Correlation of Chlorine Input and Dioxin Output from Combustors:
A Review and Reanalysis

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Abstract

After more than twenty years of research, the relationship of chlorine input and the output of chlorinated dioxins and furans (PCDD/F) of full-scale waste combustors is still in question. In their analysis of data from municipal solid waste incinerators (MSWIs) and medical waste incinerators (MWIs), Rigo et al. (1995) reported finding no significant relationship between a surrogate for chlorine input, hydrogen chloride (HCl) emissions, and emissions of PCDD/F. A closer examination of the statistical values calculated by Rigo et al. shows that increased HCl emissions were associated with higher PCDD/F emissions at two-thirds of the MSWIs and MWIs. Reanalysis of the raw data from Rigo et al (1995) corroborated these statistical values.

Introduction

Many studies with laboratory- and pilot-scale combustion systems have demonstrated that chlorine input correlates positively with PCDD/F output or specific fractions of PCDD/F output, such as stack emissions or flyash.[1, 2, 3, 4, 5, 6, 7, 8] In contrast, Rigo et al. (1995) reported finding no significant relationship between chlorine input and PCDD/F emissions from full-scale MSWIs and MWIs.[9] This conclusion is at odds with those of other recent studies of full-scale combustors.[10, 11, 12, 13, 14, 15] Despite this apparent inconsistency, rapprochement is possible through a review of the statistical values calculated by Rigo et al. and reanalysis of the raw data presented in their report.

Experimental Methods

The confidence levels of the correlation coefficients calculated by Rigo et al. for each MSWI and MWI were determined. Also, the raw data for these individual facilities were reanalyzed, following the statistical method used by Rigo et al.

Results and Discussion

The statistical values calculated by Rigo et al. for individual MSWIs and MWIs are presented in Tables 1 and 2, categorized by confidence level. These values were corroborated, with generally good agreement, by reanalysis of the raw data for these combustors. The correlation coefficients

from Rigo et al. for MSWIs and MWIs are plotted in Figures 1 and 2, respectively, with confidence levels annotated. As shown, HCl and PCDD/F concentrations correlated positively at two-thirds of both MSWIs and MWIs.

At 15 of the 22 MSWIs for which Rigo et al. presented statistical values, HCl and PCDD/F emissions exhibited positive correlations at >95 percent confidence levels at five facilities and >90 percent at two. Among those facilities where negative correlations were evident, the correlation achieved >90 percent confidence at one facility. In comparison, Rigo et al. concluded that "17 facilities displayed no relationship -- two increased and one decreased."

For 10 of 15 MWIs, the statistical values from Rigo et al. show HCl and PCDD/F to correlate positively. Confidence levels of these positive correlations are as follows: >95 percent at two MWIs; >90 percent at one; >80 percent at two; and the remainder < 80 percent. At the five MWIs where the variables correlated negatively, data from one MWI achieved a confidence level of >95 percent, while the remainder were <80 percent. In comparison, Rigo et al. concluded that "14 [MWIs] showed no statistically significant trend, two increased and one decreased."

Data from trial burns, compliance tests, emission tests, etc., such as those evaluated by Rigo et al., are commonly regarded as insufficiently robust for rigorous statistical analysis.[13, 16, 17, 18] In other words, weak correlation coefficients and low confidence levels are to be expected. Further, simple correlation analysis as used by Rigo et al.(1995) in assessing MSWIs and MWIs, is appropriate for assessing linear relationships. However, its application to variables that correlate in a non-linear fashion, as has been reported for HCl and PCDD/F emissions in one study[19] and suggested by the data from other studies,[2, 20] can be expected to generate weak correlation coefficients with low confidence levels.

Despite these and other limitations, the statistical values calculated by Rigo et al. show that HCl and PCDD/F emissions correlated positively at two-thirds of both MSWIs and MWIs. This predominance of positive correlations is in agreement with the findings of recent, more rigorous studies of individual, full-scale combustors in which increased chlorine input has been accompanied by higher PCDD/F output in stack gases and/or other combustor residues.

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Table 1 Municipal Solid Waste Incinerators -
Statistical Values from Rigo et al. (1995)

RRID	Facility	n	R	p
Positive Correlation at >95% Confidence				
153	Detroit	6	0.94794	0.0040
191	Helsingor	8	0.79663	0.0180
44	Lancaster	18	0.50202	0.0338
51	Pittsfield (Vicon)	38	0.46688	0.0031
195	Refa	30	0.36768	0.0456
Positive Correlation at >90% Confidence				
188	Kara	15	0.47298	0.0750
189	Reno Syd	33	0.31156	0.0776
Positive Correlation at <80% Confidence				
156	Hartford	26	0.02270	0.9123
71	Horsholm	26	0.25478	0.2091
150	MERC	8	0.12076	0.7758
92	Quebec	13	0.10524	0.7322
145	Quebec SS	35	0.01812	0.9177
171	Roosendaal	3	0.89936	0.2881
196	Thyra	7	0.16151	0.7294
89	Wurtzburg	30	0.14258	0.4523
Negative Correlation at >90% Confidence				
100	Albertslund	11	-0.53511	0.0898
Negative Correlation at <80% Confidence				
217	Amager	8	-0.49805	0.2091
194	Brondby	14	-0.24906	0.3905
168	Oswego	21	-0.25401	0.2665
175	PRRI	7	-0.03593	0.9390
187	Reno Nord	37	-0.21551	0.2089
80	Westchester	37	-0.0560	0.7420

Table 2 Medical Waste Incinerators
**Statistical Values from Rigo et al. (1995)**

RRID	Facility	n	R	p
Positive Correlation at >95% Confidence				
84	AMI Central	9	0.97287	0.0000
203	Frederikssund	6	0.96237	0.0021
Positive Correlation at >90% Confidence				
214	Borgess	11	0.55923	0.0737
Positive Correlatin at >80% Confidence				
190	Kaiser	4	0.89140	0.1086
207	Lenoir	9	0.55092	0.1242
Positive Correlation at <80% Confidence				
208	Cape Fear	9	0.41341	0.2687
132	Cedars Sinai	5	0.42033	0.4810
198	St. Bernardines	3	0.74254	0.4672
199	Sutter	3	0.47290	0.6864
211	U. of Michigan	6	0.30728	0.5536
Negative Correlation at >90% Confidence				
213	Morristown	12	-0.86203	0.0003
Negative Correlation at <80% Confidence				
193	Huldovre	6	-0.14038	0.7908
46	Rochester	3	-0.86035	0.3405
206	Stanford	6	-0.06997	0.8952
205	USC Medical	3	-0.2137	0.8629

FIGURE 1

Municipal Solid Waste Incinerators

Correlation of HCl and Dioxin Concentrations, as
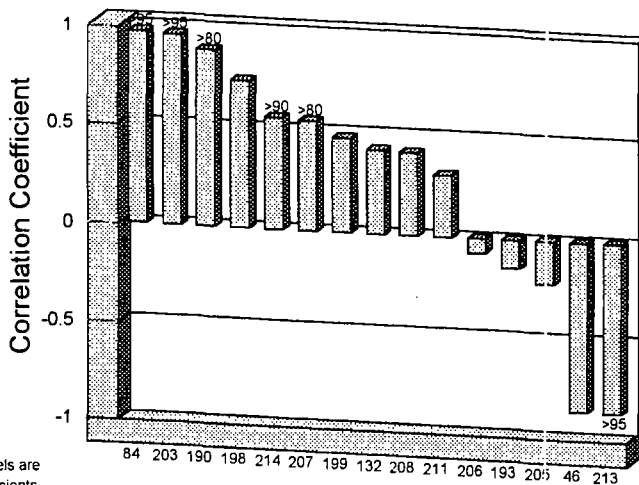Calculated by Rigo et al.
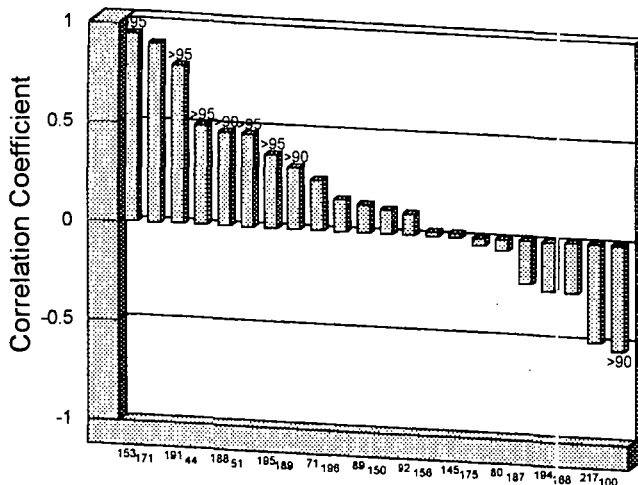
Confidence levels are based on
coefficients and p-values from
Rigo et al. Those that are 80%
and higher are as noted.

22 Facilities by Identification Code

FIGURE 2

Medical Waste Incinerators

Corrrelation of HCl and Dioxin Concentrations,
as Calculated by Rigo et al.

Confidence levels are
based on coefficients
and p-values from Rigo
et al Those that are
80% and higher are as
noted

15 Incinerators by Identification Code