Chapter 9

Environmental Considerations of We Energies Coal Combustion Products and Regulatory Requirements

Introduction

Fly ash and bottom ash consist of residual inorganic components in coal that are not vaporized or emitted as volatile gases when coal is burned. The ash contains other non-combustible constituents that are not inorganic. The most common mineral elements found in coal ash in the form of oxides are primarily silicon, aluminum, iron, calcium and magnesium (46).

Oxidation takes place in the furnace due to the heat of combustion. Coal ash contains trace quantities (in the parts-per-million/billion range) of other naturally occurring elements in their oxidized form. Coal ash composition and mineralogy, including their trace element contents, vary primarily based on the source of coal and the combustion conditions.

The major chemical components of both fly ash and bottom ash obtained from the same plant are essentially the same. However, the availability of minor and trace elements are often quite different between fly ash and bottom ash. The chemistry of coal ash is very similar to many naturally occurring soils and natural aggregates. The availability of trace elements from all of these materials is directly related to the particle size. Therefore, the leaching potential of fly ash is higher than bottom ash due to the exponentially higher total surface area available in samples of the same mass.

After reviewing research work on the environmental and health risks associated with coal ash utilization, the U.S. EPA has determined that coal ash is nonhazardous. However, current regulations require protective measures when either fly ash or bottom ash is placed in solid waste disposal sites or other non-contained applications to prevent trace elements from reaching drinking water sources. The use of a respirator is also recommended when handling dry fly ash, which is the same for other finely divided siliceous materials.

Fly ash does not possess any threat to people who do not handle dry unprocessed ash for extended hours. Studies have also proved that there are no inhalation risks from manufactured products containing fly ash. Precautions are generally taken to prevent ash from blowing or dusting during handling. [We Energies material safety data sheet (MSDS) for coal ash is shown in Appendix A]

The utilization of CCPs has several added benefits that are not directly visible. For example, the controlled emissions from a typical cement plant producing 245,000 tons of cement (which is similar to the quantity of We Energies fly ash used as a cementitious material) are 12,000 lbs. of HCl; 54 lbs. of Hg; 220 lbs. of HF; 171 lbs. of Pb; and 49 lbs. of Se. This is in addition to approximately one ton of CO_2 emissions for every ton of cement produced.

Hence, if the entire 245,000 tons of cement is replaced by Class C fly ash (produced anyway from coal combustion), we are reducing CO_2 emissions into the atmosphere by 490,000,000 pounds. This is a large step in reducing greenhouse gas emissions and preserving our virgin raw materials for future generations (sustainable development).

Chemical Elements in Coal Ash

Coal ash may contain nearly all of the naturally-occurring chemical elements, most of them in trace quantities. Table 9-1 gives the list of commonly found chemical elements in coal ash.

Table 9-1: Chemical Elements in Coal Ash

Group 1 (Major) 25% to 1%	Group 2 (Intermediate) 1% to 10 ppm	Group 3 (Minor) 50 to 5 ppm	Group 4 (Minor) 10 ppm to BDL	Group 5 (Usually Minor) 100 to 1 ppm
Silicon	Barium	Silver	Mercury	Carbon
Aluminum	Strontium	Arsenic	Chloride	Cesium
Iron	Manganese	Cadmium	Fluoride	Rubidium
Calcium	Boron	Chromium	Selenium	Germanium
Magnesium	Molybdenum	Copper	Beryllium	Tin
Sodium	Vanadium	Nickel	Antimony	Cobalt
Potassium	Sulfur	Lead	Uranium	Gold
Titanium	Phosphorus	Zinc	Thorium	Platinum

The type and quantity of trace elements in the ash primarily depends on the source of coal. The presence of trace elements in coal ash is a reason that good judgment is required for new applications. State regulations provide guidelines for safe utilization practices.

Leaching From Coal Ash Land Applications

We Energies fly ash and bottom ash has been successfully used in several varieties of land applications. Bottom ash is commonly used as a road base and sub-base, in parking lots as a base material, structural fill, backfill and in top soil. Fly ash is also sometimes used as a road base or structural fill material.

We Energies performs total elemental analysis by the Test Method for Evaluating Solid Waste Physical/Chemical Methods (SW-846) and Proton Induced X-ray Emission Spectroscopy (PIXE) methods and leaching tests of ash samples in accordance with the ASTM distilled water method (ASTM D3987). These tests are used to assess the elemental composition and leaching potential of the ashes as well as to categorize each combustion product source for permitted applications under state rules.

The Wisconsin Department of Natural Resources (WDNR) adopted NR 538 in January, 1998, with the purpose of encouraging the beneficial use of industrial by-products. NR 538 also requires generators to provide certification information on their by-products to the WDNR. The results of the total elemental analysis by SW-846 and PIXE methods on We Energies fly ash and bottom ash are shown in Tables 9-2 and 9-4, respectively. The results of the ASTM D3987 extraction analysis on We Energies fly ash and bottom ash are shown in Tables 9-3 and 9-5. NR 538 has defined limits for several categories of industrial by-products based on the concentration of certain specified parameters.

There are five categories in total with Category 1 having the lowest concentration of the listed parameters. Category 1 by-products have the lowest level of regulatory requirements in terms of beneficial utilization. It can be seen from the following tables that the concentration of elements leaching from fly ash and bottom ash is very low. We Energies fly ash and bottom ash contain only very limited quantities of the trace elements.

Most of these parameters meet the requirements set for Category 1 or Category 2 material. The WDNR can grant an exemption to be classified in a particular category if the concentration of one or two elements is slightly in excess of the set limits. However, this is done on a case-by-case basis. If no exemptions are granted, We Energies bottom ash is primarily a Category 2 material and fly ash is primarily a Category 4 material (with a few exceptions for both fly ash and bottom ash). MCPP mixed ash is also a Category 4 material.

Table 9-2: NR 538 Fly Ash Analysis - Bulk Analysis Data Summary

Parameter	Units	NR538 Category 1 Standard	NR538 Category 2 Standard	VAPP Flyash AC33525	PWPP 1 Flyash AC33526	PWPP 2&3 Flyash AC33527	PIPP 1-4 Flyash AC33528	PIPP 5&6 Flyash AC33529	PIPP 7-9 Flyash AC33530
Total Antimony	ppm	6.3		<0.68	2.7	2.3	2	1.5	<0.53
Total Boron	ppm	1400		480	290	290	760	820	730
Total Barium	ppm	1100		530	150	180	910	930	4000
Total Cadmium	ppm	7.8		<0.22	1.3	1.3	<0.21	1	2.4
Total Lead	ppm	50		4	20	25	17	12	15
Total Molybdenum	ppm	78		8.2	15	16	16	18	13
Total Nickel	ppm	310		34	49	58	59	70	60
Total Vanadium	ppm	110		120	120	140	220	260	210
Total Zinc	ppm	4700		12	59	78	34	25	100
Total Arsenic	ppm	0.042	21	7.4	110	110	19	10	23
Total Beryllium	ppm	0.014	7	0.92	5.2	5.7	2.8	1.9	3.9
Total Thallium	ppm	1.3		<0.50	2.4	2.6	<0.51	<0.53	<0.39
Total Mercury	ppm	4.7		0.21	0.8	1.2	0.35	0.17	0.0007
Hexavalent Chromium	ppm	14.5		0.57	2	5.1	2.9	2.9	28
1-Methylnaphthalene	ppm	8.8		<0.014	0.21	0.62	0.05	<0.014	<0.007
2-Methylnaphthalene	ppm	8.8		<0.015	0.15	0.65	0.075	<0.015	<0.0075
Acenaphthene	ppm	900		<0.022	<0.022	0.029	<0.022	<0.022	<0.011
Acenaphthylene	ppm	8.8		<0.036	<0.036	<0.036	<0.036	<0.036	<0.018
Anthraceme	ppm	5000		<0.022	0.053	<0.022	<0.022	<0.022	<0.011
Benzo(a)anthracene	ppm	0.088	44	<0.012	<0.012	0.041	<0.012	<0.012	<0.006
Benzo(a)pyrene	ppm	0.0088	4.4	<0.012	<0.012	0.097	<0.012	<0.012	<0.006
Benzo(b)fluoranthene	ppm	0.088	44	<0.013	<0.013	0.06	<0.013	<0.013	<0.0065
Benzo(g,h,I)perylene	ppm	0.88		<0.024	<0.024	<0.024	<0.024	<0.024	<0.012
Benzo(k)fluoranthene	ppm	0.88		<0.018	<0.018	0.039	<0.018	<0.018	<0.009
Chrysene	ppm	8.8		<0.014	<0.014	0.041	<0.014	<0.014	<0.0069
Dibenzo(a,h)anthracene	ppm	0.0088	4.4	<0.015	<0.015	<0.015	<0.015	<0.015	<0.0074
Fluoranthene	ppm	600		<0.016	<0.016	<0.016	<0.016	<0.016	<0.008
Fluorene	ppm	600		<0.012	<0.012	0.02	<0.012	<0.012	<0.006
Indeno(1,2,3-cd)pyrene	ppm	0.088	44	<0.022	<0.022	<0.022	<0.022	<0.022	<0.011
Naphthalene	ppm	600		<0.015	0.37	0.95	0.027	<0.015	<0.0075
Phenanthrene	ppm	0.88		<0.016	0.057	0.11	<0.016	<0.016	<0.008
Pyrene	ppm	500		<0.026	<0.026	<0.026	<0.026	<0.026	<0.013
Total PAH's	ppm		100	<0.33	0.84	2.66	0.152	<0.33	<0.17

NR 538 Table 1B exceedances are highlighted in *bold* type.

Table 9-2: NR 538 Fly Ash Analysis - Bulk Analysis Data Summary *(Continued)*

Parameter	Units	NR538 Category 1 Standard	NR538 Category 2 Standard	OCPP Flyash AC33531	PPPP Flyash AC33532	P4 Landfill 1st 10000 AC27609	P4 Landfill 2nd 10000 AC33540	P4 Landfill 3rd 10000 AC33541
Total Antimony	ppm	6.3		<0.63	1.4	28	<0.51	<0.63
Total Boron	ppm	1400		670	950	230	310	290
Total Barium	ppm	1100		4800	4400	3300	3700	3500
Total Cadmium	ppm	7.8		2.6	2.2	1.4	1.6	0.91
Total Lead	ppm	50		31	29	9.6	<6.6	<7.0
Total Molybdenum	ppm	78		7.8	13	5.2	5.5	4.4
Total Nickel	ppm	310		49	96	7.5	39	40
Total Vanadium	ppm	110		190	330	140	150	150
Total Zinc	ppm	4700		75	73	36	27	24
Total Arsenic	ppm	0.042	21	17	25	5.1	6.6	6.8
Total Beryllium	ppm	0.014	7	4.2	5.4	5.7	3	3.2
Total Thallium	ppm	1.3		<0.47	<0.58	<0.69	<0.37	<0.47
Total Mercury	ppm	4.7		0.36	0.22	0.06	0.0069	0.0087
Hexavalent Chromium	ppm	14.5		26	17	5.8	0.58	0.76
1-Methylnaphthalene	ppm	8.8		<0.007	<0.007	<0.0082	0.0076	0.0082
2-Methylnaphthalene	ppm	8.8		<0.0075	<0.0075	<0.0088	0.01	0.0076
Acenaphthene	ppm	900		<0.011	<0.011	<0.013	<0.011	<0.011
Acenaphthylene	ppm	8.8		<0.018	<0.018	<0.021	<0.018	<0.018
Anthraceme	ppm	5000		<0.011	<0.011	<0.013	<0.011	<0.011
Benzo(a)anthracene	ppm	0.088	44	<0.006	<0.006	<0.0071	<0.006	<0.006
Benzo(a)pyrene	ppm	0.0088	4.4	<0.006	<0.006	<0.0071	<0.006	<0.006
Benzo(b)fluoranthene	ppm	0.088	44	<0.0065	<0.0065	<0.0077	<0.0065	<0.0065
Benzo(g,h,I)perylene	ppm	0.88		<0.012	<0.012	<0.014	<0.012	<0.012
Benzo(k)fluoranthene	ppm	0.88		<0.009	<0.009	<0.011	<0.009	<0.009
Chrysene	ppm	8.8		<0.0069	<0.0069	<0.0081	<0.0069	<0.0069
Dibenzo(a,h)anthracene	ppm	0.0088	4.4	<0.0074	<0.0074	<0.0087	<0.0074	<0.0074
Fluoranthene	ppm	600		<0.008	<0.008	0.011	<0.008	0.0094
Fluorene	ppm	600		<0.006	<0.006	<0.0071	<0.006	<0.006
Indeno(1,2,3-cd)pyrene	ppm	0.088	44	<0.011	<0.011	<0.013	<0.011	<0.011
Naphthalene	ppm	600		<0.0075	<0.0075	0.013	0.022	0.014
Phenanthrene	ppm	0.88		<0.008	<0.008	<0.0094	<0.008	0.0099
Pyrene	ppm	500		<0.013	<0.013	<0.015	<0.013	<0.013
Total PAH's	ppm		100	<0.17	<0.17	0.024	0.04	0.049

Table 9-3: NR 538 Fly Ash Analysis - ASTM D3987 Leachate Test Result Summary

Parameter	Units	NR538 Category 1 Standard	NR538 Category 2&3 Standard	NR538 Category 4 Standard	Extraction Blank AC33823	VAPP Flyash AC33824	PWPP Unit 1 Flyash AC33825	PWPP Unit 1 F/A Dupl. AC33826	PWPP 2&3 Flyash AC33827	PIPP 1-4 Flyash AC33828	PIPP 5&6 Flyash AC33829
Dissolved Aluminum	mg/l	1.5	15		0.029	2.6	0.2	0.16	47	7.9	8.2
Dissolved Antimony	mg/l	0.0012	0.012		<0.0019	0.0054	0.04	0.039	0.0069	0.014	0.009
Dissolved Arsenic	mg/l	0.005	0.05		<0.0012	0.004	0.062	0.04	0.0078	0.0067	0.0035
Dissolved Barium	mg/l	0.4	4		<0.0010	0.5	0.11	0.11	0.11	1	1
Dissolved Beryllium	mg/l	0.0004	0.004		<0.00005	<0.00005	<0.00005	<0.00005	0.021	<.00010	0.00005
Dissolved Boron	mg/l				<0.0077	7.6	10	10	11	21	24
Dissolved Cadmium	mg/l	0.0005	0.005	0.025	<0.00004	0.000065	0.00015	0.00014	0.019	<0.00004	0.00051
Chloride	mg/l	125			<0.039	1.5	208	207	2.2	0.65	0.96
Dissolved Chromium	mg/l	0.01	0.1	0.5	<0.00020	0.0027	0.0024	0.0038	0.018	0.049	0.024
Dissolved Copper	mg/l	0.13			<0.00054	<0.00054	0.00067	<0.00054	0.043	0.0017	0.0006
Dissolved Iron	mg/l	0.15			0.0041	0.0032	<0.0012	<0.0012	1.9	0.0059	0.0027
Dissolved Lead	mg/l	0.0015	0.015		<0.0014	<0.0014	0.0035	0.0038	0.0038	<0.0014	<0.0014
Dissolved Manganese	mg/l	0.025	0.25		<0.00042	<0.00042	0.084	0.083	1.8	<0.00042	<0.00042
Mercury	mg/l	0.0002	0.002		0.000007	0.000007	0.000004	0.000004	0.000005	<0.000002	<0.000002
Dissolved Molybdenum	mg/l	0.05			<0.0062	0.12	0.49	0.49	0.026	0.5	0.56
Dissolved Nickel	mg/l	0.02			<0.00056	<0.00056	0.0078	0.0079	0.41	<0.00056	<0.00056
Nitrate-Nitrite as N	mg/l	2			<0.095	<0.095	<0.095	<0.095	<0.095	<0.095	<0.095
Dissolved Selenium	mg/l	0.01	0.1	0.25	<0.0015	0.041	0.17	0.16	<0.0015	0.21	0.16
Dissolved Silver	mg/l	0.01	0.1	0.25	<0.00004	<0.00004	0.00021	0.00025	<0.00004	<0.00004	<0.00004
Sulfate	mg/l	125	1250	2500	<0.10	96	2650	2730	1340	244	192
Dissolved Thallium	mg/l	0.0004	0.004		<0.0014	<0.0014	0.004	<0.0014	0.0057	<0.0014	<0.0014
Dissolved Zinc	mg/l	2.5			<0.0016	<0.0016	0.003	0.0056	0.69	0.0057	0.011

Note: A value highlighted in bold exceeds the NR 538 Category 1 Standard.

Table 9-3: NR 538 Fly Ash Analysis - ASTM D3987 Leachate Test Result Summary *(Continued)*

Parameter	Units	NR538 Category 1 Standard	NR538 Category 2&3 Standard	R538 Category 4 Standard	Extraction Blank AC33823	PIPP 7-9 Flyash AC33830	OCPP Flyash AC33831	PPPP Flyash AC33832	P4 Landfill 1st 10000 AC27750	P4 Landfill 2nd 10000 AC33841	P4 Landfill 3rd 10000 AC33842
Dissolved Aluminum	mg/l	1.5	15		0.029	55	34	64	10	4.8	7.2
Dissolved Antimony	mg/l	0.0012	0.012		<0.0019	<0.0019	<0.0019	<0.0019	<0.0019	<0.0019	<0.0019
Dissolved Arsenic	mg/l	0.005	0.05		<0.0012	<0.0012	<0.0012	<0.0012	<0.0012	0.0013	0.0024
Dissolved Barium	mg/l	0.4	4		<0.0010	2.2	42	6.6	0.24	0.21	0.22
Dissolved Beryllium	mg/l	0.0004	0.004		<0.00005	0.00011	0.00017	0.000089	<0.00005	<0.00005	<0.0005
Dissolved Boron	mg/l				<0.0077	0.16	4.3	0.44	1	1.5	1.5
Dissolved Cadmium	mg/l	0.0005	0.005	0.025	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004
Chloride	mg/l	125			<0.039	1.9	0.61	0.34	0.16	0.34	<0.039
Dissolved Chromium	mg/l	0.01	0.1	0.5	<0.00020	0.45	0.00024	0.2	<0.0025	0.0021	0.0014
Dissolved Copper	mg/l	0.13			<0.00054	<0.00054	0.0018	0.00074	0.0012	0.00089	<0.00054
Dissolved Iron	mg/l	0.15			0.0041	0.016	<0.0012	0.027	0.011	0.0031	0.0025
Dissolved Lead	mg/l	0.0015	0.015		<0.0014	<0.0014	0.0015	<0.0014	<0.00083	<0.0014	<0.0014
Dissolved Manganese	mg/l	0.025	0.25		<0.00042	<0.00042	<0.00042	<0.00042	<0.00045	<0.00042	<0.00042
Mercury	mg/l	0.0002	0.002		0.000007	0.000011	0.000004	<0.000002	<0.00016	0.000006	0.000004
Dissolved Molybdenum	mg/l	0.05			<0.0062	0.16	<0.0062	0.12	<0.012	0.013	<0.0062
Dissolved Nickel	mg/l	0.02			<0.00056	<0.00056	<0.00056	<0.00056	<0.00056	<0.00056	<0.00056
Nitrate-Nitrite as N	mg/l	2			<0.095	<0.095	<0.095	<0.095	<0.027	<0.095	<0.095
Dissolved Selenium	mg/l	0.01	0.1	0.25	<0.0015	0.045	0.0027	0.011	<0.0015	0.0033	0.0016
Dissolved Silver	mg/l	0.01	0.1	0.25	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004
Sulfate	mg/l	125	1250	2500	<0.10	180	<0.10	26	112	180	138
Dissolved Thallium	mg/l	0.0004	0.004		<0.0014	<0.0014	0.0018	<0.0014	<0.0014	<0.0014	<0.0014
Dissolved Zinc	mg/l	2.5			<0.0016	0.0025	0.031	0.0099	<0.0042	0.0092	<0.0016

Table 9-4: NR 538 Bottom Ash Analysis - Bulk Analysis Data Summary

Parameter	Units	NR538 Category 1 Standard	NR538 Category 2 Standard	MCPP Mixed Ash AC33533	PWPP Bottom Ash AC33534	VAPP Bottom Ash AC33535	PIPP 1-6 Bottom Ash AC33536	PIPP 7-9 Bottom Ash AC33537
Total Antimony	ppm	6.3		4	<0.80	0.76	<0.51	<0.58
Total Boron	ppm	1400		94	32	190	76	220
Total Barium	ppm	1100		240	36	400	180	3200
Total Cadmium	ppm	7.8		0.46	<0.20	0.37	<0.20	1
Total Lead	ppm	50		53	<3.1	<3.2	<3.1	<3.3
Total Molybdenum	ppm	78		12	2.6	1.7	2.5	2.6
Total Nickel	ppm	310		52	11	8.6	11	27
Total Vanadium	ppm	110		67	22	28	33	99
Total Zinc	ppm	4700		100	9.4	12	3.4	24
Total Arsenic	ppm	0.042	21	47	16	5	1.6	4.2
Total Beryllium	ppm	0.014	7	6.6	1.1	0.8	0.58	2
Total Thallium	ppm	1.3		2.9	<0.59	<0.54	<0.37	<0.43
Total Mercury	ppm	4.7		0.067	0.17	0.063	0.0024	0.007
Hexavalent Chromium	ppm	14.5		0.47	0.28	0.67	<0.20	0.95
1-Methylnaphthalene	ppm	8.8		0.022	0.26	<0.0093	<0.014	0.007
2-Methylnaphthalene	ppm	8.8		0.029	0.39	<0.010	<0.015	0.0097
Acenaphthene	ppm	900		<0.011	<0.015	<0.015	<0.022	<0.011
Acenaphthylene	ppm	8.8		<0.018	<0.024	<0.024	<0.036	<0.018
Anthraceme	ppm	5000		<0.011	<0.015	<0.015	<0.022	<0.011
Benzo(a)anthracene	ppm	0.088	44	<0.006	0.0088	<0.008	<0.012	<0.006
Benzo(a)pyrene	ppm	0.0088	4.4	<0.006	<0.008	<0.008	<0.012	<0.006
Benzo(b)fluoranthene	ppm	0.088	44	<0.0065	<0.0087	<0.0087	<0.013	<0.0065
Benzo(g,h,I)perylene	ppm	0.88		<0.012	<0.016	<0.016	<0.024	<0.012
Benzo(k)fluoranthene	ppm	0.88		<0.009	<0.012	<0.012	<0.018	<0.009
Chrysene	ppm	8.8		<0.0069	0.014	<0.0092	<0.014	<0.0069
Dibenzo(a,h)anthracene	ppm	0.0088	4.4	<0.0074	<0.0099	<0.0099	<0.015	<0.0074
Fluoranthene	ppm	600		<0.008	0.014	<0.011	<0.016	<0.008
Fluorene	ppm	600		<0.006	0.013	<0.008	<0.012	<0.006
Indeno(1,2,3-cd)pyrene	ppm	0.088	44	<0.011	<0.015	<0.015	<0.022	<0.011
Naphthalene	ppm	600		0.02	0.23	<0.010	<0.015	0.0095
Phenanthrene	ppm	0.88		0.012	0.099	<0.011	<0.016	<0.008
Pyrene	ppm	500		<0.013	<0.017	<0.017	<0.026	<0.013
Total PAH's	ppm		100	0.083	1.03	<0.22	<0.33	0.026

NR 538 Table 1B exceedences are highlighted in bold type.

Table 9-4: NR 538 Bottom Ash Analysis - Bulk Analysis Data Summary *(Continued)*

Parameter	Units	NR538 Category 1 Standard	NR538 Category 2 Standard	OCPP Bottom Ash AC33538	PPPP Bottom Ash AC33539	OCPP Grounds BA/Asphalt AC29510	OCPP Grounds BA/Asphalt Increased 1/3	CemRock w/P4 Flyash AC33542
Total Antimony	ppm	6.3		<0.53	<0.66	<20	<Detect	<0.74
Total Boron	ppm	1400		250	260	41	54.530	710
Total Barium	ppm	1100		3300	2500	100	133.000	4000
Total Cadmium	ppm	7.8		<0.49	0.73	2.4	3.192	1.9
Total Lead	ppm	50		<7.4	<6.4	16	21.280	20
Total Molybdenum	ppm	78		4.4	4.2	5.8	7.714	11
Total Nickel	ppm	310		130	45	15	19.950	66
Total Vanadium	ppm	110		110	140	22	29.260	230
Total Zinc	ppm	4700		18	14	100	133.000	61
Total Arsenic	ppm	0.042	21	3.4	5.3	6.6	8.778	18
Total Beryllium	ppm	0.014	7	2.6	2.9	0.67	0.891	3.8
Total Thallium	ppm	1.3		<0.39	<0.48	0.48	0.638	<0.54
Total Mercury	ppm	4.7		0.0049	0.0022	<0.038	<Detect	0.16
Hexavalent Chromium	ppm	14.5		1.1	0.27	3.2	4.256	11
1-Methylnaphthalene	ppm	8.8		<0.007	<0.007	0.15	0.200	<0.007
2-Methylnaphthalene	ppm	8.8		<0.0075	<0.0075	0.18	0.239	<0.0075
Acenaphthene	ppm	900		<0.011	<0.011	0.008	0.011	<0.011
Acenaphthylene	ppm	8.8		<0.018	<0.018	0.0089	0.012	<0.018
Anthraceme	ppm	5000		<0.011	<0.011	0.031	0.041	<0.011
Benzo(a)anthracene	ppm	0.088	44	<0.006	<0.006	0.077	0.102	<0.006
Benzo(a)pyrene	ppm	0.0088	4.4	<0.006	<0.006	0.097	0.129	<0.006
Benzo(b)fluoranthene	ppm	0.088	44	<0.0065	<0.0065	0.083	0.110	<0.0065
Benzo(g,h,I)perylene	ppm	0.88		<0.012	<0.012	0.067	0.089	<0.012
Benzo(k)fluoranthene	ppm	0.88		<0.009	<0.009	0.074	0.098	<0.009
Chrysene	ppm	8.8		<0.0069	<0.0069	0.089	0.118	<0.0069
Dibenzo(a,h)anthracene	ppm	0.0088	4.4	<0.0074	<0.0074	0.024	0.032	<0.0074
Fluoranthene	ppm	600		0.0094	<0.008	0.1	0.133	<0.008
Fluorene	ppm	600		<0.006	<0.006	0.022	0.029	<0.006
Indeno(1,2,3-cd)pyrene	ppm	0.088	44	<0.011	<0.011	0.058	0.077	<0.011
Naphthalene	ppm	600		0.034	<0.0075	0.086	0.114	<0.0075
Phenanthrene	ppm	0.88		0.0084	<0.008	0.18	0.239	<0.008
Pyrene	ppm	500		0.014	<0.013	0.14	0.186	<0.013
Total PAH's	ppm		100	0.066	<0.17	1.47	1.955	<0.17

Table 9-5: NR 538 Bottom Ash Analysis - ASTM D3987 Leachate Test Result Summary

Parameter	Units	NR538 Category 1 Standard	NR538 Category 2&3 Standard	R538 Category 4 Standard	Extraction Blank AC33823	MCPP Mixed Ash AC33823	PWPP Bottom Ash AC33534	VAPP Bottom Ash AC33535	PIPP 1-6 Bottom Ash AC33536	PIPP 1-6 B/A Dupl. AC33837	PIPP 7-9 Bottom Ash AC33537
Dissolved Aluminum	mg/l	1.5	15		0.029	0.07	0.68	1.2	0.54	0.67	9
Dissolved Antimony	mg/l	0.0012	0.012		<0.0019	0.026	<0.0019	0.0052	<0.0019	<0.0019	<0.0019
Dissolved Arsenic	mg/l	0.005	0.05		<0.0012	<0.0012	0.051	0.012	0.0046	0.0044	<0.0012
Dissolved Barium	mg/l	0.4	4		<0.0010	0.33	0.017	0.48	0.15	0.14	0.67
Dissolved Beryllium	mg/l	0.0004	0.004		<0.00005	0.00019	<0.00005	<0.00005	<0.00005	<0.00005	<0.00005
Dissolved Boron	mg/l				<0.0077	1.9	0.17	4	0.44	0.4	0.71
Dissolved Cadmium	mg/l	0.0005	0.005	0.025	<0.00004	0.0042	<0.00004	<0.00004	<0.00004	<0.00004	0.000042
Chloride	mg/l	125			<0.039	2.2	0.62	1.1	0.71	0.74	0.38
Dissolved Chromium	mg/l	0.01	0.1	0.5	<0.00020	<0.00020	0.00063	0.0024	0.00028	0.00023	0.0048
Dissolved Copper	mg/l	0.13			<0.00054	0.0038	<0.00054	0.00075	<0.00054	<0.00054	<0.00054
Dissolved Iron	mg/l	0.15			0.0041	<0.0012	0.01	0.0035	0.02	0.014	0.0052
Dissolved Lead	mg/l	0.0015	0.015		<0.0014	<0.0014	<0.0014	<0.0014	<0.0014	<0.0014	<0.0014
Dissolved Manganese	mg/l	0.025	0.25		<0.00042	0.26	0.0006	<0.00042	<0.00042	<0.00042	<0.00042
Mercury	mg/l	0.0002	0.002		0.000007	<0.000002	0.000012	0.000003	0.000005	0.000003	<0.000002
Dissolved Molybdenum	mg/l	0.05			<0.0062	0.058	0.008	0.028	0.019	0.013	<0.0062
Dissolved Nickel	mg/l	0.02			<0.00056	0.37	0.00093	<0.00056	<0.00056	<0.00056	<0.00056
Nitrate-Nitrite as N	mg/l	2			<0.095	<0.095	<0.095	<0.095	<0.095	<0.095	<0.095
Dissolved Selenium	mg/l	0.01	0.1	0.25	<0.0015	0.002	<0.0015	0.015	0.0022	0.0022	<0.0015
Dissolved Silver	mg/l	0.01	0.1	0.25	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004	<0.00004
Sulfate	mg/l	125	1250	2500	<0.10	372	44	47	28	30	65
Dissolved Thallium	mg/l	0.0004	0.004		<0.0014	0.0031	<0.0014	<0.0014	<0.0014	<0.0014	<0.0014
Dissolved Zinc	mg/l	2.5			<0.0016	0.88	<0.0016	<0.0016	0.0031	0.0019	<0.0016

Note: A value highlighted in bold exceeds the NR538 Category 1 standard.

Table 9-5: NR 538 Bottom Ash Analysis - ASTM D3987 Leachate Test Result Summary *(Continued)*

Parameter	Units	NR538 Category 1 Standard	NR538 Category 2&3 Standard	R538 Category 4 Standard	Extraction Blank AC33823	OCPP Bottom Ash AC33538	PPPP Bottom Ash AC33539	OCPP Grounds BA/Asphalt AC29510	OCPP Grounds BA/Asphalt Increased 1/3	CemRock w/P4 Flyash AC33542
Dissolved Aluminum	mg/l	1.5	15		0.029	17	12	0.44	0.5852	27
Dissolved Antimony	mg/l	0.0012	0.012		<0.0019	<0.0019	<0.0019	<0.0019	<Detect	0.0022
Dissolved Arsenic	mg/l	0.005	0.05		<0.0012	<0.0012	0.0015	0.004	0.00532	<0.0012
Dissolved Barium	mg/l	0.4	4		<0.0010	0.47	0.54	0.053	0.07049	0.8
Dissolved Beryllium	mg/l	0.0004	0.004		<0.00005	<0.00005	0.000053	0.000058	0.00007714	0.00008
Dissolved Boron	mg/l				<0.0077	0.79	0.85	0.02	0.0266	2.7
Dissolved Cadmium	mg/l	0.0005	0.005	0.025	<0.00004	0.00004	0.000055	0.00024	0.0003192	0.00006
Chloride	mg/l	125			<0.039	0.37	0.74	6.8	9.044	2
Dissolved Chromium	mg/l	0.01	0.1	0.5	<0.00020	0.0049	0.003	<0.0025	<Detect	0.22
Dissolved Copper	mg/l	0.13			<0.00054	0.0038	<0.00054	<0.0022	<Detect	0.2
Dissolved Iron	mg/l	0.15			0.0041	0.016	0.0069	0.027	0.03591	0.011
Dissolved Lead	mg/l	0.0015	0.015		<0.0014	<0.0014	<0.0014	<0.00083	<Detect	<0.0014
Dissolved Manganese	mg/l	0.025	0.25		<0.00042	<0.00042	<0.00042	0.0008	0.001064	<0.00042
Mercury	mg/l	0.0002	0.002		0.000007	0.000051	0.000005	<0.00016	<Detect	0.000004
Dissolved Molybdenum	mg/l	0.05			<0.0062	0.0065	<0.0062	<0.012	<Detect	0.12
Dissolved Nickel	mg/l	0.02			<0.00056	<0.00056	<0.00056	<0.0035	<Detect	0.029
Nitrate-Nitrite as N	mg/l	2			<0.095	<0.095	<0.095	0.98	1.3034	0.11
Dissolved Selenium	mg/l	0.01	0.1	0.25	<0.0015	<0.0015	0.0028	<0.0015	<Detect	0.028
Dissolved Silver	mg/l	0.01	0.1	0.25	<0.00004	<0.00004	<0.00004	<0.00004	<Detect	<0.00004
Sulfate	mg/l	125	1250	2500	<0.10	34	70	7.7	10.241	76
Dissolved Thallium	mg/l	0.0004	0.004		<0.0014	<0.0014	<0.0014	<0.0011	<Detect	<0.0014
Dissolved Zinc	mg/l	2.5			<0.0016	<0.0016	<0.0016	<0.0042	<Detect	0.0028

Leaching From Products Containing Coal Combustion Products

Fly ash has found great applications in construction products like concrete, CLSM and in the manufacture of Portland cement. It is well established that leaching of trace elements from concrete is negligible. Concrete is very dense and impermeable, making it hard for water to penetrate into the interior of a concrete structure. The reaction products in concrete are stable, dense and do not leach significantly in the natural environment.

The composition of CLSM material is different from that of concrete. It is a low-strength material, often with a compressive strength of less than 300 psi. When prepared with large amounts of fly ash, the permeability is also very low. However, the potential for future removal and handling could allow the material to be broken up into smaller particles with more leachable surface area. Hence, ASTM D-3987 Extraction Analysis has been performed on this material to determine the amount of trace elements leached out of high fly ash content CLSM.

Table 9-6 shows the total results of total elemental analysis for CLSM produced with PWPP Units 2 and 3 fly ash. Table 9-7 gives the results of ASTM D-3987 Extraction Analysis for the same material. The extract meets all requirements for Category 2 per NR 538.

Table 9-6: Total Elemental Analysis – CLSM Produced with Port Washington Power Plant Units 2 & 3 Fly Ash

Parameter	Detection Level	Units	NR 538 Category 1 Standard	NR 538 Category 2 & 3 Standard	Collected 11/19/97 AB 59506	Collected 11/19/97 AB 59507
Antimony – PIXE	166	Mg/kg	6.3		<166	<199
Arsenic - SW-846	0.06	mg/kg	0.042	21	57	58
Barium - SW-846	0.056	mg/kg	1100		168	160
Beryllium - SW-846	0.06	mg/kg	0.014	7	3.3	3.6
Boron - SW-846	0.014	mg/kg	1400		200	180
Cadmium - SW-846	0.005	mg/kg	7.8		1.3	0.92
Chromium - PIXE	39.8	mg/kg	14.5 as Hex		171	239
Lead - PIXE	41.6	mg/kg	50		212	160
Mercury - SW-846	0.0037	mg/kg	4.7		<0.0037	<0.0037
Molybdenum - SW-846	0.19	mg/kg	78		12	9.2
Nickel	13.1	mg/kg	310		103	94.7
Thallium - PIXE	33.5	mg/kg	1.3		<33.5	<25.5
Vanadium - PIXE	80.6	mg/kg	110		<80.6	<81.1
Zinc - PIXE	14.6	mg/kg	4700		179	173

PIXE - Proton Induced X-Ray Emission Spectroscopy
SW-846 - Test Methods for Evaluating Solid Waste Physical/Chemical Methods

Table 9-7: ASTM D3987 Extraction Analysis – CLSM Produced With Port Washington Power Plant Units 2 & 3 Fly Ash

Parameter	Detection Level	Units	NR 538 Category 1 Standard	NR 538 Category 2 & 3 Standard	Collected 11/19/97 AB 59630	Collected 11/19/97 AB 59631
Aluminum	0.011	mg/l	1.5	15	6	5.5
Antimony	0.0015	mg/l	0.0012	0.12	0.0051	0.005
Arsenic	0.0006	mg/l	0.005	0.05	0.03	0.031
Barium	0.0009	mg/l	0.4	4	0.041	0.047
Beryllium	0.0002	mg/l	0.0004	0.004	<0.0002	<0.0002
Cadmium	0.0001	mg/l	0.0005	0.005	0.0001	<0.0001
Chloride	0.15	mg/l	125		2	3.2
Chromium	0.0005	mg/l	0.01	0.1	0.029	0.03
Copper	0.0012	mg/l	0.13		0.0047	0.0053
Iron	0.0007	mg/l	0.15		0.0013	0.002
Lead	0.0007	mg/l	0.0015	0.015	<0.0007	<0.0007
Manganese	0.0015	mg/l	0.025	0.25	0.0015	<0.0015
Mercury	0.00067	mg/l	0.0002	0.002	<0.00067	<0.00067
Molybdenum	0.0029	mg/l	0.05		0.2	0.25
Nickel	0.0044	mg/l	0.02		<0.0044	<0.0044
Nitrate-Nitrite as N	0.02	mg/l	2		0.05	0.03
Selenium	0.0007	mg/l	0.01	0.1	0.049	0.051
Silver	0.00014	mg/l	0.01	0.1	<0.00014	<0.00014
Sulfate	0.09	mg/l	125	1250	52	63
Thallium	0.0014	mg/l	0.0004	0.004	<0.0014	0.0017
Zinc	0.0013	mg/l	2.5		0.0061	0.0046

Radioactivity of Coal Ash (60)

The radioactivity levels in coal ash do not constitute a safety hazard. Based on the concentration process as a result of coal combustion, the Ra-226 concentrations in ash could be on the order of 1-30 pCi/g. Analyses of various ashes and ash products produced at We Energies plants in 1993 and 2003 found Ra-226 concentrations in the range of 1 – 3 pCi/g. This is comparable to the concentrations in soil (0.2 – 3 pCi/g) and within the range of 1 – 8 pCi/g found in ash from analyses of other fly ash in the US (Cement and Concrete Containing Fly Ash, Guideline for Federal Procurement, Federal Register, Vol. 48 (20), January 28, 1983, Rules and Regulations; Zielinski and Budahn, Fuel Vol. 77 (1998) 259-267).

Given that the ash may be landfilled or may be used in building materials as a cement substitute, the doses resulting from these applications have been studied to determine if there is any risk. The British Nuclear Radiation Protection Board conducted a detailed evaluation of the doses from fly ash released to the air to people living within 500 meters (547 yards) of a plant stack, to landfill workers burying fly ash, to workers manufacturing building products from fly ash, and to people living in a house built with fly ash building products. The maximum doses determined from this evaluation were 0.15 mrem/yr for the person living near the plant, 0.13 mrem/yr from releases from the ash landfill, 0.5 mrem/yr for workers manufacturing building products, and 13.5 mrem/yr to a resident of a home constructed with fly ash building materials. The latter is not that different from the 13 mrem/yr from living in a conventional brick/masonry house mentioned earlier.

The levels of radioactivity are within the range found in other natural products. The doses resulting from using the ash in various products are comparable to doses from other human activities and from other natural sources. These doses from the radionuclides in ash are much less than the 300 mrem/yr received from normal background radiation. See Appendix B for the report prepared by Dr. Kjell Johansen for We Energies.

Coal Ash Exemptions

The WDNR monitors the beneficial utilization of CCPs. NR 538 was adopted to categorize by-products and to recommend self-implementing rules to be followed for utilization. However, CCPs have been beneficially utilized for a long time and the WDNR has granted We Energies specific exemptions for many proven applications such as use in concrete, asphalt, CLSM, soil amendment and various aggregate applications.

With increased understanding of coal combustion products and their relationships with the natural environment, We Energies continues to perform research and seek exemptions for additional beneficial use applications.

Table 9-8: Typical Heavy Metals Found in Fly Ash and Soil

Element	Fly Ash Mean ppm	Fly Ash Range ppm	Soil Mean ppm	Soil Range ppm
Aluminum	128,000	106,990 - 1,139,700	71,000	10,000 – 300,000
Arsenic	28	11 – 63	6	0.1 - 40
Barium	1278	73 - 2,100	500	100 - 3,000
Cadmium	1.8	0.68 – 4.4	0.06	0.01 - 0.7
Chromium	86	34 – 124	100	5 - 3,000
Copper	94	18 – 239	20	2 – 100
Iron	33,000	17,050 – 45,910	38,000	3,000 – 550,000
Lead	89	63 – 111	10	2 – 200
Manganese	171	54 – 673	850	100 - 4,000
Mercury	0.01	0.00008 - 0.1	0.03	0.01 - 0.3
Nickel	41	8-65	40	10 - 1,000
Selenium	9.9	3 – 16	0.3	0.01 - 2
Vanadium	246	184 – 268	100	20 – 500
Zinc	63	9 – 110	50	10 – 300

Regulations of Ash Utilization - Wisconsin Department of Natural Resources

The Wisconsin Department of Natural Resources has the authority to regulate the utilization of individual by-products, including coal combustion products, in the State of Wisconsin. Until recently, there was no single guideline that governed the beneficial utilization of industrial by-products. The NR 538 sets rules for 12 predefined industrial by-product utilization methods.

According to the WDNR, the purpose of Chapter NR 538 is “to allow and encourage to the maximum extent possible, consistent with the protection of public health and the environment and good engineering practices, the beneficial use of industrial by-products in a nuisance-free manner.” NR 538 does not govern hazardous waste and metallic mining waste, nor does this apply to the design, construction or operations of industrial waste water facilities, sewerage systems and waterworks treating liquid wastes.

Figures 9-1 to 9-5 give flowchart guidance for beneficial use of industrial by-products in accordance with NR 538. This flowchart can be used as a ready-reference to understand the various requirements and beneficial applications governed under NR 538. WDNR NR538 can be found on the website at:

http://www.legis.state.wi.us/rsb/code/nr/nr538.pdf

Regulations of We Energies Ash Utilization - Michigan Department of Environmental Quality

The Michigan Department of Environmental Quality (MDEQ) is responsible for regulating ash utilization in Michigan. The regulations in Michigan are different than in Wisconsin. Fly ash has been used in concrete widely. However, other land applications have been limited. The readers are referred to the following websites for Michigan statues and rules:

http://www.deq.state.mi.us/documents/deq-wmd-swp-part115.pdf

http://www.deq.state.mi.us/documents/deq-wmd-swp-pt115rls.pdf

Environmental Protection Agency (EPA) Guidelines and C^2P^2 Program

The EPA regulates the ash utilization program in the United States, together with many other environmental issues. Based on the studies conducted by various power plants, universities and research institutions, EPA has determined that large volume wastes from coal-fired electric utilities pose minimal risk to human health and the environment.

On January 28, 1993, the EPA issued a guideline for purchasing cement containing fly ash. This guideline requires that all federal agencies and all state and local government agencies, and contractors that use federal funds to purchase cement and concrete, must implement a preference program favoring the purchase of cement and concrete containing coal fly ash (61). Additional preference guidelines have recently been issued for CLSM and car stops produced with CCPs as well.

EPA recognizes the significant environmental, economic, and performance benefits from using CCPs in a number of applications and sponsors the Coal Combustion Products Partnership (C^2P^2) program. The C^2P^2 program is a cooperative effort between EPA and various organizations to help promote the beneficial use of CCPs and the environmental benefits which can result from that beneficial use. The initiative includes three primary activities:

(1) A challenge program;

(2) Development of environmental effects and benefits booklets focusing on coal ash use in the highway and building construction industries; and

(3) Support for the development of CCP use workshops.

The voluntary C_2P_2 Challenge Program focuses on the beneficial use of CCPs and encourages organizations to participate as Champions for generators and users of CCPs and Leaders for federal agencies, professional groups, and trade associations. EPA is developing two booklets outlining the environmental effects and benefits from the beneficial use of coal fly ash and other CCPs in certain applications: one for highway construction and the other for cast-in-place concrete building construction. EPA is working with Federal Highway Administration, the Department of Energy, and the American Coal Ash Association to develop a series of workshops for users of CCPs. EPA C^2P^2 program can be found on the website at: http://www.epa.gov/c2p2/

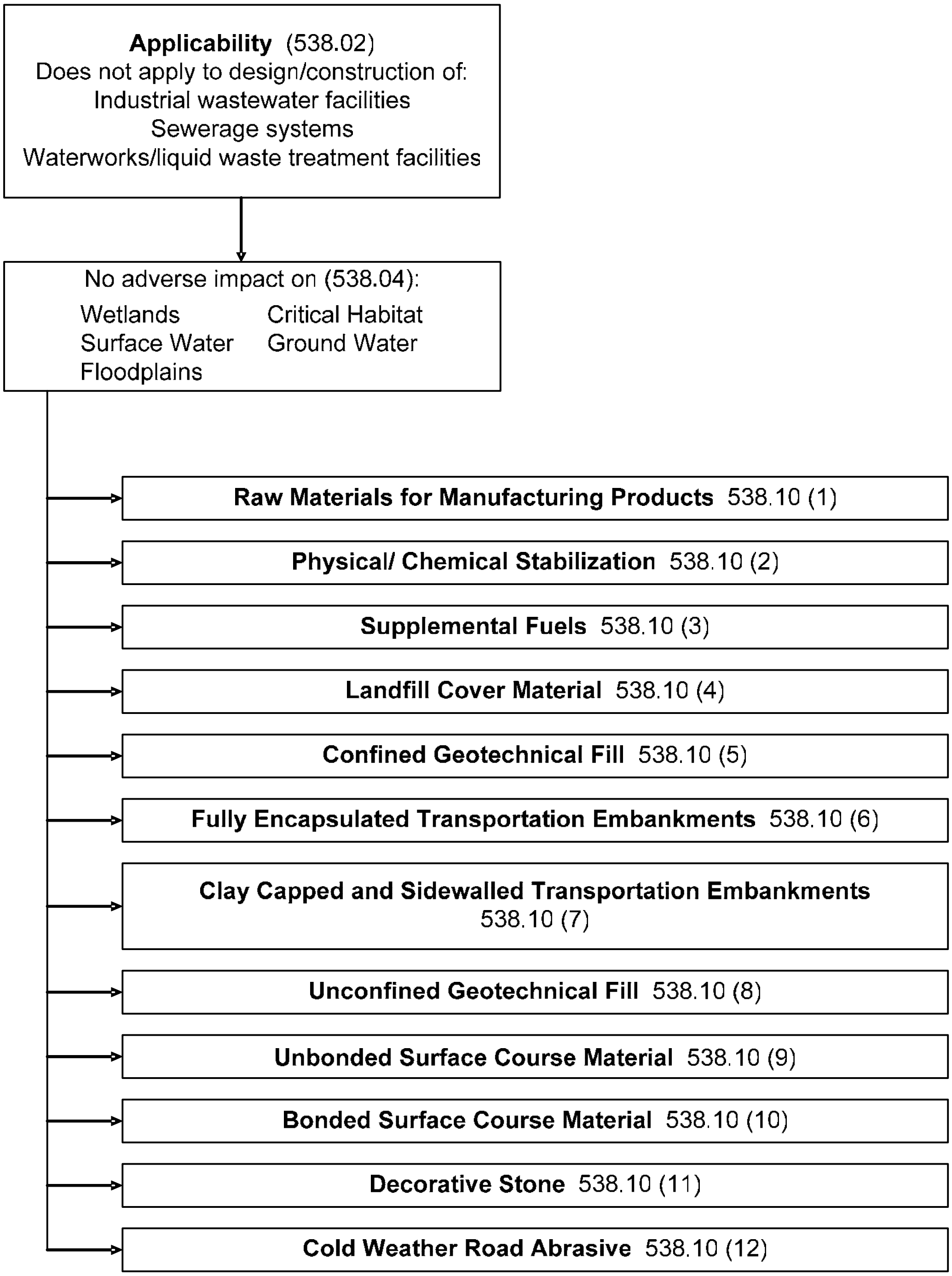
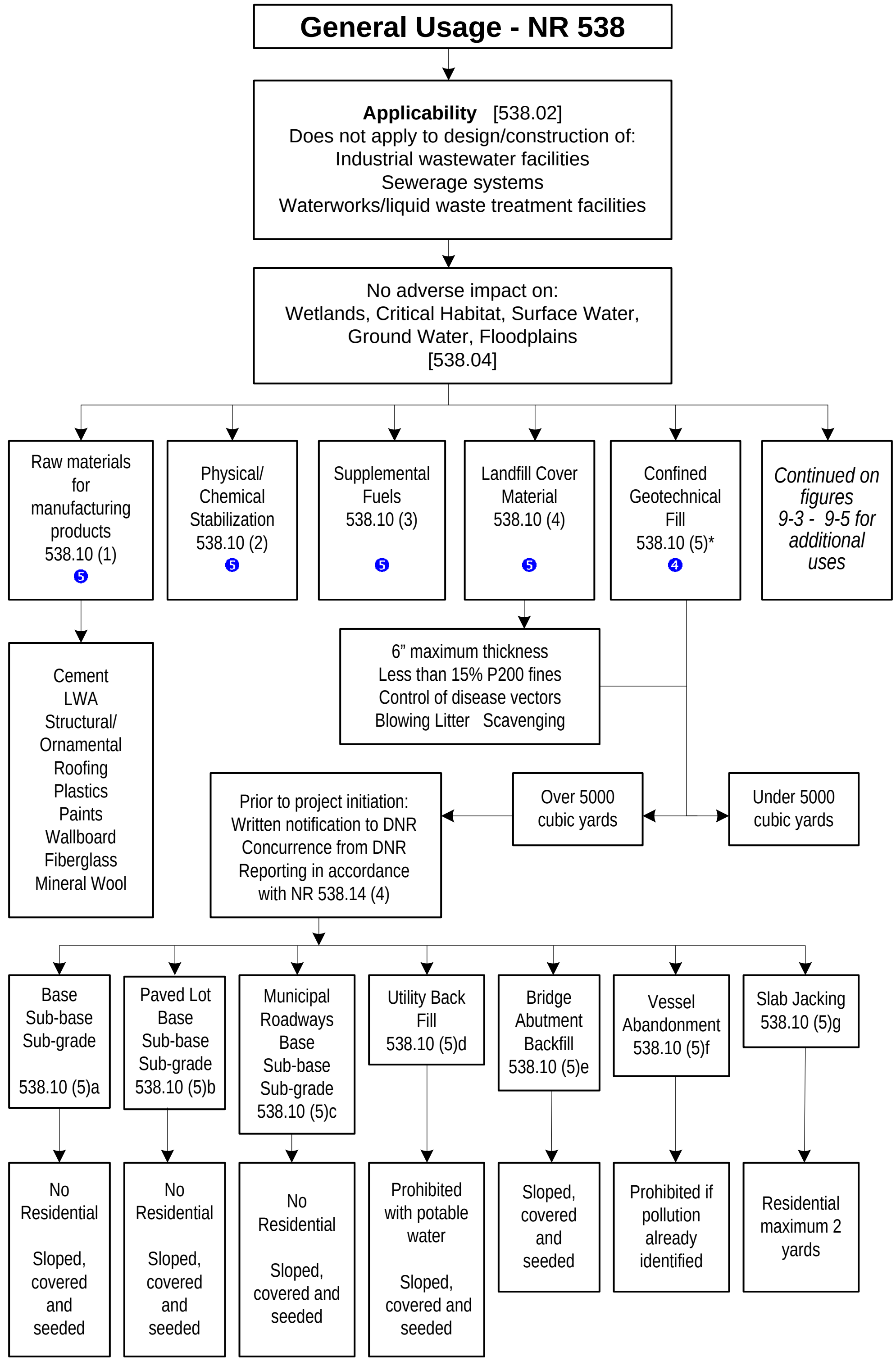
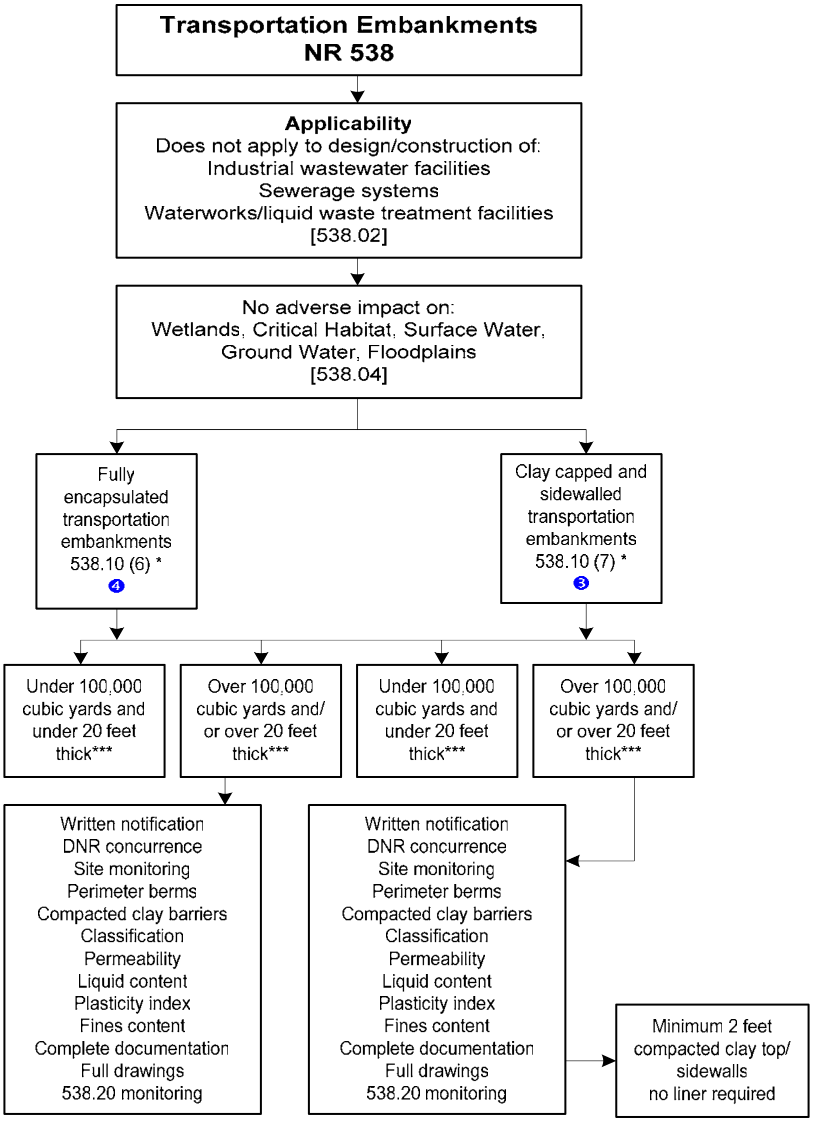


Figure 9-1: NR 538 Beneficial Use of Industrial By-Products



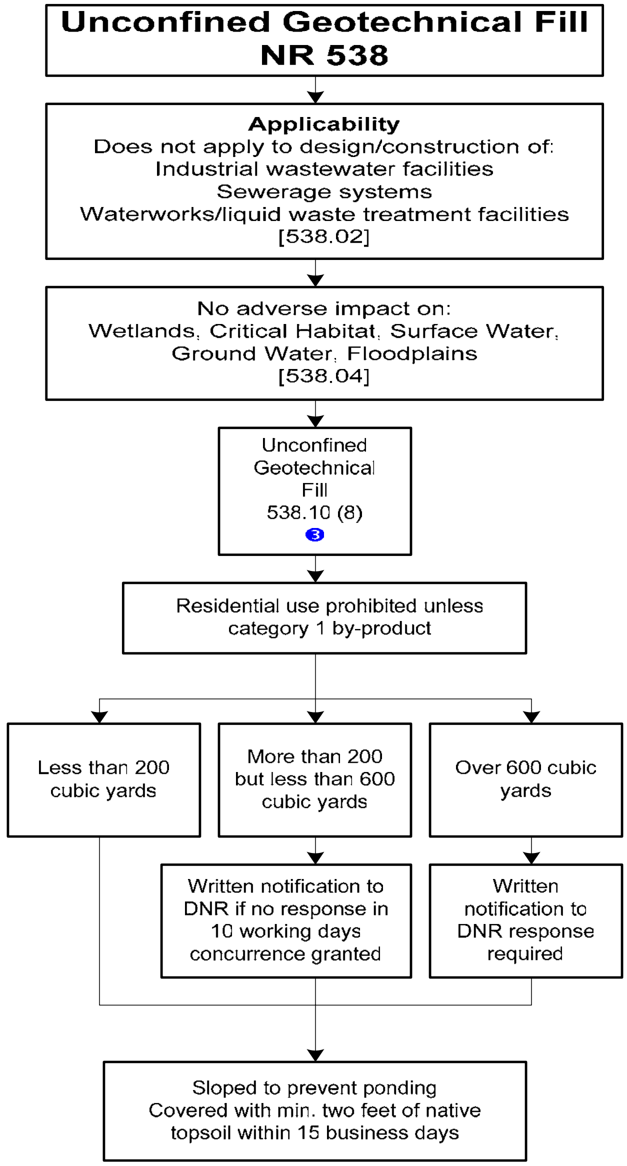
*Use Property Owner Notification – form 4400-199 Wisconsin DOT
**See attachments for details ***Use affidavit – form 4400-200 Wis. DOT
⓿ Industrial By-product Category – By-product must have category number equal or lower than the one shown

Figure 9-2: Flow Chart for General Usage of Industrial By-Products



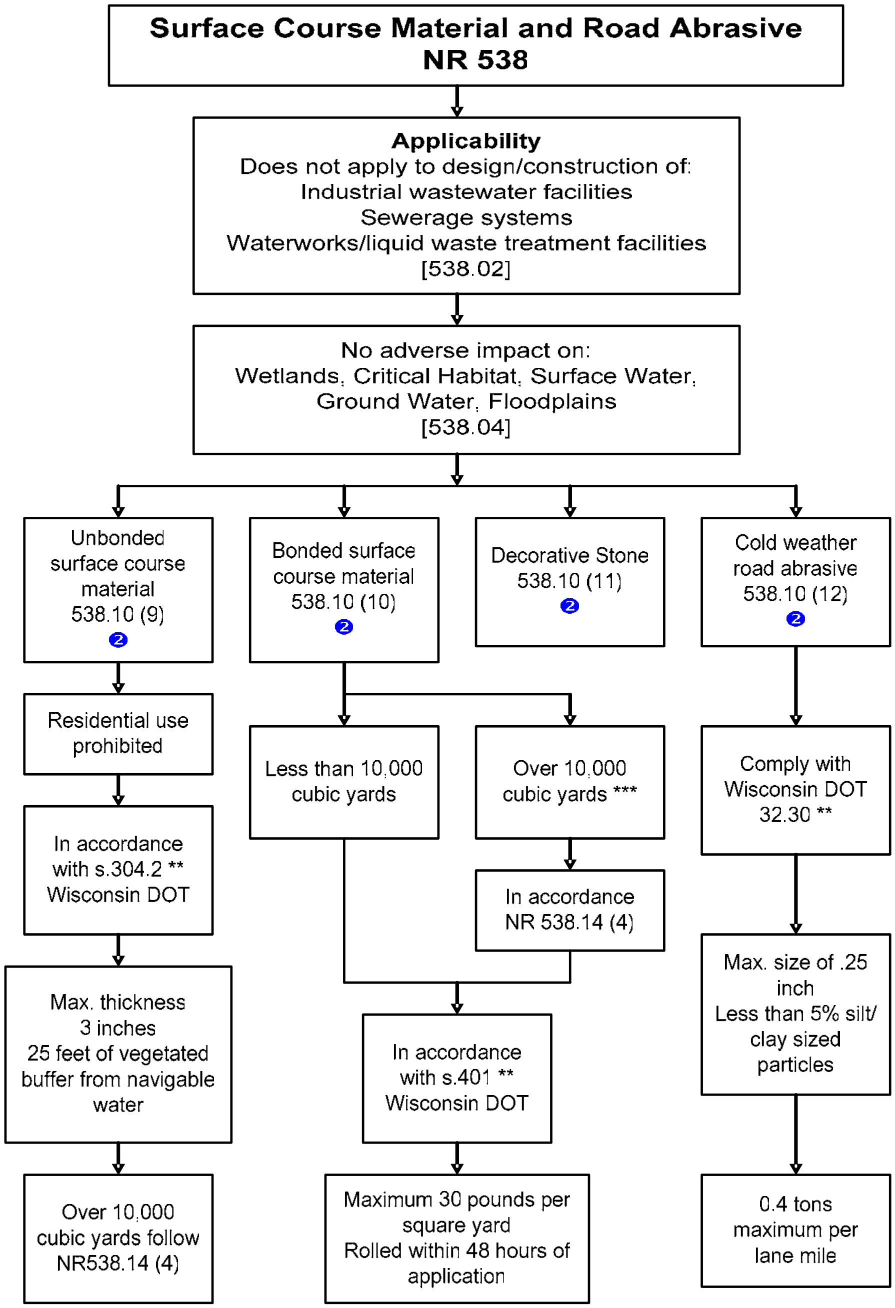
* Use Property Owner Notification – form 4400-199 Wisconsin DOT
**See attachments for complete details
*** Use affidavit – form 4400-200 Wis. DOT
0 Industrial By-product Category – By-product must have category number equal or lower than the one shown

Figure 9-3: Flow Chart for Application of Industrial By-Products in Transportation Embankments



* Use Property Owner Notification – form 4400-199 Wisconsin DOT
**See attachments for complete details
*** Use affidavit – form 4400-200 Wis. DOT
❶ Industrial By-product Category – By-product must have category number equal or lower than the one shown

Figure 9-4: Flow Chart for Application of Industrial By-Products in Unconfined Geotechnical Fill.



* Use Property Owner Notification – form 4400-199 Wisconsin DOT
**See attachments for complete details
*** Use affidavit – form 4400-200 Wis. DOT
❶ Industrial By-product Category – By-product must have category number equal or lower than the one shown

Figure 9-5: Flow Chart for Application of Industrial By-Products as Surface Course Material and Road Abrasive

Mercury Removal-Ash Beneficiation (Patent Pending)

The emission of mercury compounds from all sources, including coal-fired power plants, has drawn national and international attention due to the fact that certain forms of mercury have deleterious effects on wildlife and can be toxic to humans. Activated carbon injection (ACI) is by far the most effective and widely accepted technology to remove mercury from the flue gas of power plants. However, the implementation of ACI ahead of the primary electrostatic precipitator (ESP) or baghouse will inevitably increase the mercury concentration and carbon content in coal ash and is expected to affect the value of the ash.

We Energies conducted a study to develop and demonstrate a technology to liberate and recapture the mercury adsorbed onto activated carbon and fly ash, and provide high quality fly ash for reuse in concrete applications or recycle sorbent used in mercury removal (62).

A bench scale study was done to select an optimum combination of temperature and retention time to maximize mercury (Hg) recovery. Fly ash samples taken from Presque Isle Power Plant (PIPP) were used in the experiments. The total Hg concentration in the sample was determined by cold-vapor generation atomic fluorescence spectroscopy (AFS). Samples were treated in a muffle furnace in an inert atmosphere at different temperatures ranging from 371ºC to 538ºC for retention times of one to five minutes. A nitrogen atmosphere was maintained to keep the carbon from igniting. The percent of Hg liberated from the ash samples was determined by measuring the total Hg left in the ash after thermal treatment. PIPP fly ash Units 5 & 6 was derived from western bituminous coal and colleted using a precipitator. The original total Hg concentration in the sample was 0.42 ppm. The results indicated that both temperature and retention time are important parameters in the thermal desorption process. At temperatures lower than 482ºC, the maximum Hg removal was 40% even with prolonged thermal treatment. More Hg can be removed with higher temperature and longer treatment. At 538ºC, 90% of the Hg was liberated from the fly ash within four minutes. Figure 9-6 shows the rate of Hg removal from PIPP fly ash in the muffle furnace using different combinations of temperature and retention time.

Based upon the test results obtained from the bench scale study, a test program was designed to generate experimental data from a pilot apparatus

The pilot test apparatus is comprised of seven main components: a cone-shaped hopper, air slide, baghouse, burner, collector underneath the air slide, Hg condenser, and wet scrubber. During each fly ash processing run, samples were fed into the air slide through the cone-shaped hopper. The speed of sample going through the system was controlled by a rotary feeder. Inside the

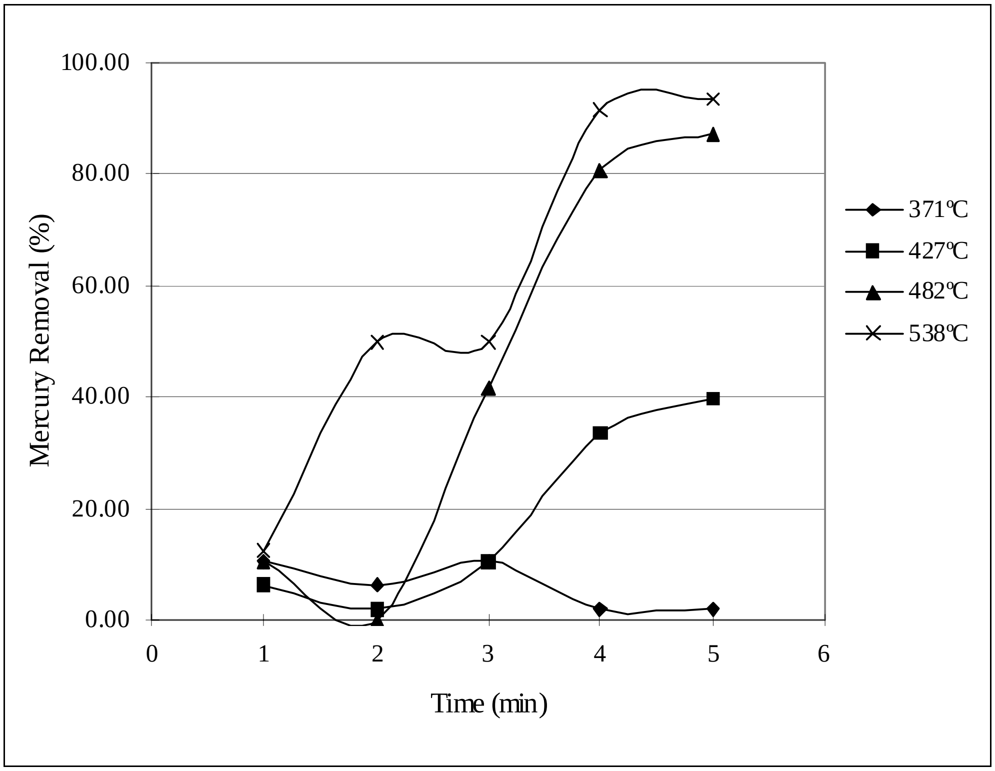


Figure 9-6: Effect of temperature and retention time on mercury removal from PIPP fly ash.

air slide, samples were heated by hot air coming from the burner. The temperature inside the air slide was controlled by adjusting the air flow rate of the burner. A data logger connected to five thermocouples located at the burner, baghouse inlet, and the inlet, midpoint and outlet of the air slide, were used to record the temperature readings. After traveling through the air slide, part of the sample went to the collector at the discharge end of the air slide and the rest of the sample went to the baghouse. Hot air that exited the baghouse passed through a mercury condenser and wet scrubber before being emitted into the ambient environment. Fly ash samples from Presque Isle Power Plant (PIPP), Valley Power Plant (VAPP) and Pleasant Prairie Power Plant (PPPP) were used for the pilot study. Hg concentration and carbon content were measured before and after thermal treatment for comparative purposes. Loss on ignition was used as the indicator of carbon content.

A total of ten fly ash samples from three different power plants were used in the pilot study. The pilot study was conducted in two phases: first, ash samples (two from PIPP, one from PPPP and one from VAPP) were treated in the pilot scale apparatus under fixed temperature and rotary feeding rate (retention time); second, fly ashes (three split samples from PIPP and three split samples from PPPP) were tested under different temperatures and rotary feeding speed. The Hg concentrations in these fly ash samples ranged from 0.11 ppm to 1.00 ppm. For each test in phase one, the initial temperature of the air slide inlet was set at 538ºC and the rotary feeding speed was set at 1000 rpm. The results of these tests are shown in Table 9-9 and Figure 9-7. All four initial tests indicated that Hg could be liberated from various ash samples at 538ºC using the pilot scale apparatus. The majority of the sample passing through the air slide discharged to the collector under the air slide with very low concentrations of Hg detected in these samples. A small proportion of the sample passed with the air flow to the baghouse and contained a higher Hg content.

Table 9-9: Pilot test data for PIPP, PPPP and VAPP samples at 538ºC and 1000rpm

Sample Description		PIPP-I	PPPP	VAPP	PIPP-II
Samples collected before Experiment					
	Hg Content (ppm)	0.18	0.97	0.20	0.15
	Loss on ignition	26.7	3.2	33.5	21.7
Samples collected under the air slide					
	Hg content (ppm)	0.05	0.14	0.03	0.03
	Hg Removed (%)	74.4	85.6	84.5	79.3
	Loss on Ignition	38.1	9.8	36.9	26.1
Samples collected under the Baghouse					
	Hg content (ppm)	0.38	1.00	0.38	0.32
	Hg Increased (%)	111.1	3.1	90.0	113.3
	Loss on Ignition (%)	22.6	10.5	26.9	22.0

Further experiments were performed to determine how temperature and rotary feeding speed would impact the Hg desorption process using PIPP and PPPP samples. Three experiments were run with the rotary feeder speed set at 800, 1000 and 1200 rpm and the air slide inlet temperature set at 538ºC using PIPP samples. The initial Hg content in these samples was around 0.14 ppm. PPPP samples were treated with different heating temperatures, 538ºC, 593ºC and 649ºC and the rotary feeder speed fixed at 1000 rpm. The results are shown in Table 9-10.

Data analysis shows no obvious correlation between the rotary feeding speed and Hg removal. The Hg content in fly ash samples collected under the air slide was 77.3% to 89.3% lower than that found in the original samples. It is possible that rotary feeder speed does not significantly impact the retention time of samples in the air slide.

Table 9-10: Effects of temperature and retention time on mercury liberation

Sample Description			PIPP			PPPP	
Experiment Sequence		1st	2nd	3rd	4th	5th	6th
Rotary Feeder Speed (RPM)		800	1000	1200	1000	1000	1000
Temperature (ºF)		538	538	538	538	593	649
Samples collected before Experiment							
	Hg Content (ppm)	0.14	0.14	0.11	0.69	0.62	1.00
	LOI (%)	25.7	25.3	26.6	2.7	2.6	2.7
Samples collected under the air slide							
	Hg content (ppm)	0.025	0.015	0.025	0.10	0.054	0.055
	Hg Removal (%)	82.14	89.29	77.27	85.51	91.29	94.50
	LOI (%)	42.3	31.3	14.6	3.2	1.9	1.8
Samples collected in the Baghouse							
	Hg content (ppm)	0.38	0.40	0.36	0.81	1.2	1.4
	Hg Increased (%)	171.43	185.71	227.27	17.39	93.55	40.00
	LOI (%)	22.7	20.9	20.5	5.3	3.9	4.0

Ammonia Removal-Ash Beneficiation (US Patent 6,755,901)

Coal-fired power plants are utilizing several proven technologies to improve the quality of air emissions through the reduction of nitrogen oxides (NO_x). These include Low NO_x burners, Selective Catalytic Reduction (SCR), Selective Non-Catalytic Reduction (SNCR), and Amine Enhanced Lean Gas Reburn (AEFLGR). These modifications and additions to coal-fired combustion systems normally result in additional residual carbon and/or ammonia compounds. We Energies has developed the ammonia liberation process (ALP) as a way to overcome the far reaching effects that the installation of NO_x reduction technologies may have. The process developed by We Energies employs the application of heat to liberate the ammonia compounds from the ash, consume undesirable carbon and render the ash a marketable product. The process design employs few moving parts to keep wear and maintenance low. The system is adaptable to meet the different ash characteristics generated by the various NO_x reduction systems as well as the quantity of ash needing beneficiation.

Ammonia Removal Process

The type of NO_x reduction process used typically determines the type and characteristics of the ammonia contaminants. In general the most common and abundant species are the bisulfate and sulfate forms. These species have the required removal temperatures of 813ºF and 808ºF, respectively. The ammonia liberating process preheats the ash and then feeds it to a processing bed where its temperature is increased to about 1,000ºF with hot fluidizing air. The fluidizing air is supplied by a burner and forced through a porous metal media. This high temperature media provides support for the ash and distribution for the air flow. The heat breaks down or consumes the contaminants and the air flow carries the contaminants away from the ash. The ash leaves the processing bed and is cooled with a heat exchanger. This reclaimed heat can be used to preheat the incoming untreated ash. The clean ash is transferred to storage for subsequent use. The contaminated air flow leaving the processing bed is passed through a baghouse where any fugitive ash is captured and returned to the ash exiting the processing bed. The dust free ammonia laden gas may then be passed into a wet scrubber for removal of the contaminants for disposal or passed back into the combustion process or NO_x reduction process.

ALP Pilot Plant Test

We Energies has assembled and tested a small-scale prototype ALP unit. The unit is operated under the parameters described above. Figure 9-10 shows the properties of fly ash before and after the tests. The amount of ammonia in the ash was significantly reduced. The resulting fly ash is a marketable ash that could be beneficially utilized as a "green" construction material.

ASTM C 618 Class F Fly Ash
Ammonia Removal Results

Base Case - Ammonia Before Processing	160 mg/kg
Baghouse Ash – Ammonia After Processing	16 mg/kg
Product Bin Ash – Ammonia After Processing	Less than 2 mg/kg

ASTM C 618 Class F Fly Ash
Loss on Ignition Results

Base Case - LOI Before Processing	2.7%
Baghouse Ash - LOI After Processing	2.6%
Product Bin Ash – LOI After Processing	2.8%

High Carbon Bituminous Coal Fly Ash *
***(No Ammonia Present in Fly Ash)**
Loss on Ignition Results

Base Case - LOI Before Processing	16.2%
Baghouse Ash - LOI After Processing	9.9%
Product Bin Ash – LOI After Processing	7.2%