EVALUATION OF CARBON DIOXIDE CAPTURE FROM EXISTING COAL FIRED PLANTS BY HYBRID SORPTION USING SOLID SORBENTS

TOPICAL REPORT: ENVIRONMENTAL HEALTH & SAFETY ASSESSMENT

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PRINCIPAL AUTHORS:
Steven A. Benson, University of North Dakota
Daniel R. Palo, Barr Engineering
Srivats Srinivasachar, Envergex LLC
Daniel A. Laudal, University of North Dakota

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SUBMITTED BY:
Institute for Energy Studies
University of North Dakota
P.O. Box 7101
Grand Forks, ND 58202

SUBCONTRACTORS:
Envergex LLC
10 Podunk Road
Sturbridge, MA

Barr Engineering Company
4700 West 77th St., #200
Minneapolis, MN 55435

Solex Thermal Science, Inc.
Suite 250, 4720-106 Ave. SE
Calgary, AB T2C 3G5 Canada

PRINCIPAL INVESTIGATOR: Steven A. Benson, University of North Dakota

DISCLAIMER

ABSTRACT

Under contract DE-FE0007603, the University of North Dakota conducted the project *Evaluation of Carbon Dioxide Capture from Existing Coal Fired Plants by Hybrid Sorption Using Solid Sorbents.* As an important element of this effort, an Environmental Health and Safety (EH&S) Assessment was conducted by Barr Engineering Co. (Barr) in association with the University of North Dakota. The assessment addressed air and particulate emissions as well as solid and liquid waste streams. The magnitude of the emissions and waste streams was estimated for evaluation purposes. EH&S characteristics of materials used in the system are also described. This document contains data based on the mass balances from both the 40 kJ/mol CO_2 and 80 kJ/mol CO_2 desorption energy cases evaluated in the Final Technical and Economic Feasibility study also conducted by Barr Engineering.

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EXECUTIVE SUMMARY

Complementary to the technical and economic feasibility analysis of the solid-sorbent-based carbon-dioxide-capture project conducted by the University of North Dakota and its partners, an Environmental Health and Safety (EH&S) Assessment was conducted for the process. The project, titled *Evaluation of Carbon Dioxide Capture from Existing Coal Fired Plants by Hybrid Sorption Using Solid Sorbents* is based on a regenerable solid sorbent that removes CO_2 from desulfurized, coal-fired, power plant flue gas. The flue gas is first contacted with the sorbent in an adsorption step to remove CO_2 from the flue gas. The CO_2-lean flue gas is then released to atmosphere. CO_2-loaded sorbent is conveyed to a regeneration step where CO_2 is stripped by indirect steam heating and direct steam stripping. The recovered CO_2 is compressed, steam condensate is removed, and the purified CO_2 is liquefied for sequestration or utilization. The regenerated sorbent is returned to the adsorber for reuse.

This adsorption system was evaluated for EH&S issues, including air and particulate emissions and solid and liquid waste streams. Expected emission rates were calculated and reported. Other than the cleaned flue gas emission, uncaptured particulates from baghouse filters, solid sorbent waste, and steam condensate/washdown water (with some associated contaminants) are the main emission/waste streams from the plant. Two versions of the Final Technical and Economic Feasibility Study were completed by Barr Engineering, which were based on two sorbent energies of desorption (40 kJ/mol CO_2 and 80 kJ/mol CO_2). Based on the mass balance for the 80 kJ case, particulate emissions (from baghouse filters) were estimated at less than 200 tons/yr., and spent solid sorbent waste was estimated at ~31,000 tons/yr. These values are slightly less for the 40 kJ case. Captured condensate and washdown water is planned to be cleaned and recycled, so its quantity was not evaluated as an effluent.

This assessment takes into account the following elements as per DOE guidance:

1. Air and water emissions as well as solid wastes
2. Toxicological effects of the materials utilized
3. Hazardous properties (e.g., volatility, flammability, etc.) of the materials utilized
4. How the process is impacted by applicable EH&S laws (e.g., CERCLA, TSCA, CWA, etc.)
5. Engineering analysis and potential for material substitution
6. Storage, handling, and incompatibilities

The materials used in this system are well known in the industry, have not been modified to increase their toxicity/hazardousness, and have well-established safety data sheet information available. Therefore, items 2, 3, 4, and 6 are fully addressed in the safety data sheets provided with this report. Because of the relatively benign nature of the materials utilized and the dependence of the system performance on these specific materials, item 5 is not seen as necessary at this time.

INTRODUCTION

A solid-sorbent-based, carbon-dioxide-capture technology was developed and demonstrated under agreement DE-FE0007603 by the University of North Dakota and its project partners. The following process flow diagram illustrates the relevant materials and flows that were considered under this EH&S assessment. The process is described below as an introduction to the EH&S assessment.

Scrubbed flue gas enters the system (SF1) where it contacts the solid sorbent in the adsorber. Gas and sorbent enter a cyclone separator, the overflow of which reports to a baghouse filter, yielding a CO_2-lean and largely particulate-free flue gas (SF6), which is sent to the stack. The used sorbent reports (SF14) to a regeneration cycle consisting of direct and indirect steam stripping where CO_2 is removed and sorbent is regenerated. The regenerated sorbent (SF19) reports back to the sorption cycle along with fresh make-up sorbent.

The CO_2 and steam (SF20) are sent to the cooling/condensing/compression cycle where water is removed (SF28) and CO_2 is liquefied (SF33) for sequestration or reutilization.

Under normal operation, the only exit streams from the system are:

1. Cleaned flue gas, which is emitted through the stack
2. Solid-sorbent particulate material that is not captured in the baghouse filters
3. Compressed CO_2, which is not emitted but sequestered or reutilized
4. Condensed steam, which is captured and recycled
5. Spent sorbent, which is captured and disposed of

To the extent that any of these exit streams affect the EH&S considerations of the system, they are described and quantified in this report. This assessment takes into account the following EH&S elements as per DOE guidance:

1. Air and water emissions as well as solid wastes
2. Toxicological effects of the materials utilized
3. Hazardous properties (e.g., volatility, flammability, etc.) of the materials utilized
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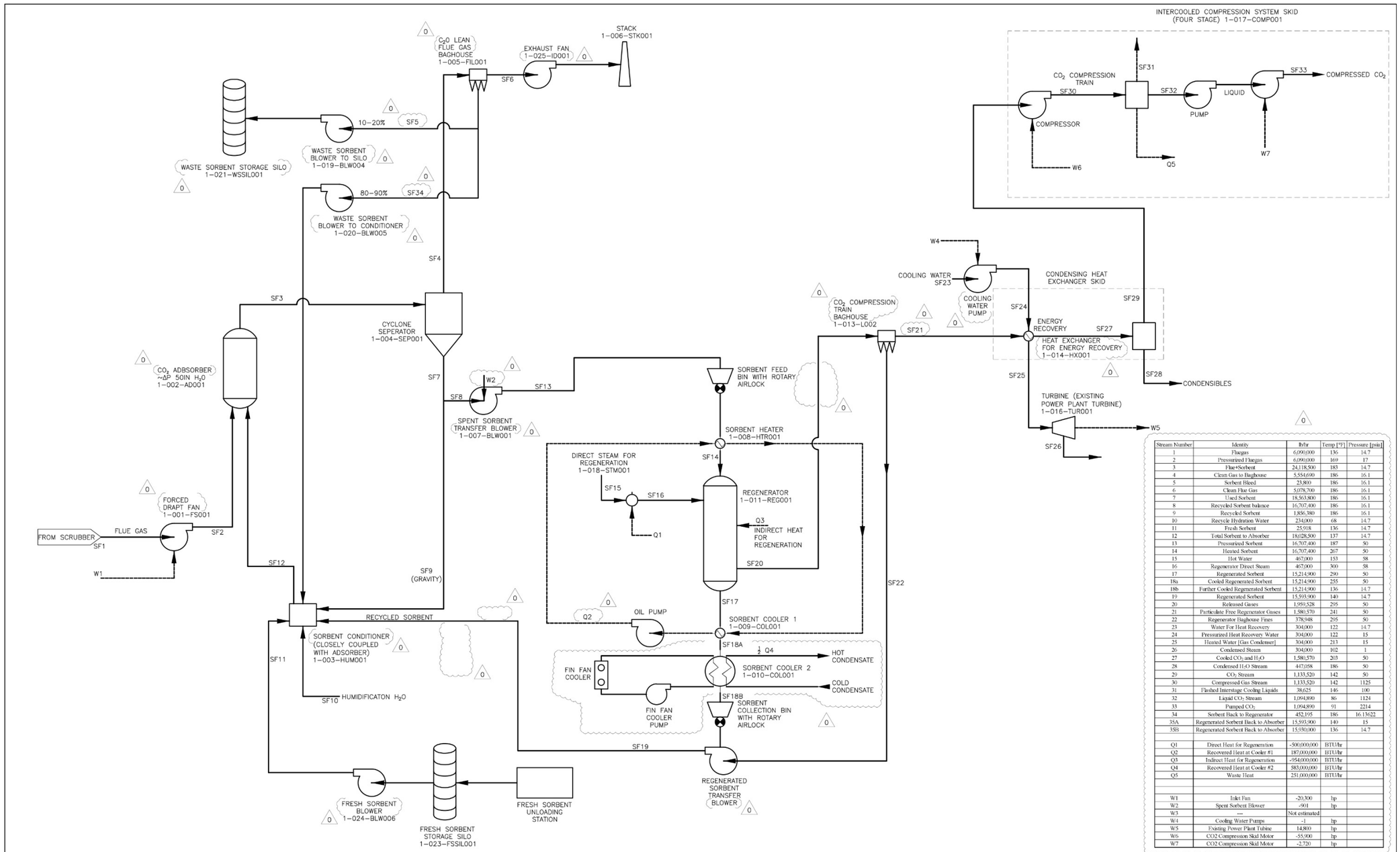


Stream Number	Identity	lb/hr	Temp [°F]	Pressure [psia]
1	Fluegas	6,090,000	135	14.7
2	Pressurized Fluegas	6,090,000	169	17
3	Flue+Sorbent	24,118,500	183	14.7
4	Clean Gas to Baghouse	5,554,600	186	16.1
5	Sorbent Bleed	23,800	186	16.1
6	Clean Flue Gas	5,078,700	186	16.1
7	Used Sorbent	18,563,800	186	16.1
8	Recycled Sorbent balance	16,707,400	186	16.1
9	Recycled Sorbent	1,856,380	186	16.1
10	Recycle Hydration Water	234,000	68	14.7
11	Fresh Sorbent	25,918	136	14.7
12	Total Sorbent to Absorber	18,028,500	137	14.7
13	Pressurized Sorbent	16,707,400	187	50
14	Heated Sorbent	16,707,400	267	50
15	Hot Water	467,000	153	58
16	Regenerator Direct Steam	467,000	300	58
17	Regenerated Sorbent	15,214,900	290	50
18a	Cooled Regenerated Sorbent	15,214,900	255	50
18b	Further Cooled Regenerated Sorbent	15,214,900	136	14.7
19	Regenerated Sorbent	15,593,900	140	14.7
20	Released Gases	1,959,528	295	50
21	Particulate Free Regenerator Gases	1,580,570	241	50
22	Regenerator Baghouse Fines	378,948	295	50
23	Water For Heat Recovery	304,000	122	14.7
24	Pressurized Heat Recovery Water	304,000	122	15
25	Heated Water [Gas Condenser]	304,000	213	15
26	Condensed Steam	304,000	102	1
27	Cooled CO_2 and H_2O	1,580,570	203	50
28	Condensed H_2O Stream	447,058	186	50
29	CO_2 Stream	1,133,520	142	50
30	Compressed Gas Stream	1,133,520	142	1125
31	Flashed Interstage Cooling Liquids	38,625	146	100
32	Liquid CO_2 Stream	1,094,890	86	1124
33	Pumped CO_2	1,094,890	91	2214
34	Sorbent Back to Regenerator	452,195	186	16.13622
35A	Regenerated Sorbent Back to Absorber	15,593,900	140	15
35B	Regenerated Sorbent Back to Absorber	15,930,000	136	14.7
Q1	Direct Heat for Regeneration	-500,000,000	BTU/hr	
Q2	Recovered Heat at Cooler #1	187,000,000	BTU/hr	
Q3	Indirect Heat for Regeneration	-954,000,000	BTU/hr	
Q4	Recovered Heat at Cooler #2	583,000,000	BTU/hr	
Q5	Waste Heat	251,000,000	BTU/hr	
W1	Inlet Fan	-20,300	hp	
W2	Spent Sorbent Blower	-901	hp	
W3	---	Not estimated		
W4	Cooling Water Pumps	-1	hp	
W5	Existing Power Plant Tubine	14,800	hp	
W6	CO2 Compression Skid Motor	-55,900	hp	
W7	CO2 Compression Skid Motor	-2,720	hp	

NO.	BY	CHK.	APP.	DATE	REVISION DESCRIPTION
0	BAC	WJM	BAB2	12/19/14	FINAL REPORT

CLIENT
BID
CONSTRUCTION
RELEASED TO/FOR

A	B	C	0	1	2	3

DATE RELEASED

BARR
Project Office:
BARR ENGINEERING CO.
4700 WEST 77TH STREET
MINNEAPOLIS, MN 55435
Ph: 1-800-632-2277
Fax: (952) 832-2601
www.barr.com
Corporate Headquarters:
Minneapolis, Minnesota
Ph: 1-800-632-2277

Scale	NONE
Date	5/21/12
Drawn	SDS
Checked	WJM
Designed	BAB2
Approved	BAB2

UNIVERSITY OF NORTH DAKOTA
GRAND FORKS, NORTH DAKOTA

CACHYS™

PROCESS FLOW DIAGRAM

BARR PROJECT No. 34181003.01
CLIENT PROJECT No.
DWG. No. MF-01
REV. No. 0

AIR, WATER, AND SOLID WASTE STREAMS

Air Emissions

Due to the extremely low (or zero) volatility of the sorbent materials, no volatile air emissions are expected. [1,2,3,4] The air emissions (SO_x, NO_x, etc.) associated with the flue gas fed to the system are not considered here, as they would be the responsibility of the power generator.

Particulate Emissions

The main sources of particulate emissions are the baghouse filters[1] which can be broken down as follows:

1. CO_2-lean flue gas baghouse (SF6)
2. Pneumatic transport filter for process conveying [i.e., Adsorber to Regen (SF13) and Regen to Adsorber (SF19)]
3. Pneumatic transport filter for fresh sorbent makeup (SF11)

Particulate emissions consist of the very fine sorbent particles that are not captured in the baghouse filters. The composition of these particles will be the same as the sorbent – alkali carbonate, alkali bicarbonate, alkali sulfate and substrate material. The largest single source of emissions is the CO_2-lean flue gas baghouse, but the magnitude of each of the three sources is discussed below.

CO_2-lean flue gas baghouse

Prior to being sent to the power plant's exhaust stack, the CO_2-lean flue gas is passed through a baghouse fabric filter to remove fine sorbent particles that are entrained in the gas flow. Using the mass balance from the Final Technical and Economic Analysis (Final TEA) 80 Kilojoule case, an estimate of the magnitude is provided below.

- CO_2-lean flue gas flow rate: 2,026,026 Nm^3/hour
- Baghouse Filter Emission Rating: 10 mg/Nm^3 (Industry Standard)
- Total Particulate Emissions: ~ 20 kg/hour or 170 tons/year (85% Operating Factor)

For the 40 kJ case, the flue gas flow rate is ~10% lower, resulting in total particulate emissions of about 150 tons/year.

Sorbent particles escaping this baghouse would have originated from the exit of the adsorber, and thus, would be expected to contain a higher fraction of alkali bicarbonate. However, a smaller fraction of the alkali carbonate and alkali sulfate will also be present in addition to the substrate material.

In-process pneumatic conveying baghouse

Sorbent must be conveyed within the CO_2 capture system from the regenerator exit to the adsorber feed hopper as well as from the adsorber exit to the top of the regenerator. This is likely to be accomplished using dense-phase pneumatic conveying. For the 80 kJ case, a total of about 8,350 tons/hour of sorbent is circulated within the system, but since there are two sections of the conveying system, double that amount of sorbent must be conveyed on a continuous basis during operation. The pneumatic conveying system contains feed hoppers, feeders, conveying lines, discharge hoppers, and discharge filters. The emissions will result from particles not captured in the discharge filters.

[1] The baghouse filters associated with streams SF11, SF13, and SF19 are not shown on the process flow diagram (PFD), as the PFD is focused on the process mass and energy balance and represents the major flow components of the system.

An estimate of the magnitude is provided below for the 80 kJ case.

- Sorbent conveying requirements: 16,700 tons/hour
- Typical Solid/Air Ratio: 50 wt/wt (Industry standard for dense phase conveying)
- Total pneumatic air requirements: 247,200 Nm^3/hour
- Baghouse Filter Emission Rating: 10 mg/Nm^3 (Industry Standard)
- Total Particulate Emissions: ~ 2.5 kg/hr. or 20 tons/year (85% operating factor)

For the 40 kJ case, this value is reduced to about 18 tons/year.

Sorbent particles emitted from the baghouse located at the adsorber inlet (regenerated sorbent) will contain a higher fraction of alkali carbonate than alkali bicarbonate and a small fraction of alkali sulfate in addition to the substrate material. The opposite will be true for the particles emitted from the baghouse located at the regenerator inlet (more bicarbonate than carbonate).

Fresh feed pneumatic conveying baghouse

Due to reaction with SO_2, continuous sorbent waste and fresh sorbent makeup streams are required. Fresh sorbent makeup is likely to be performed by dense phase pneumatic transport of the fresh sorbent from the bulk storage container (rail car, truck, bulk storage silo, etc.), into the in-process fresh sorbent feed hopper. Particulate will be emitted from the baghouse filter located at the fresh-sorbent feed hopper. An estimate of the magnitude is provided below for the 80 kJ case.

- Fresh sorbent makeup requirements: 4.2 tons/hour
- Typical Solid/Air Ratio: 50 wt/wt (Industry standard for dense phase conveying)
- Total pneumatic air requirements: 62 Nm^3/hour
- Baghouse Filter Emission Rating: 10 mg/Nm^3 (Industry Standard)
- Total Particulate Emissions: ~ 620 mg/hour or 4.6 kg/year (85% operating factor)

For the 40 kJ case, this value is reduced to about 4.2 kg/year.

The particles emitted in this baghouse are the fresh sorbent particles and will consist of approximately 65 wt% substrate and 35 wt% alkali carbonate.

Another source of particulate emissions would be from non-contained mechanical/manual conveying/ handling activities that may result in formation of dust that could be dispersed in the ambient air. This source is difficult to quantify, but is expected to be negligible compared to the sources discussed above.

Approximately 89% of the total particulate emissions originate from the CO_2-lean flue gas baghouse, and although it was not the focus of this research, there is a practical and potentially beneficial (to the CO_2 capture performance) method to eliminate the emissions that would occur from in-process pneumatic conveying. Rather than using pneumatic air to convey the sorbent to and from the adsorber/regenerator systems, it is possible to use the flue gas stream itself. In doing so, the conveying baghouses would be eliminated and all of the sorbent particles would be sent to the CO_2-lean flue gas baghouse. This would result in a reduction in emissions of about 11%. An additional benefit is that CO_2 capture may potentially be improved due to increasing the contact time between the sorbent and flue gas.

Solid Waste Streams

As part of the Final TEA, the magnitude of this waste stream was estimated by calculating the amount of sorbent that reacts with the SO_2 that is allowed to enter the adsorber. Based on the known reaction kinetics of the active component in the sorbent (i.e., SO_2 is more reactive than CO_2 with CACHYS™

sorbent), we can expect that essentially all of the SO_2 that enters the adsorber will react with the sorbent and produce non-regenerable alkali-sulfate species. For the 80 kJ case, with the process boundary conditions specified by DOE for the Final TEA and in DOE's Case 11 & 12 baseline studies (45 ppm SO_2 after desulfurization scrubber), we estimate that 4.2 tons/hour (50% sulfated) of sorbent will be rejected from the system and need to be replaced. This equates to ~31,000 tons/year of sorbent waste (85% operating factor). For the 40 kJ case, the sorbent waste stream is reduced to 3.8 tons/hr or about 28,300 tons/year.

This waste stream is expected to contain approximately 65% by weight of the substrate material with the rest made up of mainly alkali-sulfate compounds. A lesser fraction of non-sulfated active component will also be present in the stream which is made up of a mixture of alkali carbonate and alkali bicarbonate compounds.

This waste stream has minimal environmental hazard and can be landfilled; however, the alkali sulfate compounds have value as a fertilizer [5]. Further, there exist several methods [6, 7] to convert the alkali sulfate back into alkali carbonate/bicarbonate. The sorbent waste stream will be collected from the CO_2-lean flue gas baghouse at the adsorber exit and consists of sorbent particles that are of a finer particle size distribution than the fresh sorbent.

While the cyclone at the adsorber exit is expected to be highly efficient for the more coarse particles (20-50 mesh), there will be a portion of the sorbent particles that are not captured in the cyclone that is considered large enough to be re-used. Re-use can be done relatively simply by washing the sorbent to dissolve the alkali components followed by filtering and sieving the substrate particles. The "coarse" particles can be re-used in the process, and the "fines" potentially have value for use in a multitude of other applications.

Although not the focus of this research and not presented in this document or in the Final TEA, if these methods were employed, the sorbent waste stream, and thus the fresh makeup requirement, could be reduced (or potentially eliminated) in the following manner:

1. Recovery of substrate by water wash (dissolve alkali components) and filter collection of solids
2. Sieving of the substrate to the correct size range (i.e. "coarse" and "fine")
3. Drying/crystallization of the alkali components
4. Chemical conversion of sulfate to carbonate compounds
5. Re-impregnation of carbonate compounds into recovered "coarse" substrate (with addition of fresh substrate to make up for loss of "fines")
6. Sale or re-use of substrate "fines" in another application
7. Recycle recovered sorbent to reduce fresh makeup requirement

Liquid Waste Streams

There are several cooling water and condensate streams in the process. However, in each case, these streams are recycled through the process and are not considered as waste streams.

The only possible exception is the condensate collected from the regenerator exhaust gasses (CO_2/steam mixture). This condensate stream may potentially contain trace amounts of alkali, carbonate, and sulfate ions. Depending on the concentration, the condensate may need to be treated before re-use within the plant.

The main source of liquid waste generated by the CACHYS^{TM} process is expected to be during maintenance, specifically during wash-down of the sorbent regeneration system. In the event of a major

upset (or periodic maintenance), the system may need to be washed down with variable quantities of sorbent in the system. Washing the sorbent-containing regeneration system will result in a stream containing dissolved sorbent components (alkali, carbonate, bicarbonate, and sulfate) as well as the substrate material.

The wash-down procedure will involve containment of the wash-down fluids as well as filtration to capture the solid substrate particles (which can be dried and re-used). The remaining water stream will be collected in a sealed containment tank/pond and will be treated as necessary prior to re-use or disposal.

IDENTIFICATION OF TOXICOLOGICAL EFFECTS AND MATERIAL PROPERTIES

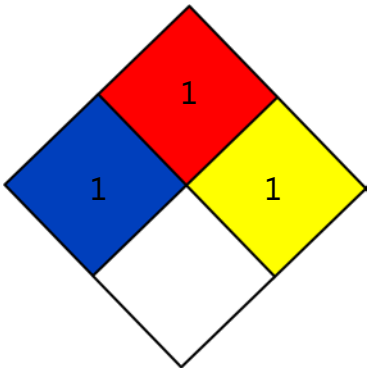
The following pages discuss the properties of the sorbent materials with regard to their impact on environmental and human health and safety. Specifically, the data presented below addresses the following elements of the DOE guidance for the EH&S assessment:

- Toxicological effects and hazardous properties of the materials utilized
- Applicable EH&S laws (e.g., CERCLA, TSCA, CWA, etc.)
- Material storage, handling, and incompatibilities

The majority of the information contained in these sections was generated from the material safety and data sheets. [1, 2, 3,4] The fresh sorbent contains two components – the substrate and alkali carbonate. There are two other products that are generated during the process – alkali bicarbonate and alkali sulfate. Each of the above components is discussed below.

Beyond these four main compounds, no other potentially hazardous materials are utilized in the process.

Sorbent Substrate



Health Hazard: 1 – exposure to dust could cause irritation but only minor residual injury even if no treatment is given

Fire Hazard: 1 – not flammable under normal use, but potential for combustion under elevated temperatures or in the presence of strong oxidizers

Reactivity: 1 – stable under normal conditions but may be unstable under elevated temperatures or in the presence of strong oxidizers

The primary concerns for occupational exposure are skin contact and inhalation in the form of dust. The dust may cause eye irritation, slight skin irritation, and possible respiratory tract irritation that can cause coughing or sneezing.

The substrate material can adsorb oxygen, so personnel must never enter a confined space containing the material, or asphyxiation may result.

When burned, hazardous products of combustion including oxides of carbon can occur. Irritating and/or toxic gases due to decomposition of the product may be generated during a fire. Contact with strong oxidizers such as ozone or liquid oxygen may cause rapid combustion. Ignition temperature of the product is >400°C in air.

Property	Value/Comments
Solubility (water)	Insoluble
pH	2.5-10
Hazardous Decomposition	CO, CO2
Hazardous Polymerization	Does not occur
Stability	Stable with proper storage and handling
Incompatibility	Rapid combustion is possible when in contact with strong oxidizers

Toxicological Information

Eyes: Not an eye irritant other than dust
Skin: Not a primary skin irritant, sensitizing or corrosive agent
Inhalation: Not established
Ingestion: Oral LD50 > 5g/kg (rats)

Subchronic Effects: Not established
Tertology (Birth defects): Not established
Mutagenicity (Genetic effects): Not established

Ecological Information

Because the material is a relatively inert substance and is insoluble in water, it is not expected to pose significant ecological hazards. The environmental persistence of the material would be primarily based on

its physical form, that is, fine particles of the material could be dispersed in the environment by wind and water while large particles would persist with little dispersion. No data is available on chemical fate information.

Regulatory Information

Sara Hazard Classification:

Immediate (Acute) Health:	Yes
Delayed (Chronic) Health:	No
Sudden Release of Pressure:	No
Reactive:	No
Fire:	No

Sara Title III, Section 302: Does not contain any chemicals under this section

Sara Title III, Section 313: Does not contain any chemicals under this section

TSCA: The material is tested on the TSCA inventory list

California Proposition 65: The material does not contain any chemicals currently on the California List of known carcinogens and reproductive toxins

U.S. Federal Regulations:

OSHA (29 CFR 1910.1200)	Air contaminate, Table Z-1-A
CERCLA (40 CFR 302.4)	Contains no CERCLA hazardous substance
RCRA (40 CFR 261.33, 261.20-24)	Listed hazardous waste: No

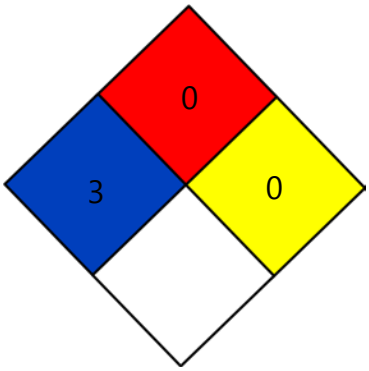
Handling/Storage Procedures

Storage: The material should be stored in sealed containers in a dry, well-ventilated area away from strong oxidizers (chlorine, permanganate, ozone, etc.), ignition sources, combustible materials, and heat.

Handling: Avoid contact with eyes and skin. Avoid scattering of dust into air and breathing of dust. Keep containers dry and closed. Wash skin thoroughly after handling.

Accidental Release Measures: When leaks or spill occur, clean up in a fashion that does not dissipate dust into air. Manage in accordance with good industrial hygiene and safety practices such as avoiding unnecessary exposure and removal of material from skin, clothing, and eyes.

Alkali Carbonate



Health Hazard: 3 – Harmful if swallowed. Causes serious eye irritation. Causes skin irritation.

Fire Hazard: 0

Reactivity: 0

Potential health effects:
Inhalation: Not acutely toxic by inhalation
Skin contact: Substance may cause slight skin irritation
Eye contact: May cause eye irritation, which if untreated, can be severe and permanent
Ingestion: May cause irritation and burns from the mouth to the stomach. Ingesting massive Amounts may cause ulcerations, vomiting, and death from shock.
Chronic effects: Repeated or prolonged contact may result in dermatitis

Property	Value/Comments
Solubility (water)	100%
pH	Moderately basic in solution
Volatility	Not applicable
Evaporation Rate	Not applicable
Hazardous Decomposition	Carbon oxides, alkali oxides
Hazardous Polymerization	Does not occur
Stability	Stable at normal temperatures and pressures
Incompatibility	Acids, prolonged contact with: aluminum, brass, bronze, copper, lead, tin, zinc or other alkali sensitive metals or alloys

Toxicological Information

LD50 Oral: 1,870 mg/kg (rat); 2,570 mg/kg (mouse)
LC50 Inhalation: > 4.96 mg/l (rat/4.5 hours)
LD50 Dermal: > 2,000 mg/kg

Acute Toxicity: May cause eye irritation, that if untreated can be severe and permanent; May cause slight skin and respiratory irritation. The material when applied to the skin of guinea pigs did not elicit and dermal sensitization reaction. Ingestion may cause irritation and burns for the mouth to the stomach. Ingesting massive amounts may cause ulcerations, vomiting, and death from shock.

Carcinogenicity: The material is not classified as a carcinogen by NTP, IARC or OSHA.

Mutagenic Data: Tested negative in test systems evaluated

Reproductive Toxicity: No studies located

Developmental Toxicity: No discernable effects on maternal or fetal survival were observed in animal studies.

Ecological Information

Freshwater Fish Toxicity:
LC50 Bluegil sunfish 230 mg/l/96 hr.
LC50 Rainbow trout 68 mb/l/96 hr.
LC50 Pimephales promelas (flathead minnow) 940 mg/l/24 hr.
LC50 Pimephales promelas (flathead minnow) 820 mg/l/48 hr.
LC50 Pimephales promelas (flathead minnow) <510 mg/l/96 hr.

Invertebrate Toxicity:
EC50 Daphnia magna 430 mg/l/48 hr. (hard water)
EC50 Daphnia pulex 200 mg/l/48 hr. (soft water)

Other Toxicity:
LC50 Ceriodaphnia dubia (water flea) 630 mg/l/24 hr.
LC50 Ceriodaphnia dubia (water flea) 630 mb/l/48 hr.
LC50 Daphnia magna (water flea) 670 mg/l/24 hr.
LC50 Daphnia magna (water flea) 650 mb/l/48 hr.

Biodegradation: The material is inorganic and not subject to biodegradation

Persistence: The material is believed not to persist in the environment

Bioaccumulative Potential: The material is believed not to bioaccumulate

Additional information: The material may increase the pH of waterways and adversely affect aquatic life.

Regulatory Information

U.S. Regulations:
OSHA regulatory status: The material is considered hazardous by the OSHA 29 CFR 1910.1200
CERCLA CFR 302.4): Not regulated
EPCRA (40 CFR 355.30): Not regulated
EPCRA (40 CFR 370.21): Acute Health Hazard
EPCRA (40 CFR 372.65): Not regulated
Department of Homeland Security (6 CFR 27): Not regulated
OSHA Process Safety (29 CFR 1910.119): Not regulated

FDA: The material has Generally Recognized as Safe (GRAS) status under specific FDA regulations. Additional information is available from the Code of Federal Regulations which is accessible on the FDA's website.

National Inventory Status:
U.S. Inventory Status: Toxic Substance Control Act (TSCA): All components are listed or exempt
TSCA 12(b): The material is not subject to export notification
Canadian Chemical Inventory: All components of the material are listed on either DSL or the NDSL

State Regulations:

California Proposition 65 Cancer WARNING:	Not Listed
California Proposition 65 CRT List – Male reproductive toxin:	Not Listed
California Proposition 65 CRT List – Female reproductive toxin:	Not Listed
Massachusetts Right to Know Hazardous Substance List:	Not Listed
New Jersey Right to Know Hazardous Substance List:	Not Listed
New Jersey Special Health Hazards Substance List:	Not Listed
Pennsylvania Right to Know Hazardous Substance List:	Not Listed
Pennsylvania Right to Know Special Hazards Substance List:	Not Listed
Pennsylvania Right to Know Environmental Hazard List:	Not Listed
Rhode Island Right to Know Hazardous Substance List:	Not Listed

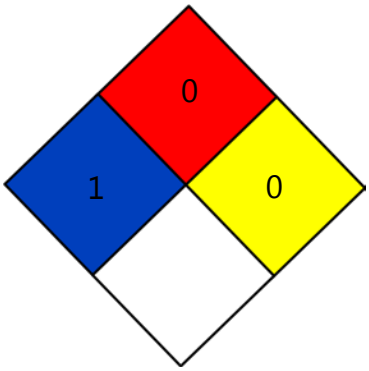
Handling/Storage Procedures

Storage: Containers should be tightly closed and properly labeled. Granular and powdered material is very hygroscopic. Store in a cool, dry area. Keep separated from incompatible substances identified previously.

Handling: Avoid breathing dust. When using, do not eat, drink, or smoke. Wash thoroughly after handling. Do not reuse containers.

Accidental Release Measures: Wear appropriate PPE. Shovel dry material into suitable container. Flush spill area with water, if appropriate. Keep out of water supplies and sewers. Releases should be reported, if required, to appropriate agencies.

Alkali Bicarbonate



Health Hazard: 1 – causes eye irritation; causes mild skin irritation; harmful if inhaled; may cause respiratory tract irritation

Fire Hazard: 0

Reactivity: 0

Major Health Hazards: causes eye irritation; causes mild skin irritation; harmful if inhaled; may cause respiratory tract irritation

Potential health effects:
Inhalation: Causes respiratory irritation; Upper airway irritation; may cause cough, redness of mouth and upper airways
Skin contact: May cause redness or irritation
Eye contact: May cause eye irritation and redness to the eye lids, conjunctiva
Ingestion: No effects identified
Chronic Effects: No delayed or chronic effects were identified
Medical conditions aggravated by exposure: May aggravate preexisting conditions, such as eye disorders that decrease tear production or have reduced integrity of the eye; skin disorders that compromise the integrity of the skin.

Property	Value/Comments
Water Solubility	23% at 20°C
pH	Slightly basic in solution; pH 8.2 for 1% solution at 25°C
Volatility	Not applicable
Evaporation Rate	Not applicable
Hazardous Decomposition	Alkali oxides, carbon oxides. Heating above 100°C may cause dangerous levels of carbon dioxide gas to be present in the atmosphere
Hazardous Polymerization	Does not occur
Stability	Stable at normal temperatures and pressures
Incompatibility	Lime, acids; Prolonged contact with: aluminum, brass, bronze, copper, lead, tin, zinc or other alkali sensitive materials or alloys

Toxicological Information

Product Toxicity Data:
LD50 Oral 2064 mg/kg (rat)
LD50 Dermal >2000 g/kg (rabbit)
LC50 Inhalation >4.88 mb/l/4.5 hr. (rat)

Interaction with other chemicals which enhance toxicity: None known

GHS Health Hazards:
Acute Toxicity – Dermal: Not classified as acutely toxic for dermal exposure
Acute Toxicity – Inhalation: Category 4 – Harmful if inhaled
Contact Hazard – Skin: Category 3 – Causes mild irritation
Contact Hazard – Eye: Category 2B – Causes eye irritation
Sensitization Hazard: Not classified as a skin sensitizer per GHS criteria. The material when applied to the skin of guinea pigs did not elicit any dermal sensitization reaction.
Carcinogenicity: The product is not classified as a carcinogen by NTP, IARC or OSHA
Specific Target Organ Toxicity (Single Exposure): Category 3 – Respiratory Tract Irritation

Ecological Information

Fish Toxicity Data:
LC50 Bluegill sunfish: 1500 mg/l/96 hr. (practically nontoxic)
LC50 Rainbow trout: 1300 mb/l/96 hr. (practically nontoxic)

Invertebrate Toxicity Data:
EC50 Daphnia magna: 1200 mb/l/48 hr. (practically nontoxic)

Biodegradation: The material is inorganic and not subject to biodegradation

Persistence: The material is believed not to persist in the environment

Bioconcentration: The material is believed not to bioaccumulate

Soil mobility: No data available

Regulatory Information

U.S. Regulations:
OSHA Regulatory Status: This material is considered hazardous by OSHA 29 CFR 1910.1200
CERCLA (40 CFR 302.4): Not regulated
SARA EHS Chemical (40 CFR 355.30): Not regulated
EPCRA (40 CFR 370.10): None
EPCRA (40 CFR 372.65): Not regulated
OSHA Process Safety (29 CFR 1910.119): Not regulated

National Inventory Status:
U.S. Inventory Status: Toxic Substance Control Act (TSCA): All components are listed or exempt
TSCA 12(b): The material is not subject to export notification
Canadian Chemical Inventory: All components are listed on either the DSL or the NDSL

State Regulations:
There are no applicable state regulations for the material

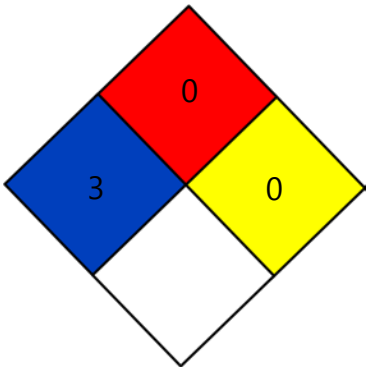
Handling/Storage Procedures

Safe Handling: Avoid breathing dust. Wash thoroughly after handling. Handle in accordance with good industrial hygiene and safety practice. When using, do not eat, drink, or smoke. Do not reuse containers. Wear appropriate PPE.

Storage: Keep containers tightly closed and properly labeled. Material is very hygroscopic. Story in a cool, dry area and keep separated from incompatible substances described previously.

Accidental Release Measures: Shovel dry material into suitable container. Flush spill area with water, if appropriate. Keep out of water supplies and sewers. Releases should be reported, if required, to appropriate agencies.

Alkali Sulfate



Health Hazard: 3 – skin and eye irritant; harmful if ingested or inhaled; slightly hazardous for skin permeation

Fire Hazard: 0

Reactivity: 0

Acute Health Effects:
Inhalation: dust can cause irritation of the respiratory tract and cause coughing
Absorption of High Quantities: Gastrointestinal complaints, nausea, diarrhea, irritation of the gastric/intestinal mucosa, decreased renal function, disturbances of heart rate, inflammation/damage of the eye tissue
Eyes: Irritation of the eye tissue – inflammation/damage of the eye tissue including redness
Skin: Slight skin irritant

Chronic Health Effects:
Continuous exposure: Respiratory difficulties, skin rash/inflammation. Not classified as toxic to reproduction. Not listed in mutagenicity class. Not listed in carcinogenicity class. No cumulative effect.

Property	Value/Comments
Water Solubility	11% at 20°C
pH	7
Volatility	Not applicable
Evaporation Rate	Not applicable
Hazardous Decomposition	Decomposes at elevated temperatures that results in release of toxic and corrosive gases/vapor - sulfur oxides.
Hazardous Polymerization	Does not occur
Stability	Stable under proper handling, storage and treatment
Incompatibility	Reacts violently with some metals when in molten state - take care when using at elevated temperatures

Toxicological Information

LD50 Oral >2000 mg/kg (rat)
LD50 Dermal > 2000 mb/kg (rat)

Carcinogenicity: Not considered carcinogenic substance by IARC, ACGIH, NTP, or OSHA standards

Mutagenicity/Toxicity: Not data available regarding reproductive or mutagenic toxicity

Ecological Information

Slightly harmful to fishes (LC50 100/1000 mg/l)

Not harmful to aquatic organisms (EC50 > 1000 mg/l)

LC50 (for fish)	Comp 1: 3500 mg/l Comp 2: 653-796 mg/l
EC50 (for crustacean)	Comp 1: 890 mg/l/48 hr.
ErC50 (for algea)	Comp 1: 2900 mg/l/72 hr.

Biodegradation: The material is inorganic and not subject to biodegradation

Bioaccumulative potential: no data available

Mobility in soil: soluble in water

Regulatory Information

SARA 302 Components: The material is not subject to reporting requirements in SARA Title III, Section 302

SARA 313 Components: The material does not contain any components with known CAS numbers that exceed the threshold (De Minimis) reporting levels established by SARA Title III, Section 313.

SARA 311/312 Hazards: None

Massachusetts Right to Know Components: Not Listed

Pennsylvania Right to Know Components: CAS-No. 7778-80-5

New Jersey Right to Know Components: CAS-No. 7778-80-5

California Proposition 65 Components: The material does not contain any chemicals known to cause cancer, birth defects or any other reproductive harm.

Handling/Storage Procedures

Handling: Avoid dust formation; Avoid contact with eyes, skin and clothing; Apply normal hygiene rules – do not eat, drink or smoke; wash thoroughly after handling

Storage: Store in a cool, dry and well ventilated area. Keep material in tightly sealed containers. Keep away from heat, ignition sources, flammable substances and incompatible substances. Suitable storage media includes: wood, glass, synthetic materials.

Accidental Release Measures:

- Personal precautions, PPE and emergency procedures
    - Evacuate and stake out danger area
    - Wear appropriate PPE when entering danger area
    - Avoid inhaling dust
    - Avoid contact with eyes, skin and clothing
- Environmental precautions
    - Prevent spreading in sewers
    - Prevent soil and water contamination
    - Make sure to completely contain the spill
- Methods and materials for containment and cleaning
    - Any spillage should be cleaned immediately
    - Collect as much as possible in a suitable, clean container
    - Clean contaminated surfaces with an excess amount of water
    - Make sure to keep washing fluids contained
    - Wash clothing and equipment after handling

REFERENCES

1) Material Safety Data Sheet – Activated Carbon. Carbon Resources LLC
2) Material Safety Data Sheet – Potassium Carbonate (Anhydrous). Laguna Clay Company
3) Material Safety Data Sheet – Potassium Bicarbonate (Anhydrous). Armand Products Company
4) Material Safety Data Sheet – Potassium Sulfate. Van Iperen International
5) Midwestern BioAg. Better Farming through Better Soil. "Sulfate of Potash (0-0-50)." Available at http://www.midwesternbioag.com/product/sulfate-of-potash-0-0-50/
6) Babcock & Wilcox Company. "Conversion of Potassium Sulphate to Potassium Carbonate." U.S. Patent No. 3,127,237. March 31, 1964.
7) Gloss, G. et al. "Production of Potassium Carbonate." U.S. Patent No. 2,903,336. Sept. 8, 1959.