed as NOx (NO2) for new facilities exceeding 6 t/h	200 mg/m^3*)
NO and NO_2, expressed as NOx (NO2) for new facilities less and inclusive 6 t/h	400 mg/m^3*)

For cement waste co-incineration systems

Pollutant	C (mg/Nm^3) in ref to 10 % O2		
	(a) 31 December 2002 - 31 December 2006	(b) 1 January 2007 -31 December 2008	(c) starting 1 January 2009
Particles	50	40	30
HCl	Measured value	50% from the measured value, but no more than 1,5	10
HF	Measured value	50% from the measured value, but no more than 1,5	1
NO_x for existing facilities	1.000 - 500*)	900 - 500*)	800 - 500*)
Cd+Tl for new facilities	0,05	0,05	0,05
Hg	0,05	0,05	0,05
Sb+As+Pb+Cr+Co+Cu+ Mn+Ni+V	0,5	0,5	0,5
Dioxins and furans	0,1 ng/Nm^3	0,1 ng/Nm^3	0,1 ng/Nm^3
SO_2	Measured value	50% from the measured value, but no more than 70	50
TOC	Measured value	50% from the measured value, but no more than 15	10
CO	No more than 500	No more than 500	No more than 500

* for cement co-incinerators limits are not considered as for new incinerators.

WP2 Results:

Study by means of FLUENT CFD simulation concerning the 100 t/h Romanian steam boiler working on coal, under different hypothesis.

One makes an analyse of how an existing Romanian steam boiler might match the tendencies open by the application of the UPSWING concept in a municipal power plant, in the city of Timisoara. One selected for study a Romanian boiler that is owned by the municipality and is an energetic boiler in the municipal power plant. It is to be mentioned that it is also the problem of the municipality as well to annihilate the large quantities of municipal waste, so one suggests that the UPSWING concept will offer a reasonable solution to the politicians. The boiler is a Romanian steam pulverized coal combustion facility producing 100-105 t/h, 16 bar, 250 ° C, using as main fuel coal with a low calorific value H_i = 6700 kJ/kg, and consuming a nominal flow of Lignite of 42 029 kg/h with an air excess ratio of λ= 1.3.

Thus several scenarios have been tested, in order to depict if, the coupling of the waste combustion facility by means of a scrubber, determines:

- the boiler's thermodynamic affection,
- the reduction of dioxins in the coal boiler,
- the appearance of peculiar aspects generated in the functionality of the boiler.

The cases that have been taken into consideration are

a - without flue gas addition (case zero),

b – with addition of flue gas with λ = 1.3, temperature of 70 ºC,

c – with addition of flue gas with λ = 1.6, temperature of 70 ºC.

The fuel gases from the scrubber, being introduced further at low temperature into the boiler, have been used in the frame of a simulation by the FLUENT code, in order to establish the results concerning the potential benefit of the additional gases in the coal boiler.

One found for example (Figure 1 and 2) that temperature profiles, as well as oxygen ones are comparative minimally influenced. In Figure 3 the profile of NO_x is given.

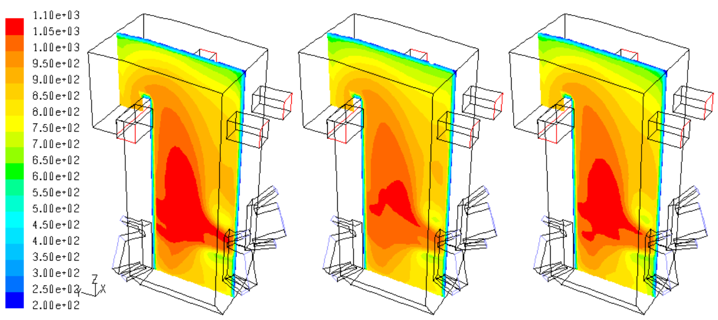


Figure 1: Temperature profiles: a - case without flue gas addition, b - addition of flue gas with λ = 1.3, temperature of 70 ºC, c - addition of flue gas with λ = 1.6, temperature of 70 ºC

No particular unexpected results were achieved, except that:

1. the general efficiency of the boiler is reduced by approx. 1.2 points
2. NO_x generation is not disturbed in the boiler, even temperature and oxygen concentration fields are in the coupled case slightly differ comparative to the original one.

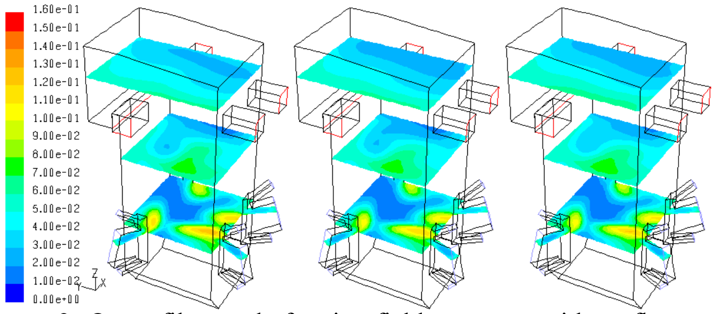


Figure 2: O_2 profiles, mole fraction fields: a - case without flue gas addition, b - addition of flue gas with λ = 1.3, temperature of 70 ºC, c - addition of flue gas with λ = 1.6, temperature of 70 ºC.

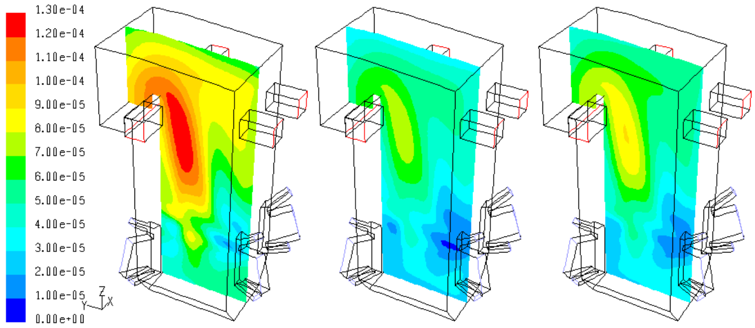


Figure 3: NOx profiles along the boiler: a - case without flue gas addition, b - addition of flue gas with λ = 1.3, temperature of 70 ºC, c - addition of flue gas with λ = 1.6, temperature of 70 ºC.

General conclusions versus the simulation are:

- More air means also a little bit higher temperatures in the furnace, in the central combustion area, but at the end of the boiler, rather no significant differences exist;
- If the addition of flue gases is done at reduced temperatures, no differences in the oxygen profile appears;
- For higher temperatures of the flue gases added, the Oxygen concentration are rather the same for λ = 1.3, but a little bit improved for λ = 1.6;
- NO_x for the cases when waste flue gases are added is much lower;
- A very reduced temperature decrease generates a large influence of the NO_X reduction rate;
- Oxygen concentration is also paying an influence role on the NO_x generation;
- Generally, expected answers of the NO_x production determined by O_2 and temperature were obtained;
- Dioxins are expected to be destroyed, as residence time and temperatures are appropriate.

By calculating the thermal behavior of the heat exchangers in the boiler, one particularly found:

- Entrance temp into the convective zone (case 0) is approx. 20 °C lower as in the cases with additional gases.
- More gases mean enhanced flows and velocities, thus the heat exchange by convection is also enhanced, in comparison to the basic case.
- That means more heat is exchanged when gases are added. This fact is also relevant for the final heat exchangers.
- The air pre heaters are compensating themselves, so generally the same temperature is reached (298 ° in comp. to 300 °C), so no problems with air preheating may appear.
- The same compensation interferes also in the case of the economizer (158 ° in stead of 160 C), also no problems should be expected.
- The super heater receives less heat (by 12.7 %) that represents a temperature less with 9 °C for the steam. This conclusion must be checked with the client.
- Temperature at the stack is higher (148 °C in comparison to 140 C), as the heat exchangers – especially the super heater – do not achieve to extract the same amount of heat rate.
- More flue gases through the boiler represent more gases in exhaust, meaning a higher loss with flue gases exhaust (17 % more, meaning augmentation from 9.4 % to 11.0 %). Thus the boiler efficiency from this point of view is reduced by 1.4%.

In conclusion one mentions:

- The boiler resists from the thermal point of view, and keeps its parameters (except a little temperature decrease of the steam, and less efficiency). Heat from the incinerator for the case of Timisoara power plant should be used in the de-aerator.
- *Economic benefits* must be found in applying the regulation for environmental protection, less penalties, trading with ETS, etc. One might count also on additional support from the local authorities and population solving of the present waste problem, that really is very uncomfortable and environmental dangerous.
- One of the main tasks of the EU founded research project is to evaluate the capability of the boiler and additional secondary treatment methods for flue gas cleaning, and to determine the potential supplementary use of heat energy from the waste combustion, into the scheme of the existing plant.

WP4 Results:

- Latest results concerning simultaneous Hg, heavy metals, particles retention in the scrubber.

- Balance of the elements: input flue gas, output flue gas, in dependence to the scrubber washing solution.

The simple acid scrubber (Figure 4) removes more than 95 % HCl and approx. 90 % of Hg. Other heavy metals are removed by a common filter system (EPS or bag filter), whereas the classic pollutants NO_x, SO_2 and PCDD (poly-chlorinated di-benzol dioxins and furans) are introduced into the furnace of the coal power plant.

One indicates results from experiments, achieved on a the build up scrubber in order to retain the heavy metals, especially Hg, and HCl.

The scrubber is meant to test different technologies and optimise the costs and efficiency of retention of the special metals and HCl, as well, under real conditions. One simulated the flue gas composition input, as result of mixing natural gas combustion flue gases with controlled dosseded amounts of specific pollutants. Mainly, the facility is composed by several main parts: Dosing Pump, Furnace, Flue Gases Cooler, Rota-meter, Gas Burner, Protection, Safety Valve, Flame Visualization, Natural Gas, Primary Air, Secondary Air, Cooling Air, Pollutants, Controlled Dosage of Pollutants, Controlled Dosage of Particle, Analysis of Input Flue Gases, Analysis of Output Flue Gases.

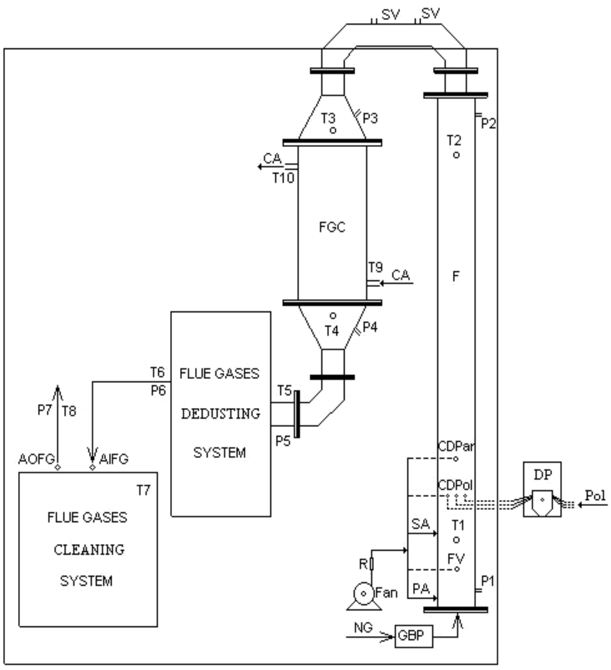


Figure 4: Experimental Lab scale facility for testing the Hg retention (photo and schematics):

DP – Dosing Pump, F – Furnace , FGC – Flue Gases Cooler, R – Rota meter , GBP – Gas Burner Protection, SV – Safety Valve, FV – Flame Visualization , NG – Natural Gas, PA – Primary Air, SA – Secondary Air, CA – Cooling Air, Pol – Pollutants: HCl, $HgCl_2$, SO_2, CDPol – Controlled dosage of pollutants, CDPar – Controlled dosage of Particles, AIFG – Analysis of Input Flue Gases, AOFG – Analysis of Output Flue Gases, Pressure:P1 / P2 – Lower / Upper Furnace, P3 / P4 – Gas Cooler Input/Output, P5 / P6 – Dedusting System In/Out, P7 – Gas Exhaust, ΔP = P1 – P7, Temperature:T1 / T2 – Lower / Upper Furnace, T3 / T4 – Flue Gas Cooler In/ Out, T5 / T6 – Dedusting System In/ Out, T7 – Washing Sorbent, T8 – Clean Flue Gases Output, T9 / T10 – Cooling Air Input / Output.

The optimization of the Hg retention in the scrubber has been achieved by using two scrubbers in stead of the initial proposed flue gas cleaning system (see Figure 5).

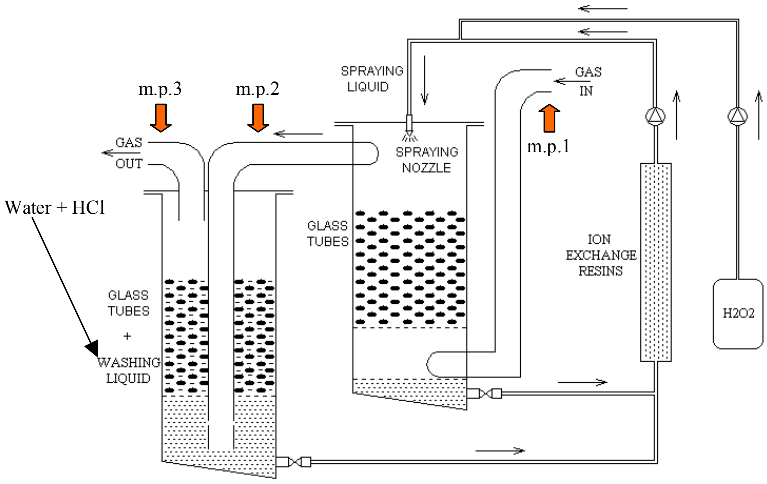


Figure 5: The combination of the spraying and the bubbling steel scrubbers.

Thus one built and tested:

- A spraying scrubber in order to convert metallic Hg to ionic Hg;
- A bubbling scrubber in order to retain the ionic Hg into the liquid washing solution.

In order to find out the retention of the Hg and all other thermodynamic parameters and status of the pollutants in the flue gases, one measured in three points: mp1, mp2, mp3.

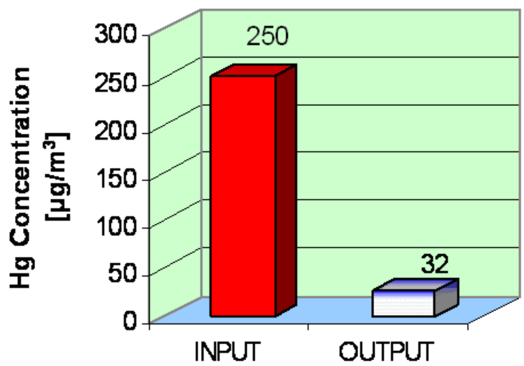


Figure 6: The Hg_{tot} concentration before and after the cleaning process.

Using this combination and a spraying liquid (at a flow rate of 1,5 l/h) containing water and hydrogen peroxide H_2O_2 (84 ml/h at a concentration of 3 mg/ml), the maximum Hg retention was about 87 % at a pH = 1 (Figure 6).

The residence time in the glass tubes column was in the range of 3.39 s.

The optimum temperature for the Hg retention was 70 °C. The results have been confirmed running several repeated tests.

Table 1 and Figure 7 show the evolution of the pollutants and thermodynamic parameters. The evolutions of the total and metallic mercury are shown in Table 2.

Table 1: The evolution of the pollutants and thermodynamic parameters.

Pos.	t_{fg}	O_2	CO	NO	NO_2	NO_x	SO_2	CO_2	λ
	[°C]	[%]	[ppm]	[ppm]	[ppm]	[ppm]	[ppm]	[%]	[–]
m.p.1	89.6	10.4	8.4	66.2	0	66.2	343	6.2	1.978
m.p.2	80.92	10.26	0	51.4	0	51.4	47	6.36	1.954
m.p.3	72.26	10.14	0	55.6	0	55.6	5	6.16	1.936

Table 2: The mean results for total and metallic mercury.

[mg/m^3]	m.p.1	m.p.2	m.p.3
Total mercury	250	180	32
Metallic mercury	190	65	30

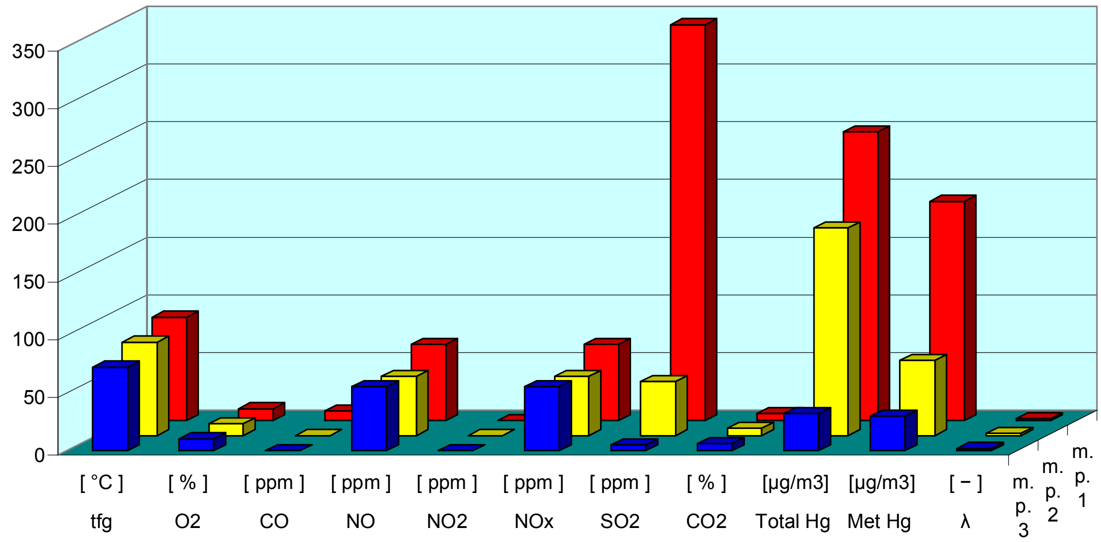
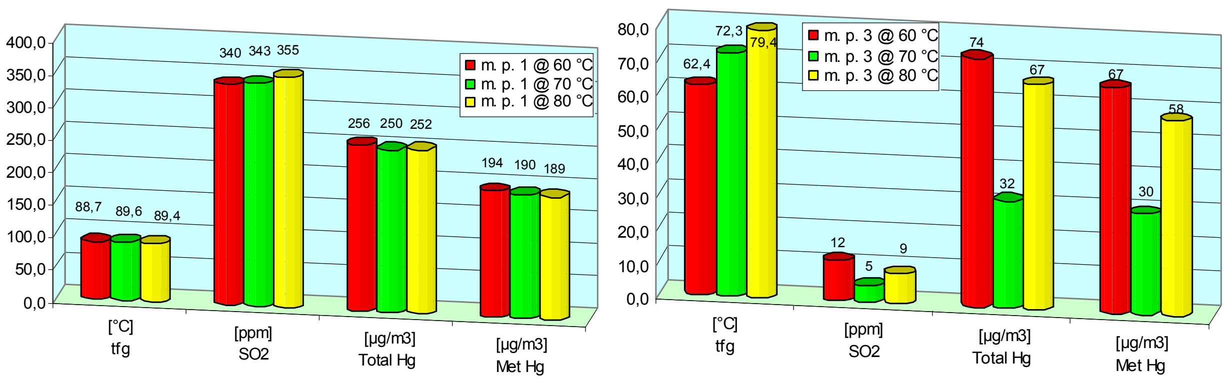


Figure 7: The evolution of the pollutants and thermodynamic parameters.

In order to find out the optimum temperature for the Hg retention, different temperatures of the washing liquid of the wet scrubber were tested.

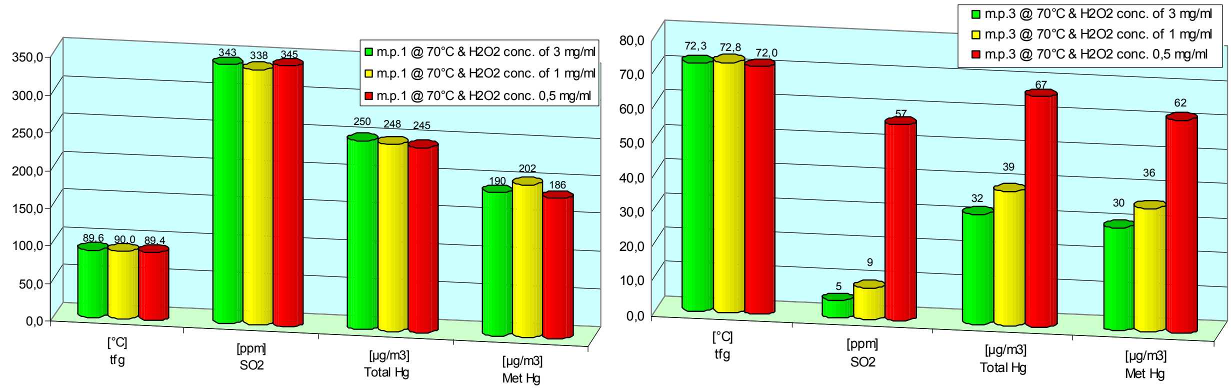


a b

Figure 8: Evolution of SO_2 and Hg investigated before (a) and after the cleaning process (b) for three temperatures of the scrubbing liquid: 60 ºC, 70 ºC and 80 ºC.

These investigations lead to the conclusion that the optimum temperature for the scrubbing liquid is 70 ºC. At this temperature the maximum Hg retention was about 87 %.

Figure 9 shows the influence of the H_2O_2 concentration on the efficiency of the scrubber.



a) b)

Figure 9: Evolution of SO_2 and Hg investigated before (a) and after the cleaning process (b) for three concentrations of hydrogen peroxide: 3 mg/ml, 1 mg/ml and 0,5 mg/ml; washing liquid temperature: 70 ºC.

In order to investigate the influence of H_2O_2 concentration on the efficiency of the wet scrubber, several and repeated solution have been tested. Best results were obtained using a spraying liquid (at a flow rate of 1.5 l/h) containing water and hydrogen peroxide H_2O_2 (84 ml/h at a concentration of 3 mg/ml), but for economy reasons of H_2O_2 the concentration can be reduce up to 1 mg/ml with no significant changes in terms of efficiency. Trying to reduce even more this concentration to 0.5 mg/ml, the results are not satisfactory.

Table 3 shows the evolution of heavy metals before and after the cleaning process. With the exception of Mn which has a higher value at the output of cleaning system, the other metals investigated have a lower value.

In Table 4 the measurements of heavy metals in the washing liquid of the scrubbers are presented. The first scrubber is the one were the H_2O_2 is injected in order to convert the Hg^0 to Hg^{2+} and the second one is used to retain the pollutants from the flue gases.

Table 3: The evolution of heavy metals before and after the cleaning process (mg/m^3 of flue gas).

mg/m^3	m.p.1 - input into the cleaning system	m.p.3 - output from the cleaning system
Cu	0,0035	0,0020
Zn	0,0320	0,0012
Fe	0,0210	0,0067
Mn	0,0020	0,0034

Table 4: Measurements of heavy metals in the washing liquid of the scrubbers (mg/m^3 of flue gas).

mg/m^3	Washing liquid from the 1st scrubber	Washing liquid from the 2nd scrubber
Cu	0,0620	0,0840
Zn	0,0351	0,0186
Fe	2,762	3,912
Mn	0,0675	0,0560

Table 5 shows the values of heavy metals found in the ash. The “clean ash” is the ash from a lignite boiler and the “contaminated ash” is the same ash which was passed through the lab facility. The conclusion of these measurements is that Fe and Mn lay on the walls of the installation and only a small concentration can be found in the “contaminated ash“.

Table 5: Measurements of heavy metals in the ash.

mg/kg	Clean ash	Contaminated ash
Cu	10,2	21,7
Zn	11,5	29,7
Fe	15392	2249
Mn	80,0	19,7

WP 5 Results:

Input data for the accomplishment of the guidebook.

In conclusions, the retention of Hg from waste combustion flue gases should be optimised by applying following guidelines:

(i) Scrubber technique (using two scrubbers - spraying and the bubbling steel scrubbers - instead of one single)

(ii) Efficient Hg reduction is accomplished by a combination of two scrubbers and a spraying liquid (at a flow rate of 1,5 l/h), containing water and hydrogen peroxide H_2O_2 (84 ml/h at a concentration of 3 mg/ml),

In detail one mentions as essential to assure that during the technology:

1. Hg metal turns into Hg ionic, and thus might be captured,
2. Using H_2O_2 in the spraying system, one makes possible the transformation of Hg^0 into Hg^{2+},
3. Hg^{2+} is retained in a ion exchange column, simultaneously one achieved also that heavy metals have been also retained,
4. Optimal process temperature for washing out Hg and other pollutants is 70 °C (in the scrubber).

Acid environment should be implemented in the scrubber in order to achieve simultaneously HCl, SO_2 concentration diminishing.

The tested solutions are fully satisfying from the point of view of retaining the metals, SO_2 and HCl, and might be applieed on real cases, as well.

I.4 Coordination of information, communication activities and management issues[1]

[1] This item will be completed by the Coordinator

I.5 Deviations from the work plan and/or time schedule

No deviation

I.6 Publications

- Claudiu Gruescu, Ioana Ionel – *Experimental research concerning mercury removal from waste incinerators flue gases*, Scientific Bulletin of ”Politehnica” University from Timişoara, Tom 49 (63), Fasc. 2, 2004, Timişoara, ISSN 1224-6077, p 35-38.
- Claudiu Gruescu – *Experimental research concerning the cleaning of the waste incineration flue gases*, Sustainability for humanity & environment in the extended connection field science – economy – policy, Scientific reunion of the special program of the Alexander von Humboldt Foundation concerning the reconstruction of the South Eastern Europe, Vol. 1, 24-25 feb. 2005, Timişoara, ISBN 973-625-205-1, p 107-110.
- M. Savu, B. Savu, V. Gruescu, I. Ionel, A. Savu – *Co-firing of biomass / domestic wastes with coal and flue gas cleaning*, Sustainability for humanity & environment in the extended connection field science – economy – policy, Scientific reunion of the special program of the Alexander von Humboldt Foundation concerning the reconstruction of the South Eastern Europe, Vol. 1, 24-25 feb. 2005, Timişoara, ISBN 973-625-205-1, p 268-271.
- Alexandru Savu, Ioana Ionel, Claudiu Gruescu, Gavrilă Trif-Torday, Monica Savu – *Tehnologie de epurare a gazelor de ardere rezultate din incinerarea combinată (Translation: Technology for cleaning the flue gases from combined combustion processes)*, “Omul şi mediul” Symposium, 26.05.2005, Timisoara, ISBN 973-625-225-6, p. 77-82.
- Ioana Ionel, Dan Oprisa-Stanescu, Claudiu Gruescu, Vasile Gruescu, Gavril Trif-Tordai, Corneliu Ungureanu – *Ecologic and Thermal Consequences of Coupling a Steam Boiler with a Waste Incinerator. Case Study.* Deutscher Flammentag 21/22 September 2005, Braunschweig, Germany.
- Ioana Ionel, Claudiu Gruescu, Dan Oprisa-Stanescu, Alexandru Savu – *Case study for coupling of a waste incinerator to a Romanian coal fired steam boiler*. Kraftwerkstechnisches Kolloquium, Dresden, Germany 18/19 October, 2005.

Under print

- Claudiu Gruescu, *Experimental research on a wet scrubber lab facility for simultaneous removal of heavy metals and other pollutants from the waste incinerators' flue gases*, Wastes & Biomass Thermal Treatment, Combustion & Co-Combustion- Workshop, Nov. 2005, Wrocław University of Technology.
- Ionel Ioana, *Environmental concern & global risks of the mercury emission sources, Wastes & Biomass Thermal Treatmen*t, Combustion & Co-Combustion- Workshop, Nov. 205, Wrocław University of Technology.
- Ioana Ionel, *Achievements and future development trends of the department of thermal machines and transportation in the extended field of renewable energies*, Renewable energy for Europe-Research Action. Bruessels 21-21 November, 2005.

I.7 Other issues