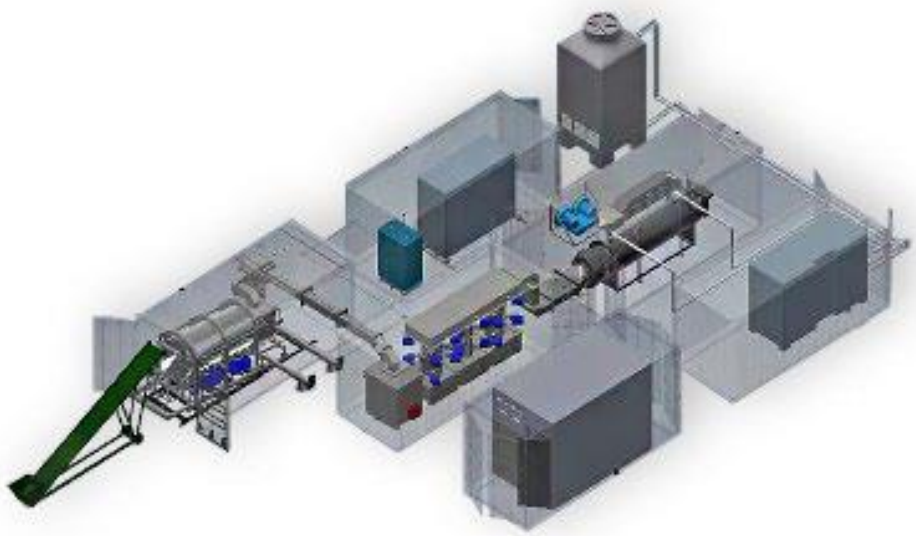
We make waste disappear



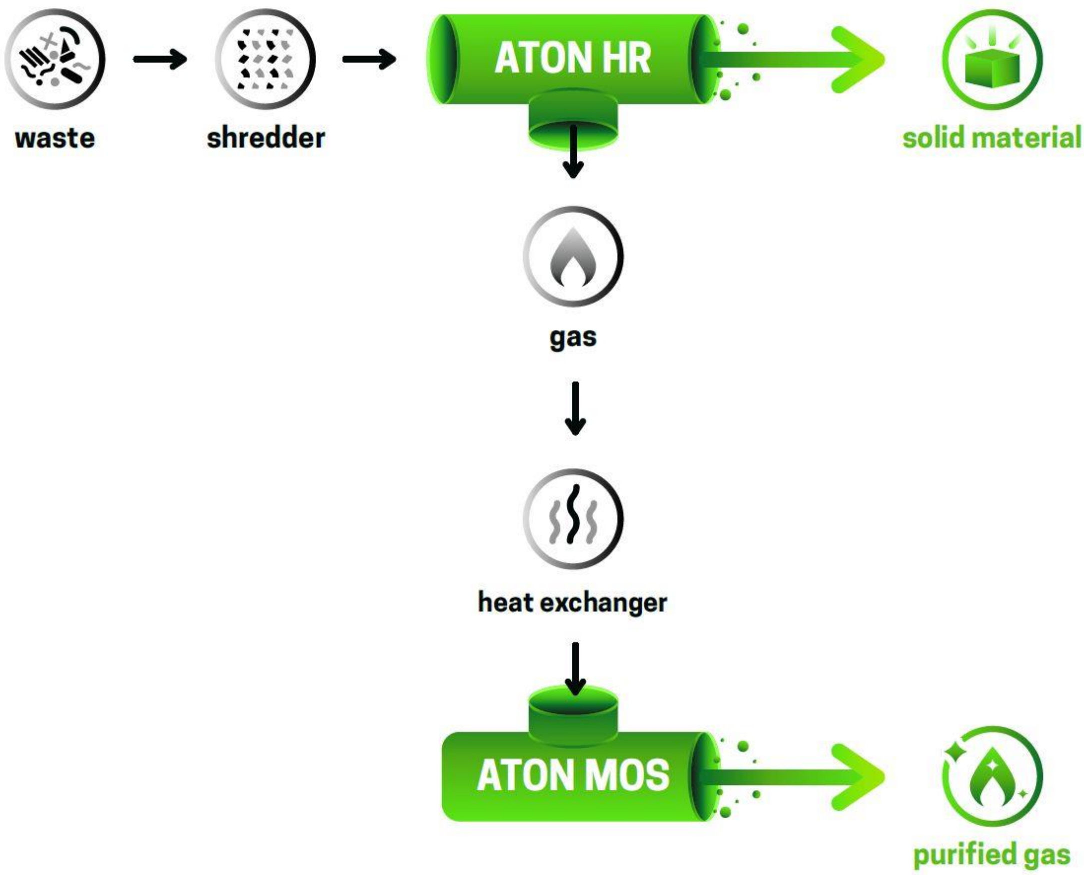
Operation report of the ATON system

Gustaw Koenig, Eng., Faculty of Mechanical Engineering,
Wrocław University of Science and Technology

Operation report of the ATON device

Units

The ATON device consists of two working blocks, a heat exchanger and a control unit. In the first block called ATON HR, material thermal decomposition process is carried out. As source of energy for decomposition process concentrated microwave field is used. The process products are: environmentally safe solid material and high-calorie process gases containing volatile organic compounds. Process gases are routed to the second block called ATON MOS, which conducts a process of cleaning the gases from harmful compounds by oxidation of pollutants in high temperature. Purified gases can be safely released to atmosphere.

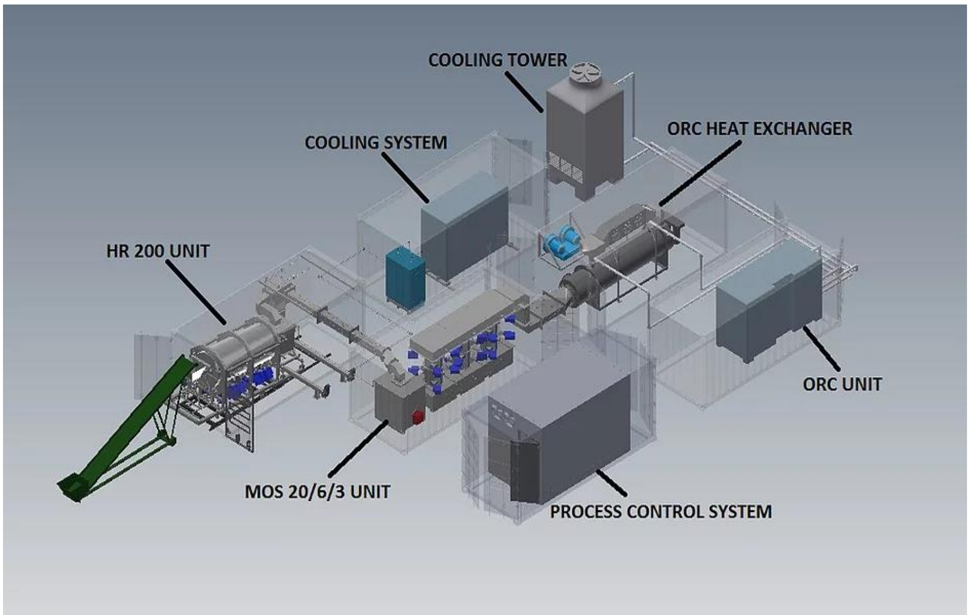


1.1 Scheme of operation of the Aton device

Device construction

The individual modules of the unit are installed in 20 ft containers The shredded waste material is delivered with belt conveyor to a hopper of the HR module.

The main element of the MOS module is a rotating ceramic drum, equipped with generators that concentrate the microwave field on the treated material. The cylinder rotates around its own axis so that the material is mixed evenly, which reduces the duration of the process. The slope of the cylinder results in gradual material movement to the back of the drum.



2.1 The Aton device diagram For example THE HR-S system

2.2 Discharge of the solid material resulting from the water bath in THE HR module

2.3 View of THE HR module of microwave radiation generators

The conditions inside the drum are closely linked to the material type and process conditions. It is possible to control the temperature in the range up to 1200°C, with high accuracy. The composition of process gas is constantly measured, with focus on oxygen content, to automatically adjust the technological parameters within preselected range. The solid material is ejected into the water bath on the side of the HR module.

Hot process gases are directed to MOS module, where they are cleaned at a temperature of approx. 1000°C. At final stage the hot gases are directed to a heat exchanger where they are cooled and then in purified form released into the atmosphere. The composition of released gases is 20% O_2, 10% CO_2 and N_2. During cooling process inside the heat exchanges water is heated (here to 96°C). This hot water may be used for technical purposes

2.4 MOS Module

2.5 Heat Exchanger

The control module built using high-end PLC made by German company Beckhoff. The programmed control algorithm automatically regulates the operational parameters of MOS module by controlling the temperatures and output gasses and keeping the values within specified range. The HR control is also automatically controlled by regulating electromagnetic field strength, drum pitch and rotation speed.

Processed material

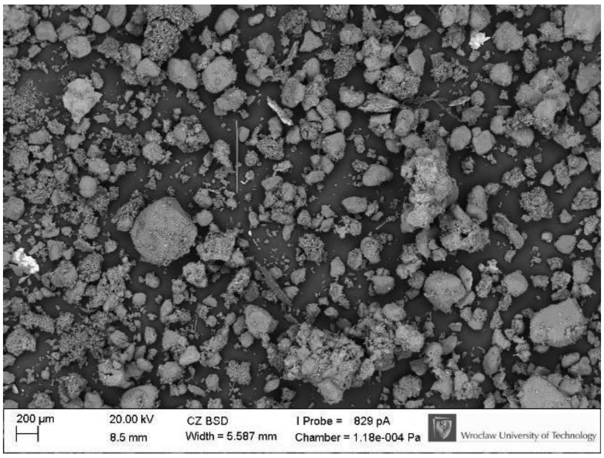
Before the process the material it is crushed to a loose form with a fraction size of about 2x2 cm. Contamination with metallic materials does not create any hazard as long as these components are small enough not to cause mechanical damage to the ceramic drum linings of the machine during its rotation.

Liquid waste can be disposed of by using a solid medium that can carry the liquid during the process such as sand.

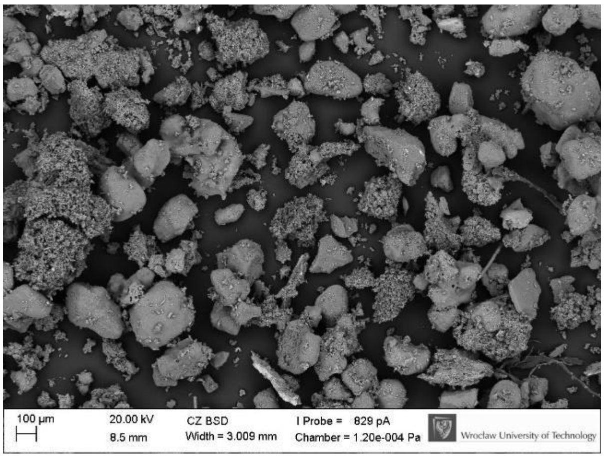
As a representative example, the batch of high-calorie fraction of waste material is used, sorted from industrial or urban waste. This waste typically contains non-recyclable plastics (excl. PVC) paper cardboard, labels and other wavy materials, wood, rubber and textiles. This sorted waste is used for the production of RDF (alternative fuel). Refuse-derived fuel, whose calorific content is about 18-20 MJ/kg. RDF has European waste code 19 12 10.
To increase calorific value the input material is soaked with used N-Methyl-2-pyrrolidone (NMP) solvent that is used in industry as paint remover, pigment suspension agent, in chemical and electrical industry as well as electronics. According to regulations NMP is a hazardous waste and is classified under waste code 16 03 06.

Output material

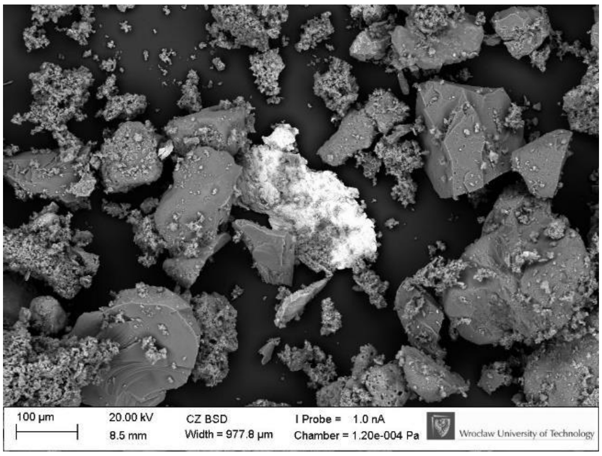
The sampled solid material appearing at the exit of the ATON HR module was tested using a scanning electron microscope (SEM). The sample was dried in an oven at 120°C for 2 hours without the protective atmosphere nor Au-Pd coating.



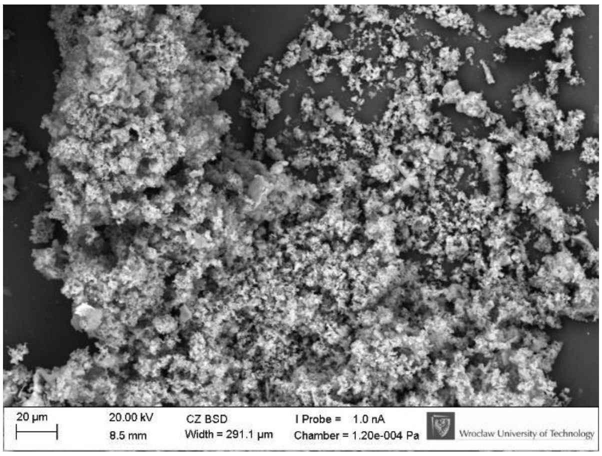
4.1 Particle output material
(magnification 54x)



4.2 Angular and spongy particles
(magnification 100x)

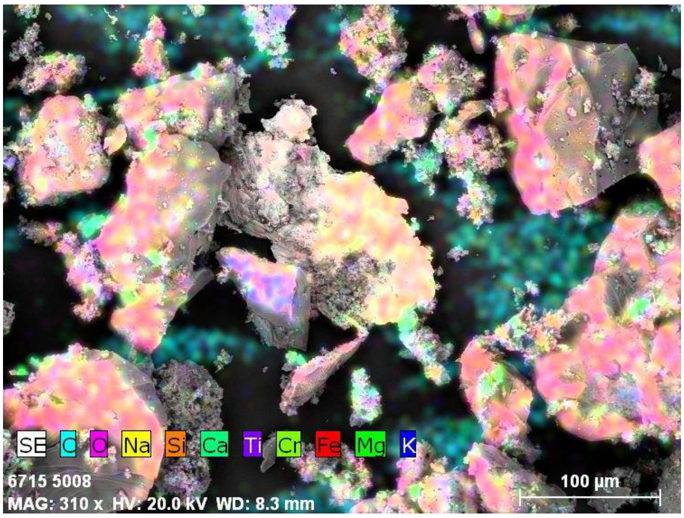


4.3 Metallic angular particle
(magnification 310x)



4.4 Spongy particle
(magnification 1000x)

The initial observation of the sample showed that the sample has a powder form (Figure 4.1) with angular (Figure 4.2) or spongy shape particles (Figure 4.4). Among the angular particles metallic particles can be clearly distinguished by brightness (Figure 4.3). Spectrum analysis in the selected area identified presence of many elements with a majority of silicon, calcium and iron (Figure 4.5).

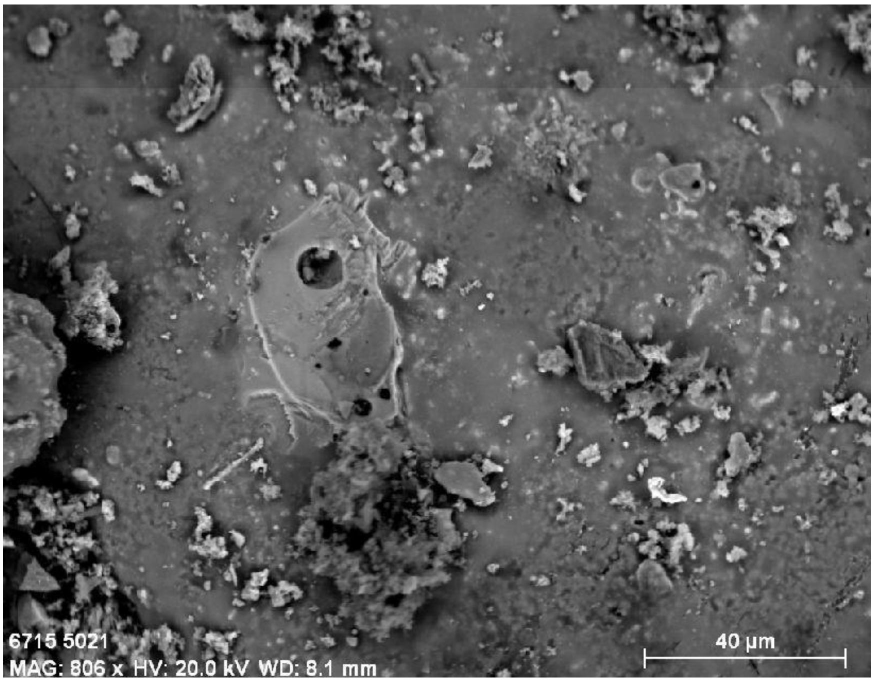


4.5 Spectrum Analysis in selected area (magnification 310x)

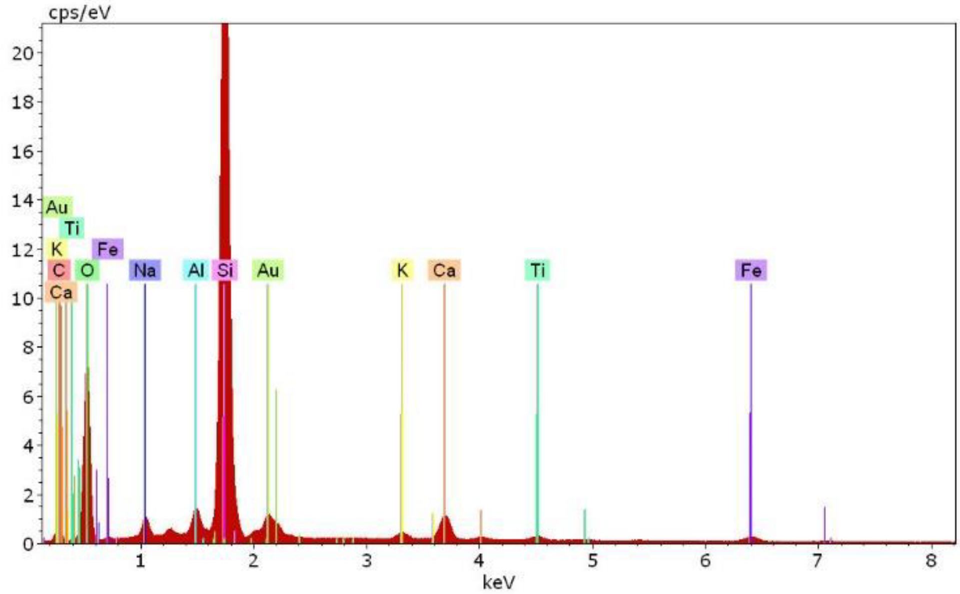
A detailed analysis was carried out by extracting three areas which are described in detail in the subsections below.

Angular particles

In this region there is a majority of silicon and calcium with trace amounts of sodium. Small amounts of metallic elements such as iron and aluminum also appear.



4.6 Angular particle (magnification 806x)



4.7 Characteristic X-ray spectrum (intensity dependence on acceleration voltage)

Element	Series	unn. C [wt.%]	norm. C [wt.%]	Atom. C [at.%]	Error [%]
Carbon	K-series	2.23	3.05	4.84	0.6
Oxygen	K-series	43.36	59.47	70.70	14.6
Sodium	K-series	1.25	1.72	1.42	0.1
Aluminium	K-series	1.03	1.41	1.00	0.1
Silicon	K-series	21.53	29.54	20.00	0.9
Potassium	K-series	0.29	0.39	0.19	0.0
Calcium	K-series	1.72	2.36	1.12	0.1
Titanium	K-series	0.39	0.54	0.21	0.0
Iron	K-series	1.11	1.52	0.52	0.1
	Total:	72.91	100.00	100.00	

Tab. 4.1 Percentage of elements in angular particles (see column 2;do not take into account the values for oxygen and carbon-only for illustrative purposes)

Angular metallic particles

In these particles, iron dominates. Silicon also appears in smaller amounts with trace of magnesium and niobium.

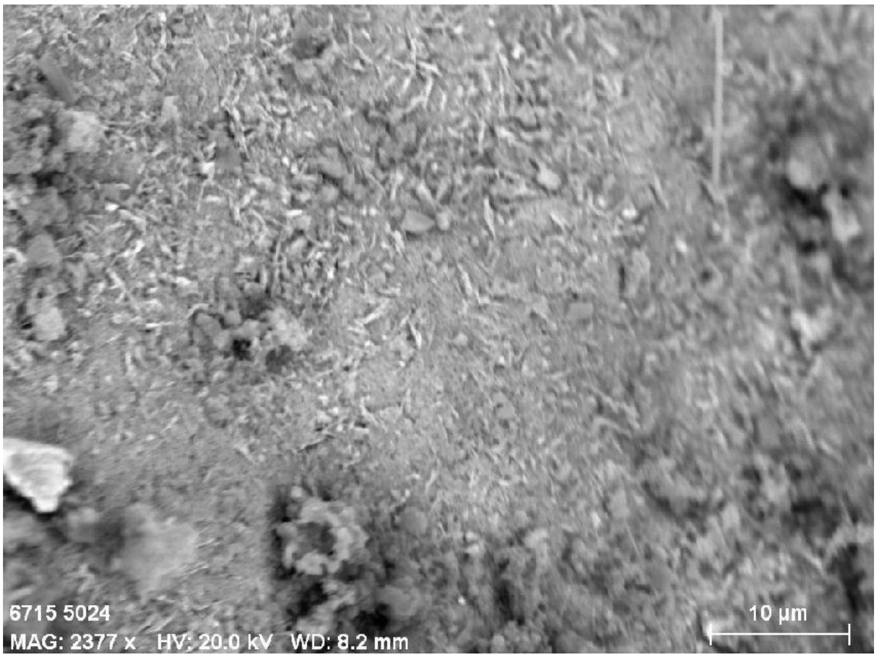
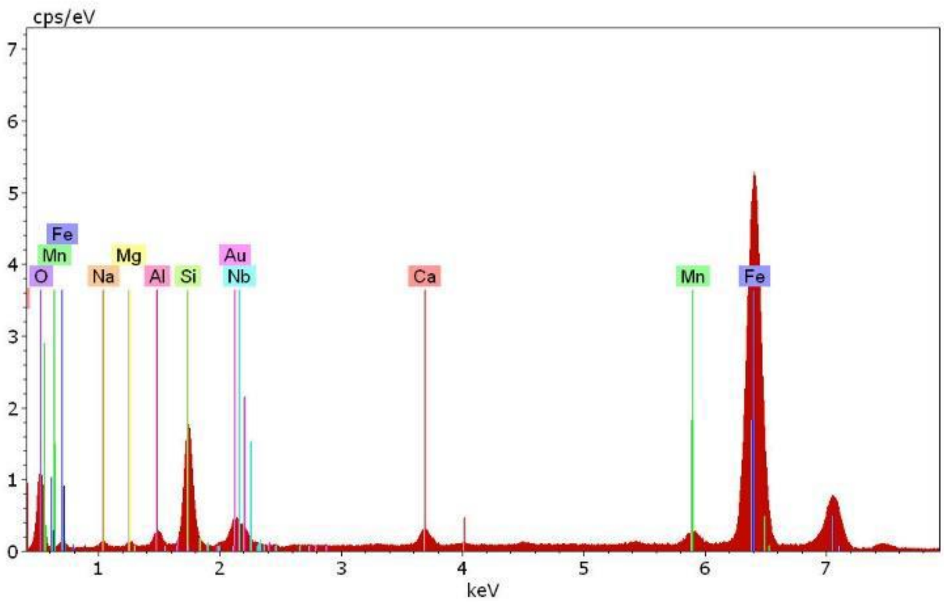


Figure 4.8 Angular metallic particle (magnification 2377x)



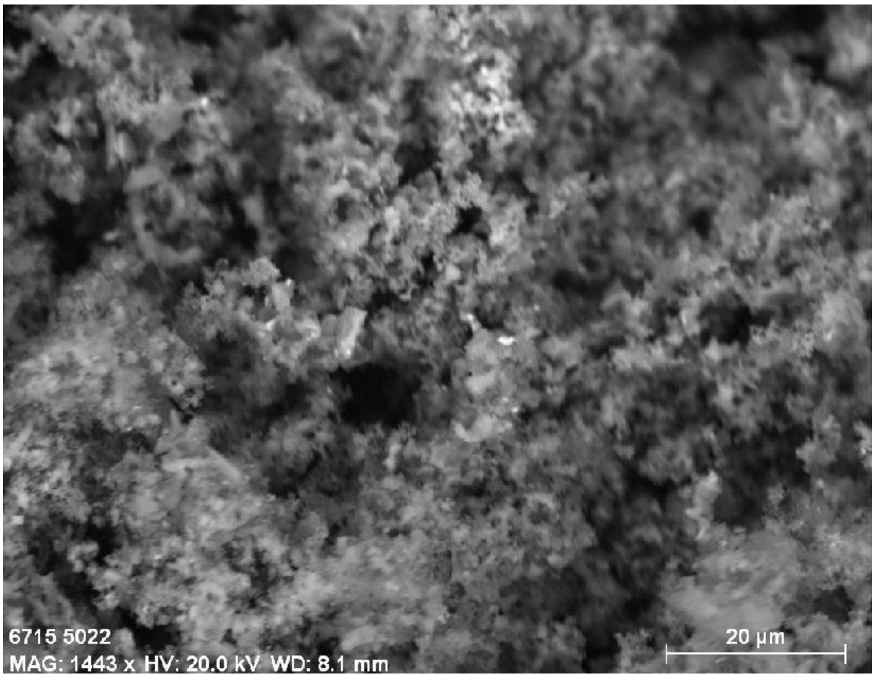
4.9 Distinctive Spectrum of radiation x -rays it (intensity dependence on acceleration voltage)

Element	Series	unn. C [wt.%]	norm. C [wt.%]	Atom. C [at.%]	Error [%]
Carbon	K-series	1.80	1.56	5.88	0.3
Oxygen	K-series	5.18	4.47	12.69	0.8
Sodium	K-series	0.59	0.51	1.00	0.1
Magnesium	K-series	0.11	0.10	0.18	0.0
Aluminium	K-series	0.72	0.62	1.04	0.1
Silicon	K-series	6.07	5.24	8.48	0.3
Calcium	K-series	0.96	0.83	0.94	0.1
Manganese	K-series	4.59	3.96	3.28	0.2
Iron	K-series	93.03	80.27	65.31	2.5
Niobium	L-series	2.84	2.45	1.20	0.1
	Total:	115.90	100.00	100.00	

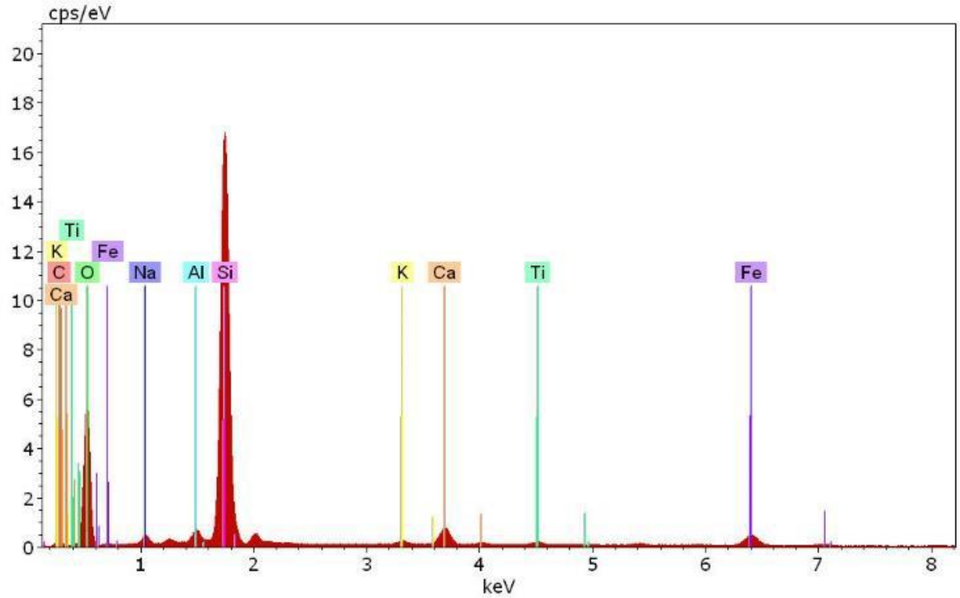
Tab. 4.2 Percentage of elements in angular metallic particles (see column 2; do not take into account the values for oxygen and carbon-only for illustrative purposes)

Spongy particles

In this region there is a majority of silicon and calcium, or silicon and iron, depending on the area being observed. Small amounts of other elements also appear.



4.10 Dendritic particle (magnification 1443x)



4.11 Characteristic X-ray spectrum (intensity dependence on acceleration voltage)

Element	Series	unn. C [wt.%]	norm. C [wt.%]	Atom. C [at.%]	Error [%]
Carbon	K-series	3.26	3.26	4.78	2.3
Oxygen	K-series	75.52	75.52	83.10	49.7
Sodium	K-series	0.56	0.56	0.43	0.1
Aluminium	K-series	0.41	0.41	0.27	0.0
Silicon	K-series	15.61	15.61	9.78	0.7
Potassium	K-series	0.07	0.07	0.03	0.0
Calcium	K-series	1.26	1.26	0.55	0.1
Titanium	K-series	0.28	0.28	0.10	0.0
Iron	K-series	3.03	3.03	0.96	0.1
	Total:	100.00	100.00	100.00	

Tab. 4.3 Percentage of elements in spongy particles (see column 2; do not take into account the values for oxygen and carbon-only for illustrative purposes)

Purified output gas

The parameters of purified gas appearing at the outlet of the exchanger were tested using the MRU NOVA 2000 analyzer. The results are presented in Table 5.1.

	Printout 1	Printout 2	Printout 3
M R U NOVA 2000	010 477	010 477	010 477
Date / time	30.01.2019 14:52	30.01.2019 14:52	30.01.2019 14:52
Gaz ziem.50	12.1 %	12.1 %	12.1 %
Programm 1			
T-Gaz	39.2 °C	39.2 °C	39.2 °C
T-Pow.	22.8 °C	22.3 °C	22.9 °C
O2	10.8 %	10.8 %	10.7 %
CO2	5.8 %	5.8 %	5.9 %
CO	0 ppm	0 ppm	0 ppm
NO	86 ppm	86 ppm	87 ppm
NOx	91 ppm	90 ppm	91 ppm
SO2	1 ppm	1 ppm	1 ppm

Tab. 5.1 Output gas parameters

Disposal of arsenic and other hazardous metallic materials

The metallic elements contained in the input material will be output in a solid material that appears at the exit of the HR module. It is possible to close these elements in a sheathing of innate material (SiO_2) in with specialized process. This process can be implemented in an additional small HR module that would be connected to main device.

Performance and scaling

The performance of a single device depends on the type of batch material up to 350 kg/h (value specified for oil-contaminated soil treatment).

The efficiency limiting factor is the dimensions of the HR reactor drum, which currently has a diameter of about 36 cm, this dimension is derived from the applied wavelength of about 12 cm at a frequency of microwaves of 2.45 GHz. Increase of this diameter while using the same wavelength, would reduce the electromagnetic field performance. Change to the industrial frequency range is possible which will allow the diameter to be increased up to approximately 1 m. This would result in 9 times the performance improvement. Further performance enhancement requires the installation of additional ATON HR modules.

For the RDF mixture of the NMP (described in Chapter 3), the efficiency is approximately 60-80 kg/h.

Power and energy balance

During start-up, as the machine heats up, it consumes about 350 kW of electrical power. During continuous operation consumption is reduced to 70 kW.

The energy consumption during continuous operation is balanced with the calorific content of the batch material. Above value of 16 MJ/kg the energy balance is positive and the system can be used to generate energy form heat of process gasses. Below the limit value the energy balance is negative which means that the system draws more energy than it can produce. For wastes contaminated with oil the process gases are high-calorie enough that the balance will be positive.

The calorific value of the RDF mixed with NMP (described in Chapter 3) is approximately 30 MJ/kg. For this calorific strength at the exit of ATON MOS module there is a heat energy of 350 kW generated, while the electrical power consumption is 48 kW for continuous operation. For presented installation a heat exchanger and power generator was used, that were capable of producing 35 kW electrical power. However, despite the calorie input exceeding almost 2 times the limit value of 16 MJ/kg, the energy balance was still negative due to the low efficiency of the electric generator. To make the balance positive, a 1MW heat exchanger with larger generator has to be used.

Installation conditions

Installation requires approximately 20x30m area with solid and hardened ground.
We shall issue a CE conformity declaration for his device. The device is tested for electromagnetic compatibility. The noise generated by the device does not exceed 60 DB.

Installation of the equipment

Small units were delivered to research institutions such as Polish Institute for Ferrous Metallurgy. Some were used in the Amiante Research project (grant no 222142 under FP7SME).
MOS devices are installed at TOTAL Bitumen Production Plant (Poland) , OVI Pumping gas station (Latvia), MASKPOL Combustible gas disposal system (Poland).

Contact us:

Monika Swierc
m.swierc@daytonalubricants.com
m. +48 660 434 120

Krzysztof Hawryszczuk
k.hawryszczuk@daytonalubricants.com
m. +48 796 018 954

Daytona Lubricants Polska Sp. z o.o. Sp. k.
Domaniewska 47, 02-672 Warszawa
NIP PL5213642067, www.daytonalubricants.com