

Production and use of solid recovered fuels

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Please cite as: CHEMIK 2011, 65, 6, 572-579

Introduction

In situation of the accruing global fuel crisis, energy of combustible substances contained in many types of wastes should not be wasted since it can be rationally utilised. Unfortunately the wastes are characterised by a significant non-heterogeneity of their composition, this impedes their energy utilisation. In such a situation the solution can be in an appropriate organised system of wastes processing directed at the production of the so called alternative fuels. These fuels are characterised by more stable physical and chemical parameters than the raw material from which they are made. During the process of production of these fuels one can influence on their quality through the selection of the waste raw material or through the application of the appropriate processing techniques. In the EU countries research has been conducted for many years on reprocessing different groups of wastes into the alternative fuels [1]. The research has brought about the implementation of the series of technological solutions on the industrial scale. Both powerful international corporations such as REMONDIS and ALBA (Germany), SITA (France), or Pirelli & C. Ambiente (Italy) and local companies are engaged in technology development process of alternative fuels from wastes. The result of this is the appearance of many technological solutions that are suited to the composition of the local raw material and to the requirements of the local consumer of the alternative fuel.

Fuels produced from wastes are labelled in Europe by different names, this can lead to misunderstanding in both legal issues as well as in trading issues. For example in Germany they are labelled SBS (Sekundärbrennstoffe), EBS (Ersatzbrennstoffe) or BRAM (Brennstoff aus Müll), in Italy - CDR (Combustibili Derivato di Rifiutti) or CSS (Combustibili Solido Secondario), and in other European countries - RDF (Refuse Derived Fuel) [1]. Also in Poland the issue of labelling these fuels is not unequivocally regulated. Here in Poland the names „alternative fuel” (paliwo alternatywne) and „substitution fuel” (paliwo zastępcze), „PAKOM” (paliwo komunalne), or “formed fuel” (paliwo formowane) are functioning in parallel [2].

Solid Recovered Fuels:

In recent period in the European Union series of activities have been undertaken to establish uniform quality standards for the solid fuels produced from wastes for which the name was accepted: „solid recovered fuels” (SRF) [3-5]. This name can be translated into Polish as: „stałe paliwa odzyskane” (solid restored fuels), or better - „stałe paliwa wtórne” (solid secondary fuels). This second proposal was accepted by the Polish Standardisation Committee, PKN [6,7]. This indicates (per analogy to secondary raw material (surowce wtórne) such as - scrap metal, waste paper, or scrap glass) that we have to do with waste material but with strictly defined chemical and physical properties in accordance with major concept of standardising the SRF.

In course of normalisation works regarding elaboration of the standards for SRF's both, the experience has been used from functioning of the in-country standards among others in Germany, (RAL- GZ 724), Finland, (SFS 5875) and Italy (UNI 9903) as well as all available data coming from the European producers and users of alternative fuels. [3].

According to information contained in basic for SRF Technical Specification CEN/TS 15359, solid recovered fuel can be produced

solely from wastes other than hazardous and burnt only in installations complying with the emission standards deriving from the EU Directive 2000/76/EC covering incineration of wastes [5]. The SRF cannot comprise fossil fuels. In accordance with the foregoing provisions the SRF is then the waste (!) that belong to category „other than hazardous” and its place among other wastes is schematically presented in Figure 1.

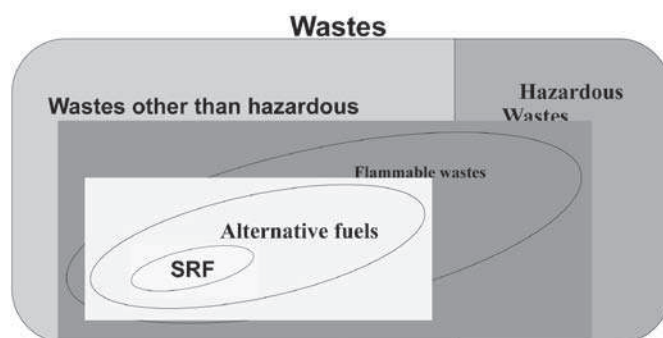


Fig. 1. The SRF fuels on the map of wastes

As yet no legal procedure has been in force that would make it possible to prequalify SRF (wastes) for product both in country as well as in the EU legal system (such activities are currently underway on the EU level, but they cover selected groups of wastes such as scrap metals). It derives from the foregoing that cofiring of the SRF at the industrial scale is possible exclusively after the appropriate permits have been obtained and in accordance with the waste management regulations with a special emphasis on thermal processing of wastes. The conditions of accepting the installation to co-combust wastes as well as procedures of emissions measuring are regulated by the series of Environmental Protection Law stipulations.

In accordance with the stipulations of the Waste Act:

- utilisation of the solid recovered fuels constitutes process of recovery **RI** (i.e. utilisation as a fuel or other means for producing energy - acc. to Appendix. nr 5 to the Waste Act)
- on the other hand production of the solid recovered fuels constitutes process of recovery **RI5** (wastes reprocessing in order to prepare them for recovery, recycling included).

The SRF Classification:

The CEN system comprises series of Technical Specifications stipulating: nomenclature, principles of classification, requirements for the quality management system during production of fuels from wastes, and methods of sampling and preparation of samples for tests and methodology of making individual assays. Majority of Technical Specifications were issued in 2006. After three years of functioning of these documents, to which members of CEN (including also Poland) can introduce corrections, were to be converted into the European valid in the entire area of the EU. (up to date - 05.2011 - it was issued 11 EN standards covering solid recovered fuels). The updated lists of Technical Specifications and the EN standards already published covering the solid recovered fuels can be found on the CEN web page [www.cen.eu].

The basic document describing the new classification system of the solid recovered fuels that was elaborated by the CEN has been Technical Specification CEN/TS 15359 „Solid recovered fuels – specifications and classes” [5]. This new classification system is based on three key parameters determining properties of the solid recovered fuels: calorific value, contents of chlorine and mercury. Selection of these parameters was dictated by three principal aspects of utility evaluation of fuel: economic, technological and environmental (emissions). For each of those three quality parameters five classes were assigned and for each of them the limit values were also given. Combination of numbers of classes for the group of three classification parameters gives as a result fuel's classification code. All three parameters have an equal meaning, hence none of the single numbers describe the fuel's code. In addition in the Specification it was established that the values of the individual parameters should be presented with the application of the statistical rules and taking into account strictly defined frequencies of the tests as:

- for the net calorific value (NCV [MJ/kg], in a as received state) – arithmetic mean
- for the chlorine content (Cl [%], in a dry state) - arithmetic mean
- for the mercury content (Hg [mg/MJ]), in a as received state) - median and 80th percentile.

In table I are presented ranges of the individual classification parameters for the solid recovered fuels.

Table I

Values of classification parameters for the solid derived fuels according to CEN

Classification parameter	Statistics	Unit of measurement	Class				
			1	2	3	4	5
Net Calorific Value (NCV)	average	MJ/kg, as received	≥ 25	≥ 20	≥ 15	≥ 10	≥ 3
Chlorine content (Cl)	average	%, in a dry state	≤ 0.2	≤ 0.6	≤ 1.0	≤ 1.5	≤ 3
Mercury content (Hg)	median 80 th percentile	mg/MJ, as received	≤ 0.02	≤ 0.03	≤ 0.08	≤ 0.15	≤ 0.50
		mg/MJ, as received	≤ 0.04	≤ 0.06	≤ 0.16	≤ 0.30	≤ 1.00

The classification and quality system developed by the CEN for the solid recovered fuels makes it possible to unambiguously classify selected fuel to the concrete class and to specify in great detail its chemical and physical properties. This system requires to characterise the solid recovered fuel in great detail, which gives the guarantee to avoid abuses that take place from time to time when introducing fuels produced from wastes into market place.

At the same time it (the system) enables operators of the energy installations in which the solid recovered fuels are to be utilised to acquire credible information on quality of this material and foremost of all the selection of the fuel with guaranteed quality in compliance with technical requirements of the selected installation.

Of special interest to the operators from public power sector is the introduction of methodology to establish biodegradable fraction in the SRF, this is because of the issues in connection of fulfilling the obligation to produce electricity from renewable energy resources. Technical Specifications developed by the CEN lay the foundations for unification (on the European level) of the classification system, quality control and of qualifying energy produced from biomass

(biodegradable fraction in solid recovered fuels including) as renewable energy. based on the Technical Specification CEN/TS 15440, at the Institute for Coal Processing there was elaborated technical procedure: Q/ZK/P/15/29/B:2007 *Wastes and alternative fuels for energy purposes. Determination of biodegradable fraction content. (Odpady i paliwa alternatywne do celów energetycznych. Oznaczenie zawartości frakcji biodegradowalnej)*. This procedure is applied and biodegradable fraction content is determined by the selective dissolution [8].

Production of the SRF

Sources for raw materials to produce solid recovered fuels are first of all: residues from the production processes, after utility industrial wastes, wastes from the selective collection from trade and households, solid municipal waste and construction-overhaul waste. On the other hand the most popular groups of wastes used as fuels or as components for their production are: paper, scrap tyres, plastic wastes and wood wastes.

For the production of the SRF can be both heterogenous industrial waste, as well as mixed wastes (the more components in wastes the more complex is production process).

Composition and level of pollution in the final product depends on many factors, but one of the most important has been the source of acquiring wastes for further processing. One can distinguish two major types of solid recovered fuels: comminuted (or granular) (characterised by variable size of granules) and formed (or moulded) (as pellets, cubes and briquettes). The adherence to the quality requirements put by the fuel's recipient often enforces application of the well extended technological systems, comprising series of operations, including comminution, separation, mixing and compacting of wastes. At the same time the number and order of these operations must as a rule be customised to the type of the waste raw material [9, 10].

waste processing into (Fig. 2) solid recovered fuels has first of the following objectives:

- to produce fuel with possibly high capacity
- valorisation (enhancement) of energy parameters of wastes
- reduction of concentrations of hazardous substances in final product through their concentration in streams of by-products removed from installation.

Often these objectives cannot be executed simultaneously (in parallel).

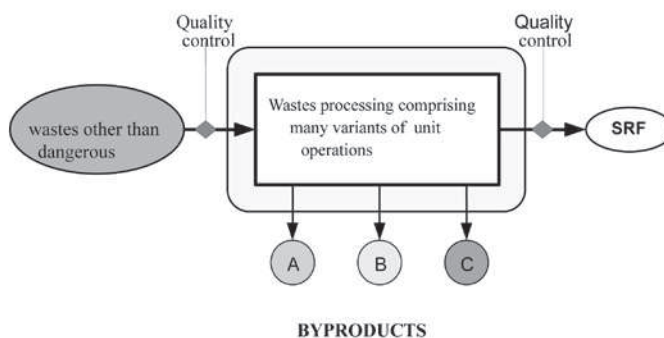


Fig. 2. Simplified flow diagram of technological process of producing solid recovered fuels from wastes

Designing and accommodation of installations producing solid recovered fuels to the quality requirements of the consumer and minimisation of wastes processing costs are subject of many research and development as well as design-implementation works. For this purpose are used among others elements of the MFA (Material Flow Analysis), the methodology of which with regard to wastes was elaborated at the beginning of XXI century [11].

Arrangement of equipment in technological line for sorting of wastes has a marked influence on the quality of the achieved fuel fraction. In table 2 are presented literature data with regard to analysis of several Italian technological lines for sorting municipal solid waste with different arrangement (and thus order of operations) of equipment [12].

Table 2
Calorific values of solid secondary fuels produced from municipal solid waste with different arrangement of technological lines [12]

Arrangement of equipment	Net calorific value , NCV of the SRF, kJ/kg
R – PB – SM – M – SM – KPC – PB – W	12 150
M – SM – PB – SM	12 570
M – PB – M – KPC – G	13 200
PB – SM – KPC – PB – SM – KPC	16 760
M – PB – KPC – M – S – G	16 780
PT – SR – SM – R – SB – SM – M – PB	16 800
R – PB – SM – SR – M – SM – PB	18 240

where:

KPC – air classifier with cyclone, S – drier, W – extruding machine, SR – hand separation, M – mill, SM – electromagnetic separator, G – granulator, R – comminuter, PB – drum sieve.

Utilisation of the SRF's

Fuels fabricated from wastes are markedly cheaper (sometimes they are even offered with additional payment for the consumer of it) than primary fuels and because of this they are willingly utilised in energy intensive branches of industry such as clinker production or pulp and paper industry. Production and utilisation of the SRF increase level of wastes recovery (what influences positively the compliance of the EU requirements with regard to waste management). The increased interest in this fuel is stimulated also by the recently introduced Emission Trading System for Greenhouse gases. (CO₂ including Application of fuels produced from wastes in the co-combustion processes contributes to reduction of the greenhouse gases emissions created during combustion of the fossil fuels (among them mainly carbon dioxide, CO₂), and makes also savings of resources possible. It (i.e. application of fuels from wastes) allows also to reduce emissions of greenhouse gases (including mainly methane, CH₄) from depositing wastes comprising biodegradable fractions. Share of these fractions in the SRF can repeatedly exceed 50% by weight.

Below is presented basic characteristics of the equipment pieces at which as a rule are used solid secondary fuels.

Cement kilns (in principle rotary since they dominate in modern cement industry). Rotary kiln is built from kiln shell (tube with length up to 180 m and diameter up to 6 m), which by means of the thrust roller is rotated around longitudinal axis. Inside of this kiln occur the physical and chemical processes (calcinations, sintering, granulation, combustion etc.) in temperatures up to 1600°C. The shell of the kiln is lined with fire resistant lining. Substitution of solid recovered fuels for the basic fuel at the European cement factories ranges from 1 to 60% (Belgium). Residence time of the SRF in the cement kiln is high enough that in practice all detrimental organic substances undergo degradation (which was proved experimentally). Because of high legislative allowable levels of emissions the concentration of pollutants contained in the flue gases from the cement kilns can be maintained below upper limit values regulated by the stipulations of the required

air quality. One should emphasize that cement industry is the biggest consumer of the solid recovered fuels as well as of some groups of wastes that are used as energy sources. These groups of wastes are practically accepted without greater processing (including also hazardous wastes).

Lime kilns. Shaft kiln constitutes classic type of metallurgical kiln for thermal processing of minerals. The lime kiln is of the shaft shape furnished from the top with the stone charging bucket and extraction of the flue gases and from the bottom with the system of technological air supply (draught) and discharge of condensed products. The process lies in chemical reactions taking place in counter-current between charge flowing down and gases flowing upward (these gases are usually the products of the controlled combustion of coke in lower part of the kiln). In lime kilns up to 1% of fuels from wastes is added to the kiln, mainly because of the hazard of deteriorating quality of the product with too much of waste derived fuels.

Power plant boilers

- with travelling grate furnace (boilers with travelling grates arte used in smaller industrial power plants and cogeneration plants). Good combustion with minimal excess air is achieved by primary air supply to the several grate zones. Temperature of combustion in travelling grate furnaces ranges from 900 to 1400°C, and air velocity is equal from 0.3 to 1.2 m/s
- pulverised coal boilers (pulverised coal furnaces are applied in boilers with stream capacities from 20 kg/s to the biggest ones. In those boilers coal is burnt after the preliminary drying and pulverising. Residence time of coal particles in the zone of combustion is equal to several seconds. Unburned coal particles are carried over with the flue gases - (fly-ash) or fall down to the combustion chamber slag hopper (slag). Temperature of combustion in pulverised coal boilers ranges from 1200 to 1400°C but air (flue gas) velocity is higher than 9.1 m/s.

fluidised bed boilers, in fluidised bed furnaces the fuel burnt is carried upward by the stream of the fluidised air thus securing good oxidation and combustion of fuel. During combustion to the fluidised bed created from non combustible particles the grains of fuel are delivered which mix themselves with air. This allows to achieve good conditions of combustion and enables application of fuels with low net calorific value and with higher ash contents. Low combustion temperature (800 ÷ 950°C) influences positively on of NO_x emission. The sorbents introduced to the bed mostly in a form of milled/ crushed limestone bind the sulphur compounds and desulphurisation efficiency can reach even 97%.

In power plant boilers amount of the SRF to the primary boiler ranges from 1 to 50%, depending on type of boiler, system of the flue gases cleaning and requirements with regard to the commercial utilisation of the combustion products (fly-ashes, slag and gypsum) [13]. Despite of un-doubtful ecological benefits deriving from using SRF in the energy sector it was found out however those not beneficial phenomena of erosion-corrosion occur during boilers operation. That is why in case of beginning to co-combustion the SRF's at the existing energy units one should Carry a regular control of the heating surfaces state as well as of the steam re-heaters surfaces.

Detailed technical-economic and environmental analysis of different options to utilize solid recovered fuels-conducted by the authors of publication [14] – has proved that the most beneficial method of thermal conversion of these fuels is their co-combustion with hard coal at cement kilns. The consecutive options according their descending attractiveness are according to the above mentioned authors co-combustion of the SRF's with hard coal at large power plant boilers, then incineration at large incineration plants and combustion of the SRF's at large biomass fired boilers. Simultaneously the most financially attractive option has proved to

be co-combustion (*co-combustion and cofiring are used in this paper interchangeably*) of the SRF's at large power plant boilers (one should however take account that the assumptions were for the conditions of the British market).

Summary

Production of the solid recovered fuels has been a chance for the absorption of energy contained in wastes not only in installations specially suited to this purpose, but also in such branches of industry as production of cement, power sector and district heating. As raw materials for their (i.e. the SRF's) manufacture should be used exclusively wastes other than hazardous which significantly improves ecological security both on stage of their production and during their utilization.

Production potential as well as utilization of the solid recovered fuels in Europe has been quickly rising, this brings measurable economic and ecologic effects. Thus production of the solid secondary fuels from wastes should be one of the basic elements of the integrated waste management system.

Currently the solid recovered fuels produced from the wastes are - even when in compliance with the tough quality standards - still regarded as waste. Such situation is limiting an interest from the power sector in absorption of these fuels. It can however be improved by introducing proper economic incentives. For the power sector such a chance can be a possibility to rate part of electricity produced from the solid recovered fuels as the so called green energy (renewable energy) and reduction of the reported emission of CO₂ (in proportion to the combusted amounts of the SRF's).

Translation into English by the Author

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