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EPA

Project Summary

Emissions of Air Toxics from a Simulated Charcoal Kiln Equipped with an Afterburner

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A laboratory-scale charcoal kiln simulator was constructed and tested to determine if it could be used to produce charcoal that was similar to that produced in Missouri-type charcoal kilns. An afterburner was added later to study conditions for oxidizing the volatile organic compounds contained in the combustion gases that are produced when wood is converted to charcoal. Five burns were conducted to shake down the operation of the afterburner. Then four full burns were completed to measure the effectiveness of the afterburner. Based on these simplified studies on the effect of an afterburner on emissions from Missouri-type charcoal kilns, it appears that, while the afterburner can offer significant benefits under some conditions, the operation of the afterburner is not a trivial matter. A system, such as a charcoal kiln, that relies on natural draft for operation may be upset by adding an afterburner due to pressure changes in the stack that influence the natural draft. Optimizing the process, both in the sense of good charcoal quality and good afterburner performance, may be difficult without the benefit of continuous emission monitors.

This Project Summary was developed by the National Risk Management Research Laboratory's Air Pollution Prevention and Control Division, 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

A Missouri-type charcoal kiln is a small building (usually about 40 ft wide, 60 ft long, and 16 ft high), often constructed with brick, cement, or metal, that is used to burn wood in a limited supply of air to produce charcoal. The U.S. Environmental Protection Agency, National Risk Management Research Laboratory, Air Pollution Prevention and Control Division (APPCD) agreed to provide EPA Region 7 Air, RCRA (Resource Conservation and Recovery Act), and Toxics Division with chemical and physical information to characterize the plumes from Missouri-type charcoal kilns. That work was completed as planned and resulted in several important conclusions, including:

- Charcoal could be produced in the laboratory-scale kiln simulator. The charcoal produced in the simulator was identical to that produced in Missouri-type kilns according to characteristic measurements performed on the two charcoals.
- The simulated charcoal kiln produced combustion gases containing significant amounts of volatile and semivolatile organic compounds. Benzene was found in the combustion gases at concentrations approaching 2000 ppmv.
- Many oxygenated organic compounds were found in the combustion gases from the simulated charcoal kiln.
- Several polycyclic aromatic hydrocarbons (PAHs) were found in the simulated charcoal kiln combustion gases.

As the earlier experiments were being conducted, Region 7 requested that an additional research study be conducted by APPCD during fiscal year 1998 to obtain information on the effectiveness of adding afterburners to these kinds of charcoal kilns.

The objectives of this work were:

- To install an afterburner on the simulator used in the earlier experiments.
- To produce charcoal that was representative of that produced in Missouri-type charcoal kilns while using the afterburner.
- To install a larger dilution tunnel capable of greater dilution ratios and more representative samples of condensable organic matter and particulate.
- To improve the seals in the kiln simulator to minimize unknown sources of air in-leakage.
- To determine the concentrations of several pollutants that were not measured in the earlier tests in the combustion gases generated as the wood was converted into charcoal.
- To determine if any of those pollutants could be destroyed by passing them through an afterburner inserted into the exit duct from the simulated charcoal kiln.

Variables that were measured on a continuous basis included the weight of the kiln, the temperature at various places inside the simulator, and the concentrations of carbon monoxide (CO), carbon dioxide (CO_2), nitric oxide (NO), total hydrocarbon compounds (THCs), and oxygen (O_2) in the combustion gases as the gases exited the afterburner. This set of variables is referred to collectively in this document as the “continuous measurement variables.” Nine experiments were performed altogether. Five experiments (Runs A through E) were performed to optimize the operating conditions of the kiln and the afterburner. Four additional experiments (Runs 1 through 4) were performed while additional data were obtained by analyzing extractive samples for volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), aldehydes, and particulate matter (PM): two of the four runs were performed with the afterburner switched off, and two were made with the afterburner switched on. An additional blank experiment was performed to assess system contamination.

Results And Conclusions

Based on these simplified studies on the effect of an afterburner on emissions from Missouri-type charcoal kilns, it appears that, while the afterburner can offer significant benefits under some conditions, the operation of the afterburner is not a trivial matter. A system, such as a charcoal kiln, that relies on natural draft for operation may be upset by adding an afterburner due to pressure changes in the stack that influence the natural draft. Optimizing the process, both in the sense of good charcoal quality and good afterburner performance, may be difficult without the benefit of continuous emission monitors.

When pyrolysis is used to manufacture charcoal from wood, many different organic compounds are released into the air, depending on the specific pyrolysis or burn conditions. Table 1 lists compounds found in the smoke of every burn tested to date. Other compounds found in the combustion gases of most burns included the low molecular weight aldehydes, alcohols, acids and diacids, and several low molecular weight halogenated aliphatic and aromatic compounds.

Compounds found in most samples along with an approximate upper concentration range are shown in Table 1.

In addition to specific organic compounds, the concentration of THCs was usually above 5000 ppm, and the concentration of total PM was often above 20,000 $\mu g/m^3$ of air.

Additional Conclusions from the Current Study

- The afterburner attached to the laboratory charcoal kiln simulator was difficult to operate in such a way as to successfully create charcoal. The back pressure that the afterburner exerted on the system affected the natural draft of the kiln, impacting its ability to make charcoal. It is not known whether this conclusion will hold for a full-scale operation, but it is a concern.
- Other pollutants, such as aldehydes, were produced during the charcoal manufacturing process. Emissions of aldehydes were somewhat less than those of VOCs and on the same order of magnitude as those of PAHs.
- During a typical burn, the temperature increased for approximately 1 hour to about 700 °C where it peaked and then slowly decreased after the supply of O_2 was switched off.
- During a burn, the consumption of oxygen preceded the rise in temperature by 15-20 minutes. As the concentration of oxygen decreased, the concentration of all other combustion gases including CO, CO_2, NO, and THCs increased. Typical concentrations at the time of the maximum kiln temperature were: O_2, 6%; CO_2,13%; CO, 4%; NO, 100 ppm; and THCs, over 5000 ppm.
- Even under laboratory conditions, the temperature readings throughout the kiln simulator were very uneven during most runs with the afterburner on, indicating that the process was not under control as well as hoped for. It may be difficult to control the process in the field as a retrofit to existing charcoal kilns, which may affect the quality of the charcoal produced.
- On average, 3.95 g of benzene is emitted for every 1 kg of wood fed into the simulator. On this basis, therefore, 633 lb of benzene would be released by 80 tons of wood.

Table 1. Approximate Upper Concentration Ranges for Compounds as Measured in the Dilution Tunnel

Compound	Upper Concentration ($\mu g/m^3$)
Aldehydes & Ketones	
Methanol	2500
Formaldehyde	100
Acetaldehyde	10
Propanal	1
PAHs	
Napthalene	7500
Acenaphthalene	2000
Phenanthrene	1800
2-Methylnaphthalene	1200
Dibenzofuran	720
Fluoranthene	700
Pyrene	700
Fluorene	500
Anthracene	300
Acenapthene	200
Benz[a]anthracene	200
Chrysene	150
Benz[a]fluorene	100
VOCs	
Benzene	17,000
Toluene	2000
Xylenes	1800
Acetophenone	400
Styrene	200
Ethylbenzene	100
SVOCs	
Phenol	12,000
4-Methylphenol	4000
2-Methylphenol	3000
2,4-Dimethylphenol	3000

***Paul M. Lemieux** is also the EPA Project Officer (see below).*

The complete report, entitled "Emissions of Air Toxics from a Simulated Charcoal Kiln Equipped with an Afterburner," (Order No. PB2001-102799; Cost: $25.50, subject to change) will be available only from:

National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: (703) 605-6000
(800) 553-6847 (U.S. only)

The EPA Project Officer can be contacted at:

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