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Project Summary

Coal Gasification Environmental Data Summary: Low- and Medium-Btu Wastewaters

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This report is a compilation of environmental characterization data for wastewaters from low- and medium-Btu coal gasification facilities. Fixed-bed, entrained-bed, and ash-agglomerating fluidized-bed coal gasification processes were examined. The fixed-bed gasifiers are the Chapman, Wellman-Galusha, Riley, Foster Wheeler/STOIC, and Lurgi-type processes. The entrained-bed gasifiers are the Koppers-Totzek and Texaco processes. The KRW-PDU was used as an example of an ash-agglomerating fluidized-bed process. The types of wastewaters examined from the various coal gasification processes are product gas quench condensates, cyclone dust quench waters, ash pan waters, gas compression and cooling condensates, acid gas removal waters, and leachates from slag and ash disposal facilities. The available wastewater quality and quantity data for these aqueous waste streams are assembled, and the associated environmental significance is addressed. The report describes gasification process characteristics and how they relate to wastewater quality and discusses the biodegradability of quench condensates from the different gasifier types.

This Project Summary was developed by EPA's Air and Energy Engineering 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

As a result of the Energy and Security Act, EPA is one of the Consulting Agencies that review Environmental Monitoring Outlines and Plans as required by the Synthetic Fuels Corporation (SFC) for coal gasification projects receiving financial assistance. As part of this consultation, EPA advises on the adequacy of proposed Environmental Monitoring Plans and participates in Monitoring Review Committee activities for the projects.

In the past decade, EPA has conducted many environmental data acquisition studies at coal gasification facilities in the United States, Europe, and Africa. Both fixed- and entrained-bed coal gasification facilities were examined. Comprehensive data on the characteristics of process and waste streams have been obtained from these sampling programs. These data were used to estimate the wastewater pollutant characteristics from commercial coal gasification facilities and provide a basis for the evaluation of applicable control technologies.

The EPA's Environmental Assessment data, when properly compiled and summarized, can provide information to:

- Identify environmental and health issues requiring further definition through data acquisition at SFC-supported facilities.
- Recognize process-specific characteristics for both synfuels production and pollution control technolo-

gies which would influence the scope and areas of emphasis in the planned monitoring.

- Define data interpretation and presentation approaches which will facilitate the evaluation of the data addressing particular areas of concern in mitigating environmental and health problems with future facilities.

To support this effort, several documents which address specific environmental pollutant or discharge categories characteristic of coal gasification technologies have been prepared. Areas are: sulfur and nitrogen species, organics, trace elements, solid wastes, and wastewater. The documents summarize environmental data for the Chapman, Wellman-Galusha, Riley, Foster-Wheeler/STOIC, Lurgi, Lurgi-type, Koppers-Totzek, KRW Energy Systems, and Texaco gasification processes. These data are compared and contrasted to develop trends and/or correlations that can be used to assess the environmental impacts associated with the different coal gasification processes.

This report is a compilation of data on wastewater quality from the subject coal gasification processes. It presents background on the gasification technologies, defines major aqueous waste streams, summarizes all available wastewater quality and quantity data, assesses environmental impacts, describes gasification process characteristics and how they relate to wastewater quality, and discusses the biodegradability of quench condensate streams from the different gasifier types.

Objectives

The objective of this report is to present an environmental analysis of pollutant species in coal gasification wastewaters. The data available from environmental assessment efforts, supplemented by literature data, are compiled, summarized, evaluated, and documented to provide:

- A consolidated summary of the available wastewater quality data for commercial-scale coal gasification processes.
- An interpretive evaluation of the data including:
  (1) Trends in pollutant behavior between processes.
  (2) Identification of unique or specific characteristics of individual processes.
  (3) Identification of particular environmental issues, both those common to all processes and those unique to individual processes.
  (4) Recommendations for monitoring of commercial scale systems to further define environmental issues or apparent trends in pollutant behavior.
- A basis for the evaluation of synfuels facility Environmental Monitoring Plans relative to wastewater characteristics.
- A resource for EPA Regional Offices and state agencies involved in permitting of gasification facilities.

Results and Conclusions

Wastewater characterization data on the aqueous wastes from both fixed- and entrained-bed commercial coal gasification processes were gathered from many source test and evaluation studies at synthetic fuels facilities to identify environmental and health issues requiring further definition. These gasification facilities are the Wellman-Galusha (Glen - Gery), Wellman-Galusha (Fort Snelling), Chapman-Wilputte, Lurgi (Westfield, Scotland), Lurgi-type (Kosovo), Lurgi (Sasolburg), Foster Wheeler/STOIC, Riley Gas Producer, Koppers-Totzek, and Texaco processes. Information on the test periods and coals gasified is presented in Table 1. Results of wastewater characterization studies performed on the KRW-PDU are also included for comparison with the Koppers-Totzek and Texaco entrained-bed gasifiers because the quench condensates from this ash-agglomerating gasifier have similar chemistries.

The environmentally significant species evolved from coal during gasification in low- and medium-Btu processes can be broadly grouped into five categories: heavy hydrocarbons (C_6^+, oils, and tars), volatile nonmethane hydrocarbons ($C_2 - C_5$), inorganic sulfur compounds, inorganic nitrogen compounds, and trace elements. The process areas that generate wastewaters with these contaminants are coal preparation, coal pretreatment (thermal drying, mild oxidation, slurry preparation), coal gasification, particulate removal and gas cooling, shift conversion, and acid-gas removal. Wastewaters from these process areas contain some or all of the categories of pollutants identified above.

Results

Much of the data developed from the environmental characterization sampling programs did not yield wastewater quality data for the different gasification processes that were directly comparable because they were designed to focus on streams of potential environmental significance. However, these environmental characterization test programs did provide a listing of pollutants common to the different coal gasification processes, and these data were used to select wastewater discharge pollutants for environmental monitoring.

The heterogeneous nature of coal gives rise to a wide variety of organic and inorganic compounds in aqueous streams resulting from coal conversion processes. These pollutants are summarized in Tables 2 and 3 for the fixed- and entrained-bed gasification processes, respectively. These aqueous phase pollutants are characteristic of wastewaters from the Wellman-Galusha, Chapman, Lurgi-type, Texaco, and Koppers-Totzek gasifiers. Many of the substances listed in Tables 2 and 3 were detected and are typically present in coal gasification wastewaters, albeit at relatively low concentrations.

Process condensates from coal gasification have long had a reputation for being highly polluting and difficult to treat because they contain substantial concentrations of ammonia, phenols, and sulfur compounds. All of these chemicals can be directly toxic to aquatic life. They also exert an indirect toxic effect, as they undergo biochemical oxidation in the aquatic environment which consequently becomes deficient in dissolved oxygen.

Pollutants in aqueous wastes from coal gasification processes representing the highest potential for environmental (ecological) hazard are ammonia, cyanide, and phenolics. Ammonia represents the most severe potential environmental hazard because of the toxicity of undissociated ammonia to aquatic organisms. This toxicity is pH dependent and is directly related to the concentration of undissociated ammonia. Since most coal gasification processes have the potential to discharge large volumes of ammonia contaminated alkaline wastewaters, the undissociated ammonia fraction could reach toxic levels in the receiving water. Treatment for ammonia removal is, therefore, a primary concern before aqueous

Table 1. *Coal and Coal Gasification Facility Type*

Type of Gasifier	Site	Type of Coal	Year of Study	Product Gas Heat Content[a]
Chapman-Wilputte	*Kingsport, TN*	*Virginia bituminous*	*1978*	*low*
Foster Wheeler/STOIC	*U. of Minnesota Duluth, MN*	*Bituminous coal from Pinnade Seam*	*1981*	*low*
Koppers-Totzek	*Modderfontein, So. Africa*	*Bituminous, high volatile coal from So. Africa*	*1979*	*medium*
Lurgi, Dry Ash	*Westfield, Scotland*	*Rosebud, subbituminous coal from Montana; bituminous coals from Percy, Illinois; and Pittsburgh non-caking and non-swelling coal from Federal No. 1 mine*	*1973-1974*	*medium*
Lurgi-type, Dry Ash	*Kosovo, Yugoslavia*	*Lignite from Kosovo mine*	*1981*	*medium*
Lurgi, Tri-State Synfuels Test	*Sasolburg, So. Africa*	*Western Kentucky coal*	*1981*	*medium*
Riley (modification of Morgan Gas Producer)	*Worcester, MA*	*North Dakota lignite*	*1979*	*low*
KRW-PDU	*Madison, PA*	*Wyoming subbituminous, Pittsburgh No. 8 bituminous, and North Dakota lignite*	*1983*	*medium*
Texaco	*Ruhrkohle/Ruhrchemie Federal Republic of Germany*	*Illinois bituminous*	*1980*	*medium*
Wellman-Galusha	*Glen-Gery Brick Co. York, PA*	*Pennsylvania anthracite*	*1978*	*low*
	Fort Snelling, MN	*North Dakota lignite (Indian Head)*	*1978*	*low*

[a]*Low means less than 5500 kJ/m^3; medium means about 11,000 kJ/m^3.*

wastes from coal conversion processes are discharged.

In the case of cyanide, available data on the acute toxicity of simple cyanides to fish reveal that the minimum lethal (threshold) concentrations of free cyanide are usually less than 250 ppb. It is generally acknowledged that free cyanide concentrations in the range from 50 to 100 ppb as cyanide have proven eventually fatal to many sensitive fishes and levels much above 200 ppb probably are rapidly fatal to most fish species. Cyanide, a monodentate ligand, will complex with many metals and, as such, has the potential of bioaccumulating in aquatic plants and animals. The long-term effects of complexed cyanide in the aquatic environment have not been investigated adequately to determine separate water quality criteria regarding chronic toxicity impacts.

Phenolics represent an environmental hazard that is somewhat lower in magnitude than that of cyanide. Phenolic compounds can affect freshwater fish adversely by direct toxicity to fish and fish-food organisms, by lowering the amount of available oxygen because of the high oxygen demand of the compounds, and by tainting of fish flesh. Phenolic toxicity in the aquatic environment is enhanced by lower dissolved oxygen concentrations, increased salinity, and increased temperature. A major aesthetic problem associated with phenolic compounds is their organoleptic properties (i.e., ability to affect one or more organs of the body) in water and fish flesh.

The degree of hazard exhibited by sulfide to aquatic animal life is dependent on the temperature, pH, and dissolved oxygen level of the receiving water. At lower pH, a greater proportion of the sulfide is in the form of toxic undissociated H_2S. In winter, when the pH is neutral or mildly acidic, the hazard from sulfides is increased. This hazard is exacerbated when dissolved oxygen levels are low (but not lethal to fish).

The major metals in coal gasification wastewaters are boron, cadmium, copper, lead, selenium, and zinc. These metals were found in each of the different coal gasification wastewaters at varying concentration levels. All are toxic to animals and man, except boron which (like cadmium) has phytotoxic properties. Some of these metals present a particular environmental concern because they have the potential to bioaccumulate, thereby producing a chronic poisoning effect. Boron is a pollutant that represents environmental hazard only with regard to agricultural water use.

Metals which have a measurable environmental impact and are also acutely toxic to man are cadmium, selenium, and lead. Allowable levels in domestic water supplies are 10 μg/L for cadmium and selenium and 50 μg/L for lead. However, the allowable concentrations in

Table 2. Substances Identified in Fixed-Bed Gasification Wastewaters

Lurgi[a] Gas Liquor	Chapman[b] Separator Liquor	Wellman-Galusha[c] Ash Sluice Water
Aluminum	Ammonia	Ammonia
Ammonia	Antimony	Barium
Antimony	Arsenic	Benzenethiol
Arsenic	Barium	Benzo(e)pyrene
Barium	Boron	Chromium
Beryllium	Cadmium	Cresols
Boron	Calcium	Cyanide
Calcium	Carboxylic Acids	Dibenz(a,h)pyrene
Catechols	Cerium	Iron
Cerium	Cesium	Lanthanum
Chromium	Chloride	Lithium
Cobalt	Chlorine	Phenols
Copper	Copper	Selenium
Cresols	Cyanide	Thiocyanate
Cyanide	Fluorine	
Fluorine	Fused Aromatic Hydrocarbons	
Iron	Heterocyclic Nitrogens	
Lead	Heterocyclic Sulfurs	
Lithium	Iron	
Magnesium	Lanthanum	
Manganese	Lithium	
Mercury	Magnesium	
Molybdenum	Mercury	
Nickel	Phenols	
Phenol	Phosphorus	
Phosphorus	Rubidium	
Resourcinols	Scandium	
Rubidium	Selenium	
Scandium	Silicon	
Selenium	Silver	
Silicon	Thiols	
Silver	Titanium	
Sodium	Tungsten	
Strontium	Yttrium	
Thiocyanate	Zirconium	
Titanium		
Uranium		
Vanadium		
Xylenols		
Yttrium		
Zinc		
Zirconium		

[a]*For various coals (e.g., bituminous and lignite).*
[b]*Virginia bituminous coal.*
[c]*Pennsylvania anthracite.*

the aquatic environment for protection of certain fresh water animals/fish are considerably lower. Although these metals are present in coal gasification wastewaters at relatively low concentrations, they still present the potential for severe environmental hazard due to progressive, chronic poisoning.

Conclusions

There are considerable differences in the quality of wastewaters produced from the various coal gasification processes, both between and within gasifier types. These differences are due to process configuration, gasifier operation, nature of product gas cleanup and ash removal/handling, and the feed coal used. However, representative wastewater chemistries can be established for similar gasifiers with similar product gas cleanup and ash removal/handling operations fed with similar coals. This permits a categorization of wastewaters into two functional groups: aqueous wastes from tar producing (e.g., fixed-bed) gasification and aqueous wastes from non-tar producing (e.g., ash-agglomerating/fluidized-bed and entrained-bed) gasification. That is, coal gasification processes that produce substantial quantities of phenolics, oils, and tars, and processes that produce little or none of these pollutants.

The types of wastewaters that are generated by coal gasification processes are product gas quench condensates, cyclone dust quench waters, ash pan waters, gas compression and cooling condensates, acid gas removal waters, and leachates from slag and ash disposal facilities. The severity of the contamination associated with the individual effluents varies with the coal gasification process. However, a general assessment of pollutant strength and stream volume places the quench condensates above other aqueous waste streams as the principal wastewater source.

Quench condensates can be classified by gasifier type (in this case, fixed- or entrained-bed) and have relatively consistent chemistries for a given gasifier category. These waters are usually the largest volume aqueous waste stream from a gasification process, and (in the case of fixed-bed gasifiers) they contribute substantial organic pollutant loads to wastewater treating facilities. However, these aqueous wastes can be treated for removal of most conventional pollutants by biooxidation after the appropriate pretreatment.

Most coal gasification wastewaters from both fixed- and entrained-bed processes can be controlled with respect to the discharge of conventional pollutants (e.g., BOD, COD, and pH). The control of selected organics and trace elements varies with the gasification process. Fixed-bed gasifiers need to have specific attention paid to the discharge of phenolics, polynuclear aromatic hydrocarbons, ammonia, cyanide, and many heavy metals. Entrained-bed gasifiers need to have attention paid to such nonconventional pollutants as ammonia, thiocyanates, free and complexed cyanides, and boron.

Table 3. *Substances Identified in Entrained-Bed Gasification Wastewaters*

Koppers-Totzek Modderfontein	Texaco Ruhrkohle/Ruhrchemie
Ammonia[a]	Ammonia
Anthracene[b]	Barium
Barium[b]	Boron
Benz(a)anthracene[b]	Bromine
Benzo(b)fluoranthene[b]	Cerium
Boron[a]	Chlorine
Bromine[b]	Cyanide
Chlorine[a]	Fluorine
Copper[b]	Iron
Crysene[b]	Lead
Cyanide[a]	Magnesium
Fluoranthene[b]	Molybdenum
Fluorine[b,c]	Nickel
Iron[b,c]	Potassium
Magnesium[b,c]	Silicon
Nickel[b]	Sodium
Phenanthrene[b]	Thiocyanate
Potassium[b,c]	Zinc
Pyrene[b]	Zirconium
Silicon[a]	
Sodium[c]	
Thiocyanate[a]	
Zinc[c]	

[a]*Quench condensates.*
[b]*Rectisol wastewater.*
[c]*Compressor condensates.*

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The complete report, entitled "Coal Gasification Environmental Data Summary: Low- and Medium-Btu Wastewaters," (Order No. PB 86-192 267/AS; Cost: $16.95, subject to change) will be available only from:
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