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Industrial pollution

A QUALITATIVE AND QUANTITATIVE ASSESSMENT OF EMISSIONS PRODUCED BY INDUSTRIAL STEAM GENERATORS IN THE MASTER PLAN AREA OF THESSALONIKI

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Abstract. The qualitative as well as the quantitative assessment of emissions produced by the large industries located within the Master Plan Area of Thessaloniki is presented in this paper. Industries are considered large in terms of fuel consumed (either heavy oil or natural gas). The studies were realised by portable electronic flue gas analyser for the following parameters: flue gas temperature, ambient temperature, O_2 and calculation of CO_2 and excess air, smoke index at Bacharach scale, calculation of efficiency, CO, NO_x, SO_2, HC. Reduction of atmospheric pollution levels as a result of the increasing natural gas usage of the industry is one of the instrumental conclusions of the study.

Keywords: pollutant emissions, industrial steam generators, flue gas measurements, No 1-3 heavy oil, natural gas.

AIMS AND BACKGROUND

A process of deriving exhaust gases measurements produced by industrial steam generators is presented in the following paper. The study falls within the framework of the program: "Qualitative and quantitative assessment of emissions produced by industrial steam generators located within the Master Plan Area of Thessaloniki". The Organisation of the Master Plan and Environmental Protection of Thessaloniki is the manager of the above menioned program as it has elaborated a similar extensive Program in 1988-1990 (Ref. 1). This study aims to update the data of working conditions of steam generators from environmental and energy save point of view. The natural gas penetration in industries is in effect and already gave us the first results from the expected benefits but also the unexpected problems which appeared.

EXPERIMENTAL

The exhaust gases measurement realised in the 34 larger fuel consumer industries (either natural gas (NG) or two types of heavy oil, M1 and M3) took place from July to November 2000. The instrument used was a portable electronical flue gas analyser for stationary combustion sources with the following parameters: flue gas temperature (T_g), ambient temperature (T_a), draft, oxygen (O_2) and carbon dioxide (CO_2) and excess air (λ) calculation, Bacharach soot index (Rz), efficiency (n) calculation, carbon monoxide (CO), nitrogen monoxide (NO), nitrogen dioxide (NO_2) with separate sensor, sulphur dioxide (SO_2) and hydrocarbons – combustibles (HC). The measurements methodology is based on: the electrochemical cell principle for the exhaust gases (O_2, CO, NO, NO_2, SO_2), the thermocouple for gas temperature, a Pt500 sensor for ambient temperature, the pellistor for hydrocarbons, the Wheaston bridge for draft and the paper filter method for soot index. The analyser is automatically calibrated during the beginning of operation and by standard gases periodically, too. The sample point and the whole process was according to the Hellenic Standards FLOT 898[2], ELOT 525-1[3]. At the same time with the measurements the control group also filled out an inventory survey check list with various attributes of each installation, such as: manufacturer type, age and horsepower of boilers and burners, maintenance, etc. level of equipment, fuel consumption, hight-diameter-insulation of chimney.

RESULTS AND DISCUSSION

Figure 1 shows that the increase of excess air (λ) decreases the NO_x and SO_2 emissions at No 3 heavy oil (M3). The above applies to No 1 heavy oil (M1) as well. The increased quantity of excess air "dilutes" the emission pollutants. For this reason their adaption to normal reference conditions is necessary O_2 reference = 3% vol. ($\lambda = 20.95/20.95\text{-}O_2$ measured). For the above reasons, the $NO_{x\ rel}$, $SO_{2\ rel}$, CO_{rel} classifications (with $O_{2\ ref}$ = 3% vol.) results to higher values compared to the measured NO_x, SO_2, CO values (Figs 2-4). Table 1 also shows that the average ($NO_{x\ rel}$, $SO_{2\ rel}$, CO_{rel}) values are significantly higher than the corresponding average of measured values (NO_x, SO_2, CO) at No 1 – No 3 heavy oils. The lower excess air value observed at NG measurements shows no differences between measured and normalised ($O_{2\ ref}$ = 3% vol.) values at No 1 – No 3 heavy oil. In addition we can see in this case significantly lower values of NO_x and SO_2 compared to the corresponding average values at No1 – No 3 heavy oils.

Figures 5 and 6 show that the soot index (Rz) is not related to the excess air (λ) and flue gases temperature (T_g). It is thus related to other functional factors of the installation as proper warm up and diffusion pressure of fule, burner and boiler types, as well as proper maintenance.

We can also observe a significant decrease of efficiency (Δn) in Fig. 7. This is attributed the high concentration of unburned gases (CO and HC) due to uncompleted combustion in cases of marginal function regulations ($\lambda \sim 1$ or O_2 = 0% vol.). Only 37% of the industry are equipped the combustion monitoring

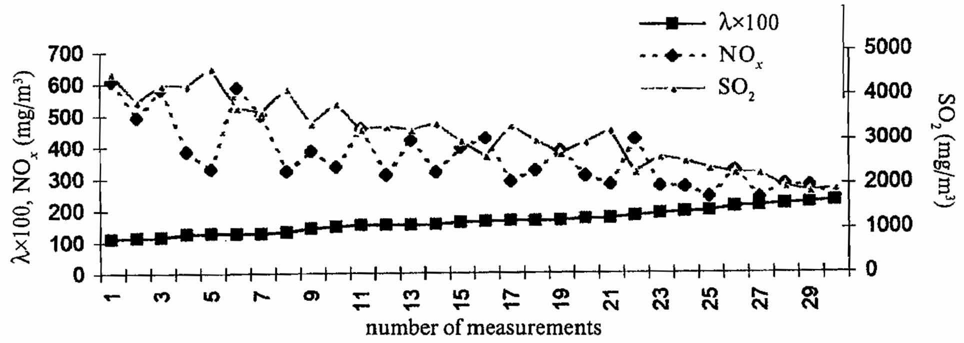

Fig. 1. Combination of fluctuation of the parameters: excess air (λ), NO_x and SO_2 of the No 3 heavy oil

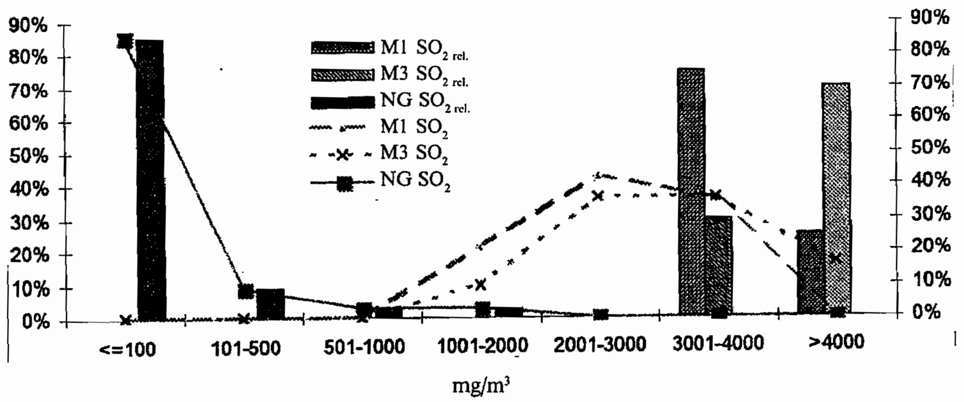

Fig. 2. Classification of SO_2 and $SO_{2\,rel}$ emissions by fuel type

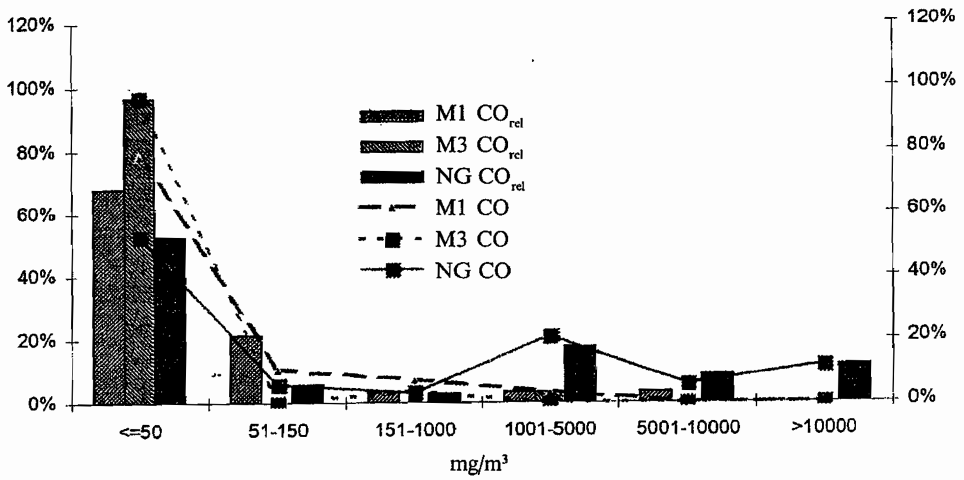

Fig. 3. Classification of CO and CO_{rel} emissions by fuel type

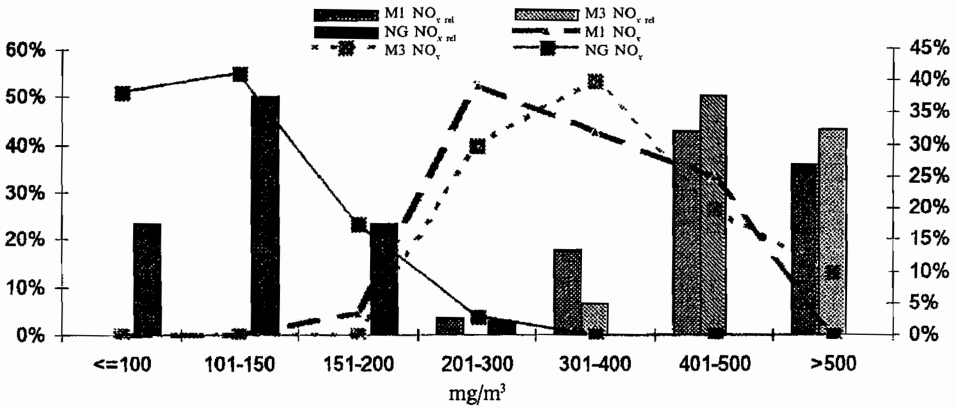

Fig. 4. Classification of NO_x and NO_{xrel} emission by fuel type

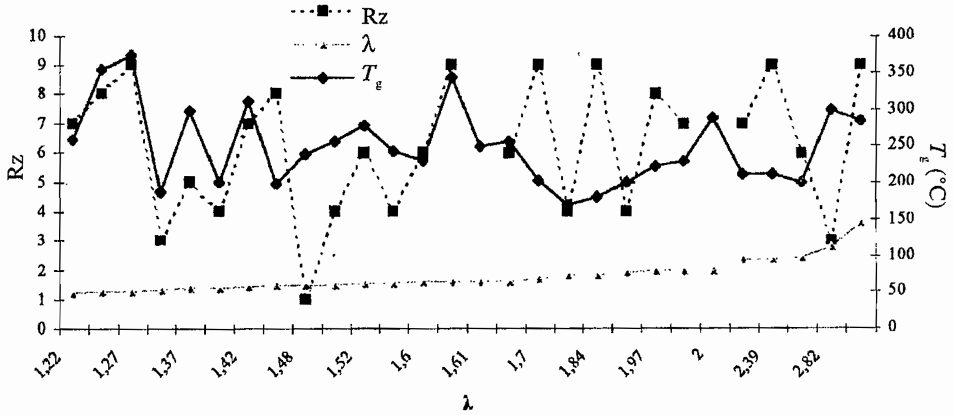

Fig. 5. Combination of fluctuation for the parameters: excess air (λ), soot index (Rz) and flue gases temperature (T_g) of the No 1 heavy oil

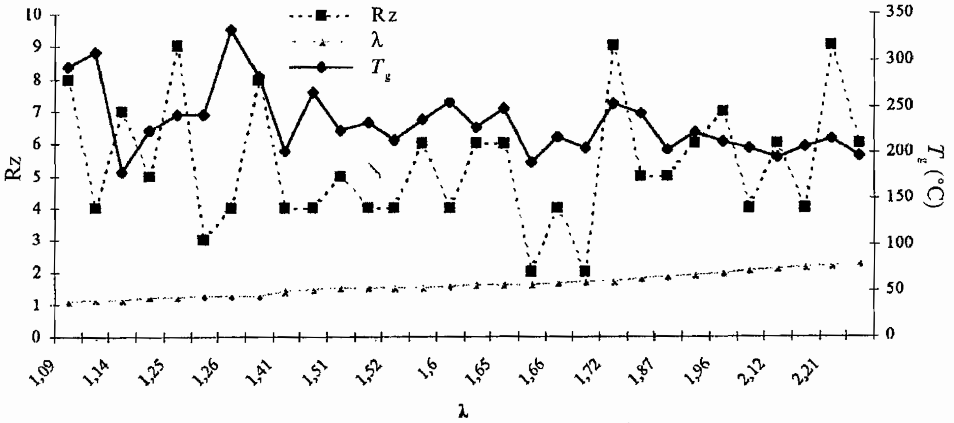

Fig. 6. Combination of fluctuation for the parameters: excess air (λ), soot index (Rz) and flue gases temperature (T_g) of the No 3 heavy oil

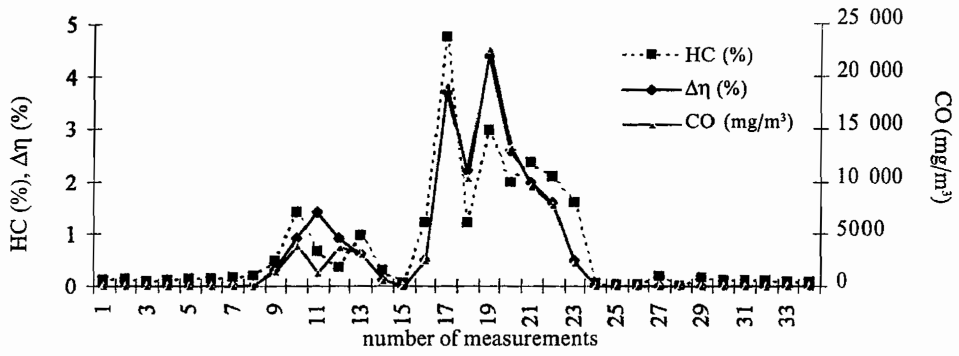

Fig. 7. Combination of fluctuation for the parameters: CO, HC with the decrease of efficiency (Δη)

insturments. On the other hand, 24% of them perform flue gases measurements on a daily or weekly basis[4].

The natural gas penetration in the industrial sector as a substitute of heavy oil is expected to bring about all the environmental benefits (such as elimination

Table 1. Average measured values of combustion exhaust gases parameters for various categories of installations and types of fuels

Fuel types Installation category	Measured values	O_2 (% vol.)	NO_x (mg/m³)	$NO_{x\,rel}$ (mg/m³)	SO_2 (mg/m³)	$SO_{2\,rel}$ (mg/m³)	CO (mg/m³)	CO_{rel} (mg/m³)
Heavy oil 1								
Total of installations	28	8.47	323.3	468.8	2652.8	3804	151.7	393.4
Heavy oil 3								
Total of installations	30	7.48	366.1	483.1	3136.9	4155.8	27	51.9
Natural gas								
Total of installations	34	3.96	109.5	122.7	241.3	241.4	3712.4	3857.5
Heavy oil 1								
Steam boilers	22	8.56	320.9	469.2	2701	3893.7	181.7	483.9
Heavy oil 3								
Steam boilers	28	7.78	356.8	488	3092.5	4192.3	28.9	55.1
Natural gas								
Steam boilers	29	3.1	115.2	124.9	283.9	284	4310.6	4313.5
Heavy oil 1 and Heavy oil 3 Thermal fluid heaters and quick-steam generators								
Total of installations	8	6.93	373.3	479.7	2796.7	3583.2	32.8	47.6

of particulates and soot emissions, drastic decrease of SO_2, NO_x, CO)[5]. The latter is to be achieved only when coordinated with proper combustion regulations and monitoring, using also the Best Available Technology.

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