Classification of alternative fuels used in the cement industry

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Abstract. The article presents the classification of alternative fuels used in the cement industry as well as the advantages of using this type of fuel. Possibilities of their use by cement plants, types of alternative fuels used as well as the amount of use of this type of fuel. Physico-chemical parameters of alternative fuels were described, which should be met in order to use the cement industry.

1. Introduction
Alternative fuels are covered by a closed system in which resources are used as an energy source or as substrates to obtain another product. One of the main normalization of such recommendations are the decisions of the European Commission, which imposes binding countries on the obligation to submit waste. In the letter 'Towards a closed economy - zero waste', there was a provision that by 2030 recycling of municipal waste should be at least 65%, and that no more than 10% of this waste should be deposited. One should also pay attention to one of the innovative directions of energy resources utilization, which is accumulated in waste in already closed landfills and which are used by countries other than Poland. It is about uncovering these landfills and recovering both valuable metals and the high-calorie fraction, which is then processed as an alternative fuel for co-firing [1,2].

2. Alternative fuels
Alternative fuel is waste with the code 19 12 10, classified as combustible waste designated as RDF (Refuse Derived Fuel) or / and SRF (Solid Recovered Fuel), which introduced the European Center for Accreditation of waste fuel standardization. Both abbreviations are still used or alternative to alternative fuels as RDF / SRF. However, according to the European Accreditation Center, SRF are fuels produced exclusively from non-hazardous waste, used only in installations that meet the emission standards regulated in the waste incineration directive. The SRF composition may not include fossil fuels. However, according to PN-EN 15375: 2011, SRF is a secondary solid fuel that is generated from non-hazardous waste, processed in an appropriate installation in the process of energy recovery. Alternative fuels from waste have also been defined in the Reference Document on Best Available Techniques for
Large Combustion Plants and are called secondary fuels (SF). These are all types of waste with high calorific value, possible to be burned and co-incinerated with conventional fuel. This document lists three types of secondary fuels: gaseous secondary fuels, liquid secondary fuels and solid (secondary secondary fuels) [14,15].

3. Waste classification for the production of fuels and fuels from waste
There are many regional and international waste classification categories. In accordance with the ordinance of the Minister of the Environment of September 27, 2011, waste is divided into 20 main distribution groups. The most important are documents prepared from the RWPG and EWG period. The Polish waste classification is mainly based on documents prepared by the European Economic Commission. Standard waste classification project according to EKG (12-16.06.1989) was adopted based on the development of these documents in Poland [3,4].

![Diagram showing fuel production with waste](image)

**Fig. 1 Production of fuels with waste [5]**

Waste in the cement industry can be used both in the raw material set and in the final stage of cement production by introducing additives into it. Alternative fuel, on the other hand, can be used in the clinker burning process. A comprehensive method of waste management can be co-incineration and obtaining energy recovery, i.e. chemical energy contained in the organic part or material recovery, i.e. the minimal waste content which is a valuable addition to the raw material set. Although by-products, such as ash or slag, are usually generated in the combustion of fuels from waste, they are built into the clinker in the cement industry. Therefore, it can be said that this process is actually waste-free [6,7].

4. Data on the possibilities of using fuels derived from waste
Every year, nearly 2 million tonnes of fuels with the code 19 12 10. are produced in Poland. About 1.1 million tonnes of RDF / SRF is used in the energy recovery process. The vast majority burn in cement plants. The implementation of co-firing of fuels with waste to other industries requires comprehensive consideration - including legal, technical and social applications [1,8].

Mixed municipal waste, which has lost all utility values, and cannot be recycled are a source of energy that can be used in a very wide range. The most commonly used methods of consumption include their
combustion in cement plants [9]. This process and opportunity have been used on a large scale for many years, as shown in Figure 2.

![Fig. 2 Amount of RDF consumed by cement plants in different years [10]](image)

The Polish cement industry consumes relatively little heat compared to industries from other European countries. As a consequence, it can also boast one of the lowest carbon dioxide emissions per ton of product into the atmosphere. However, the cost of one ton of cement produced contains over 40% of the cost of heat. For this reason, in order to increase competitiveness and reduce production costs, it is worth implementing technologies based on energy recovery from the cement production process. High energy consumption in production, as well as a steady increase in fuel prices mean that the use of alternative fuels is currently one of the main activities of the cement industry to improve production efficiency. Currently, alternative fuels are one of the most commonly used fuels for the production of thermal energy in cement plants. The main fuel there is RDF, but one can also see the consumption of unnecessary tires and other rubber waste, waste from flotation coal enrichment, sewage sludge, waste from power plants. In the coming years, this industry plans to increase the share of use of alternative fuels.

5. Types of alternative fuels used in the cement industry

RDF is one of the key fuels used in cement plants. The share of their use is increasing, especially in Poland, where this industry is located primarily in the south of the country. This placement somewhat inhibits its use due to the need to transport waste from other parts of the country [10]. For the production of RDF fuel mainly municipal waste, tires, plastics, car dismantling residues, waste solvents and residues from solvent distillation are used, used oils, sawdust and waste wood, pulp from paper mills, sewage sludge, straw and textiles. The structure of waste consumption in the cement industry is shown in Fig 3.
6. Fuel parameters with waste and their quality

Waste to be used as fuel should have specific parameters and properties, the most important of which are: calorific value, ash content, moisture content, volatile matter content, chemical composition - the presence of such elements as: coal, hydrogen, nitrogen, sulfur, potassium, sodium, phosphorus, chlorine, iron and mercury, adequate consistency, appropriate granulation (below 30 mm), no solid impurities in the case of liquid fuels. The basic technical requirements for conducting recovery from waste for energy are included, among others in the Regulation of the Minister of Development of January 21, 2016 on the requirements for conducting the process of thermal waste transformation and methods of dealing with waste resulting from this process. It contains, for example, guidelines as to the appropriate temperature and high degree of post-combustion of slag and bottom ash. On the other hand, the Regulation of the Minister of the Environment of October 30, 2014 on requirements for measuring emissions and measuring the amount of water consumed imposes an obligation to conduct extended emission monitoring. In turn, the Ordinance of the Minister of the Environment of 4 November 2014 on emission standards for some installations and devices for incineration or co-incineration of waste indicates the obligation to comply with increased emission standards [12].

Table 1 Parameters of waste from alternative fuel production [13]

| Plastics | Total moisture content [%] | Ash content [%] | Calorific value [J/g] | Total sulfur content [%] | Carbon content [%] | Hydrogen content [%] | Nitrogen content [%] | Chlorine content [%] | Mercury content [ppm] | Volatile matter content [%] |
|----------|--------------------------|----------------|-----------------------|-------------------------|-------------------|---------------------|--------------------|--------------------|-------------------|-----------------------------|
| Average  | 2.5                      | 16             | 24100                 | 0.20                    | 65.0              | 7.00                | 1.90               | 0.86               | 0.055             | 87.0                       |
| Max      | 5                        | 18             | 37956                 | 0.45                    | 89.2              | 11.89               | 11.8               | 2.50               | 0.076             | 93.2                       |
| Min      | 0.2                      | 0.2            | 14592                 | 0.02                    | 46.5              | 4.06                | 0.05               | 0.005              | 0.041             | 82.7                       |
| Median   | 2.5                      | 9.9            | 22700                 | 0.18                    | 62.1              | 6.71                | 0.3                | 0.35               | 0.048             | 86.8                       |
## Waste from furniture production

|                      | Total moisture content [%] | Ash content [%] | Calorific value [J/g] | Total sulfur content [%] | Carbon content [%] | Hydrogen content [%] | Nitrogen content [%] | Chlorine content [ppm] | Mercury content [%] | Volatile matter content [%] |
|----------------------|-----------------------------|-----------------|------------------------|--------------------------|-------------------|--------------------|----------------------|------------------------|-----------------------|--------------------------|
| **Average**          | 12.0                        | 2.0             | 15800                  | 0.04                     | 47.0              | 5.60               | 5.70                 | 0.030                  | 0.012                 | 80.60                    |
| **Max**              | 34.6                        | 9.2             | 18002                  | 0.17                     | 53.7              | 6.04               | 34.95                | 0.071                  | 0.029                 | 84.73                    |
| **Min**              | 4.8                         | 0.7             | 4188                   | 0.02                     | 44.1              | 5.30               | 0.19                 | 0.009                  | 0.003                 | 79.29                    |
| **Median**           | 8                           | 1.5             | 16696                  | 0.035                    | 47.1              | 5.65               | 4.36                 | 0.031                  | 0.004                 | 80.39                    |

## Train tracks underlay

|                      | Total moisture content [%] | Ash content [%] | Calorific value [J/g] | Total sulfur content [%] | Carbon content [%] | Hydrogen content [%] | Nitrogen content [%] | Chlorine content [ppm] | Mercury content [%] | Volatile matter content [%] |
|----------------------|-----------------------------|-----------------|------------------------|--------------------------|-------------------|--------------------|----------------------|------------------------|-----------------------|--------------------------|
| **Average**          | 23.5                        | 1.4             | 14300                  | 0.05                     | 51.5              | 5.80               | 3.15                 | 0.033                  | 0.018                 | 84.0                    |
| **Max**              | 43.8                        | 2.5             | 18945                  | 0.09                     | 55.8              | 6.23               | 0.26                 | 0.018                  | 0.049                 | 86.2                    |
| **Min**              | 9.6                         | 0.2             | 10427                  | 0.02                     | 49                | 5.24               | 0.1                  | 0.018                  | 0.006                 | 82.73                   |
| **Median**           | 27.4                        | 0.4             | 14580                  | 0.05                     | 52.8              | 5.74               | 0.16                 | 0.018                  | 0.02                  | 84.55                   |

## Tires and rubber materials

|                      | Total moisture content [%] | Ash content [%] | Calorific value [J/g] | Total sulfur content [%] | Carbon content [%] | Hydrogen content [%] | Nitrogen content [%] | Chlorine content [ppm] | Mercury content [%] | Volatile matter content [%] |
|----------------------|-----------------------------|-----------------|------------------------|--------------------------|-------------------|--------------------|----------------------|------------------------|-----------------------|--------------------------|
| **Average**          | 2.8                         | 11.3            | 32486                  | 1.65                     | 78.0              | 6.90               | 0.46                 | 0.099                  | 68.80                 |
| **Max**              | 6.1                         | 18.4            | 35039                  | 2.02                     | 85.7              | 8.84               | 1.2                  | 0.315                  | 79.56                 |
| **Min**              | 0.9                         | 5.4             | 29066                  | 0.94                     | 71.6              | 3.58               | 0.16                 | 0.005                  | 62.3                  |
| **Median**           | 2.4                         | 10.3            | 33327                  | 1.69                     | 80.75             | 7.125              | 0.365                | 0.068                  | 68.27                 |

## Paper, cardboard boxes etc.

|                      | Total moisture content [%] | Ash content [%] | Calorific value [J/g] | Total sulfur content [%] | Carbon content [%] | Hydrogen content [%] | Nitrogen content [%] | Chlorine content [ppm] | Mercury content [%] | Volatile matter content [%] |
|----------------------|-----------------------------|-----------------|------------------------|--------------------------|-------------------|--------------------|----------------------|------------------------|-----------------------|--------------------------|
| **Average**          | 13.5                        | 15.5            | 14300                  | 0.18                     | 44.5              | 5.50               | 0.65                 | 0.300                  | 0.034                 | 74.5                    |
| **Max**              | 26.4                        | 36.8            | 22842                  | 1.11                     | 55.7              | 7.56               | 2.97                 | 1.407                  | 0.051                 | 87.08                   |
| **Min**              | 2.9                         | 5.9             | 10529                  | 0.03                     | 31.1              | 3.25               | 0.07                 | 0.026                  | 0.017                 | 6.6                     |
| **Median**           | 14.35                       | 14.6            | 13557                  | 0.1                      | 45.55             | 5.22               | 0.29                 | 0.1305                 | 0.034                 | 84.1                    |
Analyze the results shown in Table 1, the most important parameter for cement production is the chlorine content. It is contained in a solid product which is clinker. Another parameter that affects the use of alternative fuel is the caloric value. Therefore, before the thermal utilization process, mixtures prepared in accordance with the technical requirements of the manufactured product are made.

### Table 2 Classes, quality of solid secondary fuels according to PN-EN 15359: 2012 standards[1]

| Parameter, unit | Statistical measure | Fuels quality class | 1 | 2 | 3 | 4 | 5 |
|-----------------|---------------------|--------------------|---|---|---|---|---|
| Calorific value in working condition [MJ/kg] | Average | ≥ 25 | ≥20 | ≥15 | ≥10 | ≥3 |
| Chlorine in a dry state [%] | Average | ≤0,2 | ≤0,6 | ≤2,0 | ≤1,5 | ≤3 |
| Mercury in working condition [mgHG/MJ] | Median | ≤0,02 | ≤0,03 | ≤0,08 | ≤0,15 | ≤0,50 |

The standardization of fuels aims to improve the quality of their production, and at the same time solve technical problems such as corrosion or negative effects on combustion products. This is also dictated in the environment at the stage of their recovery. The European Committee for Standardization (CEN) has developed quality standards for combining chlorine limit value, net caloric value, mercury requirements and the five classes included in fuels (Tab. 2).

7. **Summary**

In Poland, cement plants are located in the south of the country, which may cause problems with logistics and transport of waste for alternative fuels. However, this aspect can also be translated into success - creating conditions for opening units also in central and northern Poland. In this way, can expand business and conduct research on aggregation of cement plants with combined heat and power plants and CHP plants, or at least locating them nearby, especially since municipal waste is a source of alternative fuel production. This helps to solve another environmental problem, which is depletion of fossil fuels and moving towards renewable energy sources. Alternative fuels are fuels or energy sources that partly serve as a substitute for non-renewable sources. Environmental benefits include
reduced agricultural land degradation, as well as reduced extraction of natural resources and coal. In addition, the process is waste-free, which is why full use of non-combustible parts of alternative fuels waste can be considered a plus. Combustion takes place in closed conditions with increased ash absorption, and in addition there is a reduction of greenhouse gas emissions to the atmosphere.

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