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Metals and incinerators: The latest regulatory phase

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Abstract

Recent regulations in the United States controlling emissions of metals and halogen acid gases from boilers and industrial furnaces (BIFs) burning regulated hazardous waste pose new sampling and analysis requirements. All Resource Conservation and Recovery Act (RCRA)-permitted hazardous waste incinerators will also have to comply eventually with these new standards. A presentation concerning two captive hazardous waste incinerators presents analytical requirements for complying with Tier I standards, the sampling and analysis requirements for complying with Tier II, and how facility siting can impact on permitted emissions. Some problems are foreseen in meeting the new standards for chromium and chlorine.

Introduction

Since 1976, when Congress passed the Resource Conservation and Recovery Act (RCRA), the U.S. Environmental Protection Agency (EPA) has been charged with the responsibility of managing America's hazardous waste disposal [1–3]. Some would argue that the agency has done a poor job of implementing the intent of Congress; others will have you believe the agency went far beyond what was intended. The most important issue to come out of RCRA is the promulgation of rules and regulations covering environmentally acceptable disposal practices for wastes determined to be hazardous.

Incineration has been, and will be in the future, the disposal option of choice, because when applied in a sound engineering and professional setting, the target organic waste is destroyed. Contrary to many land disposal practices of the past where organic wastes were poured, stored or discharged into impoundments, incineration has the capability of managing the material the first time with no future costs to society. The remaining inert residuals can be safely managed by solidification/encapsulation processes and placed in a specially designed landfill with groundwater monitoring built in.

Regulators, environmental activists and citizens near incinerators have demanded strict adherence to good design and operating practices. This is accomplished by developing very strict operating controls and establishing safe op-

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erating conditions. To this end, regulations can be considered a dynamic and evolving process. In what follows, we present the newest regulatory phase for controlling emissions of particulate matter from incinerator stacks with concomitant regulation of toxic metal emissions.

Regulatory developments

The existing hazardous waste incinerator regulations partially control metal and some organic emissions through the performance standard for particulates. The EPA states in its proposed rules for hazardous waste incinerators that the present particulate standard of 180 milligrams per dry standard cubic meter (0.08 gr/dscf) may not provide adequate protection if a substantial percentage of the particulate is composed of toxic metals [4]. Continuing, it says that even relatively low concentrations of toxic metals in wastes can result in unacceptable levels of risk if the wastes are burned in incinerators with no air pollution control devices (APCDs). Using a 1981 survey, the agency goes on to say that almost half of all interim status incinerators had no APCDs, because as liquid waste incinerators, they did not emit sufficient particulate matter or acid gases to warrant an APCD to meet the 0.08 gr/dscf standard.

To add confusion, and a large degree of concern in some quarters, the EPA in its Federal Register publication of October 26, 1989 stated that they are keeping the 0.08 gr/dscf for boilers and industrial furnaces burning hazardous waste, because the agency feels it would provide a common measure of protection from particulate emissions [5]. Much concern over particulate emissions containing toxic metals has been expressed by various environmental groups; to date no agreement has been reached over what is a safe level of particulate emissions.

The EPA first proposed the possibility of regulating metal emissions from devices burning hazardous waste in May of 1987. After a couple of years reviewing comments, the agency promulgated metal emission regulations on December 31, 1990. The proposed regulations cover three tiers of procedures to define compliance. Ten metals of concern are regulated, and calculations related to effective stack height which translate into varying feed rates or emissions limits for each metal. Each tier includes land use rates and terrain-adjusted values. The agency has included a table of conservative removal efficiencies for the metals using the various combinations of air pollution control devices, assuming that a device is installed on the incinerator, or BIF. Finally, the agency presents a table of exempt quantities for small-quantity burners based on terrain-adjusted effective stack heights [6].

The exemption of small-quantity burners discussion can be summarized by saying that if a “device” has a stack 30 meters high, as found in the table, 140 gallons (530 L) per month of hazardous waste may be burned as long as it is generated by the plant’s processes.

Terrain adjustments

For purposes of the rule, the agency indicates that a facility is considered to be in flat terrain if the maximum terrain rise within 5 km of the stack is not greater than 10 percent of the physical stack height. The facility is in rolling terrain if terrain rise is greater than 10 percent but not greater than the physical stack height, and in complex terrain if terrain rise is greater than the physical stack height.

The agency further states that there is no significant difference in dispersion coefficients between flat and rolling terrain. Thus, these terrain types are merged and classified as non-complex terrain.

There are special considerations presented with the recommendation that the permit writer should require site-specific dispersion modeling in establishing screening limits, so as to demonstrate that emissions do not pose unacceptable health risks [4]. These are:

- Facility is located in a narrow valley less than 1 km wide; or
- Facility has a stack taller than 20 m and is located such that the terrain rises to the stack height within 1 km of the facility; or
- Facility has a stack taller than 20 m and is located within 5 km of the shoreline of a large body of water; or
- The facility property line is within 200 m of the stack and the physical stack height is less than 10 m; or
- On-site receptors are of concern, and the stack height is less than 10 m.

Land use adjustments

Areas in the vicinity of an incinerator are classified as urban or rural in order to set risk-based emission limits. This was required since dispersion rates differ, and thus, the risk per unit emission rate will differ accordingly.

The EPA, in its final rule, has provided two alternative procedures to determine land use: (1) land use typing, or (2) a method based on population density. Both approaches require consideration of characteristics within a 3 km radius from a source; in our case, the incinerator stack. The land use method is preferred because it is more directly related to the surface characteristics that effect dispersion rates.

Using the 3 km radius, the agency determined that if greater than 50 percent of the land was classified as urban, the models were executed in the urban mode for the facility. Similarly, if greater than 50 percent was classified as rural, the rural models were used.

Later in this presentation, the terrain adjustments, calculation for effective stack height, and land use values will be determined for two different facilities. It is noted that EPA maintains no distinction between urban versus rural land use in a complex terrain.

Regulated metals

The EPA has listed ten metals which require regulations governing their emission to the environment. Four of these are carcinogenic. The regulated six non-carcinogenic metals are: Antimony (Sb), Barium (Ba), Lead (Pb), Mercury (Hg), Silver (Ag), and Thallium (Tl). The carcinogenic metals regulated are: Arsenic (As), Beryllium (Be), Cadmium (Cd), and Chromium (Cr.)

Field results

Using the tables provided by the EPA in Ref. [6], the results of two project studies will be presented.

First field study

In the first case study, the following data is provided:

- Liquid injection incinerator, two waste streams
- Non-complex terrain
- Rural land use characteristics
- Physical stack height, 30 m
- Stack gas flow rate, 17600 ACFM
- Stack gas temperature, 117 °F
- Stream 1 feed rate = 4363 lb/h
- Stream 2 feed rate = 1020 lb/h

Some calculations must be performed which are necessary to provide an effective stack height based on Appendix VI in Ref. [6]. Since the exhaust temperature is presented in degrees Kelvin, calculations to convert degrees F to degrees K are required to use the table correctly. First convert gas temperature:

$$^\circ\mathrm{C}=\frac{^\circ\mathrm{F}-32}{1.8} \quad \text{and} \quad \mathrm{K}={}^\circ\mathrm{C}+273$$

so that for the above given stack gas temperature, we get

$$\frac{117\,^\circ\mathrm{F}-32}{1.8}=47\,^\circ\mathrm{C}+273=320\ \mathrm{K}$$

Next we convert the flow rate from ACFM to m^3/s:

$$\frac{\mathrm{m}^3}{\mathrm{s}}=\frac{17\,600\ \text{actual ft}^3}{\mathrm{min}}\times\frac{\mathrm{m}^3}{35.3\ \mathrm{ft}^3}\times\frac{\mathrm{min}}{60\ \mathrm{s}}=8.3\ \mathrm{m}^3/\mathrm{s}$$

From Appendix VI of Ref. [6], for stack gas at 320 K and flow rate of 8.3 m^3/s, three meters can be added to the physical stack height to obtain the effective stack height of 33 m.

Using Table 1B and 1D of Appendix I of Ref. [6], the following in Table 1

TABLE 1

Feed rate screening limits [6]. Effective height used in 35 m (Study 1)

Metal	Tier I limit (g/h)
Sb	720
Ba	120 000
Pb	210
Hg	720
Ag	7 200
Tl	720
As	5.4
Cd	13
Cr	1.9
Be	9.6

TABLE 2

Waste stream analysis (Study 1) [6]

Metal	Stream 1 ($\mu g/g$)	Stream 2 ($\mu g/g$)
Sb	< 0.231	< 0.231
As	< 0.247	< 0.247
Ba	< 2.00	< 2.00
Be	< 0.10	< 0.10
Cd	1.20	< 0.50
Cr	< 1.00	< 1.00
Pb	< 1.00	< 1.00
Hg	< 0.103	< 0.103
Ag	< 1.00	< 1.00
Tl	< 1.00	< 1.00

listed feed rate screening limits are observed, using an effective stack height of 35 m since 33 m is not available.

Next, the metals feed rates must be calculated. In order to accurately conduct a Tier I analysis, it is necessary to perform a metals analysis of the waste stream to the sub-part-per-million level using all approved digestion and analytical techniques given in "Test Methods for Evaluating Solid Waste—Physical/Chemical Methods," SW-846, third edition, 1986, or "Methods Manual for Compliance with BIF Regulations," EPA document No. EPA/530-SW-91-010, published as Appendix IX of Ref. [6]. For this example calculation, the following waste analysis for Streams 1 and 2 is presented in Table 2. The "<" symbol denotes metals levels below the detection limit.

To determine the quantity of each metal fed to the incinerator, multiply the concentration by the feed rate and divide by 10^6. The result of this calculation

is then summed for the two streams and compared against the allowable Tier I screening limit (Table 3). Calculate each metal feed rate as follows:
Example using Sb = 0.231 $\mu g/g$
Feed rate Stream 1 = 4363 lb/h

$$4363\ \text{lb/h} \times 0.231\ \mu\text{g/g} \times \frac{1\ \text{g}}{1\ 000\ 000\ \mu\text{g}} = 0.001\ \text{lb/h}$$

Calculating all feed rates with analysis results in the following:

Total specific metal feed rate = Stream 1 + Stream 2

Use Cd results:

$$4363\ \text{lb/h} \times 1.2\ \mu\text{g/g} \times \frac{1\ \text{g}}{1\ 000\ 000\ \mu\text{g}} \times 454\ \text{g/lb}$$

$$= 2.377\ \text{g/h} + 1020\ \text{lb/h} \times 0.50\ \mu\text{g/g} \times \frac{1\ \text{g}}{1\ 000\ 000\ \mu\text{g}} \times 454\ \text{g/lb} = 0.232$$

Total Cd fed = 2.377 + 0.232 = 2.609 g/h

For this case, the incinerator passes the Tier I screening limit standards for all metals except chromium (Table 3). Here there is a problem, since Cr is not used in any production process, but most often the pipes carrying the waste stream and the vessel used in production are stainless steel, which contains Cr. For this case to be resolved to the satisfaction of the regulators, the facility owner will have to sample the stack gases for Cr during the RCRA trial burn.

TABLE 3

Resulting metal loads to the incinerator from Streams 1 and 2 in Table 2 compared against the Tier I screening limit standards (Study 1)

Metal	Total feed rate (g/h)	Result
Sb	0.564	Pass
As	0.604	Pass
Ba	4.888	Pass
Be	0.244	Pass
Cd	2.609	Pass
Cr	2.444	Fail
Pb	2.444	Pass
Hg	0.252	Pass
Ag	2.444	Pass
Tl	2.444	Pass

To be conservative in Tier I screening limits, EPA assumes no metal partitioning, and all metals entering the incinerator are assumed to be discharged from the stack, with no allowance made for removal by air pollution devices.

In Ref. [5], Table G-3, the agency provided a conservative estimate of removal efficiencies of various metal species by various combinations of air pollution control devices. For this case, a wet scrubber with a packed bed absorber is used. The table indicates a 50% removal potential for chromium in this device. Calculations show chromium at the levels reported still to be a regulatory compliance issue, and the owner may have to evaluate reduced feed rates or an improved air pollution control device.

Second field study

In this study, the incinerator is located in a complex terrain, but in a generally rural land use area. The following data are provided:

- Liquid/fume incinerator, two waste streams
- Complex terrain
- Rural land use characteristics
- Physical stack height, 70 ft
- Stack gas flow rate, 50 000 ACFM
- Stack gas temperature, 621 °F
- Stream 1 feed rate = 12 630 lb/h
- Stream 2 feed rate = 919 lb/h

Next, upon completion of the necessary calculations, one determines that the effective stack height is 48 m. Tier I feed rate screening limits for the metals were the basic study conditions for the following results.

From Tables 1-C and 1-E of Ref. [6], the in Table 4 noted screening limits at 50 m effective stack height are obtained (instead of 48 m).

Waste analysis reveals the results listed in Table 5.

TABLE 4

Screening limits at 50 m effective stack height (Study 2) [6]

Metal	Tier I limit (g/h)
Sb	360
Ba	60 000
Pb	110
Hg	360
Ag	3 600
Tl	360
As	2.9
Cd	6.8
Cr	1.0
Be	5.0

TABLE 5

Waste analysis results of the second field study

Metal	Stream 1 (mg/kg)	Stream 2 (mg/kg)
Sb	0.175	<6.20
As	<0.08	<2.00
Ba	0.02	0.30
Be	<0.006	<0.15
Cd	<0.006	<0.15
Cr	0.0095	0.25
Pb	<0.10	<2.50
Hg	<0.003	0.075
Ag	<0.02	<2.10
Tl	<0.175	<3.50

TABLE 6

Resulting metal loads to the incinerator from Streams 1 and 2 of Table 5 (Study 2) compared against the Tier I screening limit standards

Metal	Total feed rate (g/h)	Result
Sb	3.590	Pass
As	1.293	Pass
Ba	0.240	Pass
Be	0.097	Pass
Cd	0.097	Pass
Cr	0.159	Pass
Pb	1.616	Pass
Hg	0.048	Pass
Ag	0.991	Pass
Tl	2.464	Pass

To determine the quantity of each metal fed to the incinerator using the analytical results and feed rates, the following calculation is conducted (Table 6).

Use Sb results:

$$12\,630 \text{ lb/h} \times 0.175 \text{ mg/kg} \times \frac{1 \text{ kg}}{1\,000\,000 \text{ mg}} \times 454 \text{ g/lb}$$

$$= 1.003 \text{ g/h} + 919 \text{ lb/h} \times 6.2 \text{ mg/kg} \times \frac{1 \text{ kg}}{1\,000\,000 \text{ mg}} \times 454 \text{ g/lb} = 2.587$$

$$\text{Total Sb fed} = 1.003 + 2.587 = 3.590 \text{ g/h}$$

Study 2 clearly passes all Tier I feed rate screening limits at the conditions tested. If there had been any question about a certain metal, the owner would have to conduct the emission screening test required for Tier II.

In Ref. [7] regarding the terrain-adjusted effective stack height, a statement reads:

> "Subtract the maximum terrain rise within 5 km from this value to determine the terrain-adjusted effective stack height. If the terrain-adjusted effective stack height minus the maximum terrain is less than four meters (or is a negative number), then use four meters as the terrain-adjusted effective stack height."

Using these values from Tables 1-C and 1-E for the 4 m terrain-adjusted effective stack height, the results of Table 7 are obtained. It is evident from Table 7 that As and Cr would fail the Tier I feed rate screening limits and would require Tier II testing.

Analytical requirements

The new regulations for metals will require owners and operators to quantitatively analyze the waste streams for the ten regulated metals. In almost every case, the analysis will have to be at the very low sub-ppm level with accurate detection limits presented. The analysis of many waste streams to this level can be very challenging for many analytical laboratories. Our experiences have shown that digestion and extraction can be a problem with certain metals and organic streams, and sufficient samples must be collected to permit the necessary detection limits to be achieved.

These problems exist at the front end of the metals issue. There is also the problem of adequate and/or appropriate source sampling techniques to meet the Tier II requirements. For the determination of metals in emissions from incinerators, Multiple Metals Sampling Train, as described in "Methods Man-

TABLE 7

Results from the terrain-adjusted effective stack height [7]

Metal	Tier I and Tier II feed rate and emission screening limits (g/h)	Result
Sb	14	Pass
As	0.11	Fail
Cd	0.26	Pass
Cr	0.04	Fail
Be	0.20	Pass
Pb	4.3	Pass

ual for Compliance with BIF Regulations" (Appendix IX of Ref. [6]), must be used. The incorporation of the Multiple Metals Sampling Train will be increasingly used in the future, which will have the potential of extending RCRA trial burns by several days and adding significant cost to the overall process.

The EPA has provided a new method for Cr^{6+} determination from incinerators, boilers and industrial furnaces and it is in the draft stage of development. Samples are collected isokinetically from the source. To eliminate the possibility of Cr^{6+} reduction to Cr^{3+}, the emissions samples are collected with a recirculatory train where the impinger reagent is continuously recirculated to the nozzle, the impinger train samples are analyzed for Cr^{6+} by an ion chromatograph equipped with a post-column reactor and a visible wavelength detector. It is not known at this time how the Cr^{6+} sampling will be integrated with the U.S. EPA Method 5, Modified Method 5, Volatile Organic Sampling Train, Multiple Metals Train, Continuous Emission Monitors, hydrochloride/chlorine (M-5, MM-5, VOST, M-0012/0013, CEMs, M-0050/0051) and any others to emerge. It is a fact that space on sampling platforms of most stacks is rapidly becoming scarce.

Discussion

The EPA is regulating 10 metals through the use of Tier I feed rate limits, Tier II emission limits and Tier III site-specific risk assessments. Many captive hazardous waste incinerators (those not used commercially) should meet the Tier I limits. Those not meeting Tier I will have to conduct source sampling as required by Tier II regulations.

Conclusions

In the event of special circumstances like terrain, land use, or air pollution control device efficiency, some incinerators will have to conduct risk assessments and have the results reviewed and scrutinized by officials in the permit review process. There is also the very real probability that Tier III analyses will result in capital outlay of funds for air pollution control device installation.

Many laboratories conducting metal analyses for or on hazardous waste must have staff familiar with EPA quality assurance/quality control (QA/QC) requirements, must be knowledgeable about waste reactivity upon digestion and must be capable of generating analytical data at the sub-ppm level. As the metal regulations become law, the analytical laboratory will play a very large role in the determination of a facility permit language and extent of stack sampling required.

Based upon early experience with these new regulations, it appears that some captive incineration facilities will have to add or significantly upgrade the air pollution control devices in order to pass several metal feed rate and/or emission limits. The emission limits for Cr and As are very stringent, and this is compounded by the fact that stainless steel used in the production and transportation processes has resulted in Cr not passing Tier I review.

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