

## **2 REAGENTS IN COAL PREPARATION: WHERE DO THEY GO?**

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### **1. Abstract**

A variety of reagents are utilized in coal preparation, but aside from performing their desired function relatively little is known about the behavior of these reagents within the processing circuits. Where exactly do reagents go once dosed? In this paper, we present preliminary results of partitioning studies on frother (i.e., MIBC) and collector (i.e., petro-diesel) chemicals commonly used in coal flotation, and examine implications for water management (e.g., in closed-loop systems). Additionally, we discuss the usefulness of such data in predicting environmental transport and fate of chemicals – which is currently a top priority for industry.

### **2. Introduction**

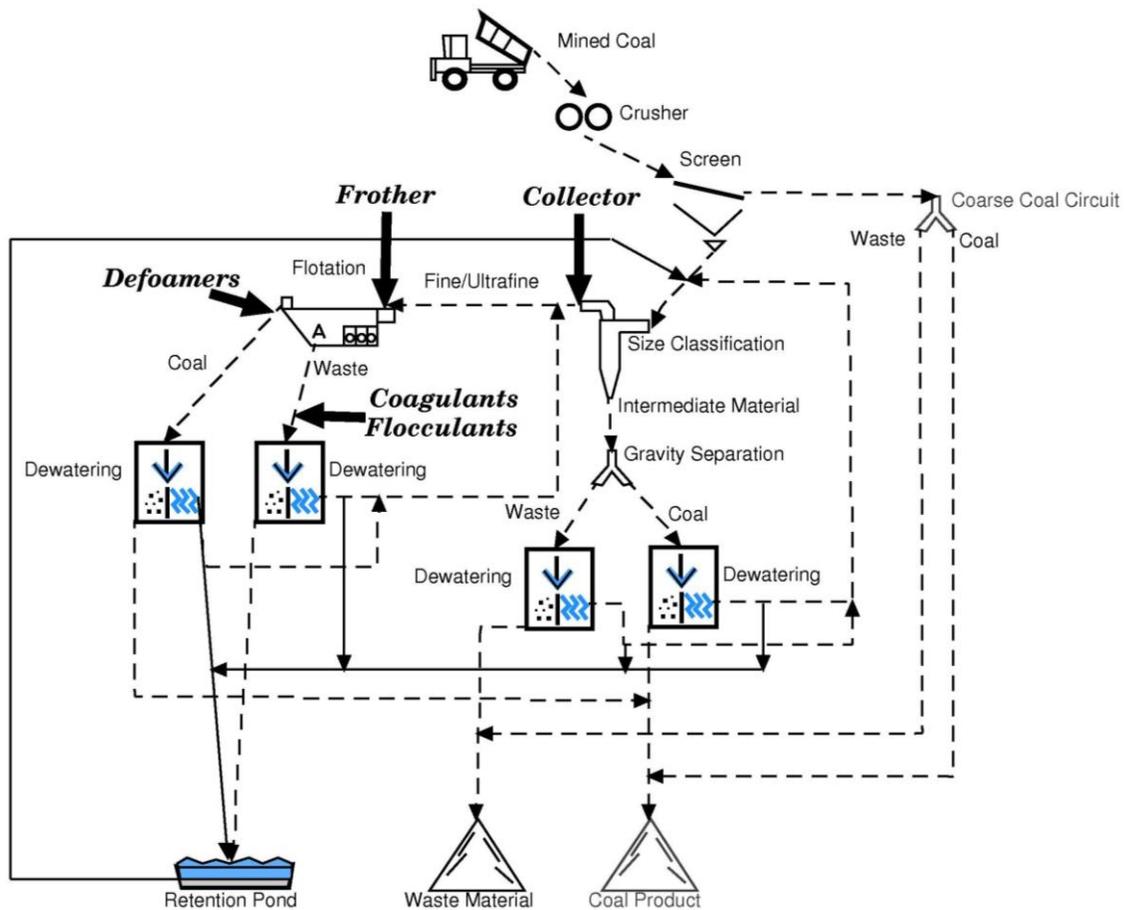
The purpose of coal preparation is to upgrade mined coal into more valuable products. Since coal is primarily used as a fuel source for electricity generation, product specifications are typically contracted to minimize unwanted constituents that detract from the overall heat value (e.g., ash and moisture) or that add to environmental pollution or other problems like corrosion at a power plant (e.g., sulfur) (Pitt and Millward 1979). Failure to meet specifications results in a financial penalty for the coal producer (Szwilski 1986), and thus preparation processes have evolved to simultaneously optimize recovery of valuable “clean” coal with rejection of mineral matter and moisture. In addition to advancements in equipment and circuitry, development and application of various chemical reagents has dramatically improved the performance of coal preparation processes.

Contemporary preparation plants typically include multiple circuits that can be categorized by the size of particles they process: coarse, intermediate, and fine/ultra-fine (Figure

2.1). Coarse and intermediate circuits generally rely on size classification and gravity separations (e.g., dense-media cyclones), and do not require significant chemical reagents. However, fine and ultra-fine circuits often use froth flotation to separate coal from impurities, which requires chemical additives (Table 2.1). The primary additives include collectors, which coat the surface of the coal particles to render them (more) hydrophobic and thus more likely to attach to air bubbles and float; and frothers, which aid in the formation and stability of the froth that will accumulate the floated coal particles. Modifiers are also commonly added to flotation circuits to regulate pH in instances where coal or impurity characteristics may change water chemistries (Laskowski 2001). Following flotation, coagulants and flocculants are often utilized in solid-liquid separations (i.e., dewatering or clarification) for coal products, and for tailings slurries prior to their disposal in impoundments. Coagulants function via double-layer compression<sup>1</sup> to bring colloidal particles together, while flocculants promote bridging between the grouped colloids – and the combined result is enhanced sedimentation (Wills 2006). Defoaming or anti-foaming agents may also be required to avoid fouling of dewatering operations.

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<sup>1</sup> Double-layer compression refers to the action of added ionic species on the electrical double layer surrounding a colloid or fine particle. In the case of negatively charged coal, the addition of a cationic coagulant effectively reduces the (repulsive) electrostatic forces between particles such that Van Der Waals' forces may attract the particles together Scott, J. H. (1976). Coagulation Study of a Bound Water Bulked Sludge. Master of Science, Virginia Polytechnic Institute and State University..



**Figure 2.1: Simple processing circuit with typical reagent addition points**

Conventional development and application of coal processing chemicals have been predominantly driven by economic motivations (e.g., to meet contract specifications, to reduce reagent costs, etc.). However, growing trends in corporate environmental and social responsibility provide a basis for more holistic approaches. In addition to understanding the effects of reagents on coal recoveries and yields, it is becoming increasingly important to understand potential effects on environments and communities. To do so, a number of important questions must be addressed: What transport mechanisms may introduce reagents into environmental media? What are the potential fates of these reagents? Do they pose risks to human or ecosystem health? Furthermore, with increased efforts to minimize net environmental impacts, a new challenge for the coal industry is to operate completely closed water loops. Given current circuit designs, will reagents have any effects on preparation plant efficiency?

The goal of this paper is to begin answering these questions. The following sections review the potential fates and impacts of coal preparation reagents, and present preliminary data regarding the partitioning of frothers and collectors between coal and process water.

**Table 2.1: Common reagents in coal preparation (McIntyre 1974; Knapp 1990; Pugh 1996; Laskowski 2001)**

Type	Group	Reagent
Collectors	Hydrocarbons	Fuel Oil No. 1 - Kerosene
		Fuel Oil No. 2 - Diesel
		Fuel Oil No. 6
Frothers	Aliphatic Alcohols	Methyl Isobutyl Carbinol (MIBC)
	Polyglycols	DF 250
	Hydroxylated Polyethers	Dowfroth M150
		Nalco 8836
		Polyoxyl Sorbitan Monolaurate (PSM)
Modifiers	Promoters	NaCl
		CaCl <sub>2</sub>
		Na <sub>2</sub> SO <sub>4</sub>
	pH Regulators	H <sub>2</sub> SO <sub>4</sub>
		CaO
Dewatering/Clarification Reagents	Coagulants (cationic)	Organic Starches
		Inorganic Salts
		Polyamines
	Flocculants (non-ionic)	Organic Starches
		Polyacrylamide
	Flocculants (anionic)	Organic Starches
		Acrylamide/Acrylate Copolymers
Polyacrylates		
Defoaming Reagents	Defoamers	Tributyl Phosphate (TBP)
		Polydimethylsiloxane (PDMS)

### 3. Reagent Fates and Implications

Determining the fate of coal processing reagents necessitates tracking those reagents from their addition points in a preparation plant (e.g., Table 2.1) to some ultimate destination. Based on a simple materials balance approach, only a fixed number of possibilities exist for reagents leaving the plant: they may end up with the clean coal products, with the tailings by-products, or with recycled water, or they may be lost (e.g., via volatilization or spills).

### ***3.1 Environmental Fate and Transport***

The environmental fate and transport of processing reagents has been scarcely examined. It is generally expected that collectors (e.g., petro-diesel) substantially partition to coal products because their chemistry promotes sorption to the coal particles (Watts 1998). Any collector that does not sorb may remain with water, either floating on the water surface, as an emulsion, or as a dissolved species – although water solubility is likely low. Frothers, on the other hand, are not expected to significantly sorb to coal (or other solids), and thus should follow water streams. Alcohol-based frothers like MIBC tend to have relatively low water solubility and low to moderate volatility (Howard 1993), which indicate that they may remain at the water-air interface; whereas glycol-based frothers like Dowfroth M150 are much more soluble in water and are relatively non-volatile. Coagulant and flocculant reagents are of course expected to partition to fine coal or tailings particulates, at least in the short-term. These chemicals may well remain with dewatered coal products; but in the case of reagents associated with tailings solids, it is difficult to predict how they might react or mobilize under disposal facility conditions.

Reagents that partition to coal products are likely to be combusted with the coal – unless they volatilize during handling and transport. The combustion by-products of the reagents may enter the atmosphere as either gaseous or particulate emissions, which may then be returned to the earth via either wet or dry deposition. In the case of petro-diesel collector (termed “diesel” in this paper), for example, it is expected that much of the alkane fraction<sup>2</sup> will be completely combusted and converted to carbon dioxide and water; however, PAHs that occur naturally in the diesel or that form as a result of incomplete combustion might also be released.<sup>3</sup> In addition to atmospheric emissions, reagents or combustion by-products of reagents might become part of the solid fly ash (i.e., waste from coal combustion) and eventually disposed (e.g., in landfills), either because the reagents were associated with the mineral fraction (i.e., noncombustible) of the coal or because their aerosols were scrubbed from flue gases. In the example of diesel

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<sup>2</sup> Diesel is not a specific compound, but rather a range of compounds collected from fractional distillation of petroleum (i.e., between 200-400 °C). Its general composition includes primarily moderate weight alkanes (i.e., C<sub>15</sub>-C<sub>25</sub>), and also cycloalkenes and polyaromatic hydrocarbons (PAHs) Watts, R. J. (1998). Hazardous Wastes: Sources, Pathways, Receptors. New York, NY, John Wiley and Sons..

<sup>3</sup> PAHs are an environmental concern because they pose human and ecological health risks ATSDR. (2009). 2012.. However, the bioavailability of PAHs derived from diesel combustion is not well understood Scheepers, P. and Bos, R. (1992). "Combustion of diesel fuel from a toxicological perspective. II. Toxicity." Int Arch Occup Environ Health 64(3): 163-177..

collector that partitions to coal products, this is another likely scenario for some PAHs (Liu et al. 2008). Following atmospheric deposition or disposal of fly ash, coal processing reagents or their by-products could move through terrestrial and aquatic ecosystems via hydraulic or biologic transport processes.

For reagents that partition to either the water or solid fractions of coal tailings, environmental fate and transport is heavily dependent on the tailings disposal conditions. If tailings are disposed via underground injection, reagent fate will be governed by chemical conditions of the storage cavity (i.e., atmosphere, water chemistry, and wall rock mineralogy); and reagent transport will depend on the degree to which groundwater interacts with the cavity. More often, tailings are disposed above ground in impoundments or ponds, where the water fraction is expected to clarify as the solid particles slowly settle. Some of the water is generally recycled back to the preparation plant and used as make-up water, but a portion of it is released to the environment via evaporation, engineered discharges (i.e., through decant structures or spillways) (MSHA 2009), or percolation to the subsurface since impoundments for coal refuse are rarely lined (USEPA 1999). If reagents or reagent by-products are present in impoundments, water releases could possibly mobilize them. Other possibilities include photo- or biodegradation within the impoundment (e.g., MIBC), or sorption to soils beneath the impoundment (e.g., diesel).

In the context of environmental fate and transport, it is also important to note that coal processing reagents are seldom pure products with constant composition. For instance, diesel can vary with the properties of the petroleum feedstock used to produce it, and some frother reagents are actually acquired as by-products from the manufacture of other products (e.g., brake fluids). While variability in reagent quality will not be discussed in detail here, it is a topic that deserves further attention.

### ***3.2 Residuals in Operations***

In addition to tracking processing reagents to better understand environmental implications, it is becoming increasingly important to understand implications for preparation plants that utilize large volumes of recycled water. Use of closed water systems (i.e., zero discharge from site) is growing in response to calls for both water efficiency and water resource protection. For coal preparation facilities, such systems generally combine the plant and tailings

water circuits, such that “clear” water from an impoundment is recycled back to the plant as makeup water. Water may also be recycled within the plant (e.g., from the coal product thickener back to cyclone or flotation circuits).

To the extent that processing reagents (or their by-products) remain in the recycled water, chemical concentration may have significant impacts on plant operation. While residual chemicals could potentially reduce the rate of new chemical addition in some cases, it is also possible that reduced efficiency or fouling of some unit processes may occur. For example, residual frothers may impact processes that cause significant agitation (e.g., dense media cyclone separations) (Lahey and Clarkson 1999), or where water chemistry promotes foaming (e.g., where recycling has caused increased salt concentrations). Even at sites where only a portion of water is recycled throughout the plant, it is already well established that such problems lead to preventative under-dosing of frother in flotation circuits, which in turn sacrifices recovery of fine coal (Coffey and Lambert 2008). For closed water systems, the implications may be far more significant, and additional water treatment efforts might be required to maintain efficient operations.

In light of the environmental and operational implications of processing reagent fates, it is important to understand how they partition between solid and liquid fractions in preparation plants.

#### **4. Experimental Methods**

Partitioning studies were carried out to obtain preliminary data on the potential fates of common frother and collector reagents for fine coal flotation<sup>4</sup>. The frothers were MIBC, polyoxyl sorbitan monolaurate (PSM), Dowfroth M150, and Nalco 8836, and the collector was diesel. Raw coal samples were ground using a laboratory hammer mill, and sized by wet screening for the desired test conditions (Tables 2.2 to 2.4). Full proximate analysis was not conducted on any of the raw coal samples, however approximate ash contents were determined (see below). For each test, a slurry sample was prepared by adding the required weight of sized raw coal to distilled water, followed by the required volume of reagent. Slurries were mixed for a

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<sup>4</sup> The frother partitioning tests were partially reported in an MS thesis (Knapp, 1991), but have not been published elsewhere.

specified contact time, and then the coal particles were separated from the water by either centrifuging or filtration. Finally, the water was then analyzed for residual reagent.

It should be noted that range of test conditions (i.e., frother and collector dosages, and coal slurry solid to liquid ratios) included in this work is much wider than that which may be encountered in practice. This is because as a major objective here was to determine under what conditions the processing reagents would sorb to coal versus remain in water, and vice versa. For the purpose of making relative comparisons, a froth flotation circuit in a typical coal preparation plant might operate with coal slurries of 1-10% solids (by weight), which require 4-20  $\mu\text{L/L}$  frother (usually specified in mg/L;  $\sim$ 5-25 mg/L) and 1.5-150  $\mu\text{L/L}$  (usually specified in lb/ton of coal;  $\sim$ 0.5-5 lb/ton).

#### ***4.1 Frother Partitioning***

For the frother partitioning tests, coal samples were obtained from the Elkhorn #3 and the Cedar Grove seams (both <5% ash), and were sized to -100 mesh prior to testing. Slurries were mixed for five minutes by rapid stirring in open beakers, and then centrifuged for three minutes. To analyze the relative amount of frother left in the clear water fraction of the slurry, surface tension measurements were conducted using a Fisher surface tensiometer. The tensiometer utilizes a platinum-iridium ring, and measures the force required to detach this ring from the liquid surface. The ring was thoroughly cleaned between tests by immersing it in benzene, then acetone, and finally passing it through a flame to remove of any surface contaminants. Glassware was also thoroughly cleaned between tests by washing with chromic acid solution and distilled water.

#### ***4.2 Collector Partitioning***

For the collector partitioning tests, two separate raw coal samples were obtained: one from the Hagy Seam ( $\sim$  35% ash), and one from Pocahontas Seam ( $\sim$  16% ash). The former sample was sized to -100 mesh for the first set of tests, and then a subsample of that material was screened to 100 x 150 mesh for the second set of tests. The later sample was only used in the second set of tests, and was also screened to obtain 100 x 150 mesh particles. For the first set of tests, slurries were mixed in a kitchen blender for four minutes and then centrifuged until the water was clear; however, it should be noted that a large amount of colloidal matter in these

samples prevented removal of all color from the water. In the second set of tests, the slurries were mixed in open flasks on a shaking table for four minutes, and then filtered (through 25  $\mu\text{m}$  paper) using a vacuum pump. The residual diesel in the clear water fraction from each test was analyzed using an Agilent 5890 gas chromatograph equipped with a flame ionization detector (GC-FID), by following EPA Method 3150 for quantifying diesel range organics (DRO) in water samples.

**Table 2.2: Experimental conditions for frother tests**

Test	Coal Seam	Coal Dosage (wt. % solids)	Frother Type	Frother Dosage ( $\mu\text{L/L}$ )
1-18	Elkhorn #3	0, 0.1, 0.5, 0.7	M150	0.4 <sup>a</sup> , 4, 40, 400, 4000
19-34	Elkhorn #3	0, 0.1, 0.5, 0.7	PSM	4, 40, 400, 4000
35-48	Elkhorn #3	0, 0.1, 0.5, 0.7	Nalco 8836	4, 40 <sup>b</sup> , 400, 4000
49-60	Elkhorn #3	0, 0.1, 0.5, 0.7	MIBC	10, 100, 1000
61-64	Cedar Grove	0.5	M150	4, 40, 400, 4000
65-68	Cedar Grove	0.5	PSM	4, 40, 400, 4000
69-72	Cedar Grove	0.5	Nalco 8836	4, 40, 400, 4000
73-75	Cedar Grove	0.5	MIBC	10, 100, 1000

<sup>a</sup> Only for 0 and 0.1% solids

<sup>b</sup> Only for 0 and 0.5% solids

**Table 2.3: Experimental conditions for first set of collector tests**

Test	Coal Seam	Coal Dosage (wt. % solids)	Diesel dosage (lb/ton coal)	Diesel dosage (mg/L)	Solid/Liquid Separation	Residual DRO (mg/L)
1	Hagy	0	N/A	500	Centrifuge	425.1
2	Hagy	1	0	0	Centrifuge	<0.05
3	Hagy	1	1	4.9	Centrifuge	0.39
4	Hagy	1	1	4.9	Centrifuge, then filtration	0.42
5	Hagy	1	1	4.9	Filtration	0.46
6	Hagy	1	10	50	Centrifuge	0.68
7	Hagy	5	0.25	6.3	Centrifuge	0.50
8	Hagy	5	1	25	Centrifuge	0.53
9	Hagy	5	10	250	Centrifuge	0.95

**Table 2.4: Experimental conditions for second set of collector tests**

Test	Coal Seam	Coal Dosage (wt. % solids)	Diesel dosage (lb/ton coal)	Diesel dosage (mg/L)	Solid/Liquid Separation	Residual DRO (mg/L)
10	Pocahontas	0	N/A	0.85	N/A	1.35
11	Pocahontas	0	N/A	0.425	N/A	0.63
12	Pocahontas	1	0.17	0.85	Filtration	0.42
13	Pocahontas	10	0.017	0.85	Filtration	0.31
14	Pocahontas	5	10	250	Filtration	0.47
15	Pocahontas	5	10	250	Filtration	0.40
16	Pocahontas	5	10	250	Filtration	0.50
17	Pocahontas	5	10	250	Filtration	0.51
18	Pocahontas	5	10	250	Filtration	0.47
19	Pocahontas	5	10	250	Filtration	0.42
20	Pocahontas	1	50	250	Filtration	0.79
21	Pocahontas	5	50	1250	Filtration	1.02
22	Pocahontas	10	50	2500	Filtration	1.92
23	Pocahontas	5	1	25	Filtration	0.49
24	Hagy	5	10	250	Filtration	0.88
25	Hagy	5	50	1250	Filtration	2.67

## 5. Results and Discussion

Results of the partitioning tests confirmed that, in general, frother and collector reagents do not partition completely to either the solid or liquid fraction of a coal slurry – and therefore it is possible that, to some extent, these reagents may end up in coal products, tailings impoundments and in recycled water.

### 5.1 Frother Adsorption

The surface tension results for varying frother dosages and varying coal slurries are shown in Figure 2.2. The dashed horizontal line at 72.8 dyne/cm represents the theoretical surface tension of pure water (Nave); the bold line shows the measured surface tension for frother only (no coal added). For all frothers, it appears that the reagent tends to sorb somewhat to the coal surface. This can be seen most clearly at moderate test dosages (i.e., 40-400  $\mu\text{L/L}$ ),

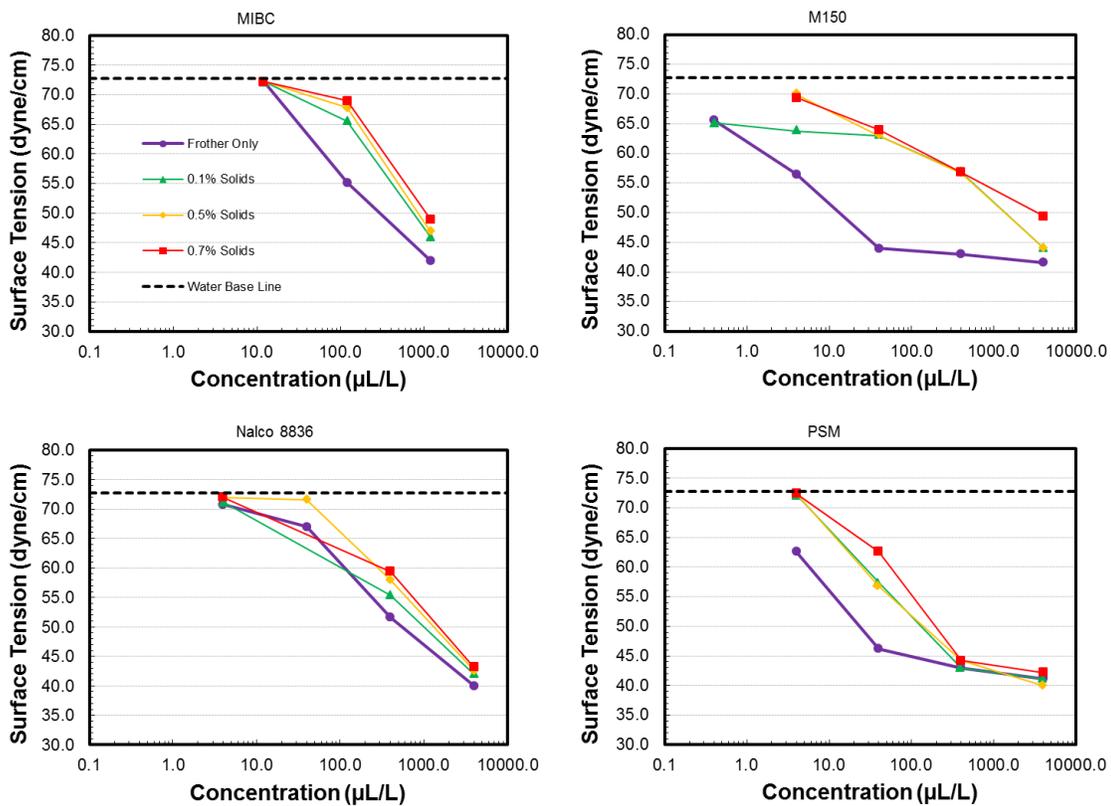
where a significant difference was observed in surface tension between tests with frother only and tests with frother and coal. As expected, more frother generally tended to sorb to coal when more coal was present (i.e., 0.7% vs. 0.1% solids).

At very high dosages (i.e., 1000-4000  $\mu\text{L/L}$ ), the effect of the coal becomes less significant for MIBC and Dowfroth M150, and nearly insignificant for PSM and Nalco 8836. This indicates that sorption sites on the coal surface may be completely filled, and thus most of the frother remains in the water. At very low test dosages (i.e., 4  $\mu\text{L/L}$ ), the PSM exhibits seemingly complete sorption to the coal particles, as the surface tension when coal is present is effectively that of pure water, as compared to substantially less with frother only. The Dowfroth M150 also exhibits significant sorption to the coal at very low dosages, although the surface tension is slightly less than that of pure water (for the 0.5 and 0.7% coal tests), which suggests that some frother did not sorb. At very low dosages of MIBC and Nalco 8836 (i.e., 10 and 4  $\mu\text{L/L}$ , respectively), it is uncertain to what extent the coal particles were able to sorb frother because the frother did not depress the surface tension of the water. This highlights a major shortcoming of the use of surface tension measurements to study frother reagents, which has been previously noted by other researchers (Sweet et al. 1997).

Coal properties were found to play a role in the sorption behavior of PSM and MIBC. As evident in Figure 2.2, at equal levels of slurry solids (i.e., 0.5% coal), the Cedar Grove coal did not appear to significantly sorb these frothers, whereas the Elkhorn #3 coal did. However, the sorption behavior of the Dowfroth M150 and Nalco 8836 was observed to be quite similar between the two coals. Since proximate analysis was not performed on the coal samples, it is difficult to speculate on specific explanations for these results; but coal properties (other than particle size) do seem to be important in terms of frother sorption capacities.

In the context of a coal preparation plant, the results from these tests indicate a significant degree of frother sorption to coal surfaces can be anticipated. While practical conditions include only the low to very low ranges of frother dosages tested here, they typically have higher slurry solids contents, and thus higher coal surface areas – which suggests that perhaps a relatively large fraction of frother reagents may associate with the coal. Given that frothers are well known to cause problems via entrainment in recycled water, there may be several plausible explanations for the findings presented here: 1) frother sorption to coal may only be temporary, and desorption may occur downstream of flotation processes (e.g., during dewatering); 2) the presence of other

reagents, particularly collectors, may substantially interfere with frother sorption to coal; and 3) the experimental conditions (e.g., mixing, effective contact time) used here may not be representative of plant conditions. Considering these, the sorption mechanisms of frothers to coal and tailings particles is deserving of further study. If, for example, frothers are identified which sorb strongly to coal through flotation and dewatering, this may have significant implications for reducing fouling of process circuits in closed water systems, as well as reducing environmental releases through tailings impoundments. For frothers that do not sorb to and remain with coal, novel water treatment strategies may be devised to remove these reagents from water prior to recycling or environmental discharges.



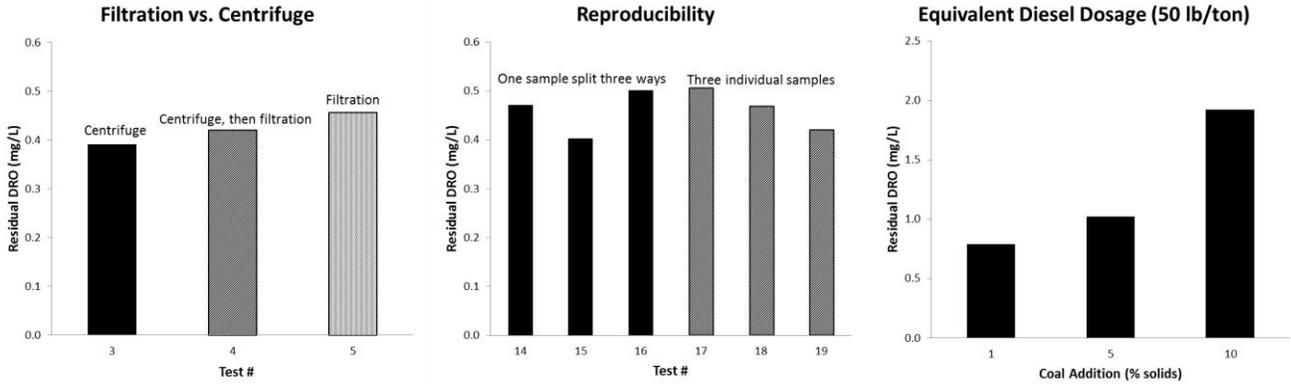
**Figure 2.2: Surface tension versus varying dosage levels of frother and coal**

### 5.2 Collector Adsorption

DRO results (i.e., the residual DRO in the clear water fractions of tested coal slurries) are presented in Tables 2.3 and 2.4 for all test conditions. The most striking observation is that there is some low level of DRO in every test, despite the addition of even large amounts of coal (i.e.,

10% solids). For instance, tests 12 and 13 clearly show that at relatively high solids content (i.e., 1 and 10%, respectively) and very low dosages of diesel (i.e., <1 mg/L; or 0.17 and 0.017 lb/ton, respectively), about 0.3-0.4 mg/L DRO remains in the water fraction of the slurry. Moreover, the level of DRO does not change dramatically between tests, considering the extreme changes in diesel and coal dosages. In test 20, for example, which had the same amount of coal but nearly 300x more diesel added than test 12, the DRO concentration was only about 2x higher than that of test 12 (i.e., 0.79 vs. 0.42 mg/L, respectively). And in test 22, which had the same amount of coal but nearly 3000x more diesel added than in test 13, the DRO concentration was only increased by about 6x (i.e., 1.92 vs. 0.31 mg/L, respectively). These results seem to indicate that a small amount of diesel (~0.3 mg/L or less) is always soluble in the water, but that the coal particles have a *very* high adsorption capacity for the diesel that is not dissolved. Another factor that may have been at play here is the possible presence of colloidal matter in the water fraction of the slurries; if diesel sticks to the colloids, it would likely be measured as DRO. However, it is important to note that, no matter what the reason, these tests indicate that a small amount of diesel will effectively partition with water in a flotation circuit.

Figure 2.3 highlights other specific observations in the collector partitioning tests. In the far left plot, the effect of solid-liquid separation technique on the results is shown. The three tests (#s 3-5) were conducted using identical slurries (i.e., % coal solids and diesel dosage), but one was centrifuged, one was filtered, and the other was centrifuged and then filtered. DRO concentrations in the clear water fraction from each of these tests were all within about 15% of each other – a reasonable range for preliminary tests – and it was concluded that the solid-liquid separation methods did not substantially impact partitioning results (e.g., by sorption of diesel to the filter paper).



**Figure 2.3: Diesel sorption test results**

The middle plot of Figure 2.3 shows the results from six tests to determine the reproducibility of the test and analytical methods used here. Tests 14-16 show DRO measured three separate times (i.e., in triplicate) from a single sample. The results for these tests are within about 20% of each other and suggest that the analytical method is fairly reproducible. Likewise, tests 17-19 show DRO measured from samples from three separate, but identical tests. In this case, the results are within about 18% of each other and indicate that the test method is also reproducible.

In the right plot of Figure 2.4 are the results from three tests conducted to determine the effect of proportionally similar coal and diesel additions (i.e., tests at 1, 5 and 10% solids, each with a diesel dosage of 50 lb/ton coal). Since the diesel was dosed on the basis of coal weight, it seems intuitive that DRO concentrations should have been similar between these tests; instead, with increasing additions of coal, less diesel actually sorbed. One possible explanation for this phenomenon may be that with more coal in the slurry, particles are sticking to each other or being bridged together by diesel such that there are effectively fewer sorption sites available. For tests where coal content remained constant (e.g., tests 7-9) but diesel dosage was varied, measured DRO in the water did increase with a substantial increase in diesel dosage – although not proportionally. For instance, in tests with 5% Hagy Seam coal (-100 mesh), DRO was roughly equal for diesel dosages of 0.25 and 1.0 lb/ton (i.e., 0.50 and 0.53 mg/L), but essentially doubled when the diesel dosage was raised to 10 lb/ton (i.e., to 0.95 mg/L).

It was further observed that the ash content of coal appears to affect diesel sorption. At equal slurry contents and diesel dosages (i.e., 5% solids, and diesel dosages of 10 or 50 lb/ton), the Pocahontas Seam coal (~16% ash) sorbed about 2-2.5x as much diesel as the Hagy Seam

coal (~35% ash) (see Table 2.4). This is likely because coal has a higher affinity for diesel than ash does. It is difficult to assess whether or not the sized Hagy Seam coal (100 x 150 mesh) behaved differently than that which was only ground (-100 mesh), since just one test condition was repeated between the first and second set of tests (i.e., tests 9 and 24; 5% coal and diesel dosage of 10 lb/ton); however, the DRO results for these tests were practically very similar.

In terms of real preparation plants, the results of the collector partitioning tests presented here indicate that, as expected, most diesel should partition with the coal. However, some (presumably soluble) diesel may well remain in the process water – eventually being sent to tailings impoundments or being recycled back through the plant. While no Federal water quality standards currently exist for DRO, some states have set levels of concern at 0.05 mg/L (e.g., through reporting levels for diesel spills or contamination from underground storage tanks) (DEP 2002). The topic of soluble DRO, including the relative solubility of specific diesel compounds and potential remediation strategies, is deserving of additional research.

## **6. Conclusions**

Processing reagents used in coal preparation have a wide range of potential environmental fates, as well as implications for preparation circuits that are designed or revised to utilize closed water systems. The preliminary test work presented in this paper confirms that common frother and collector reagents are not likely to partition completely to a single fraction of the process slurry. Instead, the partitioning phenomena are complex, and appear to depend on many operating variables including coal and reagent characteristics and dosages.

To gain a better understanding of the ultimate fates of these reagents and related impacts, further work should focus on determining the mechanisms by which various reagents may associate with solid and liquid fractions of coal slurries. Moreover, work is needed to elucidate strategies for controlling/optimizing reagent partitioning, or treatment of affected process streams.

## **7. Acknowledgments**

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expressed in this paper are solely those of the authors and do not imply any endorsement by DOE or ARIES.

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