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SELECTED ORGANIC POLLUTANT EMISSIONS FROM UNVENTED KEROSENE HEATERS

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ABSTRACT

An exploratory study was performed to assess the semivolatile and nonvolatile organic-compound emissions from unvented kerosene space heaters. A well-tuned radiant heater and a maltuned convective heater were used for this study. Each heater was operated in a 27-m^3 chamber with a prescribed on/off pattern. Organic compounds were collected on teflon-impregnated glass filters backed by XAD-2 resin and analyzed by gas chromatography/mass spectrometry. Pollutant source strengths were calculated using a mass-balance equation. The results show that kerosene heaters can emit polycyclic aromatic hydrocarbons (PAHs), nitrated PAHs; alkyl benzenes; pentachlorophenol; phthalates; hydro naphthalenes; aliphatic hydrocarbons, alcohols, and ketones; and other organic compounds.

INTRODUCTION

A wide variety of pollutants is emitted by unvented portable kerosene space heaters. Emission rates for carbon monoxide, carbon dioxide, nitric oxide, nitrogen dioxide, sulfur dioxide, and suspended particles have been reported by several researchers.[1-3] Several studies using a kerosene-fueled turbulent diffusion continuous-flow combustor showed that many polycyclic aromatic hydrocarbons (PAHs) are emitted during kerosene combustion.[4-6] Two of these studies also showed that kerosene soot is mutagenic.[5,6] One of these studies showed that essentially all of the mutagenic activity of kerosene soot was due to unnitrated PAH compounds.[6] Another study revealed that kerosene heaters emit dinitropyrene.[7] This study also showed kerosene soot to be mutagenic but, in an apparent conflict with previous work, showed that most of the mutagenic activity could be attributed to dinitropyrenes.

The above studies have shown the following: 1) kerosene combustion products can be mutagenic, 2) kerosene combustion can produce PAHs and nitrated-PAHs, and 3) much of the mutagenic activity of kerosene soot is likely due to the PAHs and nitrated-PAHs. However, it is not known whether the unvented portable kerosene space heaters commonly used indoors in the U.S. produce emissions similar to those emitted by the kerosene combustors used in several earlier studies or whether these portable space heaters produce other potentially harmful organic pollutants.

In this exploratory study, measurements were made of organic pollutant emissions (including some PAH and nitrated-PAH emissions) from portable kerosene space heaters that are common in the U.S. Two heater/tuning conditions were chosen for this study based, in part, on previously reported particulate emission data.[2] The previous study showed that particulate emissions from a well-tuned properly operated convective kerosene heater were negligible but that particulate emissions from a radiant heater were not. Therefore, it was reasoned that significant organic emissions would be more likely to be observed from a radiant heater rather than from a convective heater. A radiant heater operating under well-tuned normal conditions was chosen as the first heater/tuning combination to be tested. The other heater/tuning combination chosen for testing was a convective heater operated under maltuned conditions. This choice was based, in part, on conversations with kerosene-heater users and testers, who indicated that it was easier (more likely) for a convective heater to "soot" (i.e., emit a visible stream of particles) than it was for a radiant heater. In fact, altering the burner assembly itself was the only way the radiant heater tested in this study could be made to "soot." The convective heater was maltuned by lifting the exterior shell of the heater by approximately one cm, thereby providing excess air to the wick.

Only two heater/tuning combinations were tested because each test had to be conducted numerous times to collect enough samples for mutagenicity testing. The organic extracts of the emission samples have been sent to the Health Effects Research Laboratory at the U.S. Environmental Protection Agency for mutagenicity testing.[8]

This paper presents key preliminary results of a larger study on organic pollutant emissions from unvented kerosene space heaters.

EXPERIMENTAL METHODS

Each heater was operated in a 27-m^3 chamber. The chamber walls and ceiling are taped-and-sealed sheet rock, and the floor is concrete. The heaters were operated intermittently to avoid unrealistically high chamber temperatures. For the five radiant-heater tests, the heater was operated for one hour on, then one hour off, and the cycle was repeated four times. For the two maltuned-convective-heater tests, the on/off times were approximately one hour, and the cycle was repeated only twice. The fuel consumption rates for the radiant-heater tests averaged 7000 ± 100 kJ/h and for the maltuned-convective-heater tests averaged 6900 ± 600 kJ/h. Two eight-hour control tests were also conducted. The air exchange rates of the chamber averaged 1.1 ± 0.1 air changes per hour for all tests. An average air exchange rate for each test was computed from the decay curves of either carbon monoxide (CO) or carbon dioxide (CO_2). The air exchange rate was dominated by our sampling flow rate.

Pollutant source strengths (mass of pollutants emitted per hour) were calculated using the following single-chamber mass-balance equation.

$$S = V[C(a+k) - PaC_o] \qquad (1)$$

where:

S = pollutant source strength (mass/h)
V = chamber volume (27 m^3)
C = average indoor pollutant concentration (mass/m^3)
a = average chamber air exchange rate (h^{-1})
k = average chamber reactivity (h^{-1})
P = outdoor pollution penetration factor (dimensionless)
C_o = average outdoor pollution concentration (mass/m^3)

Average source strengths determined with Eq. 1 were multiplied by two in order to estimate the pollutant source strength while the kerosene heater was on. Only these latter source strengths are reported in this paper. P was assigned the value of 1.0 for inorganic gases, such as nitrogen dioxide (NO_2), and 0.4 for particles.[9] Somewhat arbitrarily, P was assumed to be 0.8 for semivolatile organic compounds (SVOCs). The average chamber reactivity, k, was directly determined from real-time decay curves for inorganic gases. For SVOCs, estimates of k ranged from 0 to over 2.0 h^{-1}, depending upon the compound or class of compounds used for analysis. For particles, estimates of k ranged from 0 to 0.4 h^{-1}. For the purpose of estimating pollutant source strengths, k was assigned the value of 1.0 h^{-1} for SVOCs and 0.2 h^{-1} for particles. Since different SVOCs clearly have different reactivity rates, error will be introduced to the source strength calculations by using a single k value for all SVOCs.

Indoor pollutant concentration measurement/collection techniques fell into three categories. First, real-time CO, NO, and NO_2 measurements were made with standard outdoor air pollution instruments.[9] Second, 100-cm^2 teflon-impregnated glass-fiber filters were used to collect nonvolatile and particle-bound organic compounds. And third, approximately 100 grams of XAD-2 resin was placed behind each glass filter to collect SVOCs.

Each XAD/filter sampler was operated at an air flow rate of 6.8 m^3/h for no more than eight hours. Two samplers were used inside the chamber, and one was used outside the chamber. One filter and one XAD cartridge were used per test at each sampling location except for the maltuned-convective tests, where heavy soot loading required the use of two filters per test for both indoor sampling systems.

After sample collection, the XAD resin was placed in precleaned glass jars with teflon lined caps, and the filters were folded and wrapped in aluminum foil. The samples were placed in unused precleaned paint canisters and placed in dry-ice mailing boxes. The samples were shipped from the Lawrence Berkeley Laboratory to Battelle Columbus Laboratories using overnight carriers. All analyses of the glass filters and XAD resin were done by Battelle.

The glass filters were weighed before and after sample collection to determine the total mass of collected particles. Estimated precision of this mass determination is 5%. Soluble organic material was removed from the filter and the XAD resin samples by Soxhlet extraction with methylene chloride. After this extraction, aliquots of extracts from XAD samples were removed for total chromatographable organic (TCO) analysis.[10] TCO analysis yields information on the amount of organic material with boiling points in the approximate range of 100°C to 400°C. A gas chromatograph (GC) with a flame ionization detector was used for TCO analysis. Calibration of the GC was accomplished with mixtures of known concentrations of normal C_8, C_{12}, C_{16}, and C_{20} hydrocarbons. The estimated precision for TCO analysis is 20%.

In addition, gravimetric (GRAV) analysis for extracted organics with boiling points predominantly over 300°C was conducted on selected XAD and filter extracts.[10] Aliquots of sample extracts were dried and weighed for this analysis. Repeat measurements of GRAV yield an average estimated precision of 20%.

Nitrated PAH and other organic analyses were accomplished with a combined gas chromatograph/mass spectrometer (GC/MS).[11] Analyses were performed on a Finnigan 4500 quadrapole MS equipped with an INCOS 2300 data system and a Finnigan GC. The sample extracts were quantitatively analyzed using an on-column-injection, negative-chemical-ionization (NCI) technique[12] for the following nitrated PAHs: 1-nitronaphthalene; 2-nitrofluorene; 9-nitroanthracene; 9-nitrophenanthrene; 6-nitrochrysene; 6-nitrobenzo(a)-pyrene; 3-nitrofluoranthene; 1-nitropyrene; 1,3-dinitropyrene; 1,6-dinitropyrene; 1,8-dinitropyrene; 2,7-dinitrofluorene; and 2,7-dinitrofluorenone. The accuracy and precision of this technique were within 20%.

These extracts were also analyzed by electron impact (EI) GC/MS to make tentative determinations of the various classes of compounds in the extracts. The identifications of sample components were accomplished by comparison to reference spectra in the Environmental Protection Agency/National Institutes of Health mass-spectral library. The quantitations were based on the surrogate response factors generated from partial calibration curves (2 levels, triplicate analyses) of the surrogate standards. The surrogate standards (Table I) were chosen to best represent the range of organic compound classes present in the extracts. The response factor of each standard was used for the same class of compounds (e.g., naphthalene as the standard for all 2-ring PAHs). If the identified compounds are not represented by the standards, the response factors are designated as 1. The analysis is called semiquantitative because results are estimated to be accurate only to within a factor of 3 to 4. However, the precision of the results is on the order of 30%.

The MS was operated at 70 eV and scanned from 50-540 amu every 1 sec in the EI mode. In the NCI mode, the MS was operated at 150 eV and scanned from 100 to 450 amu every 1 sec. Methane was used as the carrier and reagent gas.

RESULTS AND DISCUSSION

Carbon Monoxide, Nitric Oxide, and Nitrogen Dioxide

CO, NO, and NO_2 emission-rate results for each test are presented in Table II. The emission rate results for the well-tuned radiant heater are consistent with previously published data.[1-3] The results for the maltuned convective heater show that total nitrogen oxide (NO and NO_2 = NO_x) emissions are 27% lower than for a well-tuned convective heater. A well-tuned heater will emit approximately 15 μg/kJ of N (of NO_x),[2] whereas the maltuned convective heater emitted approximately 11 μg/kJ of N (of NO_x). The CO emissions from the maltuned-convective heater were similar to those from a well-tuned heater. This is not expected to be a universal result but is probably unique to the method of maltuning--supplying excess air to the combustion region--used in this study.

TCO, GRAV, and Total Suspended Particulate Mass

Table III lists the total suspended particulate (TSP) mass and GRAV concentration results for filter-collected samples. Both TSP mass and GRAV concentrations were higher for the maltuned-convective-heater tests than for the radiant-heater tests. However, the ratio of GRAV to TSP mass was much lower for the maltuned-convective-heater tests than for the radiant-heater tests. This observation is consistent with a previously reported observation that increased sooting does not cause a proportionate increase in organic pollutants.[13]

Table IV lists the GRAV and TCO results for XAD-collected samples. Again, notice that the GRAV and TCO indoor concentrations for the well-tuned-radiant and the maltuned-convective tests are not very different, despite the great difference in TSP concentrations. Tables III and IV clearly indicate that most kerosene heaters do emit some organic pollutants and, based on GRAV results, that most of the organic pollutants were trapped by the XAD-2 resin. TCO analysis was not performed on the filter-collected samples under the assumption that compounds with boiling points lower than 300°C would pass through the filter and be collected on the XAD. As will be discussed later in this paper, the assumption was good for the well-tuned-radiant-heater tests but was not as applicable for the maltuned-convective-heater tests. For the latter tests, the heavy soot loading on the filters trapped much of the SVOCs before they reached the XAD.

Nitrated-PAH and Other Organic Compounds

Samples of similar types were combined before organic and nitrated-PAH compound analyses were conducted. XAD samples were not mixed with filter samples. Samples for radiant tests coded RAD-1, RAD-2, RAD-4, and RAD-5 were combined (note that the TCO results for RAD-3 were much higher than for the other radiant tests); samples from maltuned-convective tests MCON-1 and MCON-2 were combined; and samples from CONTROL-1 and CONTROL-2 were combined. Indoor and outdoor samples were not mixed but were combined individually with their counterparts from other tests using the above scheme. The final result was eight XAD and eight filter samples: two indoor radiant, two outdoor radiant, one indoor convective, one outdoor convective, one indoor control, and one outdoor control.

For convenience and ease of reporting, results of the contribution of a kerosene heater to indoor air pollution concentrations will be expressed as pollutant source strengths while the heater is on. Lower-limit indoor concentrations can be calculated using Eq. 1, assuming the outdoor concentration is zero. Pollutant emission rates (expressed in units of mass of pollutants per kJ of fuel consumed) can be calculated by dividing the source-strength values by 7000 kJ/h. Rough error-propagation analyses have been conducted on our calculations of pollutant source strengths using approximate precision estimates for the variables in Eq. 1.

Except where noted, the omission of a source-strength value from the paper is due to one of three possibilities: the pollutant was not looked for, the pollutant was looked for but not found, or the pollutant source strength was not significantly different from zero. In the last circumstance, qualitative judgments were used in some cases, e.g., when the limit of detection of a compound was only approximately known and no outdoor concentrations were reported.

For comparison with other source-strength tables, the source strengths for TCO, GRAV, and TSP mass are given in Table V.

Nitrated PAHs. Table VI lists the source strengths of several nitrated-PAHs. The nitrated-PAHs searched for are listed in the "Experimental Methods" section; 1-nitronaphthalene is clearly emitted by the well-tuned-radiant and maltuned-convective kerosene space heaters. Nitronaphthalene was collected almost entirely on the XAD for the radiant-heater tests. For the maltuned-convective-heater tests, thirty percent of the nitronaphthalene was collected on the filter. This is presumably due to collection by the heavy loading of fresh soot on the filter during the maltuned-convective test.

Emissions of 9-nitroanthracene were observed in the XAD fraction of one of the radiant-heater tests and in the filter fraction of the maltuned-convective test. (Again, the heavy soot loading on the filters of the convective tests may have captured the 9-nitroanthracene before it reached the XAD.) Emissions of 1-nitropyrene were also observed in the filter fraction of both radiant test samples, whereas only trace amounts of 3-nitrofluoranthene were observed in one of the two series of radiant-heater tests in the filter-collected fraction.

Both 3-nitrofluoranthene and 1-nitropyrene have been observed to be somewhat mutagenic,[7,14] but the mutagenicity of 1-nitronaphthalene and 9-nitroanthracene is low.[14] Notably missing from Table VI are the highly mutagenic dinitropyrenes (DNPs). The 1,3-DNP; 1,6-DNP; and 1,8-DNP combined source strengths were measured by another research team to be approximately 0.2 ng/h. The estimated limit of detection in terms of source strengths for DNPs or other nitrated-PAHs investigated for this paper is 1.0 ng/h. Future studies could take advantage of various fractionation and clean-up techniques to improve the detection sensitivity for this class of compounds; however, such elaborate techniques were not appropriate for this exploratory study.

Other Organic Pollutants. Table VII presents pollutant source-strength results for selected organic pollutants emitted from the well-tuned and maltuned convective heaters. Although the table contains more information than can be discussed here, two topics are of particular interest: 1) the differences in relative source strengths among the three test/sample categories and 2) the PAH emissions.

There is a striking difference in relative source strengths between the RAD-1,2,4, and 5 tests and the RAD-3 test. The alkyl benzene emissions from the RAD-3 test were much greater than those from the other radiant-heater tests, whereas the aliphatic hydrocarbon and aliphatic ketone emissions from the RAD-1,2,4, and 5 tests were much greater than those from the RAD-3 test. From an experimental point of view, all five radiant-heater tests were identical, yet the emission spectra of the RAD-3 test are dramatically different from the other radiant tests.

The comparison of the convective-test emissions spectra with the radiant tests reveals both similarities and differences. The PAH, phthalate, and aliphatic-alcohol emissions for the radiant and convective tests are very similar, yet the aliphatic ketone and, particularly, the pentachlorophenol emissions are much greater for the convective tests than for the radiant tests. Since pentachlorophenol was used as a calibration standard for this analysis and some pentachlorophenol was emitted during the radiant-heater tests, we must conclude that the convective-heater pentachlorophenol source strength presented in Table VII is valid, although the authors do not understand how such a compound could be produced in a kerosene flame. Also of interest is the observation that many SVOCs were trapped by the soot-laden filter during the convective tests.

Relatively few PAHs were observed to be emitted by the kerosene heaters using the very broad GC/MS scanning technique employed in this study. It is anticipated that other PAHs would be found if a more compound-specific technique were employed. Our analysis shows naphthalene to be the primary PAH emission from kerosene heaters. Emissions of fluoranthene and indeno(c,d)pyrene, two slightly mutagenic compounds,[6,15] were also found. Previous research from a turbulent diffusion continuous-flow kerosene combustor showed that 18 nonvolatile or particle-bound PAHs were emitted[6]; naphthalene accounted for only 3% of the particle-bound PAHs. The earlier study also found relatively few PAHs accounted for the mutagenic activity of the kerosene-heater soot. Of those compounds, only fluoranthene was also observed in this study. A more specific study of PAH emissions using more sensitive techniques is probably warranted.

CONCLUSIONS

This study has confirmed the results of other studies, i.e., that the kerosene combustion process can emit PAHs and nitrated-PAHs. In addition, kerosene heaters were found to emit many other organic compounds, including aliphatic hydrocarbons, alcohols, and ketones; phthalates; alkyl benzenes; and pentachlorophenol. Additional analysis is needed to correlate these results with health-effects data to determine the risk associated with these organic emissions. PAH and nitrated-PAH emissions are sufficiently important to justify additional quantitative studies; furthermore, examinations of other organic compounds of toxicological significance and of unvented combustion sources should be expanded.

One very important observation of this study was that some estimates of the indoor reactivity of SVOCs were higher than 2 h^{-1}. This implies that reactivity rates for some SVOCs are more important than ventilation rates for determining indoor concentrations. Clearly, this indicates that future studies must quantify the indoor reactivity process for individual SVOCs in order to gain insight into potential indoor exposures to these compounds.

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Table I. Standard compounds for the semiquantitative analyses of organic pollutants.

Compound Name	Compound Class
Octane	Aliphatic hydrocarbons
Decane	Aliphatic hydrocarbons
Dodecane	Aliphatic hydrocarbons
Heptadecane	Aliphatic hydrocarbons
n-Eicosane	Aliphatic hydrocarbons
Docosane	Aliphatic hydrocarbons
Naphthalene	Polynuclear aromatic compounds
Phenanthrene	Polynuclear aromatic compounds
Pyrene	Polynuclear aromatic compounds
Chrysene	Polynuclear aromatic compounds
Benzo(a)pyrene	Polynuclear aromatic compounds
Benzo(ghi)perylene	Polynuclear aromatic compounds
Acridine	Nitrogen heterocyclic compounds
Pentachlorophenol	Phenols
Benzoic acid	Organic Acids
1,2,4-Trimethyl benzene	Base-neutral organic compounds
Di-n-ethyl phthalate	Phthalate
Di-n-butyl phthalate	Phthalate
Di-(2-ethyl hexyl)phthalate	Phthalate

Table II. Carbon monoxide, nitric oxide, and nitrogen dioxide emission rates for tests of well-tuned-radiant and maltuned-convective heaters.

Test Code	Average Emission Rate[a] (μg/kJ) CO	NO	NO_2
RAD-1	92	0.69	5.1
RAD-2	88	0.53	5.0
RAD-3	77	0.69	5.0
RAD-4	85	0.85	4.7
RAD-5	79	0.71	4.6
MCON-1	23	18	7.6
MCON-2	18	19	5.9

[a] Radiant (RAD) test averages are from four 1-hour burns. Maltuned-convective (MCON) test averages are from two 1-hour (approximately) burns.

Table III. Total suspended particulate mass and GRAV[a] concentration results for <u>filter-collected</u> samples for well-tuned-radiant and maltuned-convective kerosene heaters.

Test Code	Mass ($\mu g/m^3$)		GRAV[a] ($\mu g/m^3$)	
	In	Out	In	Out
RAD-1	28	18	n.m[b]	n.m
RAD-2	23	9	n.m	n.m
RAD-3	24	9	8.2	3.6
RAD-4	14	7	n.m	n.m
RAD-5	13	2	n.m	n.m
MCON-1	5300	62	n.m	n.m
MCON-2	2300	40	100	13
CONTROL-1	5	13	1.6	5.6
CONTROL-2	4	13	n.m	n.m

[a] GRAV analysis is designed to measure solvent-extractable organics with boiling points predominantly over 300°C.

[b] Not measured.

Table IV. Total chromatographable organic (TCO) and GRAV concentration results for XAD-collected samples for well-tuned-radiant and maltuned-convective heaters.

Code	GRAV[a] ($\mu g/m^3$)		TCO[b] ($\mu g/m^3$)	
	In	Out	In	Out
RAD-1	490	190	1400	150
RAD-2	360	120	930	190
RAD-3	510	120	4900	370
RAD-4	450	77	1000	92
RAD-5	380	48	1700	130
MCON-1	500	250	2100	400
MCON-2	360	220	950	240
CONTROL-1	99	94	700	290
CONTROL-2	50	29	100	110

[a] GRAV analysis is designed to measure solvent-extractable organics with boiling points predominantly over 300°C.

[b] TCO analysis is designed to measure solvent-extractable organics with boiling points between 100°C and 400°C.

Table V. TCO, GRAV, and TSP mass source strengths for a well-tuned-radiant and a maltuned-convective kerosene heater.

Pollutant Group	RAD-1,2,4,5 (mg/h)	RAD-3 (mg/h)	MCON-1,2 (mg/h)
TCO-XAD	140	540	160
GRAV-XAD	42	53	38
Filter	n.m.[a]	0.49	6.9
Total	n.m.	53	45
TSP	1.1	1.5	270

[a] Not measured

Table VI. Nitrated-PAH source strengths from a well-tuned-radiant and a maltuned-convective-tuned-convective kerosene space heater.

Compounds	RAD-1,2,4,5 (ng/h)	RAD-3 (ng/h)	MCON-1,2 (ng/h)
1-nitronaphthalene			
XAD	280	140	260
Filter	--	3	120
TOTAL	280	140	380
9-nitroanthracene			
XAD	--	53	--
Filter	--	3	41
TOTAL	--	56	41
3-nitrofluoranthene (filter only)	1.9	--	--
1-nitropyrene (filter only)	44	8.2	--

Table VII. Selected organic pollutant source strengths from a well-tuned-radiant and a maltuned-convective kerosene space heater.

COMPOUND CLASS		RAD-1,2,4,5 (μg/h)	RAD-3 (μg/h)	MCON-1,2 (μg/h)
PAH:				
Naphthalene	XAD-2:	56	230	18
	Filter:	--	--	140
	Total:	56	230	160
C2, Naphthalene (filter only)		--	--	30
C3, Napththalene (filter only)		1.1	--	4.5
Phenanthrene (XAD only)		1.9	16	5.9
Fluoranthene	XAD-2:	--	0.84	--
	Filter:	0.11	0.07	1.8
	Total:	0.11	0.91	1.8
Anthracene (filter only)		--	--	2.27
Chrysene (filter only)		0.05	--	--
Indeno(c,d)pyrene (filter only)		--	0.12	--
Total PAH in XAD-2		58	250	24
Total PAH on filter		1.3	0.2	180
Total PAH from XAD-2 and filter		59	250	200
Alkyl benzenes:				
	XAD-2:	89	61000	840
	Filter:	1.8	--	17
	Total:	91	61000	860
Pentachlorophenol:				
	XAD-2:	36	48	--
	Filter:	0.34	1.1	920
	Total:	36	49	920

Table VII - Continued

COMPOUND CLASS		RAD-1,2,4,5 (µg/h)	RAD-3 (µg/h)	MCON-1,2 (µg/h)
Phthalates:				
	XAD-2:	1200	3300	3500
	Filter:	7.8	13	1500
	Total:	1200	3300	5000
Hydro Naphthalenes:				
Decalin (XAD-2 only)		300	1000	20
C2, Decalin (XAD-2 only)		1800	6500	1800
C1, Tetralin				
	XAD-2:	700	1600	1200
	Filter:	--	--	160
	Total:	700	1600	1300
Aliphatic Hydrocarbons:				
	XAD-2:	1500	--	2900
	Filter:	9.4	6.4	1400
	Total:	1500	6.4	4300
Aliphatic Alcohols:				
	XAD-2:	10000	4900	4900
	Filter:	5.5	32	590
	Total:	10000	4900	5500
Aliphatic Ketones:				
	XAD-2:	670	--	4500
	Filter:	--	1.1	--
	Total:	670	1.1	4500
Benzoic Acids (filter only)		2.3	--	--
Aromatic Acid (XAD-2 only)		--	--	630
Fatty Acids (filter only)		14	18	220
Esters (filter only)		6.4	15	200

Table VII - Continued

COMPOUND CLASS	RAD-1,2,4,5 (μg/h)	RAD-3 (μg/h)	MCON-1,2 (μg/h)
MISCELLANEOUS:			
C1, Cyclohexane (XAD-2 ONLY)	--	530	--
C2, Methoxy Benzene (XAD-2 only)	3000	--	--
C2, Ethenyl Benzene (XAD-2 only)	--	680	--
Chlorophenyl Ethanone (XAD-2 only)	--	--	270
Acridene (filter only)	--	--	1.3
Methyl Propoxy Benzene (filter only)	--	--	57
Trichloropropene (filter only)	0.66	--	--
Aliphatic Amine (filter only)	--	--	200

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