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Reduction of Asphalt Fumes in Roofing Kettles

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The addition of polymers to asphalt in small quantities is shown to reduce the asphalt fumes from built up roofing kettles. Built up roofing asphalt (BURA) with up to 1% of a blend of polymers was tested for its fuming characteristics in roofing kettles in a Pilot Plant setting and also at several job sites. The addition of polymer forms a steady-state surface layer that reduces the release of fumes from the asphalt. Once equilibrated, the layer remains constant in thickness since as new polymer is added some of the layer dissolves in the asphalt. At least 0.32% polymer in the BURA material was necessary to get good fume reduction. A detailed Pilot Plant experiment is described which demonstrated statistically significant reductions of from 55 to 95% in both opacity and in benzene soluble particulate with this technology. These reductions were seen not only in area monitoring near the asphalt kettle but also in limited personnel monitoring of worker fume exposure in the BURA kettle area. Follow up testing confirmed reductions of this magnitude in the field.

Introduction

Asphalt is primarily obtained as the residuum from the distillation of crude oil, and it also occurs as natural deposits. It is a very complex mixture of hydrocarbons with the exact chemistry dependent on both the source of the crude oil and the processing conditions. After recovery from the crude oil, asphalt can be further modified by solvent extraction, air blowing, or blending with other petroleum products or polymers. Asphalt has been used as an adhesive, waterproofing, and paving material throughout recorded history (*1*). The major markets for this material are road paving and roofing.

Much research has been done on the potential effects on workers of asphalt fumes. The extensive literature is summarized by the American Congress of Governmental Industrial Hygienists (ACGIH) in their latest threshold limit value (TLV) publication for asphalt fume (*2*). Based on this review ACGIH has recently reduced their TLV for asphalt fume from 5.0 mg/m^3 total particulate to 0.5 mg/m^3 benzene-extractable inhalable particulate. The primary health effects identified by ACGIH in its literature review are eye and respiratory irritation. ACGIH also concluded that asphalt fume could not be considered a human carcinogen at this time (*2*). In 1992 OSHA proposed a permissible exposure limit (PEL) for asphalt fumes of 5.0 mg/m^3 total particulates based on irritation (*3*). That PEL is still pending. In addition to the issue of worker irritation, odor from asphalt jobs can be a nuisance to the surrounding community (*4*). For all these reasons it is obvious that technologies that result in reductions in asphalt fume exposure are important to the roofing asphalt industry. The purpose of the present paper is to quantify one new way in which asphalt fumes can be reduced in the asphalt roofing market.

A major segment of the asphalt roofing market uses molten asphalt to mop down a built up roofing system or a modified bitumen roofing system. The asphalt kettle used to melt and heat the asphalt to apply these low slope roofing materials has long been recognized to have the potential for fume release and odor complaints (*4*−*10*). It was estimated in 1979 that 750 000 tons of asphalt passed through asphalt kettles every year to apply built up roofing systems and that approximately 3000 asphalt kettles were in operation in the United States (*7*). A 1991 study of the sources of fine aerosol organic carbon emissions in the Los Angeles basin concluded that built up roofing asphalt (BURA) kettles contributed 752 kg/day or 2.7% of the total emissions of that type in the area (*5*). Typical BURA kettles operate at temperatures between 232 and 288 °C (450 and 550°F) to achieve the asphalt viscosity needed at the rooftop for proper system application.

Several approaches to lower the fuming at asphalt kettles have been investigated, including pollution control devices on the kettles (*8*−*10*), proper control of kettle temperatures and proper location of kettles with respect to surrounding buildings (*9*, *10*), and changes in the asphalt that can reduce the release of fumes (*11*). This paper presents data on the latter approach using polymer additives to the asphalt which float to the surface and form a steady-state barrier to fume release. Two products marketed by Owens Corning were used as the BURA/polymer mix source materials in these tests.

Experimental Methods

Materials Tested. The polymer layer described in this study was either present as a result of having a meltable container made out of an asphalt/polymer blend or having polymer dispersed in the asphalt. In the case of the meltable container, the Owens Corning TruMelt product was used, and the final level of polymer in the BURA was about 1% of the total asphalt weight. In the case of the polymer dispersed in the asphalt, variations of the Owens Corning product Tru-Lo was used. In all cases reported in this study the polymer is polypropylene or a blend of polypropylene and ethylene vinyl acetate copolymer (EVA).

Pilot Plant Asphalt Kettle. To remove as much variability as possible in the measurement of fuming from BURA kettles, a 120 gallon asphalt kettle was set up in the Owens Corning Asphalt Pilot Plant in Summit, IL. To minimize the impact of wind on the capture of the roofing kettle fumes the kettle was set up within a 6.5 × 6.5 m open air enclosure formed by a building on one side, 3 m high storage containers on two sides, and a 3 m high tarp on the fourth side. Every effort was made in the operation of the Pilot Plant kettle to mimic field operation. To accomplish that, every 20 min throughout the testing period approximately 100 pounds of asphalt was added to the kettle and approximately 13 gallons of liquid asphalt was removed, keeping the level of asphalt in the kettle constant. The kettle was heated with a propane torch in the burner tube, and the temperature was monitored with both a dial and a digital thermometer. Temperature variation was typically within 11 °C of the set point, with the addition of the colder solid asphalt causing the variation to be mostly on the low side. The Pilot Plant kettle was kept open at all times, a worst case situation not generally recommended by the industry (*10*), but a situation that does exist in the field.

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(*7*) All the asphalt used in the tests met the requirements for Type 3 BURA per ASTM D312.

In addition to tests at the Pilot Plant, kettles on job sites were also monitored as part of this study.

Opacity Measurements. Visual opacity was determined at all the Summit Pilot Plant tests and at an Atlanta job site. Opacity measures the amount of light which is blocked by the asphalt fumes and is stated as a percentage. Zero percent means there are no visible fumes, and 100% means the fumes are completely opaque. Tests in Summit were done by a qualified opacity reader from Clean Air Engineering of Palatine, IL and in Atlanta by a qualified opacity reader from Air Techniques, Inc. of Marietta, GA. In all cases the opacity measurement was taken in accordance with the EPA Method 9 (*12*). In the Pilot Plant the plume was determined approximately 1 foot above the 2 foot × 3 foot kettle opening and was read against the black steel lid. Readings were taken every 15 s for 1–2 h, and the numbers reported were the average opacity over the entire test period as well as the maximum 6 min average.

Particulate Measurements—High Volume Method. To measure the fuming potential of different asphalts, area particulate measurements were performed at all Pilot Plant tests by Clean Air Engineering in accordance with 40CFR, Part 50, Appendix B (*13*). More details on the method are available from the EPA in their Compendium of Methods for the determination of Inorganic Compounds in Ambient Air (*14*). In these measurements the total suspended particulate was determined using two GMW-GL 2000H high volume ambient air samplers with 200 mm × 254 mm glass fiber filters. The samplers were calibrated by Clean Air Engineering before and after each test. Target flow rate for the test was 1.4 m^3/min, and the flow was measured throughout the test and recorded continuously so that the actual flow collected during the test could be used in the calculation of particulate concentration. Total suspended particulates (TSP) was determined gravimetrically, and then the filters were further analyzed for the benzene soluble fraction of the particulates (BSF) using extraction methodology from Dunzik (*15*), which is a modification of NIOSH 5023 (*16*).

To collect fumes consistently regardless of ambient air flows, the samplers were placed adjacent to the south side of the asphalt kettle, on the east and west corners. The south side was the side where the kettle lid opened. The sampler inlets were positioned less than 0.3 m above the kettle opening and less than 0.3 m horizontally from the corner. Two determinations were made (east and west filter) for each test condition, and these two measures are averaged together to get a measure of total fuming from the kettle regardless of any air currents. It is important to recognize that with all types of area particulate sampling the constant collection and close proximity to the kettle generally elevates this number to greater values than seen in any industrial hygiene monitoring of actual worker exposures. Area particulate measurements are really an indicator of the inherent fuming of the system rather than the exposure of workers to fumes from the system.

Particulate Measurements—Personal Sampling Cassettes. Industrial hygiene sampling cassettes with 37 mm PTFE (Teflon) filters were used for worker exposure measurements in the Pilot Plant tests and for both area sampling and worker exposure measurements in the field trials. In all cases the measurement of total particulate matter (TPM) was done according to NIOSH 0500 (*17*) and measurement of benzene soluble matter (BSM) was done according to the Dunzik modification of NIOSH 5023 (*15*). When used for area sampling of a roofing kettle the filters were placed at all four corners of the kettle opening, horizontally within 1 m of each corner and vertically within 1 m of the surface of the asphalt, and the values obtained were averaged together to get an estimate of total fuming from the kettle. Tests were analyzed either by Heritage Environmental Services, Inc. or by the National Institute for Occupational Safety and Health (NIOSH).

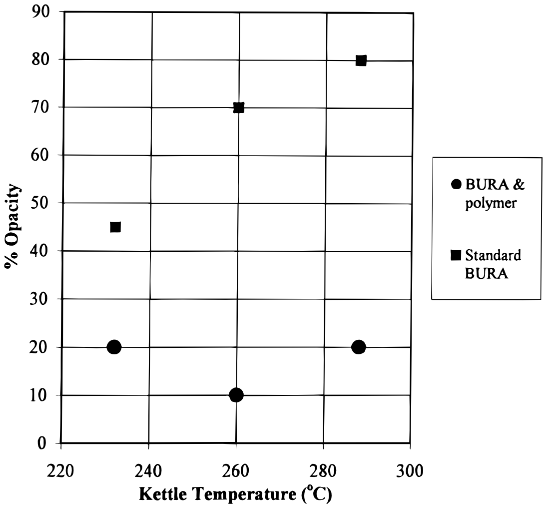

FIGURE 1. Opacity results—BURA with 1% polymer vs standard BURA.

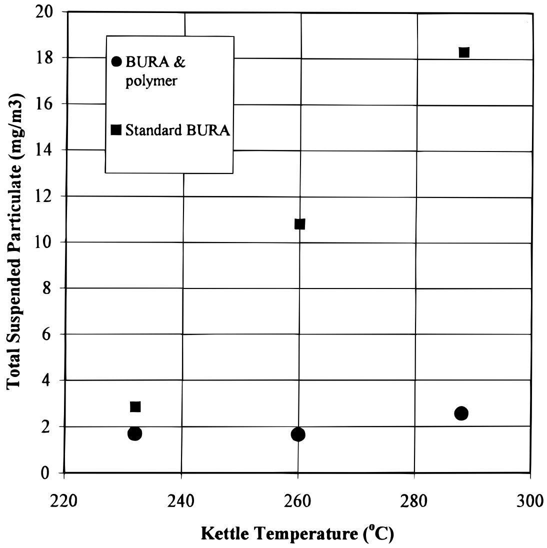

FIGURE 2. Area sampling for TSP—BURA with 1% polymer vs standard BURA.

Experimental Design. Anecdotal data from field testing of a meltable container for BURA indicated that the presence of a continuous polymer layer on the asphalt resulted in much lower fuming at the BURA kettle. An initial set of quantitative tests were done to confirm this effect under controlled conditions with methods for fume evolution that are accepted in the industry. Visual opacity testing with a BURA/polymer product (Owens Corning TruMelt) versus standard BURA asphalt was measured in the Pilot Plant kettle setup. These data are presented Figure 1. The reduction in opacity was between 56% and 98% with polymer in the asphalt when compared to standard BURA. The opacity with the standard BURA increased steadily with kettle temperature in Pilot Plant testing. With the 1% polymer in the BURA the floating polymer skin on the asphalt surface retarded fuming, and the results were a constant and low opacity regardless of the kettle temperature. The reduction in opacity was confirmed on an Atlanta job site, again using a qualified opacity reader. On that job the material with 1% polymer reduced opacity 98% (from 39% opacity with standard asphalt

TABLE 1. Optimization of the Amount of Polymer Needed To Achieve Low Fuming[a]

polymer concn (%)	kettle temp (°C)	total suspended particulate (mg/m^3)	benzene soluble fraction (mg/m^3)	opacity (2 h av) (%)	opacity (max. 6 min av) (%)
0	260 (500 °F)	3.1	1.3	20	25
0.08	260	3.0	1.1	15	20
0.32	260	1.5	0.46	10	15
0.48	260	1.3	0.50	0	5
	% change comparing 0.48 to 0 and 0.08	58%	59%	100%	78%
0	288 (550 °F)	6.4	2.9	20	25
0.08	288	7.0	4.2	25	35
0.32	288	2.2	0.85	10	15
0.48	288	2.2	0.92	5	10
	% change comparing 0.48 to 0 and 0.08	68%	74%	78%	67%

[a] All results are from area particulate samplers—not worker exposures.

TABLE 2. Repetitive Sampling of Standard (0% Polymer) BURA versus BURA with 0.32% Added Polymer

date	polymer concn (%)	kettle temp (°C)	TSP from area particulate samplers (mg/m^3)	BSF from area particulate samplers (mg/m^3)	long-term opacity (2 h av) (%)	short-term opacity (max. 6 min av) (%)	BSM personnel monitoring (worker exposure) (mg/m^3)
7/28 AM	0	260	5.4	2.8	25	30	5.2
7/29 AM	0	260	5.3	2.0	20	25	1.1
7/30 AM	0	260	4.6	2.1	25	25	1.3
7/31 AM	0	260	9.5	4.3	25	30	1.9
7/28 PM	0	288	9.5	3.5	25	30	3.9
7/29 PM	0	288	9.7	4.6	25	30	4.9
7/30 PM	0	288	11	5.0	30	35	3.4
7/31 PM	0	288	31	16	25	35	3.9
8/4 AM	0.32	260	1.2	0.73	10	15	0.92
8/5 AM	0.32	260	1.5	0.46	10	15	0.82
8/6 AM	0.32	260	0.79	0.12	5	10	0.09
8/7 AM	0.32	260	0.91	0.15	5	10	0.32
8/4 PM	0.32	288	1.3	0.53	5	10	0.42
8/5 PM	0.32	288	1.4	0.45	10	15	0.92
8/6 PM	0.32	288	1.2	0.30	5	10	0.26
8/7 PM	0.32	288	1.3	0.30	5	10	0.49

to 0.8% with the low fuming product).

Area particulate testing with the high volume method in the same Pilot Plant tests are presented in Figure 2. Again the fume emissions with standard BURA increased with kettle temperature, but with 1% polymer in the asphalt the fume emissions remained relatively constant with temperature. The benefit of reduced fuming seen with the additive compared to no additive again increased with kettle temperature. The reduction in total suspended particulate with 1% polymer in the asphalt ranged from 36% particulate reduction at the low kettle temperatures to 90% at higher kettle temperatures. As noted before, these measurements are not worker exposures but are simply measures of the fumes escaping from the asphalt kettle surface.

Based on the results obtained with 1% of polymer in the BURA from the polymer/asphalt container, tests were run in the Pilot Plant kettle to determine the minimum amount of polymer that was needed to form a robust polymer skin on the asphalt and obtain the reduction in fuming at the kettle. Table 1 gives the results of fume testing at two different kettle temperatures with four polymer concentrations added to the BURA. The reduction in fumes begins to be significant at approximately 0.32% added polymer with a little additional benefit at 0.48% in this test. The fume reduction was seen using the measurement of total suspended particulate, the benzene soluble fraction of that particulate, and opacity. The particulate data are all from area samplers, not from worker exposure sampling. Each value is the average of results from two high volume samplers.

Given the preliminary data to determine that an effect exists, to define how to measure that effect, and to determine the minimum polymer level needed to get the effect, a comprehensive experiment was designed to determine if a statistically significant fume reduction occurs with this technology. Those data are discussed below along with some data taken in the field to confirm the Pilot Plant results.

Results and Discussion

Pilot Plant Fuming Study. The kettle system at the Pilot Plant was used to run sufficient repetitive tests of kettle fuming using BURA with and without added polymer to develop data on fume reduction that would have statistical significance. In this experiment the kettle was run each day at 260 °C (500 °F) for 3–4 h and then heated to 288 °C (550 °F) for 3–4 h. Four days of tests with standard asphalt were followed by 4 days of tests with asphalt containing 0.32% polymer additive. The data from this study are presented in Table 2, with comparisons of fuming results made on the entire data set and then separately on the data taken at the two kettle temperatures presented in Table 3. Several measurements of asphalt fume were investigated: (1) short and long-term opacity, (2) area sampling of total suspended particulate (TSP) and the benzene soluble fraction of that particulate (BSF), with each reported value being the average from two high volume samplers placed on either side of the roofing kettle, and (3) benzene soluble matter (BSM) from personnel monitoring of worker exposure, each value being a single worker determination.

In all cases, significance was tested assuming normally distributed data, unequal variances between the compared data sets, and doing a one tail analysis of the fuming reduction.

TABLE 3. Summary of Effect on Fuming of Adding Polymer to BURA

date	polymer concn (%)	kettle temp (°C)	TSP from area particulate samplers (mg/m^3)	BSF from area particulate samplers (mg/m^3)	long-term opacity (2 h av) (%)	short-term opacity (max. 6 min av) (%)	BSM personnel monitoring (worker exposure) (mg/m^3)
av 0% polymer	0	overall	11	5.0	25	30	3.2
av 0.32% polymer	0.32	overall	1.2	0.38	7	12	0.53
		av % reduction	89%	92%	73%	60%	84%
		p value	0.0075	0.011	<0.0001	<0.0001	0.00079
av 0% polymer	0	260	6.2	2.8	24	28	2.4
av 0.32% polymer	0.32	260	1.1	0.36	8	13	0.54
		av % reduction	82%	87%	68%	55%	77%
		p value	0.01	0.01	<0.0001	0.0002	0.077
av 0% polymer	0	288	15	7.2	26	33	4.0
av 0.32% polymer	0.32	288	1.3	0.39	6	11	0.52
		av % reduction	92%	95%	76%	65%	87%
		p value	0.037	0.049	<0.0001	<0.0001	0.00026

The reduction in fuming with the polymer additive was dramatic in all tests. Reductions in fuming were consistently greater than 60% for opacity and greater than 75% for particulate measurements. Benzene soluble fraction reductions averaged 92% for the area monitoring and benzene soluble matter reductions averaged 84% for the personnel monitoring. All these reductions were significant at 95% confidence levels with the exception of the comparison of the BSM from personnel monitoring at 260 °C kettle temperatures, where one sample of the control had a particularly high reading, increasing the reduction but at the same time raising the variance, with the net effect of driving the significance down. Most reductions were significant at even higher confidence levels than 95% as indicated by the very low *p* values in Table 3. Note that the particulate numbers for the standard asphalt went up dramatically as temperature was increased from 260 to 288 °C, while the impact of kettle temperature on fuming was negligible with polymer in the asphalt. This is the trend we had seen in earlier tests as presented in Figures 1 and 2.

The worker exposure conditions in this Pilot Plant study were postulated to be more severe than normally encountered in the field for two reasons. The kettles were enclosed on four sides to limit the effect of wind on the results, but this also undoubtedly increased the exposure to the fumes. Also the kettle tenders not only added asphalt to the kettle every 20 min but also drained off hot asphalt to keep the level constant and poured that asphalt into drums for disposal. They were therefore exposed not only to the fumes from the surface of the kettle but also to the fumes from the draining operation, which simulated pumping in most field jobs. Indeed when compared to worker exposure data for kettlemen from Gamble (geometric mean BSM of 0.15 with maximum of 1.2 mg/m^3) (*18*) and Hicks (arithmetic mean BSM of 0.89 with maximum of 1.2 mg/m^3) (*19*) the exposure in this experiment, while on the same order of magnitude as obtained by all these studies, had several values higher than the maximums observed in those tests and were uniformly higher than the means of those studies. A surprising feature of the data from this study is the relatively small difference between worker exposure data and high volume area sampling. This is attributed to the same factors that elevated the worker exposure in the Pilot Plant study, with the draining of the kettle providing double exposure not seen by the high volume samplers and the enclosure evening out the exposure within the area.

In the Gamble and Hicks studies (*18*, *19*) both total particulate and benzene soluble particulate were measured from worker exposure, and the ratio of benzene soluble to total particulate can be compared to the high volume sampler data from this experiment to check for consistency of results. The ratio of geometric means for our data showed an average ratio of benzene soluble to total particulate of 0.45 with standard asphalt and 0.28 with polymer modified asphalt, while the Gamble study showed a ratio of 0.35 and the Hicks study 0.67 for kettlemen. Our standard asphalt result was between the values from the literature. Our polymer modified asphalt result was lower which is not surprising since the low fuming asphalt only impacts the organic asphalt fume and does nothing to reduce ambient dust.

TABLE 4. Benzene Soluble Matter Measurements at Job Sites

	standard BURA		BURA with polymer additive for low fuming		% reduction with polymer in asphalt
	av BSM (mg/m^3)	days of testing	av BSM (mg/m^3)	days of testing	
Chicago Job Site Area Sampler Measurements					
NIOSH testing	7.0	1	2.1	1	70
Ohio Job Site Worker Exposure Measurements					
OC testing	0.49	3	0.10	2	80
NIOSH testing	1.1	1	0.12	2	90
Ohio Job Site Area Sampler Measurements					
OC testing	1.5	3	0.19	2	88
NIOSH testing	1.1	2	0.24	2	78

Confirming Field Tests. While the Pilot Plant study was desirable because its controlled conditions allowed better comparison of the effect of polymer, it was recognized that the ultimate test of the technology was in field measurements of kettle fuming and worker exposure. Owens Corning is working with NIOSH to evaluate this technology in the field. The first two studies in that effort have given results very similar to the Pilot Plant study and are presented in Table 4 and discussed below. Further work is planned with NIOSH to establish the statistics on the worker exposure benefit.

NIOSH did area monitoring of benzene soluble matter at the asphalt kettle on a Chicago job site in December 1998 in order to test the low fuming concept. TruLo was the low fuming product used on that job. NIOSH saw a reduction of 70% in BSM comparing standard asphalt run 1 day with low fuming asphalt run the second day.

At a job site in Ohio in October 1999 both asphalt kettle worker exposure and kettle area sampling was done independently by NIOSH and Owens Corning. Standard asphalt was used for 3 days, followed by TruMelt for 2 days. The area samplers placed near the roofing kettle showed a reduction in BSM when using the low fuming asphalt of 88% as measured by Owens Corning and 78% as measured by NIOSH. Worker exposure showed a reduction in exposure with the low fuming asphalt of 80% as measured by Owens Corning and 90% as measured by NIOSH.

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