THE CHEMICAL PROPERTIES OF ALTERNATIVE FUEL FROM AUTOMOBILE SHREDDER RESIDUE (ARS)

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Abstract

A technical object is wearing down and stops to do its function what is connected with becoming a problem, in case of vehicles, especially in environmental aspect. The recycling rate of end-of-life vehicles (ELVs) has to increase to eighty-five per cent to 2014. Nowadays few methods of recycling can be mentioned. The most popular based on disassembly, second usage of recovered materials trough fragmentation and separation of raw materials and incineration of Automobile Shredder Residue (ARS) using maximum energy recovering and minimum emission causing processes. In this paper the methods of vehicle recycling was analyzed and discussed. Especially raw materials separation aspect was taken into consideration. An average sample of ARS which is a composition of materials like rubber, plastic, wood and fibers which is use as an alternative fuel for co-burning process in industry, was analyzed. Because of metals and organic compounds (PAHs - Polycyclic Aromatic Hydrocarbons, VOC's - Volatile Organic Compounds) toxic emission problem (combustion gas emission and waste emission with cinder) in ecology aspect it is very important to know chemical properties of burning fuel. The ARS very often consist potential hazardous on human health chemical compounds or compounds whose thermal treatment products are toxic. Even if concentration of potential dangerous compound is very low it can cause very serious consequences for environment and humans. The results of chemical properties investigation of alternative fuel from vehicle using AAS (Atomic Absorption Spectrophotometry) method are published in this paper. Also alternative solutions for those wastes (ARS) usage are proposed and discussed.

Keywords: *Automobile Shredder Residue (ARS), end-of-life vehicles (ELVs)*

1. Introduction

The number of exploiting vehicles in Poland has been increasing since years, that is why not only a problem of their exploitation (especially road infrastructure) is very important but also a problem of end-of-life vehicles (ELVs) management need to be taken into consideration.

Vehicle recycling is an extremely significant problem if we look on aging vehicle market in Poland. In Fig. 1 the age structure of passenger cars in Poland in 2007 is presented.

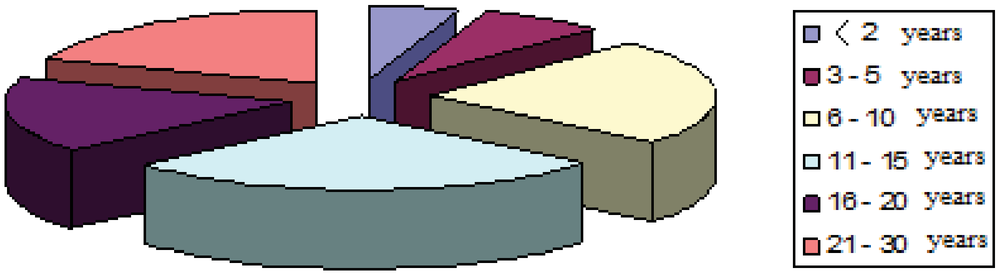

Fig. 1. The age structure of passenger cars in Poland in 2007 [3]

The legislation of EVLs treatment are defined in polish act (20 January 2005) about recycling of end-of life vehicles (Dz. U. Nr 25, poz. 202) and it base on general rules of waste management preferences (Fig. 2).

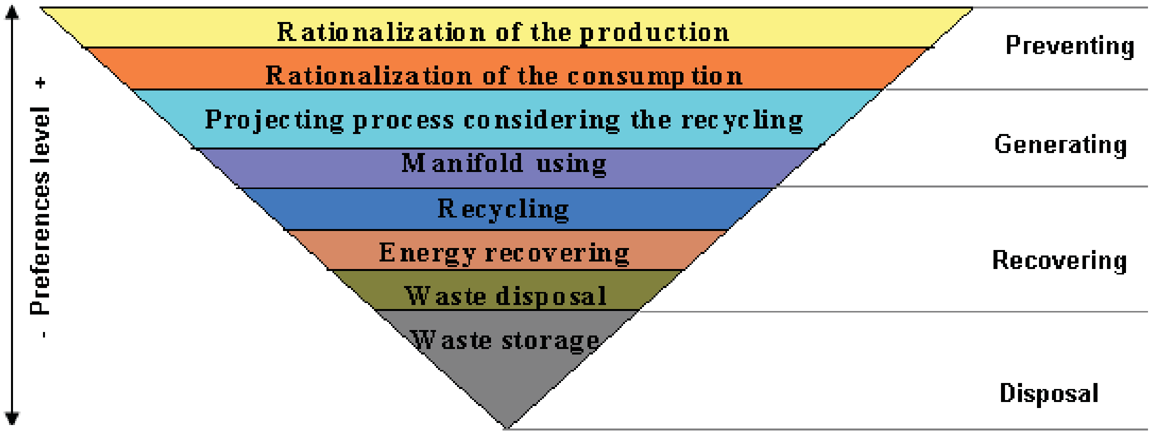

Fig. 2. General waste management preferences [4]

The vehicle recycling can be divided to 3 main stages:

- Stage I. Disassembling and vehicle drying. From vehicle every usable parts, catalyst, gas reservoir, oil filter, battery. Also vehicle drying (exploiting liquids removing) is provided.
- Stage II. Shredding. After disassembling process the vehicles are shredded. The batch scrap metal is separated (magnetic methods) which is the highest quality raw material for steel production. The rest part of the material compose automotive shredder residue (ARS).
- Stage III. Automotive shredder residue management. In this stage row material recover is steal proceed on special technological lines for waste segregation. This technology enable to recover: residual metal fraction, scale (granular fraction of ferric oxides, mineral fraction and glass) and also rubber, plastic, fibres and wood.

Recovered materials are transformed in special installations and become the products for many technologies. Hazardous wastes are disabled in proper centres. In companies equipped with shredders a problem with after shredder fraction management (ARS) appears.

The ARS are a mixture of fibers, ferrous and non-ferrous metal light fractions and plastic materials. In Fig. 3 an example of ARS composition is presented.

After sorting lines where most of metalic fraction are separated, ASR are mostly magazine on a company area where wastes are waiting for future treatment. The automotive shredder residue, because of potential of hazardous elements should be storage only in special conditions, define in the directive, because of possibility of natural environment contamination.

The ARS storage on landfills is expensive and unprofitable especially for small companies which very often stand on very thin line of uneconomic. That is why new solutions for ARS management have been developed for years which aim is ARS storage elimination or limitation.

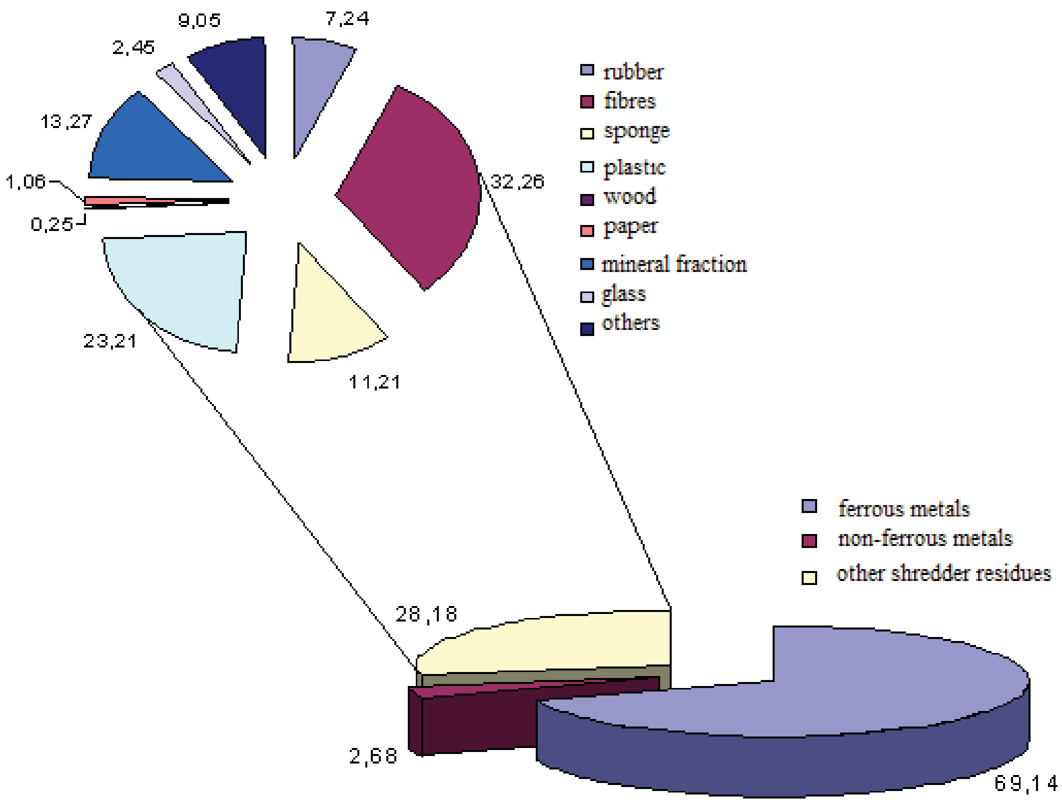

Fig. 3. The ARS composition (a statistic probe) [2]

The automotive shredder residue, because of their high heating value (Tab. 1), can be use as alternative fuel for co-combustion processes in industry (which are equipped with high effective installation of exhaust purification) i.e. cement manufacture.

Tab. 1. The ARS flammable fraction heating value [kJ/kg] in comparison with conventional oil, coal and natural gas [2]

Flammable fraction of ARS	Average mass fraction ARS [%]	Heating value [kJ/kg]	Average heating value ARS [kJ/kg]
Rubber	2.04	23209	24470
Fibres	9.09	17107	
Sponge	3.16	19034	
Plastic	6.54	38161	
Wood	0.07	15779	
Paper	0.30	16981	
Fuels fractions		Heating value [kJ/kg] (average)	
Conventional oil		46500	
Coal		28000	
Natural gas		49000	

The problem with ARS co-combustion is that not always the industry is interested in ARS alternative fuel using (or the companies already have their contractor for ARS delivering who pay for ARS disposal – often from abroad). That is why the installation for ARS thermal transformation with heat recovery are often applied [6].

In Figure 4 an example of the installation for ARS combustion is presented. The installation is special prepared for automotive shredder residue burning: equipped with re-combustion chamber and special system for outlet gas purification.

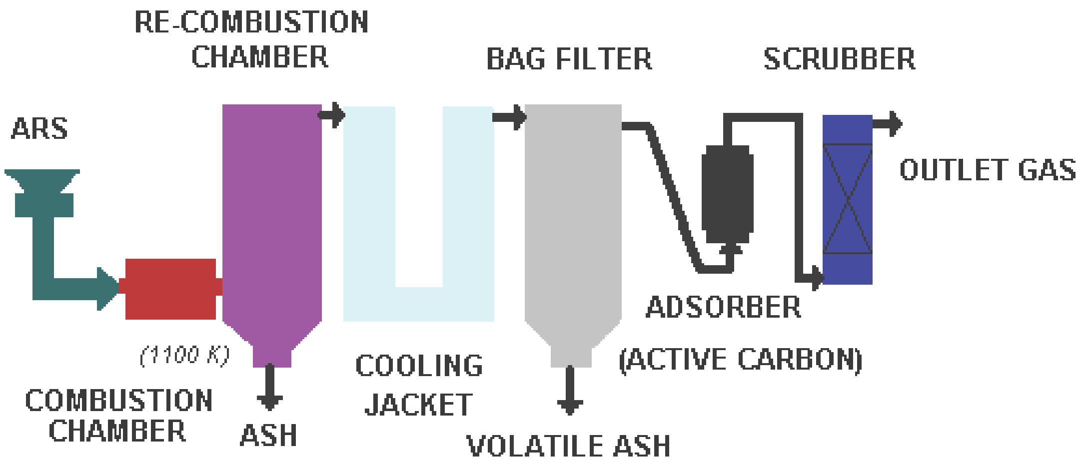

Fig. 4. An example of ARS combustion installation [1]

2. Experiment

The aim of the researches was investigation of chemical properties of ARS which assignation is a combustion as an alternative fuel for co-burning process in cement manufacture in Poland. The average sample, 5 kg weight, was taken for the research aim realization (Fig. 5).

Fig. 5. The view of ARS sample

The sample was analyzed in morphology composition aspect and divided onto 12 fractions. Next step was sample humidity estimation. Then water-extracts was prepared: a 500g of sample was treat by distillate water and distillate water acidified (H_2SO_4) to pH 3. After 24 hours the extract was separated. The concentration of metals which toxic influence on environment is well known like: zinc (Zn), magnum (Mn), iron (Fe), cuprum (Cu), nickel (Ni), cobalt (Co), cadmic (Cd) and chromium (Cr) was analyzed by atomic absorption spectroscopy (AAS) method. The AVANTA GBC analyzer was used in the experiment. The analysis was done in Laboratory of Toxicology and Environmental Investigation on Wroclaw University of Technology.

3. Results and discussion

In results of morphological analysis the sample was divided onto 12 fractions: mineral fraction, plastic, rubber, glass, paper and foil, sponge, wood, metal, plywood, heavy plastic materials, electric cables, light ARS fractions. The fraction are show in Fig. 6.

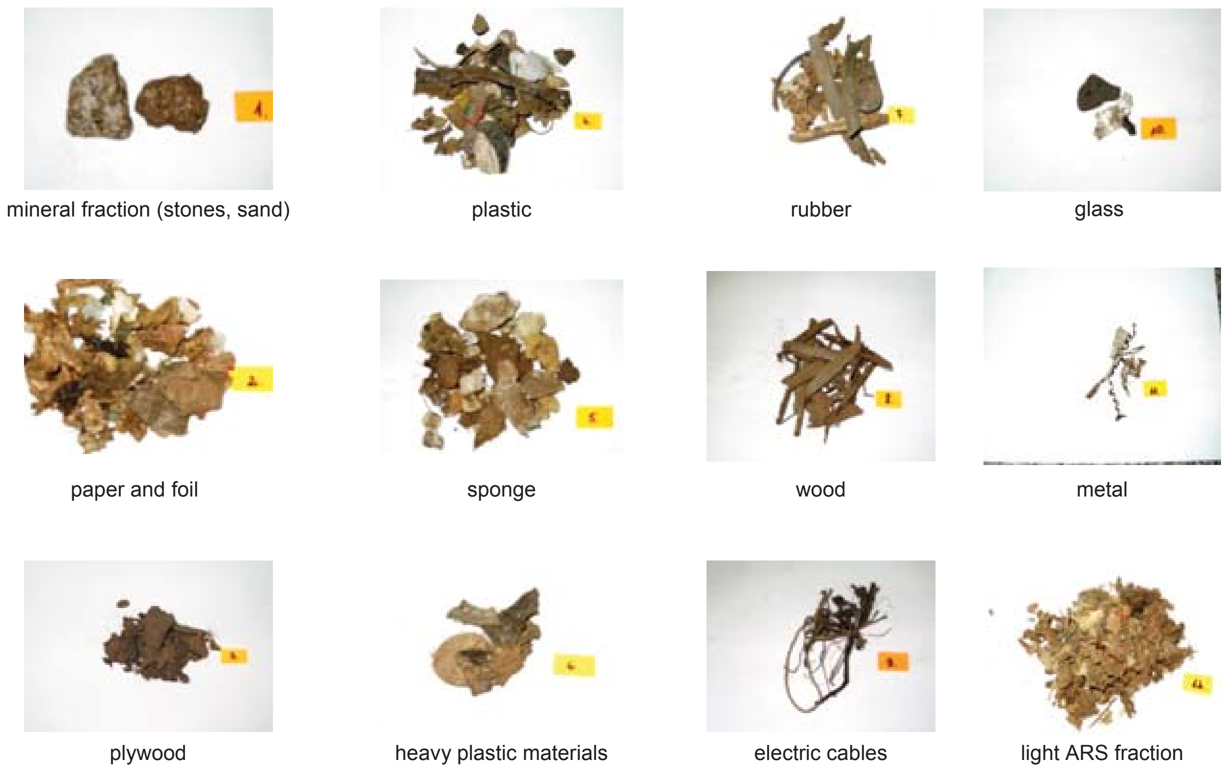

Fig. 6. A View of morphological differentiated ARS fractions

The fractions was weight and the mass fractions was estimated. The percent mass fractions was calculated according the formula:

$$X = \frac{ms}{mf} \times 100\,\%, \qquad (1)$$

where:
X - mass fraction (%),
ms - sample mass (g),
mf - fraction mass (g).

The results of the analysis are shown in Tab. 2.

Tab. 2.

Fraction number	Name	(%)
1	Mineral fraction	17
2	Paper and foil	3
3	Plywood	3
4	Plastic	27
5	Sponge	2
6	Heavy plastic materials	2
7	Rubber	2
8	Wood	5
9	Electric cables	2
10	Glass	1
11	Metal	1
12	Light ARS fraction	35

The sample humidity was estimated by 50 g weight (m_1) sample drying for 24 hours in 105°C. After 24 hours the sample was weight again (m_2). Based on mass difference (Δm) the sample humidity was estimated. The humidity was calculated according a formula:

$$\% H_2O = \frac{m_1 - m_2}{m_1} \times 100\,\% \,. \qquad (2)$$

In next step the water extracts was prepared (Fig. 7). The aim of the process was metals and their complexes extraction. 500 g of the sample was extract by distillate water for 24 hours. To simulate influence of acid rainfalls in the same time the second sample was extract by distillate water acidified (H_2SO_4) to pH 3 (the storage conditions).

Fig. 7. A view of the sample during the extraction process

The extract was separated and the analysis according to AAS method was done. The results of the analysis is shown in Tab. 3.

Tab. 3. The metal concentration [mg/dm^3] in ARS water-extracts

Metal	Concentration in extract [mg/dm^3]	
	Distillated water pH 7	Acidified distillate water pH 3
Zn	1.91 ± 0.04	48.4 ± 0.4
Mn	1.56 ± 0.02	7.10 ± 0.10
Fe	0.732 ± 0.004	1.30 ± 0.02
Cu	0.357 ± 0.007	0.461 ± 0.009
Ni	0.119 ± 0.021	0.645 ± 0.060
Co	<0.0120	0.121 ± 0.028
Cd	0.113 ± 0.067	0.726 ± 0.135
Cr	ND	ND

The results show that ARS water-extracts contain hazardous for human and natural ecosystems metals, that's why their storage on companies area cause a potential risk of environment contamination. It is important that the metals concentration is significantly higher (even almost 24 fold in case of Zn) in extract which simulate the acid rainfalls.

4. Conclusions

The automotive shredder residue management in a significant problem in ELVs recycling. Their composition is very differential (morphological and chemical properties). The authors show in the paper that ARS storage in improper conditions (i.e. on the vehicle recycling company area) can be very hazardous for local environment because of metals contamination (especially in acid rainfall environment). Relative high heat value of ARS create a possibilities of using the waste as alternative fuel in co-burning processes or special installations for ARS combustion with energy recover.

References

[1] Hwang, I. H., Yokono, S., Matsuto, T., *Evaluation method of automobile recycling systems for Asia considering international material cycles application to Japan and Thailand 2008,* Chemosphere, Vol. 71, No. 5, pp. 879-885, 2008.

[2] Hyun-Tae, J., Sung-Jin, C., Yong-Chil, S., Woo-Hyun, K., *Status of recycling end-of-life vehicles and efforts to reduce automobile shredder residues in Korea*, Waste Management, Vol. 9, pp. 159-166, 2007.

[3] Kolanek, C., *Recykling pojazdów na Dolnym Śląsku,* Logistyka i Transport, Zeszyty naukowe, Międzynarodowa Wyższa Szkoła Logistyki i Transportu we Wrocławiu, Nr 2 (7), s. 33-36, 2008.

[4] Poskrobko, B., *Zarządzanie Środowiskiem*, Polskie Wydawnictwo Ekonomiczne, Warszawa 2007.

[5] *Rozporządzenie Ministra Środowiska z dnia 27 września 2001 r. w sprawie katalogu odpadów*, Dz. U. z 2001 r. Nr 16, poz. 1206, 2001.

[6] Smith, M., Jacobson, J., Webb, B., *Abandoned vehicles in England: Impact of the End of Life Directive and new initiatives, on Likely Future Trends*, Resources, Conservation and Recycling, Vol. 41, pp. 177-189, 2004.

[7] *Ustawa z dnia 20 stycznia 2005 r. o recyklingu pojazdów wycofanych z eksploatacji*, Dz. U. Nr 25, poz. 202, z późn. zm, 2005.