RESPONSE SURFACE MODELS FOR THE POST-COMBUSTOR EFFICIENCY IN A PILOT PLANT COMBUSTION OF MSW

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ABSTRACT

Experimental data on PCDD and PCDF emission in raw gases from municipal solid waste combustion in a pilot plant were processed by a new Response Surface Model to gain information on process parameter values which optimize the post-combustor operating conditions.

KEYWORDS

Pilot plant, Combustion, MSW, PCDD, PCDF, Response Surface Models

INTRODUCTION

Our previous studies on PCDD and PCDF emissions in stack gases from municipal solid waste incinerators reflect the combined effects of combustion, heat exchange in the boiler and flue gas cleaning system (Pitea *et al.*, 1989a-g).

In a previous paper (Pitea *et al.*, 1989f), we reported the preliminary results of an extensive several-year pilot-plant testing and evaluation program conducted in order to obtain separate information on the combustion process and to investigate how operating parameters affect combustion. A preliminary chemometric analysis showed that Response Surface modelling of the emission from the combustion chamber in terms of the operative parameters permits the rationalization of the process conditions A further detailed investigation (Pitea *et al.*, 1990) lead to the finding of values for the process parameters which minimize the emissions of dioxins and furans and/or the productions of the most toxic congeners.

We have continued our interest in examining the emissions from the pilot plant, and are now able to report the results collected after the post-combustion chamber These results have been used in an evaluation of the efficiency of the post-combustor and to optimize its operating conditions, taking into account the relative decrease of the PCDD and PCDF amounts

EXPERIMENTAL DATA

A description of the pilot-plant has already been given (*Pitea et al.*, 1989f). Measurement of the process parameters such as oxygen, temperature and flue gas flow has been supplemented with the sampling of the raw gases at the exit of the combustion and of the post-combustion chamber. The furnace was fired with raw refuse. The data collected are listed in Table 1; the sample numbering refers to a wider study and only those cases where a decrease could be observed are considered here. In the computation of total PCDD and PCDF concentrations it was arbitrarily assumed (Bagnati *et al.*, 1990) that a "not detectable" (ND) value corresponds to a concentration (0.04 µg/Nm3) equal to half the lowest ND.

Table 1 lists the values of oxygen, temperature and gas flow both in the combustion and the post-combustion chamber, as well as their differences between the two points. Moreover, the same table lists the total amount of emissions from the combustor chamber and, finally, the percentage decrease of this value, due to the reactions induced in the post-combustor. The aim of this study is to relate this decrease, *i.e.*, the efficiency of the post-combustor, to its operating conditions and to those of the combustor. The numbering of samples refers to a larger study.

Table 1. Experimental data: operating conditions in sampling points A and B, total emission of PCDD and PCDF for the combustion chamber (Σ) and percent decrease induced by the post-combustor (D%).

RUN	$(O_2)_A$ % v	T_A °C	Q_A Nm^3/h	$(O_2)_B$ % v	T_B °C	Q_B Nm^3/h	ΔO_{A-B}	ΔT_{A-B}	ΔQ_{A-B}	Σ µg/Nm^3	D%
001	10.50	891.40	729.02	14.20	864.10	1869.14	3.7	-27.3	940.1	1217.95	57.30
002	9.60	784.97	588.45	12.30	1012.99	1544.46	2.7	228.0	1056.0	366.54	88.94
003	6.50	733.55	575.54	10.50	1038.16	1499.18	4.0	304.6	923.6	545.92	96.81
004	6.50	904.31	851.02	15.05	577.80	1013.66	8.5	-326.5	162.6	219.53	4.06
005	12.00	1041.04	459.48	13.50	731.78	503.52	1.5	-309.3	44.0	64.12	73.11
006	11.40	819.06	561.98	9.05	1071.22	1382.81	-2.3	252.1	820.8	21.06	88.94
009	12.80	704.54	560.93	10.85	875.63	1544.92	-1.9	171.1	984.0	250.51	98.72
010	16.60	687.27	707.38	11.00	952.11	1448.17	-5.6	264.8	740.8	62.52	90.18
011	14.10	555.03	553.13	13.80	719.40	1391.23	-0.3	164.4	838.1	8.07	94.30
012	15.10	417.55	607.69	13.80	528.78	1644.57	-1.3	111.2	1036.9	0.83	74.70
013	4.95	601.63	823.44	9.68	863.38	1268.83	4.7	261.7	445.4	3984.86	50.52
015	9.15	723.60	396.66	8.78	1011.29	1081.60	-0.4	287.7	684.9	9625.62	86.50
018	3.65	768.90	282.09	7.85	1050.24	1250.48	4.2	281.3	968.4	1522.78	38.43
019	11.00	860.59	636.15	10.75	991.78	1228.30	-0.2	131.1	592.1	79.99	79.31
021	11.50	858.04	755.79	11.50	538.28	1388.02	0.0	-319.8	632.2	388.55	67.17
022	11.50	815.11	740.76	11.50	550.89	1149.52	0.0	-264.2	408.8	368.43	61.57

RESULTS AND DISCUSSION

The capability of the post-combustor of reducing the amount of emissions, treated as relative reduction, was studied by response surface modelling. The Response Surface (RS) method (Box *et al.*, 1978) was to be used to gain insight into the possible nature of the joint effects of variables, here oxygen (O), temperature (T) and gas flow (Q), on the total PCDD+PCDF concentration (Σ).

Linear PLS modelling has been shown to be the best chemometric tool to identify causal relationships (Wold *et al.*, 1984; Clementi *et al.*, 1986). However with a few causal variables (the effect of which can be supposed to be non linear) the CARSO procedure (Clementi *et al.*, 1989), consisting in determining a linear PLS model on the expanded matrix of the raw data, and the non-linear PLS (*QPLS*) developed by Wold *et al.* (1989) appear to be more appropriate

A recent study on the two quadratic PLS models (Cruciani *et al.*, 1990) *has shown that* also the *QPLS* model, based on a non-linear inner relationship, can be described by a polynomial of second degree by means of an appropriate transformation of the *QPLS* loadings Moreover, this equation is quite similar to that obtained by CARSO in cases where the comparison was feasible. Therefore, it is possible to claim that the response surface obtainable by the two methods is substantially the same.

The CARSO procedure was suggested for handling problems with a relatively low number of variables, usually not higher than five. The finding that non linear PLS gives the same result as linear PLS on the expanded matrix permits the outlining of a new, refined, procedure for obtaining response surfaces via PLS.

Details and reasons for this are given elsewhere (Cruciani *et al.*, 1990) and only a brief summary is reported here. The method consists in modelling the raw data by *QPLS*, followed by computing the polynomial coefficients from the *QPLS* loadings, and then studying the response surface by means of the Lagrange analysis, as suggested in the ordinary procedure

The problem under investigation requires formulation as a response surface study where the post-combustor efficiency is described in terms of the operating conditions in the combustor, in the post-combustor, and therefore of their differences, as well as of the amount of emissions entering the post-combustion chamber. Since the causal variables are as many as ten it was appropriate to use the new procedure to detect the ranges of operating conditions which optimize the relative cutting down of emissions due to the post-combustor

The procedure, carried out on the data reported in Table 1, permitted both the interpretation of available data and their presentation in terms of optimal operating condition ranges It is clear that the most important features regard the oxygen in the operating conditions, the levels should be lower than in the combustion chamber. Moreover, it is necessary that the oxygen level in the combustion chamber is quite high, say higher than 12 Finally, one should also be warned that the efficiency of the post-combustor cannot be optimized when the entering amount of PCDD+PCDF is very high.

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