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Plastic Waste Management towards Energy Recovery during the COVID-19 Pandemic: The Example of Protective Face Mask Pyrolysis

Magdalena Skrzyniarz [1], Marcin Sajdak [2], Monika Zajemska [1], Józef Iwaszko [1], Anna Biniek-Poskart [3], Andrzej Skibiński [3], Sławomir Morel [1] and Paweł Niegodajew [4,*]

[1] Faculty of Production Engineering and Materials Technology, Czestochowa University of Technology, 19 Armii Krajowej Avenue, 42-200 Czestochowa, Poland; magdalena.skrzyniarz@pcz.pl (M.S.); monika.zajemska@pcz.pl (M.Z.); jozef.iwaszko@pcz.pl (J.I.); slawomir.morel@pcz.pl (S.M.)
[2] Department of Air Protection, Faculty of Energy and Environmental Engineering, Silesian University of Technology, 22 B Konarskiego Avenue, 44-100 Gliwice, Poland; marcin.sajdak@polsl.pl
[3] Faculty of Management, Czestochowa University of Technology, 19 B Armii Krajowej Avenue, 42-200 Czestochowa, Poland; anna.poskart@pcz.pl (A.B.-P.); andrzej.skibinski@pcz.pl (A.S.)
[4] Faculty of Mechanical Engineering and Computer Science, Czestochowa University of Technology, 21 Armii Krajowej Avenue, 42-200 Czestochowa, Poland
* Correspondence: pawel.niegodajew@pcz.pl; Tel.: +48-34-32-50-537

Abstract: This paper presents an assessment of the impact of the COVID-19 pandemic on the waste management sector, and then, based on laboratory tests and computer calculations, indicates how to effectively manage selected waste generated during the pandemic. Elemental compositions—namely, C, H, N, S, Cl, and O—were determined as part of the laboratory tests, and the pyrolysis processes of the above wastes were analysed using the TGA technique. The calculations were performed for a pilot pyrolysis reactor with a continuous flow of 240 kg/h in the temperature range of 400–900 °C. The implemented calculation model was experimentally verified for the conditions of the refuse-derived fuel (RDF) pyrolysis process. As a result of the laboratory tests and computer simulations, comprehensive knowledge was obtained about the pyrolysis of protective masks, with particular emphasis on the gaseous products of this process. The high calorific value of the pyrolysis gas, amounting to approx. 47.7 MJ/m^3, encourages the management of plastic waste towards energy recovery. The proposed approach may be helpful in the initial assessment of the possibility of using energy from waste, depending on its elemental composition, as well as in the assessment of the environmental effects.

Keywords: plastic waste; waste management; pyrolysis; thermal conversion; protective mask

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1. Introduction

The appearance and rapid spread of the SARS-CoV-2 virus have caused an intensive increase in the demand for personal protective equipment, especially face masks, due to the obligation to wear them in public spaces [1]. The production of disposable food packaging has also significantly risen during the pandemic [2]. Quarantine, isolation, and the fear of a personal visit to the store have caused an increase in online sales of food, as well as other products necessary in everyday life [3,4]. For practical and hygienic reasons, many of these items are packed in disposable plastic packaging [5,6]. The necessity to ship the ordered products involves the use of cardboard boxes, packaging, cling film, bubble wrap, etc. to safely deliver the ordered products [7]. In addition, shoppers are encouraged to wear disposable gloves and to pack all fresh produce separately in plastic bags when shopping in stationery stores [8,9]. The consequence of this state of affairs is, unfortunately, an enormous increase in the amount of plastic waste, which, as of 22 November 2020, in the 25 countries with the highest incidence of COVID-19, reached approximately 54,000 tons [10]. This situation was also reflected in the production of the European plastics industry, especially in the second half of 2020.

The presented data show that the production of plastics before the COVID-19 pandemic increased until 2018 and with it the amount of plastic waste (Figure 1). In contrast, the production of the European plastics industry has decreased since 2018. However, after a sharp decline in production due to the restrictions resulting from the COVID-19 pandemic in the first half of 2020, in the second half of this year, the production of plastics in EU countries began to increase rapidly, according to the Association Plastics Manufacturers in Europe (Plastics Europe) and the European Association of Plastics Recycling and Recovery Organisations (EPRO).

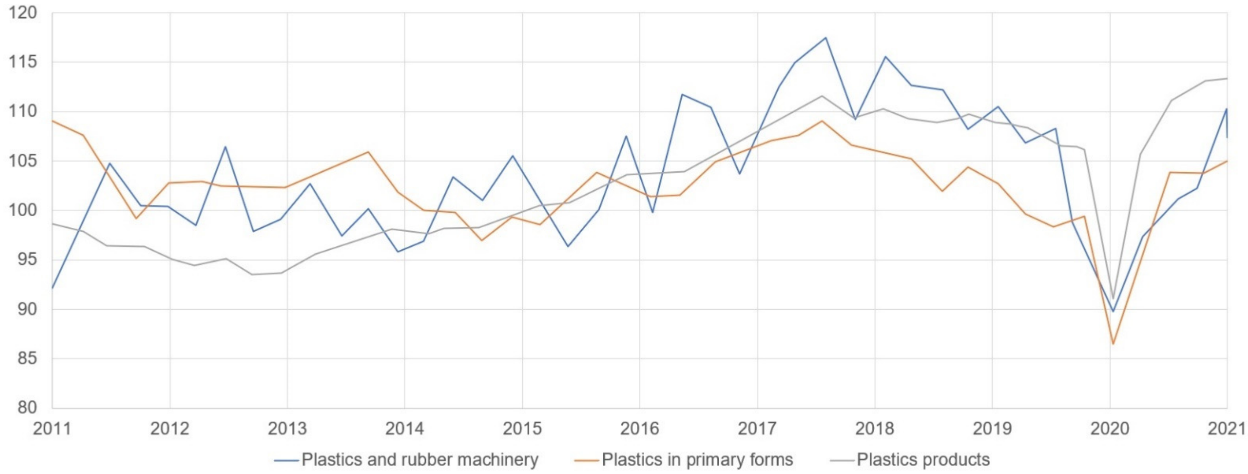


Figure 1. Plastic industry production in EU27 (index 2015 = 100, seasonally adjusted quarterly data) [11].

The pandemic has also had a negative impact on the economy and the proper functioning of local governments [12]. Municipalities and cities are struggling with an augmenting amount of municipal solid waste (MSW) [13] and medical waste, with a simultaneous lower budgetary inflow of funds as a result of the economic downturn [14]. Local governments cannot adequately manage the growing amount of hazardous waste placed in municipal landfills because of a lack of forces and resources at their disposal [15]. It should be noted that the challenges associated with plastics are largely owing to the fact that the ways in which such plastics are produced and utilised are not sustainable, because personal protective equipment (PPE) for hygiene reasons cannot be reusable, recycled, or are often made of single-use plastic. There is no doubt that the COVID-19 pandemic has changed the production and use of plastics [16]. These plastics significantly contribute to limiting the spread of the virus [12]. Nonetheless, according to the authors of this publication, the rapid increase in plastic waste due to the widespread use of masks and gloves, as well as changes in the manufacture and use of disposable products, could, in the short term, undermine EU efforts to reduce plastic pollution and move to more sustainable plastic handling [17,18].

The shock of the outbreak and expansion of the virus on a global scale poses enormous challenges to economies, public finances, and health systems with the threat of a possible recession [19]. The solid waste management sector is particularly susceptible, especially in EU countries, including Poland, which do not meet the requirement of recycling 50% of municipal waste (in 2020, recycling of MSW amounted to 26.7%, according to GUS data) [20,21]. Taking the example of Poland, it can be seen that during the pandemic there was a clear slowdown in the amount of processed waste, resulting in lower incomes in waste management treatment (WMT). Moreover, the situation in the secondary raw materials market had a negative impact on the entire waste industry. The prices of new commodities also fell, which resulted in their greater demand. On the other hand, the waste-to-energy industry (WTE) achieved good ratings and results. For example, the solid waste disposal sector in the Chinese market did not experience large deviations from the turnover recorded in 2019 [22].

The demand for personal protective equipment (PPE) has grown enormously worldwide since the start of the pandemic [23]. Such a high demand for PPE has led to the generation of huge amounts of plastic waste. For example, in Singapore, during 2 months of lockdown, an additional 1400 tons of plastic was generated [24]. Estimated calculations performed by Sazzadul Haque et al. [25] in Bangladesh have resulted in forecasts that the combined production of disposable face masks and other personal protective equipment is 3.4 billion units per month. This, in turn, translates into the production of 472.3 tons of plastic waste. According to estimates provided by Benson et al. [26], in Africa alone, assuming that people used at least one mask every day, it is estimated that the number of masks produced and disposed of during the day per person is around 412 million. Thus, more than 12 billion medical or textile masks are thrown away every month. Assuming that the average mass of the mask is 8.58 g, this gives the probability that about 105 Mt of masks per month only on the African continent may be discharged into the environment. According to Aragaw et al. [27], each month, around 129 billion masks and 65 billion disposable gloves are used and discarded worldwide.

The waste produced during the pandemic mainly consists of plastics such as polypropylene (PP), polyethylene (PE), polyester (PEs), polycarbonate (PC), polyethylene terephthalate (PET), polyvinyl chloride (PVC), and high-density polyethylene (HDPE), in addition to a small amount of paper, textiles, cotton, and natural rubber (Table 1) [28,29]. As can be seen from the literature review (Table 1), plastic waste can be a valuable fuel due to its high calorific value (38–46 MJ/kg).

Table 1. Proximate and ultimate analysis of plastic waste.

Plastic	Proximate Analysis (wt% Dry Basis)		Elemental Analysis (wt% Dry Basis)					LHV (MJ/kg)	Source
	Volatile Matter	Ash	C	H	N	S	O		
HDPE	98.2	1.8	84.5	13.8	0.1	0.1	1.5	43.0	
LDPE	99.8	0.0	86.8	12.9	0.1	-	0.2	43.6	
PP	99.6	0.4	85.0	13.9	0.1	0.0	1.0	43.6	[30]
PS	99.8	0.1	90.5	7.9	0.4	0.2	1.0	38.8	
PET	92.9	6.9	62.5	4.0	0.1	0.0	33.5	21.1	
PET-12	-	4.9	77.1	12.6	0.2	-	5.2	-	[31]
PET-28	-	12.1	67.2	9.7	0.1	-	10.9	-	
PET	86.75	6.83	63.94	4.52	0.01	0.04	31.49	-	[32]
PS	98.81	-	92.2	7.8	-	-	-	41.25	[33]
PE	99.96	-	85.5	14.5	-	-	-	-	
HDPE	91.88	3.9	83.4	12.71	1.08	0.002	2.8	46.48	
PP	93.84	3.68	83.28	13.81	1.01	0.001	1.90	44.43	[34]
PS	94.33	0.84	89.2	8.78	0.01	0.00	2.01	40.34	

"-" No data available.

Disposable face masks account for a significant share of the plastic waste stream generated during the pandemic [35]. As reported by Benson et al., the global production of disposable face masks is around 1.6 million tons/day, which means around 3.4 billion are thrown away daily due to the COVID-19 pandemic [26]. Protective masks are made of heterogeneous material, i.e., they consist mainly of several layers of PP and PE [36] (and additionally, they are equipped with an elastic band for the ears and a stiffening wire on the nose), which hinders their safe and quick recycling [37,38].

The most appropriate method of neutralising PPE should be material recycling, but due to the difficulty of separating the individual layers from each other, it would be a very time-consuming process [39]. Considering all the emerging difficulties that may arise in the recycling of PPE, one of the most effective methods of their disposal is the thermal transformation process [40–42]. Thus, effective waste management is a global concern that necessitates a reassessment of current technology and solutions. [43]. According to the introduced regulations, among others in Poland, waste generated during a pandemic and ending up in the mixed waste stream should be thermally neutralised by incineration, pyrolysis, or gasification [44,45]. In addition, mobile installations using the method of the thermal conversion of waste, i.e., pyrolysis, may occur to be an effective solution that responds to the needs of the waste industry during the pandemic. Mobile installations could be successfully utilised by entities collecting waste during the COVID-19 epidemic to neutralise hazardous (infectious) waste directly at the place of its collection, thus minimising the risk to public health and the environment. The above solution may also be used in the case of municipal waste contaminated with a biological agent from quarantine facilities and from places of isolation of patients at home. For the safe disposal of post-COVID-19 waste, a novel and sustainable approach is needed. As indicated in the literature, one of the most perspective methods of the thermal conversion of solid municipal waste, including plastic waste is pyrolysis, which can be a promising route to sustainable waste management. It is a thermochemical process carried out in the absence of oxygen in a pyrolysis reactor, in which waste decomposes at a temperature of 400–900 °C. This method enables the effective neutralisation of hazardous waste, but also leads to the formation of valuable solid (char) and gaseous (high-calorific pyrolysis gas) products that can be used, thus reducing the total cost of pyrolysis. The share and quality of individual products varies, depending, among others, on the type of pyrolysis reactor, type of waste, temperature, and residence time in the reactor [45].

The advantage of a pyrolysis installation compared with a waste incineration plant is its greater flexibility in terms of the amount of processed waste. These installations are economically justified also in the case of disposing of smaller amounts of waste than in the case of incineration plants, which gives opportunities, for example, to small municipal corporations operating, among others, in Polish conditions, for effective and profitable solid waste management. The proposed disposal method is also characterised by lower financial outlays and environmental fees, compared with incineration plants, as well as lower emissions of pollutants, i.e., SO_2 and NO_x. Hence, pyrolysis is considered to be a sustainable solution that may be economically profitable on a large scale and could minimise environmental concerns [46]. According to available data, with the limited number of possible solutions in this area, there is a great need for innovation enabling it to meet the key challenges in the field of plastic waste management in the pandemic era and to integrate new solutions in the field of thermal waste treatment technologies into the existing waste management system.

Taking into account above mentioned facts, pyrolysis seems to be the most promising thermal conversion method for such kind of waste into an environmentally inert, as well as valuable product from the energy point of view. Furthermore, considering the latest research results obtained by the authors of the article [47], in the case of RDF pyrolysis, it is justified to develop pyrolysis technology with simultaneous management of the products of this process.

Pyrolysis gas's high calorific value (30 MJ/m^3) encourages its use in both heating and the iron and steel industry. The gas produced by RDF pyrolysis can be co-incinerated with natural gas in industrial heating chambers, reducing the consumption of that fossil fuel. Pyrolysis gas can also be a substitute for coke oven gas for heating furnaces. This gas could be a viable alternative to conventional fuels, helping to reduce the role of waste storage while also improving environmental protection. The liquid fraction, in turn, is a potential source of valuable chemicals such as benzene and toluene. It can also be used as liquid fuel with properties similar to fuel oil or diesel fuel. Moreover, the preliminary technological tests carried out by the authors have shown the possibility of using the solid pyrolysis product in the production of insulating building materials, which increases the economic attractiveness of pyrolysis compared with other methods, e.g., combustion.

Bearing in mind the above, the authors of this study undertook this study to assess the impact of the COVID-19 pandemic on the waste management sector and to identify an effective method of managing selected waste generated during the pandemic.

2. Materials and Methods

The subject of the research was non-medical, three-layer, biologically uncontaminated disposable face masks presented in Figure 2, produced by Quanzhou Ruoxin Hygiene Products Co. Ltd. Caicuo, Luoyang, Huian Country, Quanzhou City, Fujian Province, China, manufactured according to the GB/T 32610-2016 standard, model NS-2020.

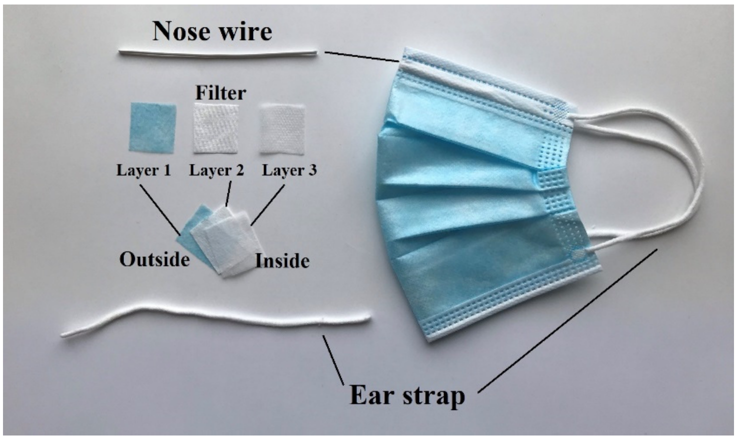


Figure 2. View of disposable protective mask used for studies.

As part of the research, both laboratory experiments and computer simulations were carried out. The research scheme is shown in Figure 3.

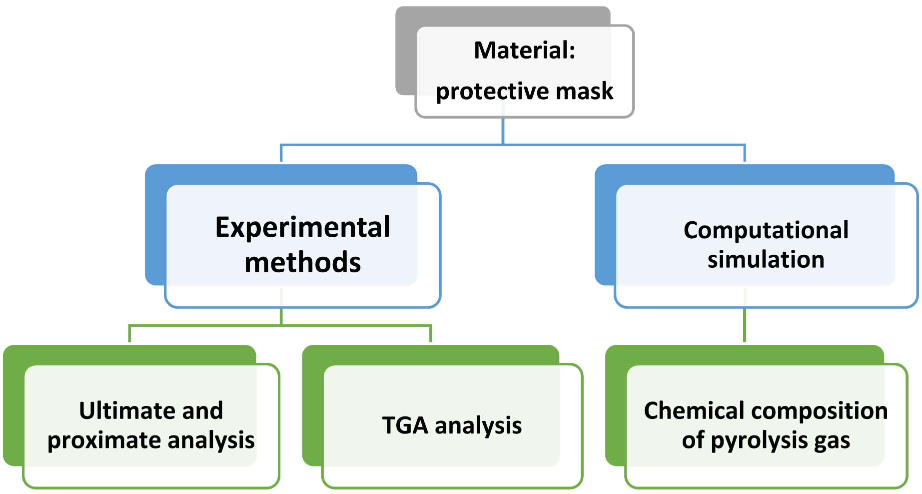


Figure 3. Research scheme.

2.1. *Experimental Procedures*

2.1.1. Proximate Analysis

Proximate analysis, e.g., the total moisture and ash content, were determined in the studied material. The total moisture content was determined by drying a sample in a laboratory dryer to a constant weight at 105 ± 3 °C. The ash content of the samples was determined by sample incineration. The investigated sample was put in a muffle furnace and heated in an air atmosphere at 600 ± 10 °C. This temperature was maintained until the sample reached a constant weight [48].

2.1.2. Ultimate Analysis

The elementary C_t^a, H_t^a, N^a, S_t^a, and O_t^a compositions in the examined material (protective mask) were measured using a Vario MACRO Cube automatic elemental analyser [49]. At 1150 °C, the material was put through an automated quantitative combustion process in an oxygen stream. Then, the combusted gases were transferred to a reduction tube (filled with copper) in which the sulphur and nitrogen oxides were reduced to SO_2 and N_2. The combustion gases were sent to a dynamic separation system after passing through the reduction tube. The absorption columns were desorbed thermally in order in the separation system. A thermal conductivity detector was used to identify gases including N_2, CO_2, H_2O, and SO_2 (TCD). An NDIR detector was used to examine low SO_2 concentrations [47].

The oxygen concentration was measured quantitatively using sample pyrolysis at 1120–1150 °C in an H_2O-, CO_2-, and O_2-free reductive environment (95% N_2 and 5% H_2). The sample was put in a pyrolysis tube containing elemental carbon, and carbon dioxide was produced as a result of the interaction between the oxygen in the sample and the carbon in the filler (Boudouard equilibrium). Granulated NaOH absorbed the acidic compounds obtained during the pyrolysis process, such as H_2S, HCN, and HCl, while a dehumidifier absorbed the generated water. The other gases did not need to be separated because the NDIR detector was only sensitive to CO. The inert pyrolysis products (N_2 and CH_4) might be immediately transported into a carbon monoxide measuring device.

2.1.3. Chlorine Determination

The chlorine content in the studied sample was determined by a potentiometric method [50]. The approach involves thoroughly burning a sample in an oxygen bomb calorimeter with an Eschka mixture (MgO and Na_2CO_3, ratio 2:1). The generated chlorides (combustion products) were extracted in nitric acid (V) and titrated for chloride ions with 0.1 mol/L $AgNO_3$. The potentiometric titration method used a silver sulphide electrode with a potential that was dependent on that of a reference electrode. The concentration of chloride ions is measured by the potential difference between the electrodes.

3. Results and Discussion

The results of the above-mentioned studies are summarised in Table 2.

Table 2. Proximate and ultimate analysis of plastic waste of protective masks.

Material	Proximate Analysis (wt% Dry Basis)			Elemental Analysis (wt% Dry Basis)					
	Ash	Moisture	Voltaire Matter	C	H	N	S	O	Cl
Plastic waste of protective mask	4.76	1.23	95.24	76.4	11.65	1.12	0.16	4.65	0.03

3.1. TGA Analysis

The tested material (protective mask) was homogenised and then pulverised with a cryogenic mill for thermogravimetric analysis. A Luxz 409 PG thermogravimetric analyser was used in conjunction with a Netzsch QMS 403D Aëolos mass spectrometer. The experiments were conducted in an argon environment with a 25 mL/min flow rate. Measurement began at a temperature of 40 °C. During the research, water jacket testing was used to stabilise the equilibrium. The pyrolysis operations reached a maximum temperature of 700 °C. The sample was 5.0 0.1 mg in weight. The samples were put in 6 mm diameter Al_2O_3 crucibles. The mass loss (TG) and maximum rate of mass loss (DTG) during the reaction, as well as the beginning and final temperatures at each step of the pyrolysis processes, could all be calculated using the data acquired (Figure S1 in Supplementary Material). To illustrate the differences between the various materials, in Figure 3, in addition to the protective mask test sample, the results of thermogravimetric analysis for pure polypropylene and pure polyethylene terephthalate are shown, as well as three biomass samples [49].

3.2. Computational Simulation

Calculations were made for the pyrolysis process carried out in a pilot continuous pyrolysis reactor, described in detail in [47], using licensed Ansys CHEMKIN-PRO software. Surgical masks with the elemental composition presented in Table 2, as well as PET and PP, the elemental composition of which were taken from studies of [51] and [49] were analysed. A detailed mechanism for the thermal conversion of solid fuels was implemented for the calculations, based on the Arrhenius equation for the rate constant of a reaction [52], developed by the CRECK Modeling Group, including 169 compounds and 4656 chemical reactions [53]. The mechanism was based on the detailed mechanism of HCl and Cl_2 high-temperature chemistry reported in [54]. The chemical mechanism adopted for calculations has been used many times by Ranzi [55,56], Faravelli [57], as well as by the authors of this article to model the thermal conversion of fuels and waste [47,58,59]. The calculations assume that pyrolysis occurs in a reactor with perfect reactant mixing, i.e., a perfectly stirred reactor (PSR) [60]. A diagram of the performed calculations with the input data and the conditions of the pyrolysis process is shown in Figure 4.

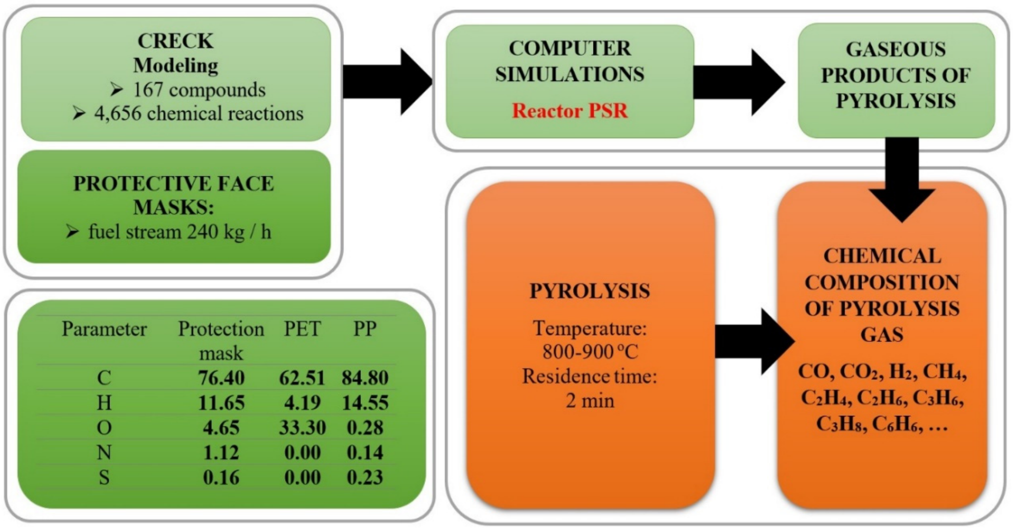


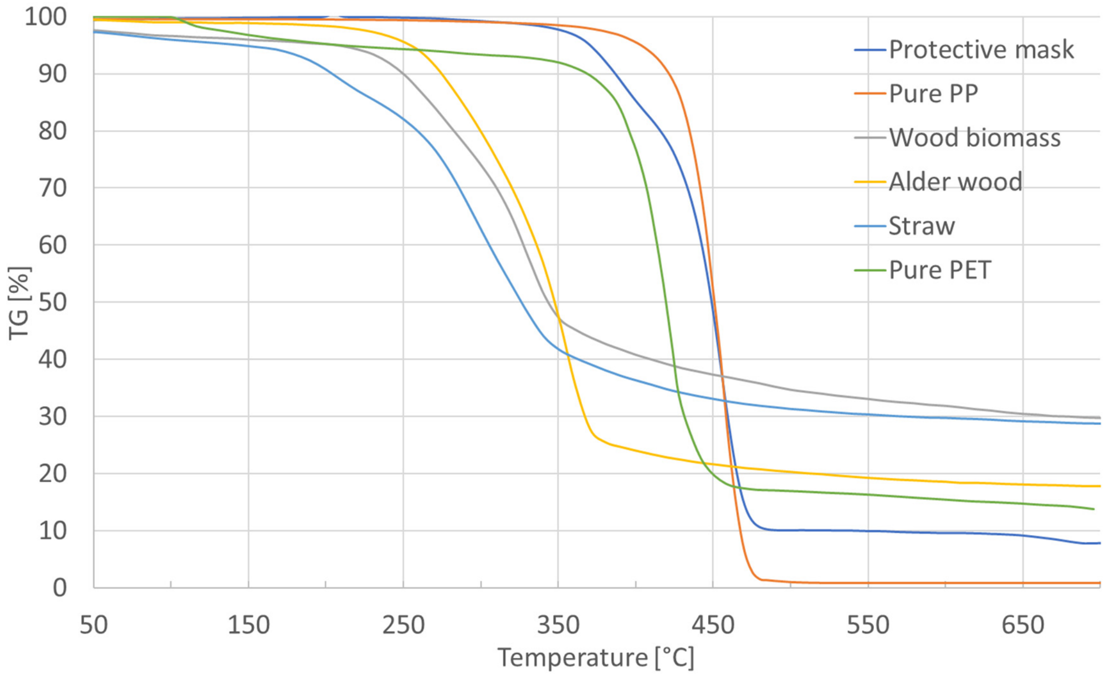
Figure 4. Scheme of calculation procedure.

As part of the computer simulations, the chemical composition of the gaseous pyrolysis products of the above-mentioned waste was determined, on the basis of which the calorific value of the pyrolysis gas was calculated. The following compounds were analysed in detail: CO, CO_2, H_2, CH_4, C_3H_8, C_4H_4, C_6H_6, C_2H_2, C_2H_4, C_2H_6, and C_3H_6. The obtained results were compared with the experimental data obtained from RDF pyrolysis with a high content of plastic waste (over 60%).

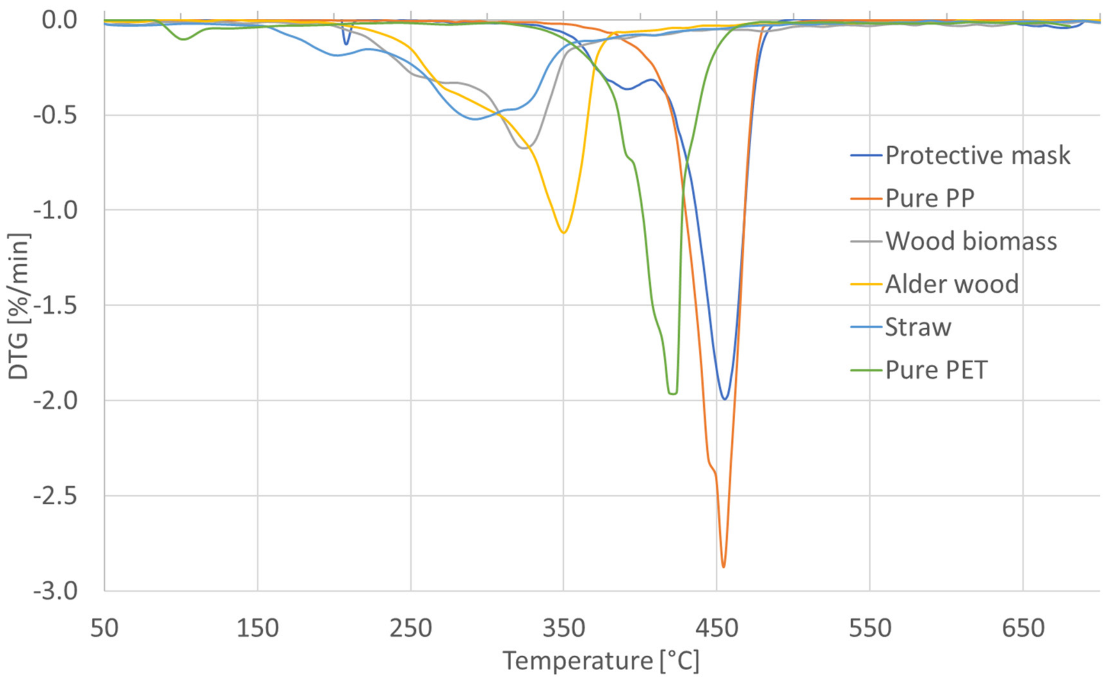
3.3. TGA Analysis

Thermogravimetric analysis (TGA) quickly shows the subsequent phases of the thermal conversion process of the studied sample. The mass loss of the examined material during heating is explained by this analysis. The TGA function's second derivative, which is mass change as a function of temperature (DTG), is used to determine the temperature at which the decomposition rate (in the considered example) is highest. The type of studied material is determined by the temperature and the shape of the DTG curve (e.g., one small and sharp peak or a wide peak).

The outcomes of the obtained repetitions are comparable, as can be shown (Figure 5.).



(**a**)



(**b**)

Figure 5. Comparison of repeated TG curves (**a**) and the TG and DTG curve (**b**).

As a result, further research may be conducted.

To optimise the number of gaseous products generated during the pyrolysis process, thermogravimetric analysis was carried out at a final temperature of 700 °C for the TGA analysis and 900 °C for the TGA-MS study. The face mask might degrade in four stages, according to TGA data (Figure 4).

The temperature ranges for the four stages were 50–200 °C, 201–392 °C, 393–500 °C, and 501–700 °C. The first stage represents minor degradation regions due to the occurrence of moisture evaporation (~2 wt%). The second stage indicates the sample's first substantial decomposition zone, with a mass loss of 16.11 wt% due to organic material degradation below 392 °C, caused by the release of pyrogenetic water from the research material made from polypropylene and a melt blown filter (PP). The third stage represents the second major decomposition region of the investigated sample, with a mass loss of 72.55 wt%, owing to the decomposition of organic materials below 455 °C, which corresponds to polypropylene thermoplastic material [61]. The last decomposition stage represents minor degradation regions due to char devolatilisation/decomposition (~2 wt%). The decomposition of the mineral portion present in the sample, magnesite (MgCO3), which is used as a filler in polymer processing, is connected with the DTG peak detected at 677.6 °C in this location. The DTG curve (Figure 6) shows that the components included in the material from which the investigated face mask were made decompose into two main components (two major degradation peaks), but both corresponded to PP pyrolysis products. During the decomposition of the polypropylene portion at 403.8 °C, one of the most significant emissions of gaseous chemicals from the examined sample is detected—pyrogenetic water (*m/z* 18) and carbon dioxide (*m/z* 44). The gaseous fraction, rich in alkanes ($C_nH_{2n+1}^+$), alkenes ($C_nH_{2n-1}^+$), is observed at a higher temperature of 455.3 °C during the pyrolysis process. They correspond to the mass ions at *m/z* 43, 55, 56, 57, 69, and 70, respectively, for $C_3H_7^+$, $C_4H_7^+$, $C_4H_8^+$, $C_4H_9^+$, $C_5H_9^+$, and $C_5H_{10}^+$. The mass ion *m/z* 53 corresponds to $C_3H_3N^+$, which may come from the degradation of a pigment added to the plastic material of one side of the mask. The results from mass spectrometry are shown in Figures 6 and 7.

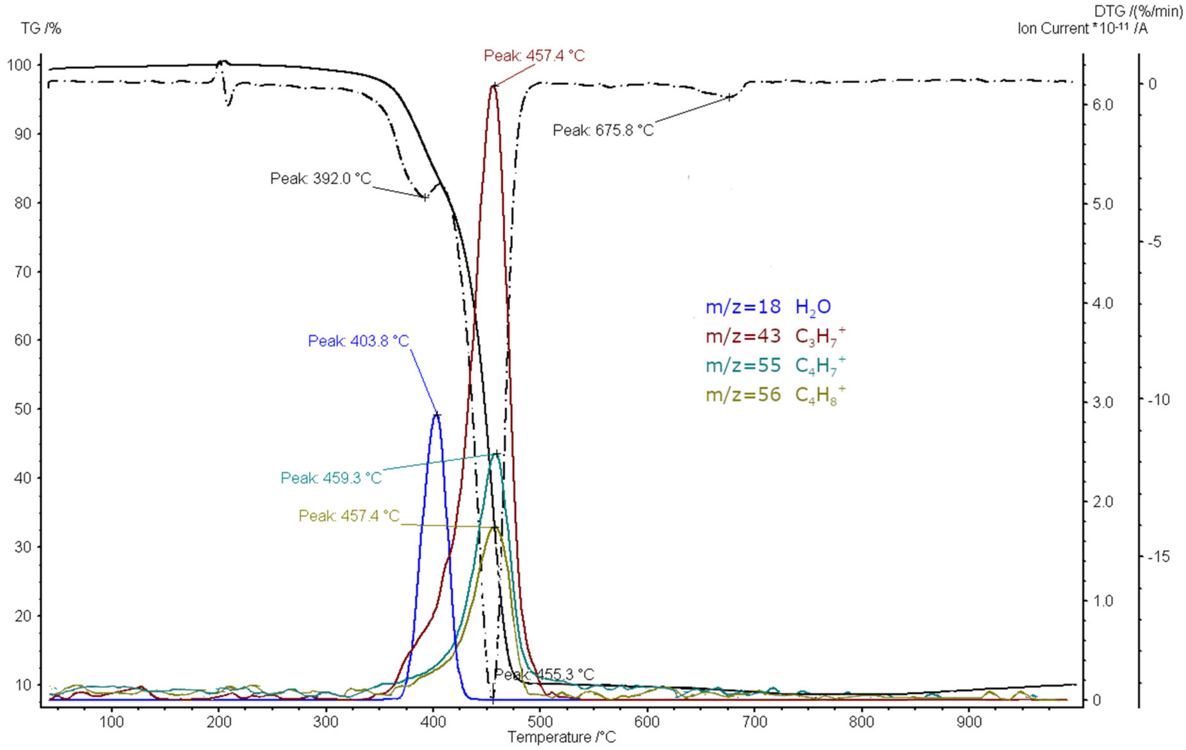


Figure 6. TG-DTG curves with curves of MS ion currents of volatile fraction (*m/z* 18, 43, 55, 56).

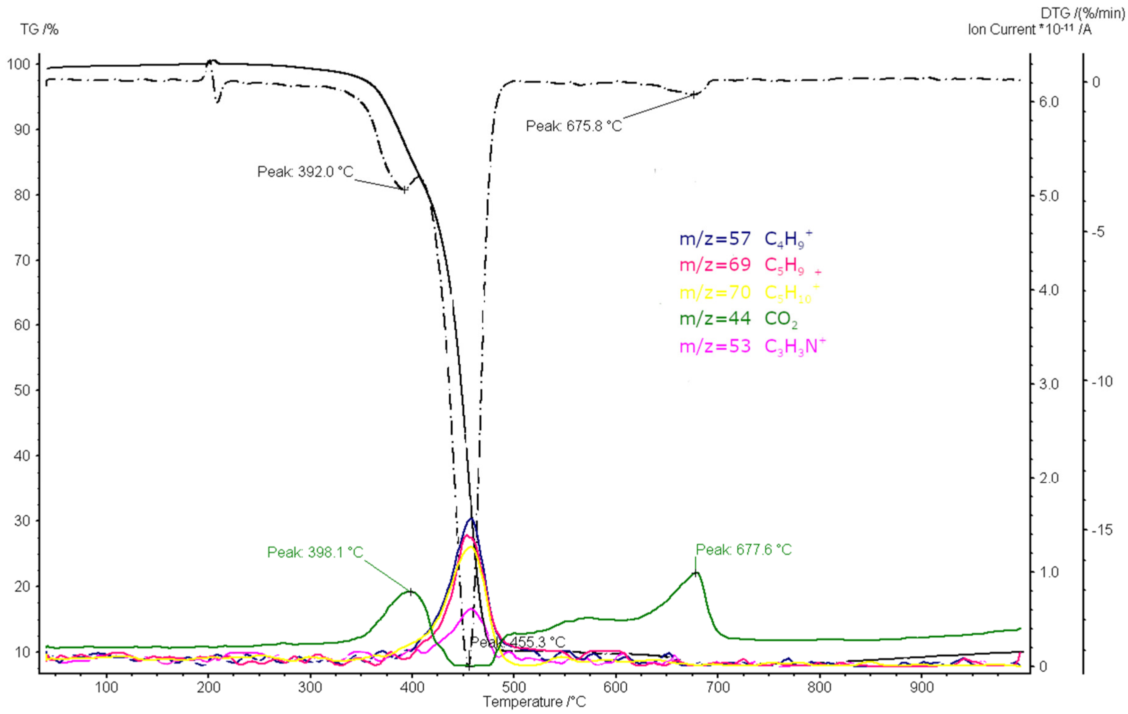


Figure 7. TG-DTG curves with curves of MS ion currents of volatile fraction (m/z 44, 53, 57, 69, 70).

3.4. Results of Computational Simulation

As part of the computer simulations, the effect of temperature was investigated on the proportion of primary pyrolysis gaseous products determining the calorific value of the pyrolysis gas—namely, CO, H_2, CH_4, C_3H_8, C_4H_4, C_6H_6, C_2H_2, C_2H_4, C_2H_6, and C_3H_6 (Figure 8).

The calculations show that the concentration of all the analysed compounds strongly depends on the process temperature. The largest share is observed for CO (up to 65%) in the entire temperature range but only for polyethylene terephthalate (PET). On the other hand, for PP and protective masks, a high proportion of hydrogen, even 50%, is visible, but only in the lower temperature range, i.e., from 400 °C to 500 °C. At the temperature of 700 °C, there is a clear decrease in the H_2 concentration to 15% for the masks and 22% for PP. At the same time, an increase in the hydrogen content from PET pyrolysis is observed; however, it does not exceed 5%. The opposite situation is observed for CH_4, the share of which increases with the rise in the process temperature, reaching a concentration of approx. 35% for both masks and PP at 700 °C, with a simultaneous low concentration (less than 5%) for PET. Noteworthy is the high proportion of C_6H_6 benzene in the pyrolysis gas for all the analysed wastes, at the level of approx. 20% for PP and masks and 17% for PET. From the energy point of view, the significant content of C_2H_4 is also significant, which grows with the temperature to approx. 9% at 800 °C for the masks and PP, and C_6H_6, reaching even 7% at the temperature of 650 °C for polypropylene. For the remaining compounds—namely, C_3H_8, C_4H_4, and C_2H_2 (except for PET), with increasing temperature, a sharp decrease in the concentration is observed for all the waste, and it does not exceed a 5% share in the pyrolysis gas.

The results of the model were compared with those of experimental research for RDF pyrolysis at 900 °C, presented in [47] (Figure 9).

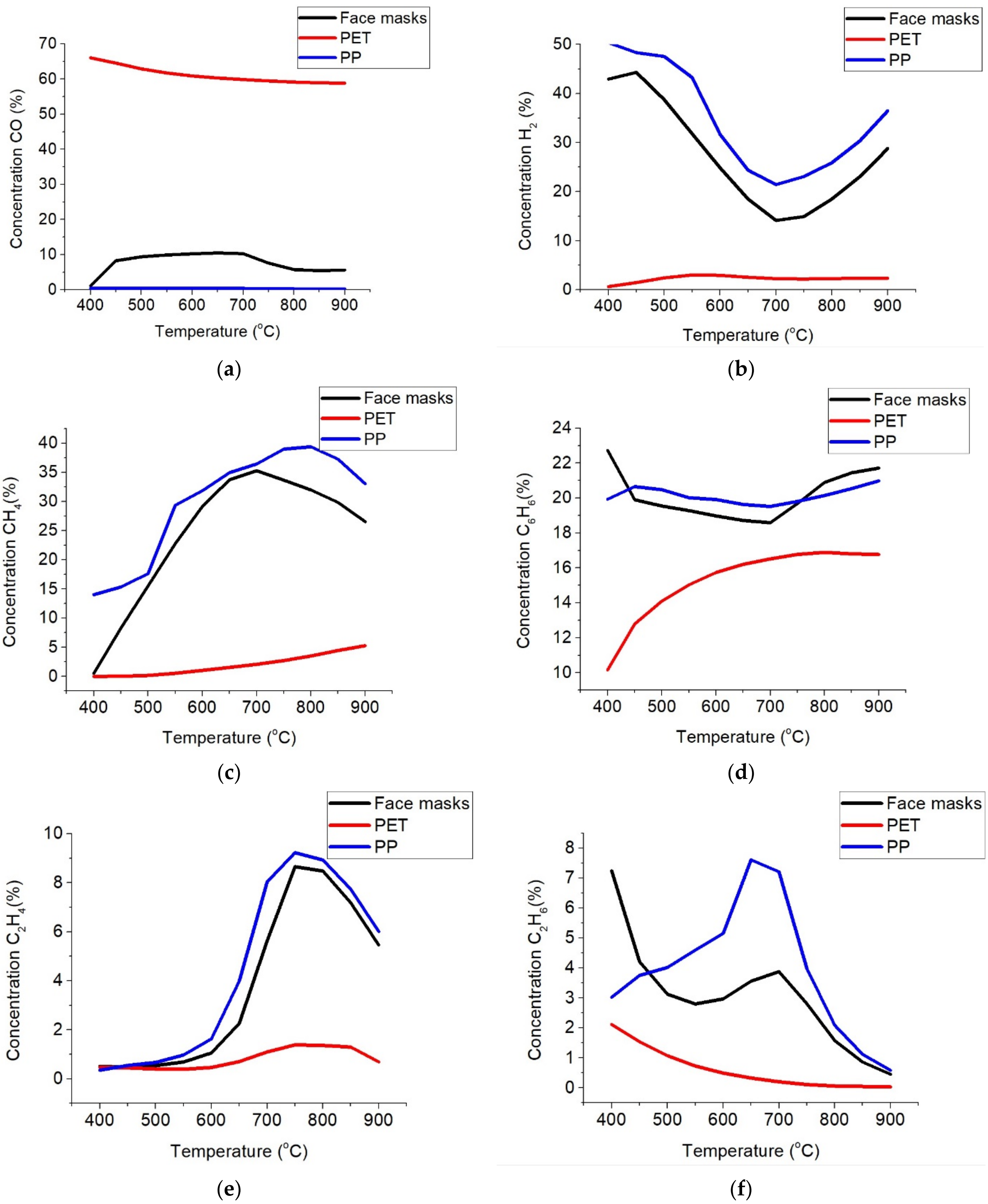


Figure 8. *Cont*.

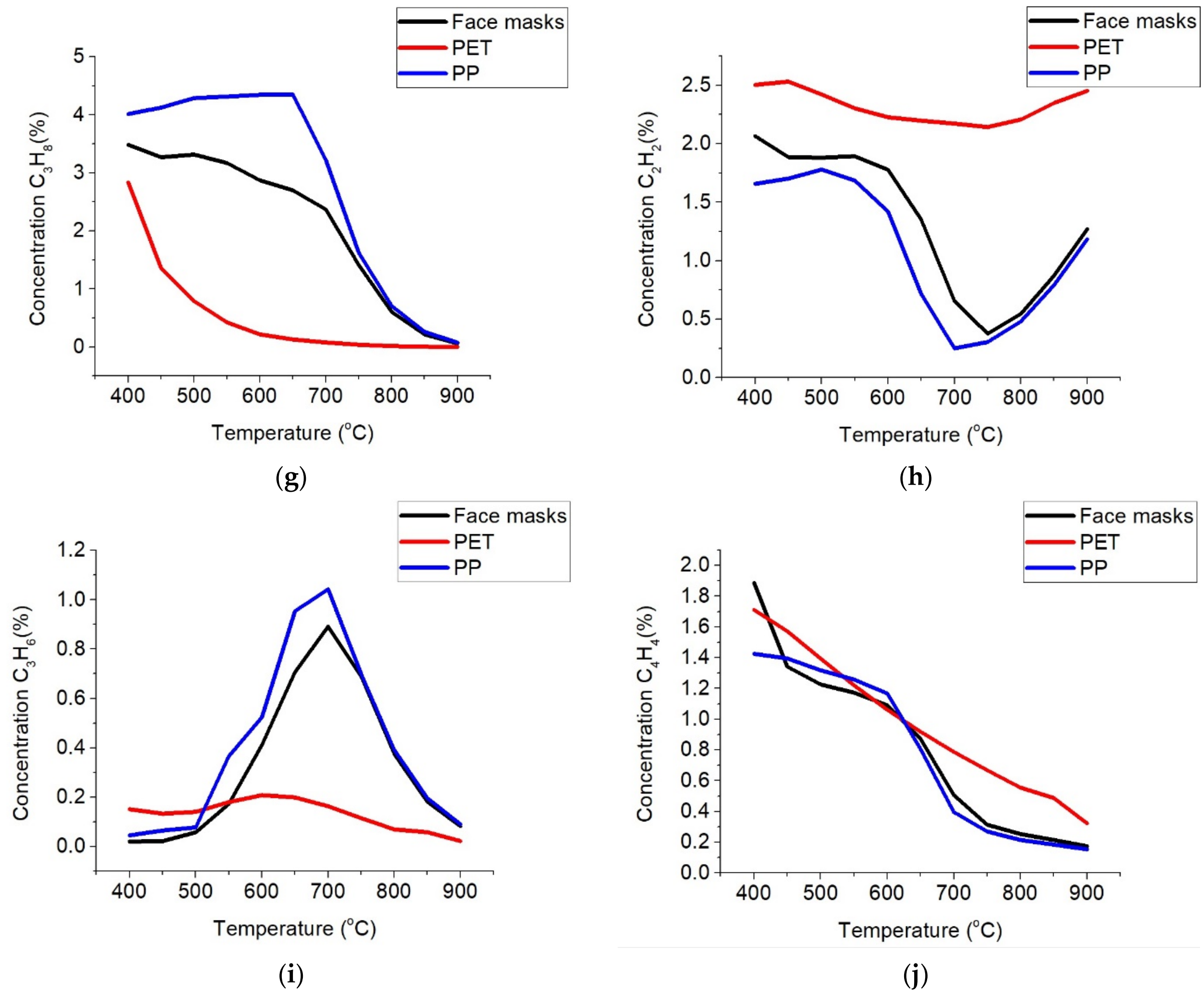


Figure 8. Influence of temperature on formation of (**a**) CO, (**b**) H_2, (**c**) CH_4, (**d**) C_6H_6, (**e**) C_2H_4, (**f**) C_2H_6, (**g**) C_3H_8, (**h**) C_2H_2, (**i**) C_3H_6, (**j**) C_4H_4.

Comparing the results obtained by modelling with the results from the experiment, the potential resulting from the pyrolysis of plastic waste, in particular polypropylene, the main component of protective masks, is visible. The high proportion of flammable compounds such as H_2, CH_4, and C_6H_6 translates into the high calorific value of the pyrolysis gas, amounting to 49.73 MJ/m^3 for PP pyrolysis gas, and 47.74% for mask pyrolysis (Figure 10). It should be mentioned that the presence of heavy organic molecules and their derivatives in the wet pyrolysis gas, which can account for up to 30% of the gas volume, has a substantial impact on the high calorific value. As a result of the condensation of these chemicals, pyrolysis oil is produced. According to preliminary research undertaken by the article's authors, direct management of wet pyrolysis gas (i.e., a mixture of pyrolysis gas and gaseous oil) in high-temperature heating chambers with temperatures exceeding 1300 °C is possible. The disposal of the problematic liquid portion, i.e., pyrolysis oil, is favoured at such a high temperature, resulting in considerable economic gains. The proposed method is described in great detail in [62].

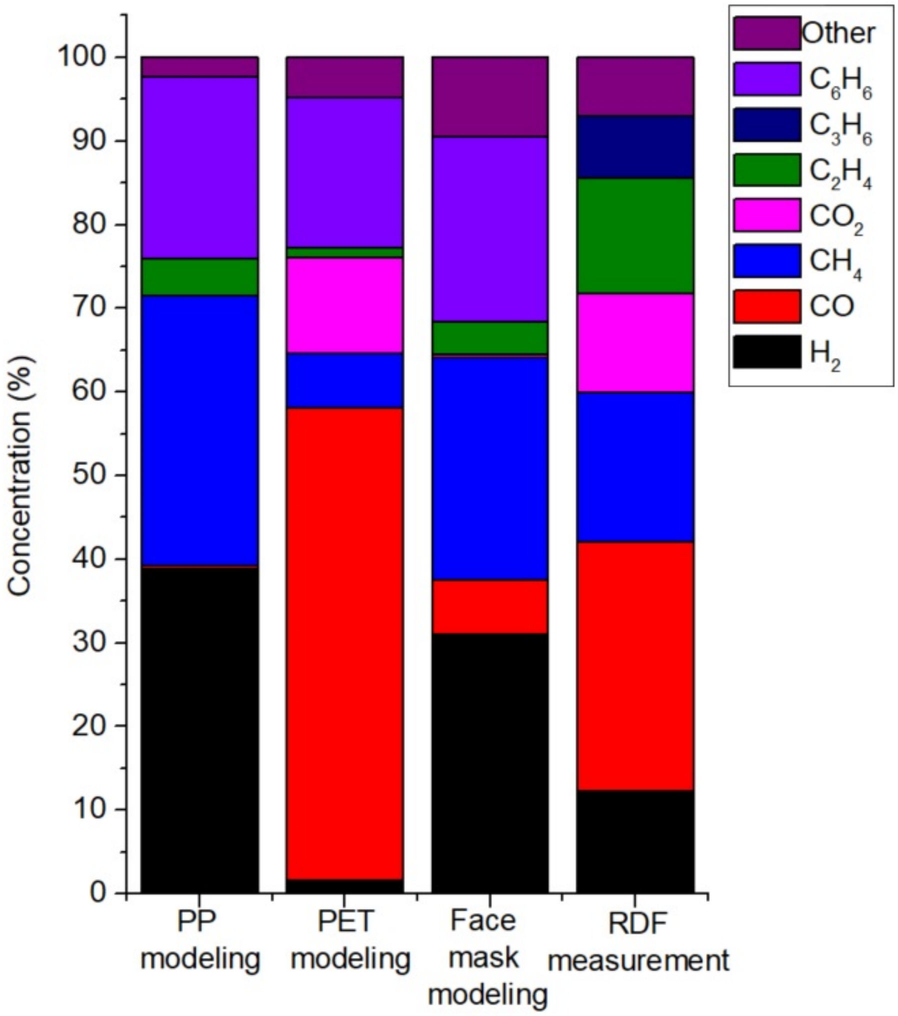


Figure 9. Comparison of selected gaseous pyrolysis products.

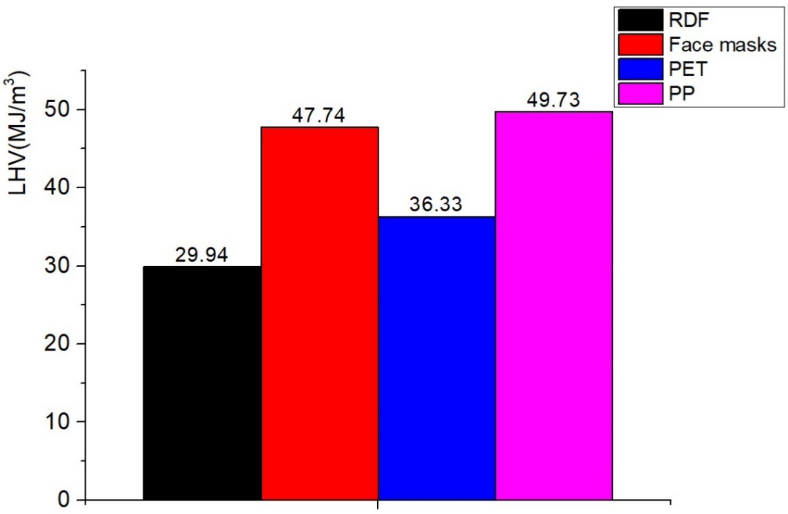


Figure 10. Calorific value of gas from pyrolysis of selected waste.

4. Conclusions

The following conclusions and statements were formulated based on the conducted research and the obtained results:

1. The pyrolysis of plastic waste generated during the COVID-19 pandemic is an effective and environmentally safe solution with great application potential.
2. Thermal conversion of waste by pyrolysis is characterized by a high yield of high-calorific pyrolysis gas. This gas can potentially be used as a substitute for natural gas for energy production.
3. It is possible to forecast the chemical composition of gaseous pyrolysis products of plastic waste and on this basis to estimate the calorific value of the pyrolysis gas produced in the process.
4. The pyrolysis of polypropylene, the main component of protective masks, allows one to obtain high-calorific pyrolysis gas (47.7 MJ/m^3), the main components of which are H_2, CH_4, and C_6H_6.
5. The results of the conducted research and computer simulations show the enormous energy value of plastic waste, especially those generated during the COVID-19 pandemic. Increasing the share of the above-mentioned waste in the municipal waste stream from which the so-called overflow and RDF fraction will increase the calorific value of the pyrolysis gas.
6. Effective disposal of the new category of waste is both a technological- and material-related challenge. Solving this challenge and creating technological techniques and know-how will enable the safe treatment of municipal waste in the COVID-19 era, and will also point the way to effective thermal conversion products management.

Supplementary Materials: The following supporting information can be downloaded at: https://www.mdpi.com/article/10.3390/en15072629/s1. Figure S1 clarified the data of mass loss (TG) and maximum rate of mass loss (DTG) during the reaction, as well as the beginning and final temperatures at each step of the pyrolysis processes.

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