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ENVIRONMENTALLY-FRIENDLY USE OF WASTE BIOMASS IN PROTECTED AREAS

Much of air pollution is due to burning of fossil fuels, but some purpose-produced biofuels and biowastes can be burned very cleanly. Historic towns should maintain high standards of air purity, but deriving all heat and power from burning of biomass cannot be feasible, but using some biowastes can help locally, with savings on energy transport and flue gas cleaning systems. It can also contribute to reducing greenhouse emissions. This has been demonstrated, e.g., at Niepołomice where several types of waste have been effectively and cleanly burned.

1. INTRODUCTION

Historic cities share the problems with all urban areas, the inhabitants want to enjoy all modern amenities. Efficient transport, sewage system, removal of wastes have to function, green spaces must be looked after. Also, the city structure and historical heritage must be preserved. This may impose limitations and barriers on, e.g., buildings and traffic. Historic structures and buildings need protection. Some deterioration with time is unavoidable, but much of the damage can be due to atmospheric pollution, as in Kraków after 1950. The Nowa Huta Steel works were built close to an aluminium plant and a power/heating plant at Skawina. Another plant, Łęg, was built in Kraków itself. They all burned coal, with no flue gas desulphurisation and the aluminium plant emitted hydrogen fluoride. The prevailing winds also brought pollutants from Silesia. This made the area one of the most polluted in Poland, both by gaseous contaminants and dust deposition. The annual sulphur deposition rate, wet and dry, was one of the highest in Europe, i.e., 10 g/m^2 [1]. After 1990, with heavy industry shrinking, the pollution level started to fall. The use of coal was restricted, the energy

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efficiency rose and flue gas was subjected to desulphurisation. But air pollution can still be of concern. Sulphur dioxide (SO_2) and the associated acid rains greatly affect stonework. Nitrogen oxide and dioxide (NO_x) contribute to acid rains but are also connected with photochemical smog and formation of ozone and peroxides that affect painted surfaces, fabrics, etc. [2]. Both SO_2 and NO_x are derived from combustion processes: SO_2 – coal and to a lesser extent fuel oil, NO_x – coal and the air of a high temperature (as in IC engines). Also, with any fuel, inefficient combustion is responsible for emissions of unburned hydrocarbons or even soot. Deposited on surfaces, together with fine dust, they give rise to the growth of layers of black grime.

With evidence for the greenhouse effect accumulating, renewable energy sources have many advocates. Clean power, with zero emissions might seem ideal, particularly in historic cities, but it is difficult to eliminate combustion from cities. Few localities have access to geothermal heat, hydroelectric schemes can only contribute to a fraction of the energy required, nuclear energy raises strong emotions, solar and wind power can be exploited only in certain areas. The environmental impact of fossil fuels falls in the following order: coal>oil>gas, because of the CO_2 formed in relation to the energy evolved (via the H/C ratio) and emissions of SO_2, NO_x and other pollutants. In typical Polish coals, there is ~1% of inorganic S, oxidised to SO_2 during combustion. All coals contain 1–2% of combined nitrogen (fuel-N), some of which (15–20%) is oxidised to NO when the coal burns [3]. Coal also contains all natural elements, in proportions roughly similar to those in the earth's crust [4]. In oxidised form these elements mainly pass to the ash, or fine flue dust [3], [4]. In fuel and diesel oil, the sulphur concentration is much lower and there is practically no fuel-N. From natural gas H_2S is removed (if present). However, NO can also be formed in high-temperature synthesis, very strongly dependent on the combustion technology (via the max. process temperature and the gas residence time). Hence at power stations low-emission pulverised fuel or fluidised bed boilers (FBC) are now used, working at ~850 °C, to optimise flue gas desulphurisation and eliminate NO_x synthesis (but not fuel-N oxidation). With oil and gas less CO_2 is formed and SO_2 emissions can be low, but some NO_x formation occurs (even with no fuel-N and using low-emission burners) [3].

2. THE COMBUSTION OF BIOMASS

Burning of renewable biomass is a popular topic. The environmental standards are strictly determined, hence it is extremely important that some biomass is poor in sulphur and fuel-N, so when burned efficiently below ~1100–1200 °C it can be a very clean fuel. The drawbacks are a low calorific value of biomass (compared with coal or oil) and bulk, precluding long-distance transport [3]. Deriving power and heat for a city of any size from biomass alone would not be feasible, but the matter seems different when we deal with small, compact groups of buildings and many small contributions can add up. Producing heat locally could make a worthwhile contribution to the energy balance. Biowaste is produced in every town; wood from tree trimming, leaves, grass, combustible wastes from small firms. Segregated municipal waste (SMW) may be available and wastewater-treatment plants produce sewage sludge (SS). In a landfill, they are degraded under oxidising or reducing conditions, giving CO_2 or CH_4, respectively. CO_2 is released with no energy benefit, CH_4, if allowed to escape, represents wasted energy and is a potent greenhouse gas [2]. So it makes sense to extract heat from burning of organic wastes. Selected properties and the elemental composition of some types of biowaste, in comparison with fossil fuels, are given in the table.

Table

Properties of biomass in comparison with fossil fuels
(moisture – average, other quantities – DAF)

Quantity, units	Fossil fuels				Combustible biomass wastes			
	Coal Polish (1)	Lignite Polish (1)	Oil, fuel (1)	Gas, natural (1)	Wood, average (2)	SMW (1) est.	Biomal (1)	SS cake (3)
Moisture, %	5–20	42–54	low	low	10–30	~30	~70	70–85
CV, MJ/kg	29–32	8–9.2*	42–46	<45	15–16	~24	21–35	13–20
Volatiles, %	~35	50	<100	100	~75	30–40	high	50–75
Ash, %	20–27	6–20	low	very low	0.2–5	~13	20–38	15–40
Elements						(4)	(4)	
C	82	70	83–87	<75	49–52	55.8	66.3	31–45
H	5	5	12–14	<25	5.7–6.3	7.5	10.1	4.8–6.4
N	1–2	1–1.5	<1.2	N_2, var.	0.1–0.16	0.34	6.8	4.4–8.3
O	12	20–27	<4	low	37–44	36.2	16.1	18–26.5
S	~0.8	0.5–1	<0.5	low	0.02–0.1	0.1	0.39	0.6–1.3
H/C(molar)	0.73	0.86	~1.84	<4	1.3–1.54	~1.6	1.83	1.7–1.9

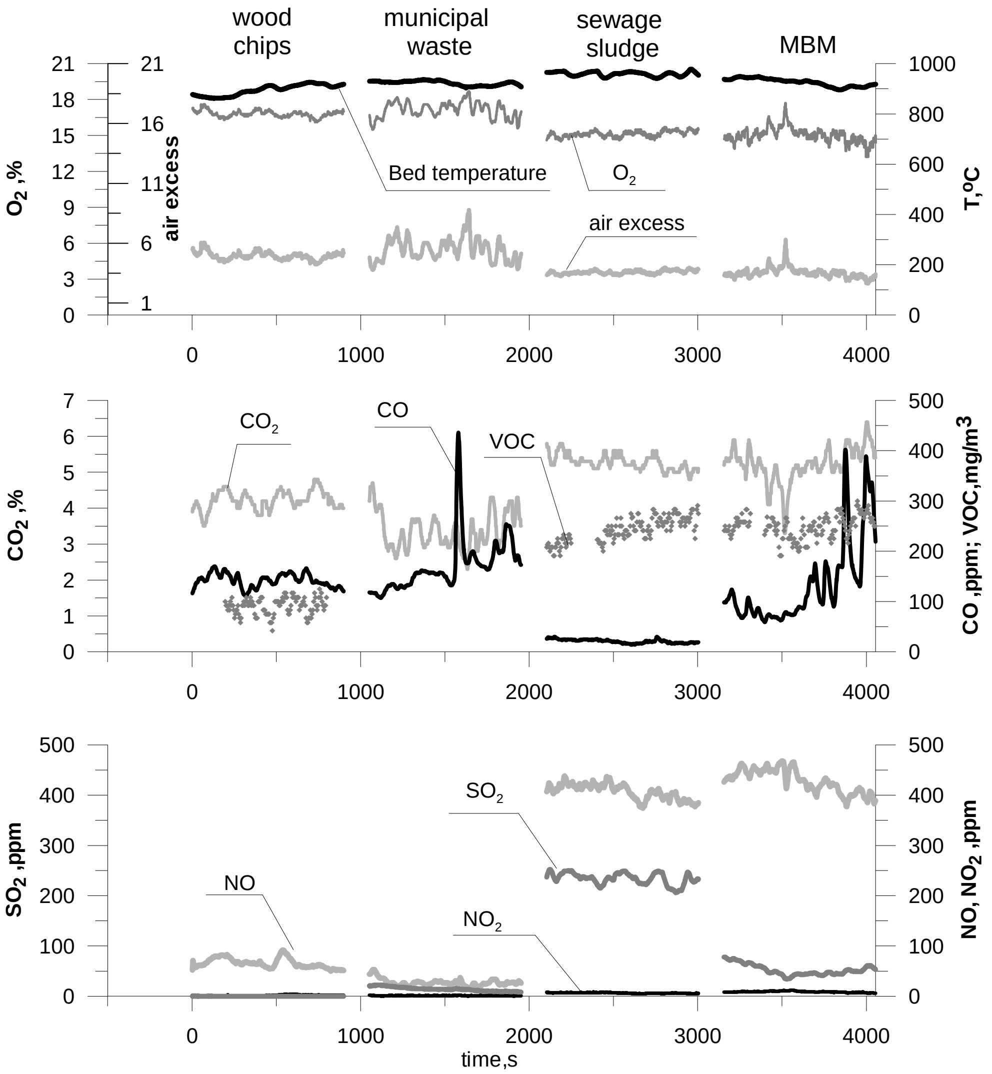
( ) – data sources, est. – estimate, * – as used.

The content of moisture in raw biomass is high, and the calorific value (CV) of the dry mass is comparable with that of wood or higher. Wood waste and segregated municipal waste (SMW) are very poor in sulphur and fuel-N. The sulphur content in animal wastes, biomal, and SS and in the coal poor in sulphur is similar, but the fuel-N content is high, so burning these can give high concentration of NO_x. Quantity and composition of the ash are also important. The main components of coal ash (expressed as oxides), i.e., SiO_2, Al_2O_3, and Fe_2O_3, are followed by CaO and MgO [3], all of them also occurring abundantly in the earth's crust [4]. The levels of SO_3, the alkali metals (Na, K) and chlorine are more variable. Many elements occur only in trace concentrations [4], but some ashes can be quite rich in heavy metals, e.g., SS ash. The ashes of wood are rich in the alkali metals [3].

Due to suitable technologies some biomass can be burned in very simple and clean way, some may need flue gas desulphurisation or reduction of NO_x emissions. Plant material and SMW could be attractive. It would not be economic to burn them at a power station, but in a historic town it might make sense to use local biowastes, burned efficiently, with overall energy saving, for heat from fossil fuels is often brought from large distances, with inevitable losses.

3. BURNING SELECTED RENEWABLE BIOWASTES TO PROVIDE LOCAL HEAT

Local central heating systems are considered to be controversial, partly due to technical ignorance of "green" activists. Combustion in 0.5–5 MW boilers can be both clean and fully automatic. Bubbling fluidised bed combustors (BFBC) can provide clean energy for local use, for compact groups of buildings, reducing local pollution and transport of combustible wastes and their deposition in landfills. We have had such boilers in operation for many years [8]. They can run on low-quality fuels and/or a variety of biowastes, often with no sophisticated, costly flue gas cleaning. The latest such a facility is a boiler designed to burn sewage sludge at Niepołomice, a small town near Kraków, with expanding industry and rising population. Within an EU program [9] a 1.5 MW FBC boiler has been built (Cracow University of Technology participation) to burn SS cake, with the moisture content approaching 80%, at a wastewater treatment plant being built. The boiler has been tested and it turns out that it is not necessary to pre-dry the SS cake, which can be burned with wood chips, with additional wood chips used to stabilise the process, if necessary. To achieve this, the fluidising air stream is preheated (heat from the flue gases) and the SS is dried in the combustor. Most of the energy is recovered when water vapour from the flue gases condenses in the scrubbers, which also remove most fine flue dust and reduce other pollutants levels. In the tests, wood chips, MSW, dried SS as well as meat and bone meal (MBM) were burned, with oxygen in excess. Typical records for the bed temperature and the flue gas concentrations of O_2, CO_2, CO, SO_2, NO, NO_2, and for MBM, concentrations of unburned hydrocarbons are shown in the figure and are such as we have expected on the basis of the table. Note that burning of MSW gave the least concentration of NO, SO_2 and CO, less than the wood chips, and SS gave high concentration of NO and SO_2 and MBM gave high concentration of NO and medium of SO_2. SO_2 could be easily reduced by liming the waste. NO_x concentration could be decreased by co-combustion with wood chips or MSW, or the emissions could be reduced by adding a re-burning fuel to a freeboard.



Typical experimental records of the bed temperature, the flue gas concentrations of O_2, CO_2, CO, SO_2, NO, NO_2, and for MBM, the concentration of unburned hydrocarbons, when selected wastes were burned in a 1.5 MW bubbling fluidised bed, with an excess air

4. CONCLUSION

It may be difficult to provide energy for a historic city from renewable sources alone, but some wastes can be burned to provide clean local heat and displacing fossil fuels.

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WYKORZYSTANIE ODPADOWEJ BIOMASY NA TERENACH CHRONIONYCH

Wiele zanieczyszczeń powietrza powstaje w wyniku spalania paliw kopalnych, ale niektóre specjalnie produkowane biopaliwa spalają się bez wydzielania zanieczyszczeń. W miastach historycznych wymaga się, aby powietrze spełniało wysokie standardy czystości, lecz całego potrzebnego ciepła i energii nie da się tu uzyskać ze spalania biomasy. Jednak stosowanie niektórych odpadów organicznych może się przydać lokalnie, przyczyniając się do oszczędności na transporcie ciepła i oczyszczaniu gazów kominowych. Może to też pomóc ograniczyć emisję gazów cieplarnianych, co zostało zademonstrowane np. w Niepołomicach, gdzie spalano skutecznie i stosunkowo czysto kilka typów odpadów.