POLITECHNIKA CZĘSTOCHOWSKA

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FLUIDIZATION XVI

May 26 - 31, 2019 | Guilin Shangri-La Hotel | Guilin, China

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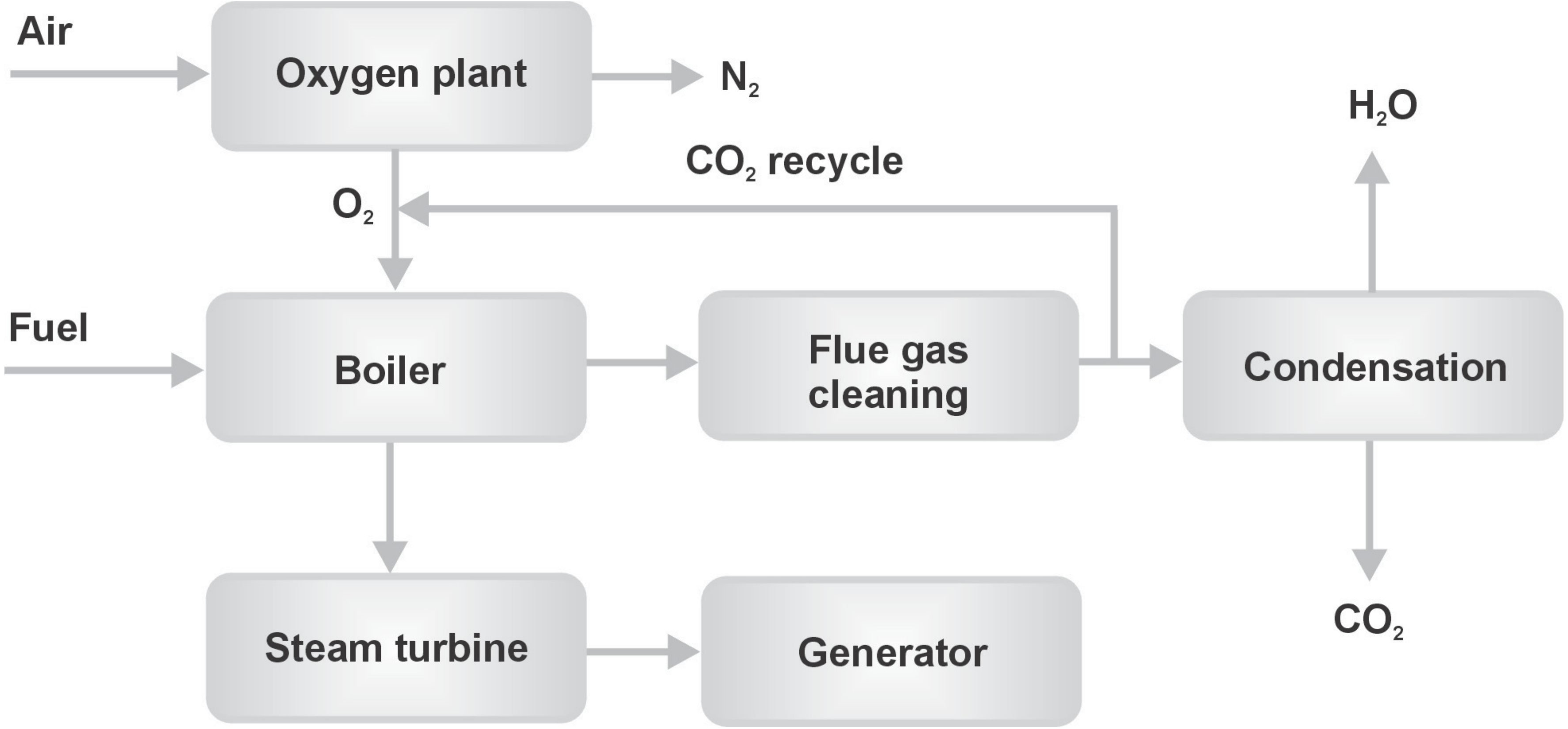
Gaseous emissions during oxy-fuel combustion of sewage sludge in a circulating fluidized bed

INTRODUCTION

1. Increasing production of sewage sludge in Poland creates environmental problems with its disposal.
2. New legislation introduced in January 2016 limits landfilling of sewage sludge.
3. Thermal treatment of sludge becomes an attractive option because:
    - It significantly reduces the volume of waste material
    - It minimizes odour and destroys toxic compounds
    - It allows energy recovery from the sludge (LHV > 6.0 MJ/kg)
4. Problems associated with sewage sludge incinerators include:
    - Emission of greenhouse gases
    - Ash disposal
5. Oxy-fuel combustion technology is the most promising option for the reduction of greenhouse gas emissions from combustion of fossil fuels and incineration of biological and industrial waste materials.

OXY-FUEL COMBUSTION PROCESS



OBJECTIVE AND SCOPE OF INVESTIGATION

Objective: To determine the influence of fuel characteristic and oxidizing atmosphere on emissions of pollutants during combustion in a bench-scale circulating fluidized-bed reactor.

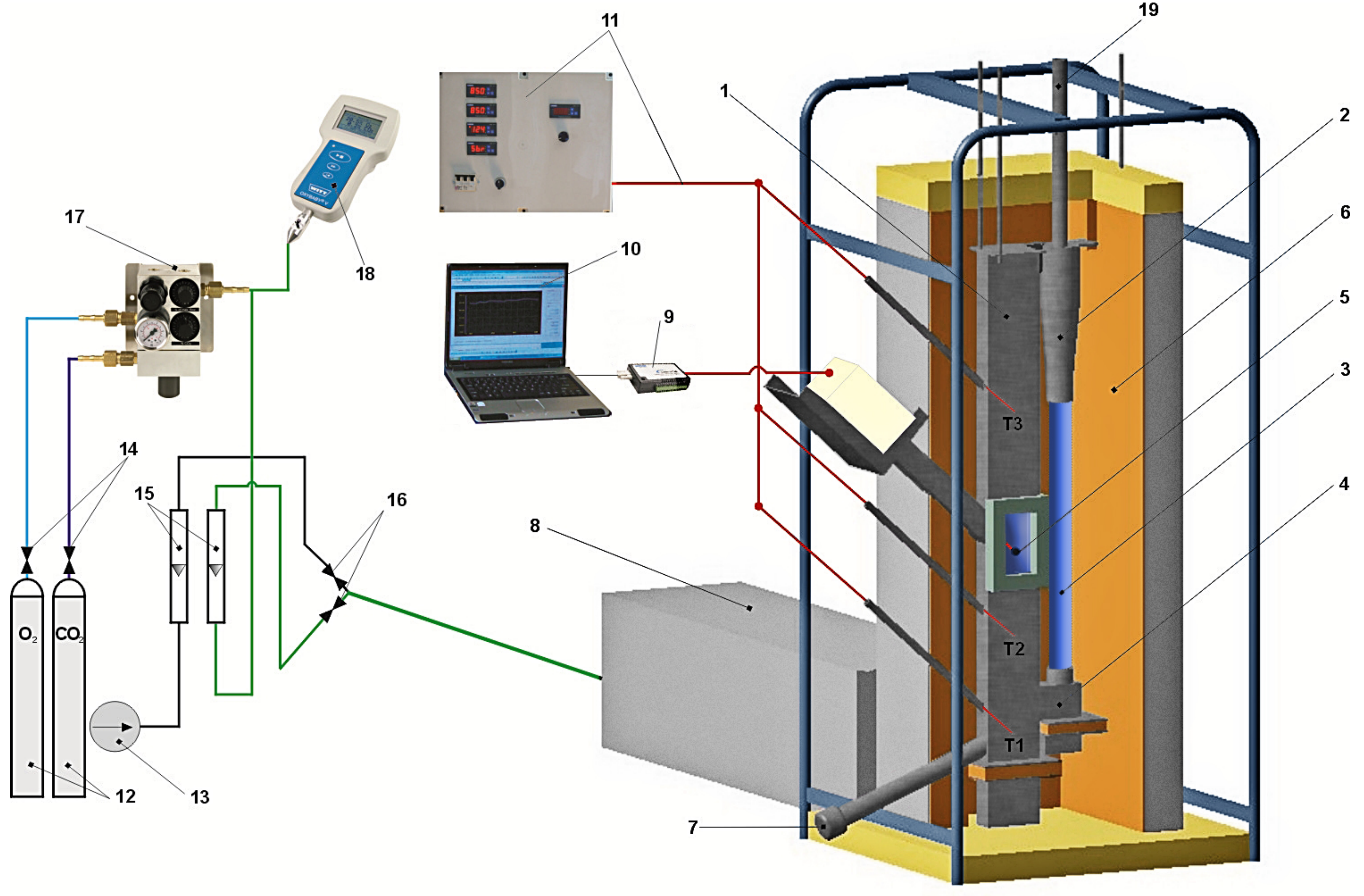
Scope:

1. Analyses of tested fuels,
2. Measurements of NO, N_2O and SO_2 during combustion in air and in O_2+CO_2 mixtures (oxy-fuel combustion),
3. Analysis of collected data.

EXPERIMENTAL APPARATUS

1 – combustion chamber
2 – cyclone
3 – downcomer
4 – loop seal
5 – fuel particles
6 – insulation
7 – drain valve
8 - preheater
9 – card
10 - computer
11 – temperature control system
12 – gas cylinders
13 – air compressor
14 - pressure regulators
15 – rotameters
16 – valves
17 – mixer
18 – gas analyser
19 – ventilation duct

T1–T3 – S-type thermocouples



EXPERIMENTAL CONDITIONS

Temperature: 850°C

Pressure: ambient

Bed material: silica sand, d_{50} ~200 µm

Fuels: dry sewage sludge, wooden biomass (willow), bituminous coal

Fuel sample mass: 0.5 g

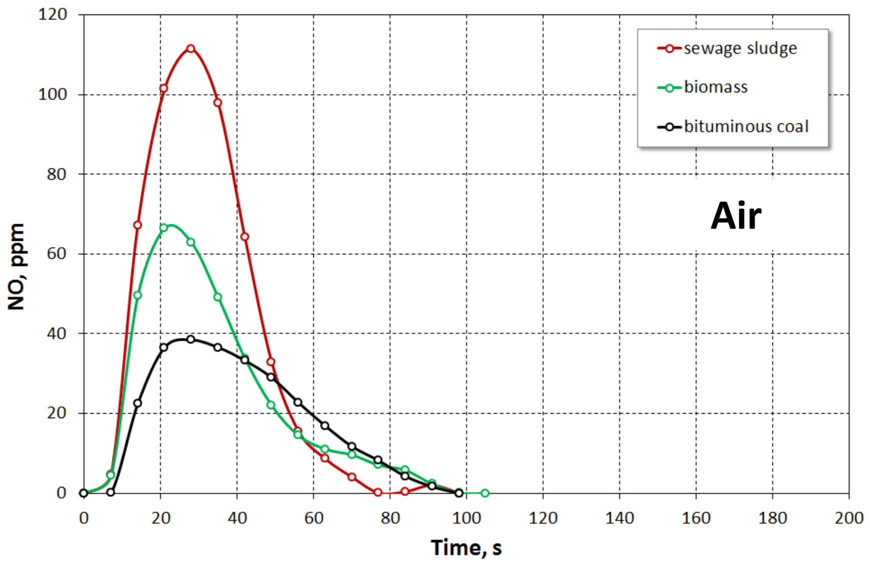
Composition of fluidizing gas:

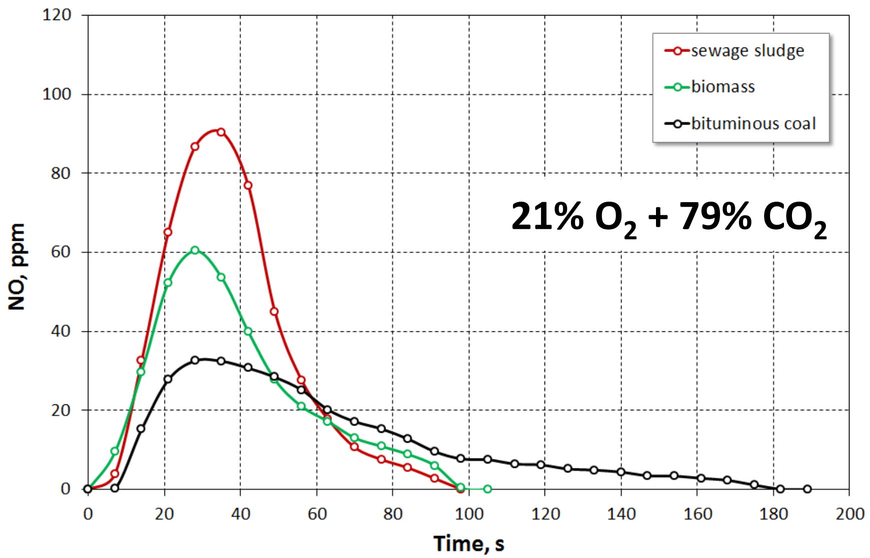
1. Air (base case)
2. 21% O_2 and 79% CO_2
3. 30% O_2 and 70% CO_2
4. 40% O_2 and 60% CO_2

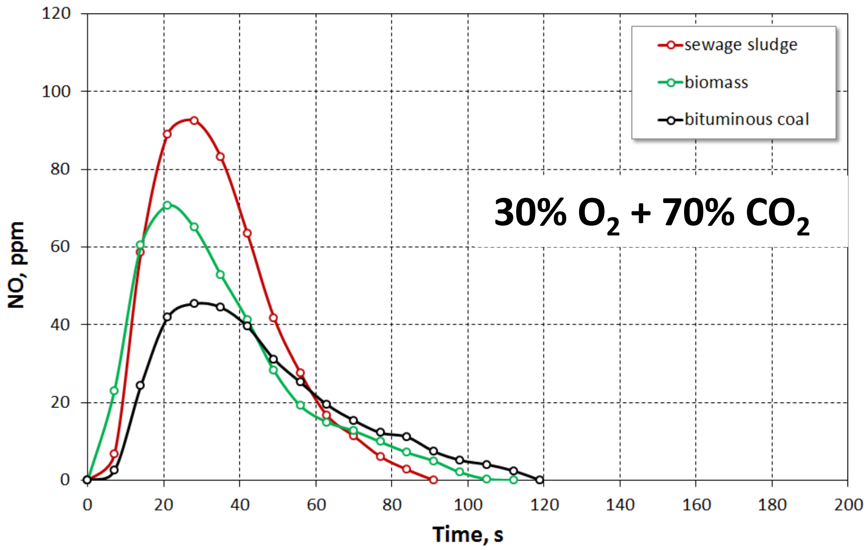
ANALYSES OF TESTED FUELS

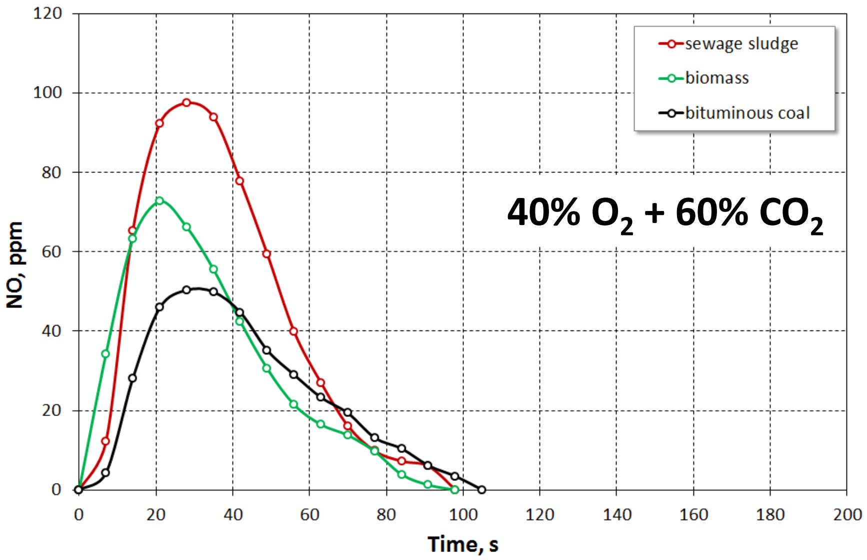
Fuel	Sewage sludge	Basket willow	Bituminous coal
Proximate analysis (air-dry basis)			
Moisture (M), %	4.9	6.9	8.7
Ash (A), %	36.4	1.4	18.9
Volatile matter (VM), %	51.4	76.3	26.8
Fixed carbon (FC), % (by difference)	7.3	15.4	45.6
Higher heating value (HHV), MJ/kg	13.55	18.20	22.75
Ultimate analysis (dry, ash-free basis)			
Carbon (C), %	52.49	49.59	73.30
Hydrogen (H), %	6.69	5.99	4.30
Sulphur (S), %	2.46	0.03	2.29
Nitrogen (N), %	7.27	0.33	1.10
Oxygen (O), % (by difference)	31.09	44.06	19.01

RESULTS – NO EMISSIONS



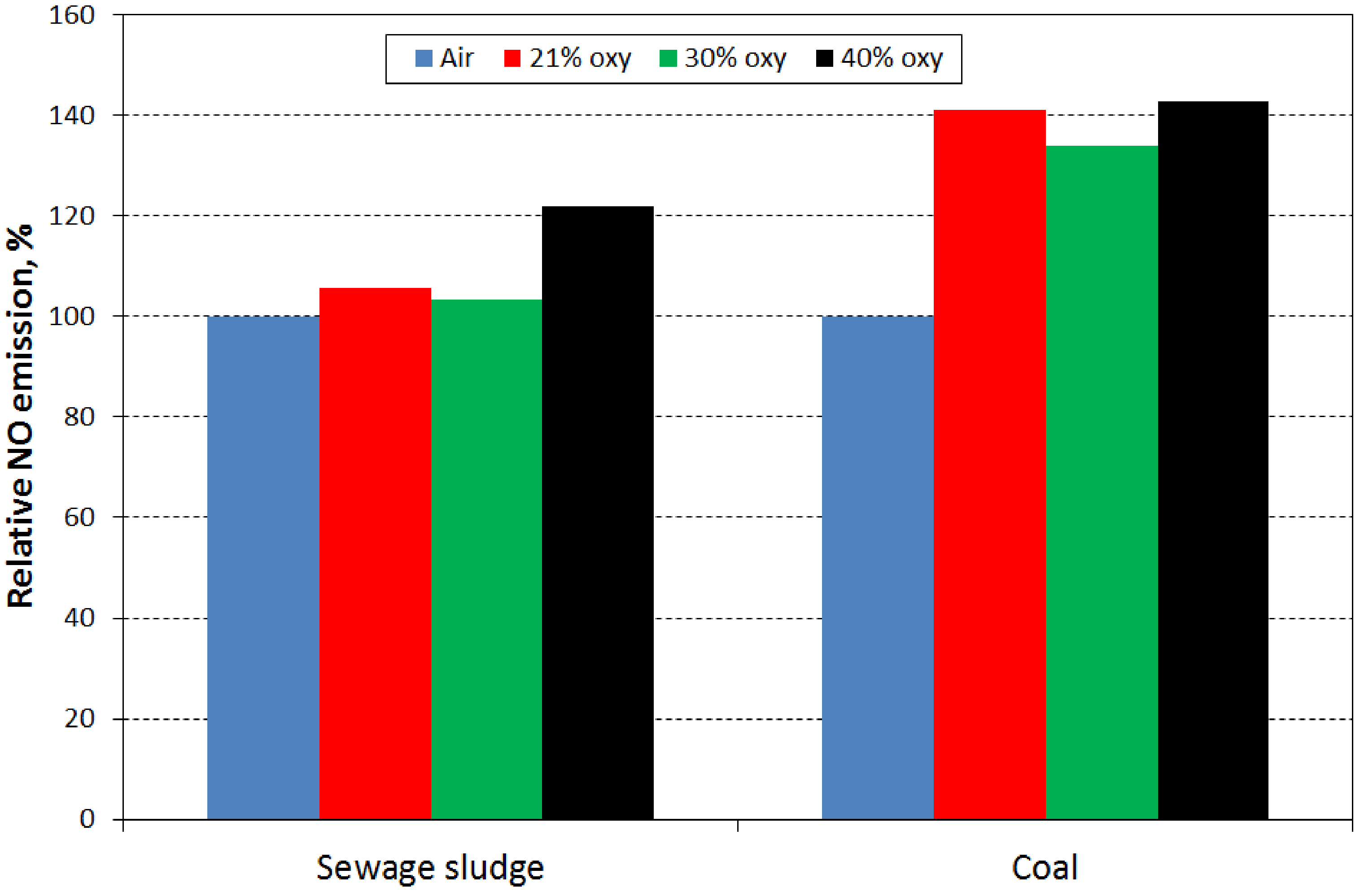




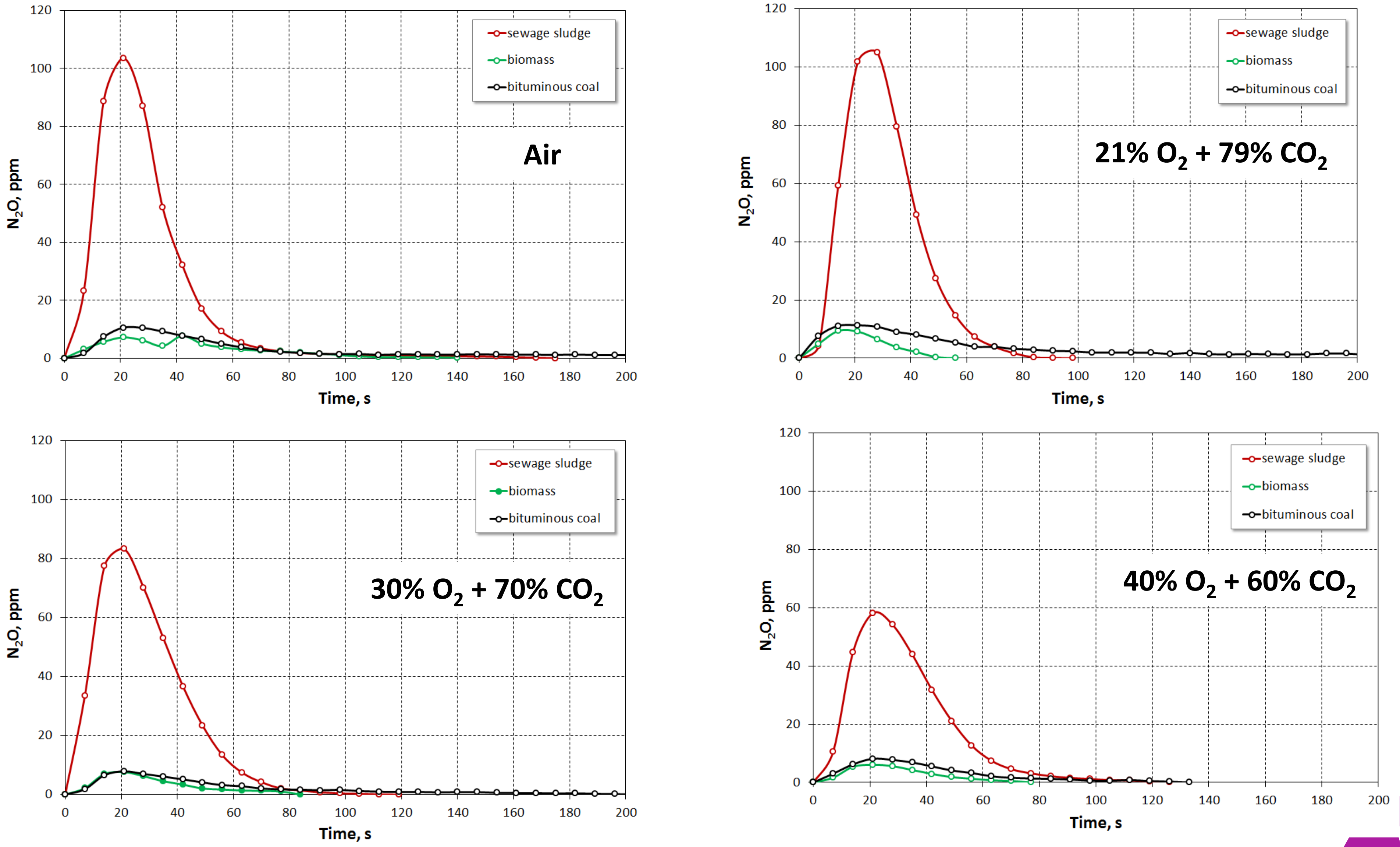


RESULTS – RELATIVE NO EMISSIONS

Influence of oxidizing atmosphere on NO emissions

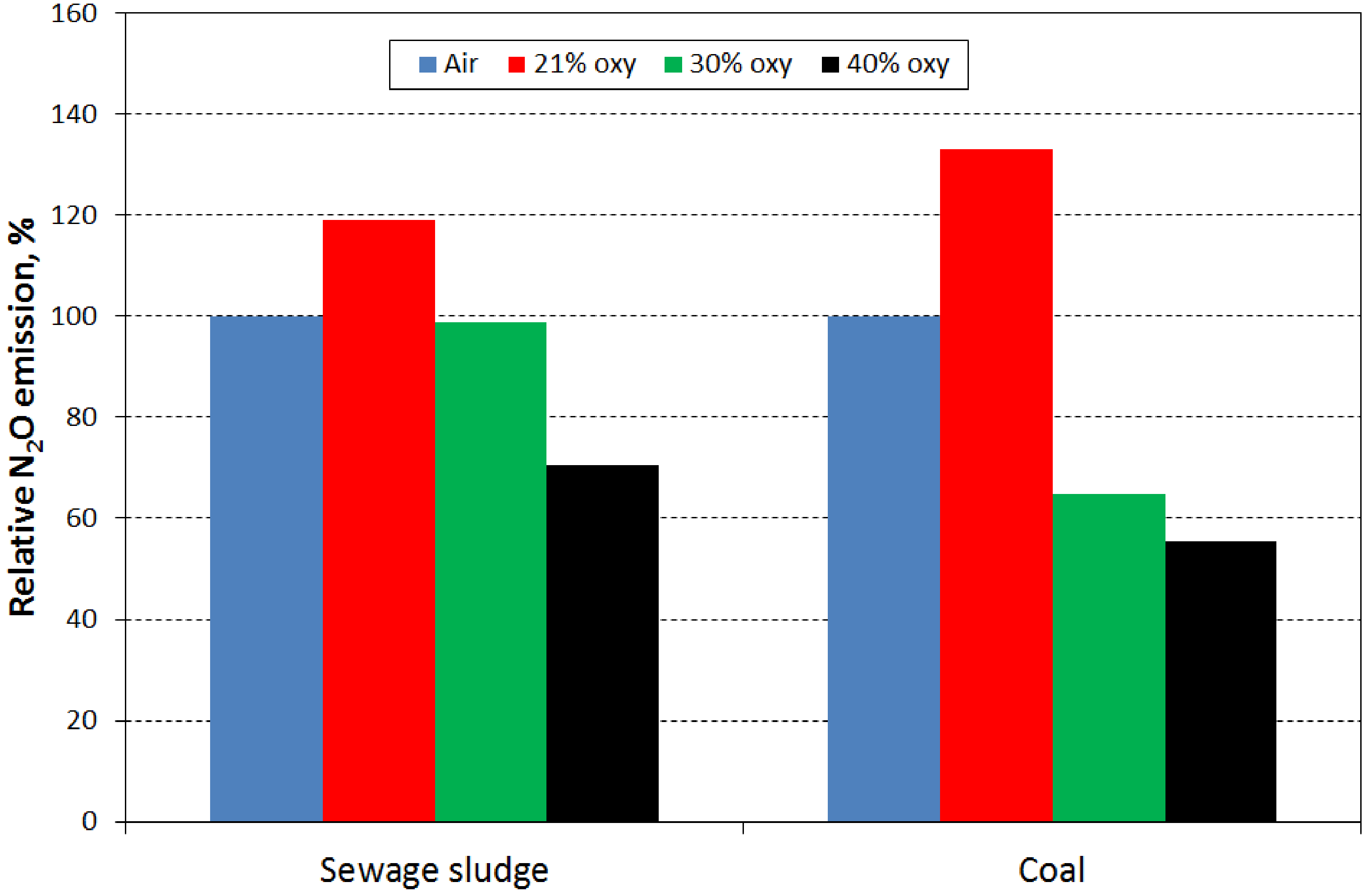


RESULTS – N_2O EMISSIONS



RESULTS – RELATIVE N_2O EMISSIONS

Influence of oxidizing atmosphere on N_2O emissions



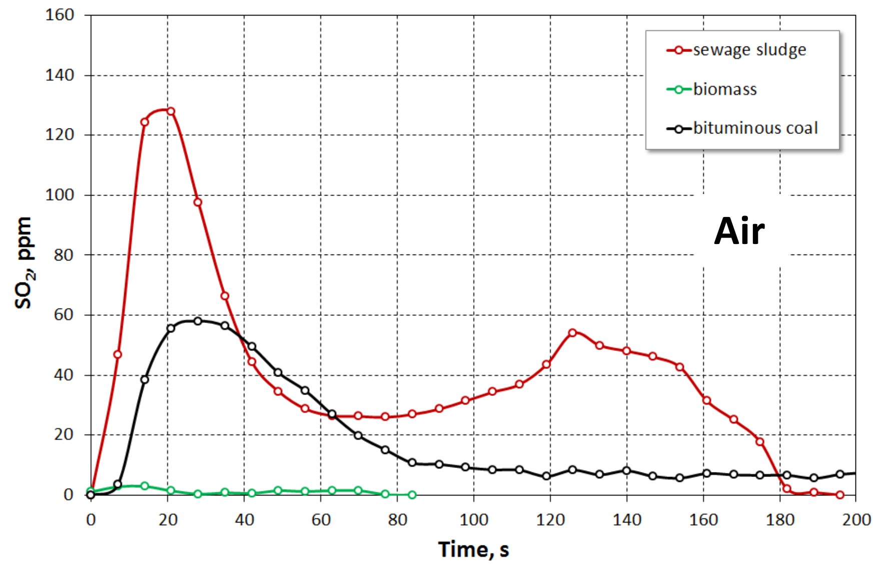
RESULTS – CONVERSION OF FUEL-N TO NO_x

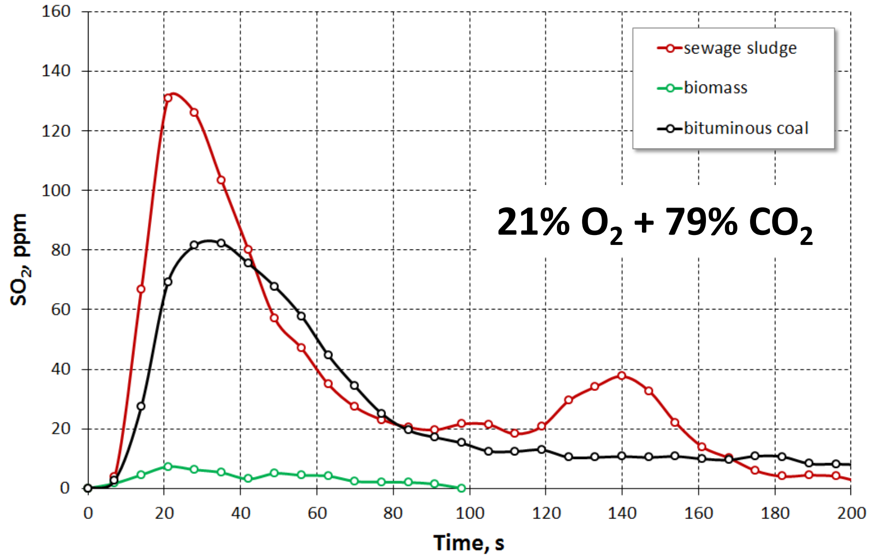
Conversion of fuel-N to NO, %				
	Air	21% O_2 and 79% CO_2	30% O_2 and 70% CO_2	40% O_2 and 60% CO_2
Sewage sludge	9.3	9.9	9.6	11.3
Coal	25.6	36.1	34.2	36.5

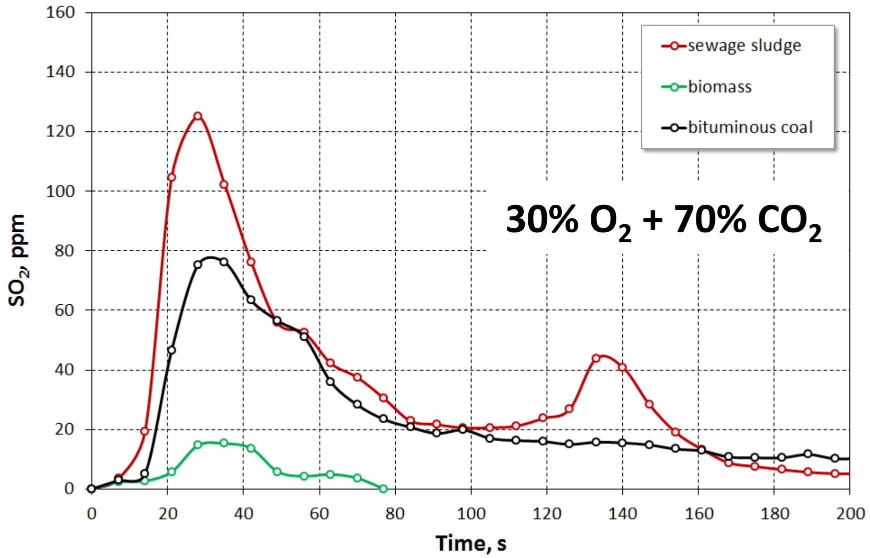
Conversion of fuel-N to N_2O, %				
	Air	21% O_2 and 79% CO_2	30% O_2 and 70% CO_2	40% O_2 and 60% CO_2
Sewage sludge	15.9	18.9	15.7	11.2
Coal	19.9	26.2	12.9	11.0

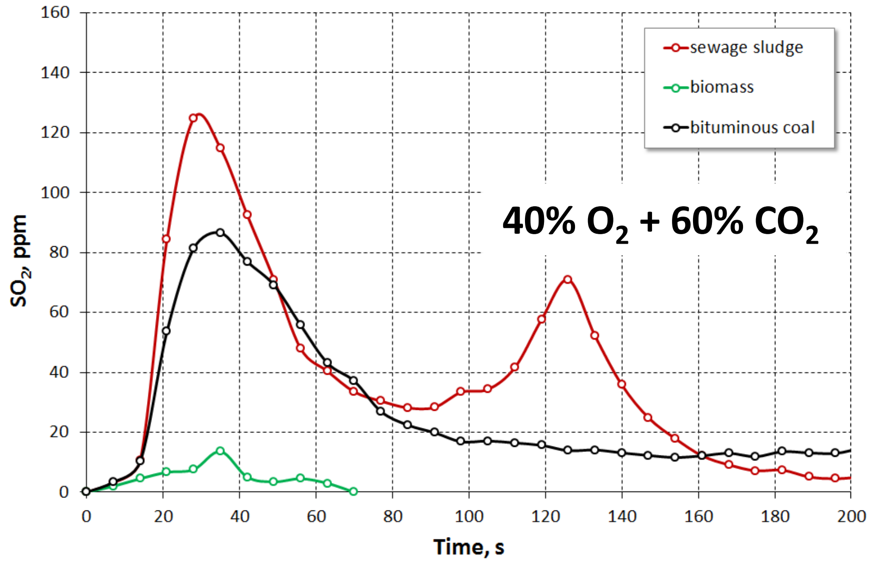
Total conversion of fuel-N to NO_x, %				
	Air	21% O_2 and 79% CO_2	30% O_2 and 70% CO_2	40% O_2 and 60% CO_2
Sewage sludge	25.2	28.8	25.4	22.6
Coal	45.5	62.6	47.2	47.6

RESULTS – SO_2 EMISSIONS



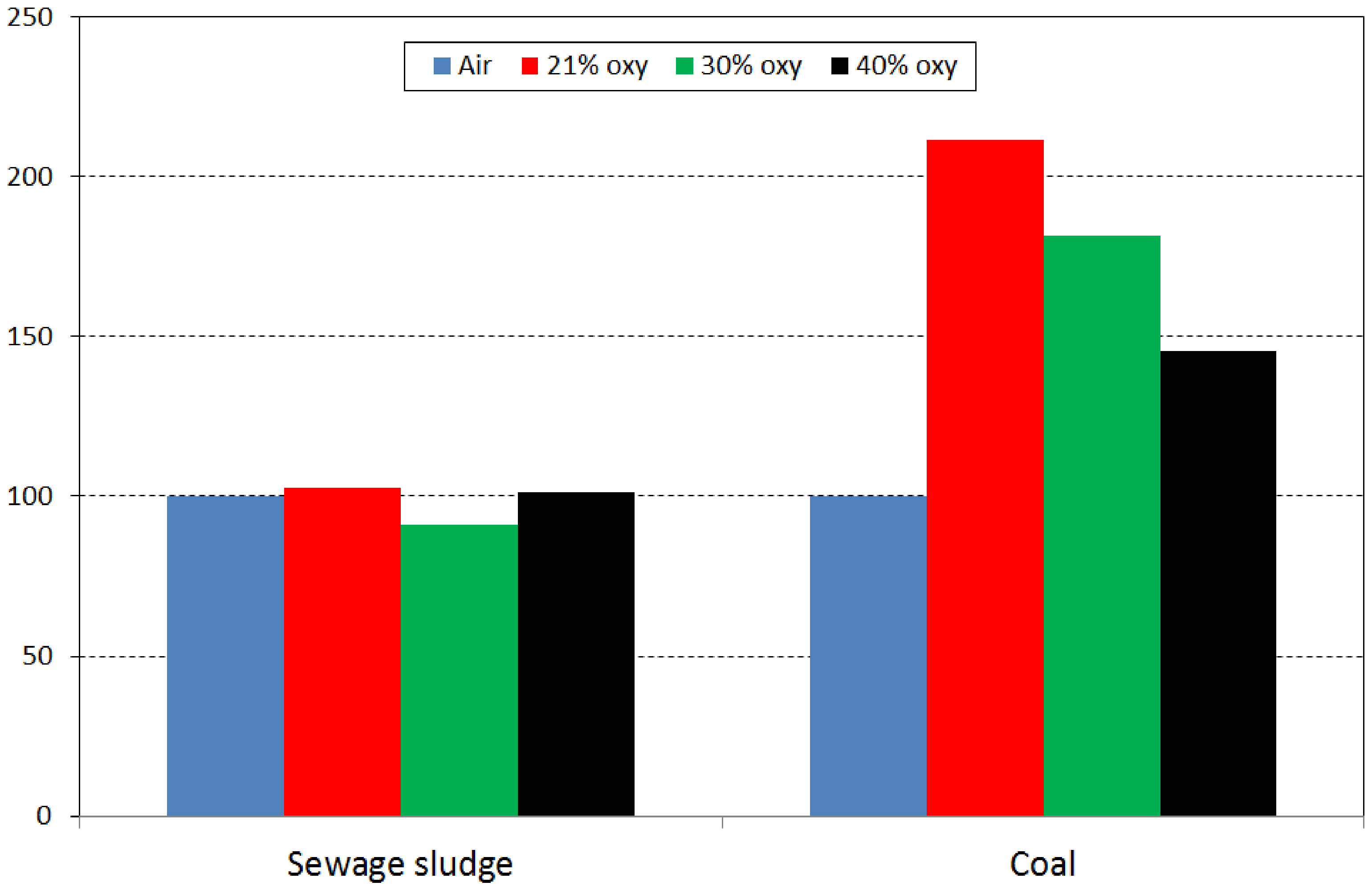






RESULTS – RELATIVE SO_2 EMISSIONS

Influence of oxidizing atmosphere on SO_2 emissions



CONCLUSIONS

1. Dry sewage sludge contains much more volatile matter, ash and nitrogen then the reference coal.
2. Instantaneous and average emissions of NO, N_2O and SO_2 for the combustion of sewage sludge in all atmospheres were much higher than those for the combustion of reference coal.
3. The SO_2 concentration profile for sewage sludge has a bimodal distribution which may suggest that SO_2 originated from both organic and inorganic sulphur sources.
4. Relative NO emissions for sewage sludge were insensitive to O_2 content up to 30% then they increased sharply. In the case of coal, combustion in O_2+CO_2 atmosphere caused sharp increase in NO emissions.
5. Relative emissions of N_2O for sewage sludge and coal have similar patterns. The highest emissions occurred for combustion in the 21% O_2 + 79% CO_2 mixture, then they decreased with increasing O_2 content.
6. SO_2 emissions for sewage sludge were insensitive to the composition of oxidizing atmosphere. In the case of coal, the highest emissions occurred for combustion in the 21% O_2 + 79% CO_2 mixture, then they decreased with increasing O_2 content.