United States
Environmental Protection
Agency

Environmental Sciences Research
Laboratory
Research Triangle Park NC 27711

Research and Development

EPA-600/S3-83-102 Dec. 1983

EPA

Project Summary

Formation of a Detached Plume from a Cement Plant

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A coordinated study of process, source emissions, and plume sampling was conducted at a coal-fired cement production plant. Both source and plume sampling consisted of particle and gas measurement and characterization. Particulate sampling of both the source and plume addressed particle size, amount, and composition. Particles were analyzed by scanning electron microscopy, x-ray fluorescence spectroscopy, and chemical means. Gas sampling of both the source and plume involved conventional source sampling methods as well as procedures adapted to this specific measurement program. Plume opacity was measured by visual observation and a LIDAR system.

Comparison of the results from the plume and source measurement indicated the formation of the plume was the result of the reaction of ammonia and hydrochloric acid. The formation of ammonium chloride occurred within the same set of reaction parameters as independent laboratory studies had previously indicated.

The results of electron microscopy analysis for one of the plume samples indicated an NH_4Cl particle size of ≤ 0.4 μm. When an estimation of the amount of these sized particles was compared to source particle sizing measurements, a 50 to 100% increase in such inhalable particulates was occurring within the plume, at less than 18 stack diameters from the exit.

This Project Summary was developed by EPA's Environmental Sciences Research Laboratory, Research Triangle Park, NC, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

This report discusses an in-depth study of a coal-fired cement production plant to determine the nature of the formation of a visible plume from the gases emitted from the stack. The plant has the capability of operating on either a regular mode or a bypass mode. The visible plume formed each time the plant operated in the bypass mode. During the regular mode, the off gases from the coal-fired kiln passed through the raw product grinding mill and a recovery electrostatic precipitator (ESP) prior to their exit to the atmosphere. During the bypass mode, the kiln gases were rerouted around the mill and through a cooling tower, after which they were passed through the ESP and vented to the atmosphere. During both operating modes, source measurements indicated that the plant was well within compliance for both opacity and particulate grain loading.

A 1-week (5-day) sampling program was conducted at the Lehigh plant at Leeds, Alabama, in May 1981. The sampling addressed both source emissions of gases and particles and plume sampling. Source emissions were sampled by conventional extractive methods to determine the concentrations of SO_2, NH_3, HCl, and NO_x as well as particulate mass emission rates, particle size, and particle composition. Gaseous HCl, NH_3, SO_2, CO and CO_2 were also measured with an optical cross-stack procedure. The plume sampling was performed with tethered balloons and various filters. The filters, which were connected to a pump box on the ground, were analyzed for such gases as

HCl, NH_3, SO_2, and the particles were analyzed for $SO_4^=$, $SO_3^=$, Cl^-, NH_3, by x-ray fluorescence spectroscopy, and scanning electron microscopy. Opacity measurements for the plume at and near the location of the balloon sampling location were performed with both a LIDAR system and by visual observation.

Results

Inclement weather and plant operating problems severely limited the time during which sampling of the bypass mode plume could be performed. However, adequate data were established to conclude how the particles were formed in the plume.

These data included:

1) In-stack measurements indicated that particulate NH_4^+ and Cl^- emissions of 0.68 (expressed as NH_3) and 7.21 (expressed as HCl) lb/hr were emitted and that ~85 percent of the NH_3 and ~50 percent of the HCl were emitted as gases. A second improved HCl reference method indicated ~80 percent of the HCl was emitted as gas phase.
2) The mass emission rate of particulates from the stack was 7.7 and 15.4 lb/hr from two samples acquired. X-ray fluorescence analyses of the particles indicated their main components as Ca, Si, K, Fe, S, and Al. A Pilat impactor sample indicated that 56 percent of the total particulate catch was on the backup filter where the particles were less than 0.4 μm in size.
3) Gas and particle composition of the plume were determined with a three-stage filter designed to collect particles and gaseous HCl, NH_3 and SO_2. The second filters following the front prefilter were chemically impregnated to absorb gaseous components passing through the particulate filter. Analyses of all three filters indicated a total catch of 1.86, 1.13, and 12.5 μ moles of HCl, NH_3, and SO_2, respectively. The first of the three filters was assumed to collect particles only. The first filter collected 1.25, 0.75, and 0.08 μ moles of HCl, NH_3, and $SO_4^=$, respectively. This indicated that ~ 40% of the HCl and NH_3 had reacted to form particles but that very little (~ 7 percent) of the SO_2 had been converted or was contained as particulate $SO_4^=$.
4) Scanning electron microscopy of two plume samples acquired during the high opacity situation indicated a particle size range of 0.2 to 0.6 μm for both samples. In one of the samples a predominant number of particles contained Cl^- and were volatile in the electron beam. It was assumed that NH_4Cl was the basic particle component. The second sample contained a large number of particles with K and S. There were no significant particles containing Cl^- in this sample. These particles were assumed to contain K_2SO_4.
5) Opacity measurements by the LIDAR system and by visual observation agreed well and ranged from less than 5 percent near the stack exit to as high as 41 percent within 50 m of the exit.

Conclusions

The change from an invisible plume just above the stack to a highly opaque plume ~ 50 m from the stack indicates some kind of particle formation.

The change in composition between in-stack and plume samples showed a conversion of gaseous NH_3 and gaseous HCl to particulate matter containing NH_4^+ and Cl^-. That this particulate matter was indeed NH_4Cl was supported by electron microscopy. There was also some evidence of $SO_4^=$ formation. The increase in particulate matter in the plume within 50 m downwind of the stack exit resulted in an estimated double amount of fine or inhalable particulate matter than that indicated by the source measurements.

It was concluded from the data that the visible plume formed during bypass mode operation was the result of fine particle formation, predominantly NH_4Cl, but with some sulfite-sulfate salt formation, probably a result of water droplet chemistry.

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The complete report, entitled "Formation of a Detached Plume from a Cement Plant," (Order No. PB 84-120 187; Cost: $11.50, subject to change) will be available only from:

National Technical Information Service
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☆U S GOVERNMENT PRINTING OFFICE 1983—759-015/7247

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