

ALASKA LEGISLATURE SPECIAL COMMITTEE/SUBJECT FILE 8672
2031 SCOMM 78: SENATE SPEC. COMM. ON OIL & GAS, 1991-1992

6.4.2 Base Case Simulations

The modeled region described in section 6.2.2.1 was selected for the base case simulation. The air/soil interfacial area was set to 75.3 km², the air/water interfacial area (equal to the sediment/water interfacial area) was set to 110.6.1 km², and the water flow rate was set to 1.04 x 10⁷ m³/hr. The emissions for the base case simulations are given in Table 6.10 and the atmospheric reaction rate constants for the base case simulations are given in Table 6.11. The mass balance results describing the distribution of the chemicals in the Port Valdez Environment and the transfer rates among the various compartments were also calculated for the half-port area. The half-port region includes the Port Valdez region east of Saw Island (see Figure 1.1) with a soil/atmosphere interfacial area of 58.9 km² and an atmosphere/water interfacial area of 43.1 km². The half-port region was selected for this representation since it is more representative of the region which encompasses the City of Valdez and the Alyeska Marine Terminal.

TABLE 6.11
BASE CASE ATMOSPHERIC REACTION RATE CONSTANTS

Compound	Atmospheric Reaction Rate (hr ⁻¹)
Benzene	0.0021
Ethylbenzene	0.0128
Toluene	0.0118
Xylenes	0.0270
n-Hexane	0.0093

(a) see Table 6.7

Since the main interest in this study was to evaluate the effect of emissions associated with the marine terminal, the contribution of sources outside of the Port Valdez area to the distribution of the study chemical in the modeled region were not considered.

Several preliminary precipitation scavenging simulations indicated that although precipitation has some effect on the fluctuations of the concentrations in the soil compartment, it has little effect on the annual average atmospheric concentrations of BETX and n-hexane. Thus, the input of BETX and n-hexane to the soil and sea via precipitation scavenging (from the atmosphere) is negligible relative to dry deposition. It is noted, however, that atmospheric removal of airborne pollutants is most significant for highly water soluble or reactive gases and for particle-bound pollutants (Ligocki et al., 1985; Tsai and Cohen, 1991).

6.4.3 Evaluation of the Effect of Model Parameters on Predicted Multimedia Distribution of BETX and *n*-Hexane

A number of scenarios were simulated for different model parameters in order to investigate the effect of these parameters on the predicted concentrations in the various compartments relative to the base case predictions. The parameters varied in the above series of simulations are listed in Table 6.12.

TABLE 6.12
PARAMETERS VARIED IN THE SMCM MODEL SIMULATIONS

MODEL PARAMETER
Size of Modeled Region
Emissions Rate
Mixing Height
Wind Speed
Organic Carbon Content of Soil, Sediment, and Suspended Solids
Water Temperature

6.4.4 Evaluation of the Multimedia Distribution of BETX and *n*-Hexane Based on Reported Atmospheric Concentrations

In this part of the analysis the emission rates for BETX and *n*-hexane were approximated based on the reported monitoring data for these compounds. This was accomplished by setting the atmospheric concentration in the SMCM model to the monitored concentrations and determining the accumulation of BETX and *n*-hexane in the Port Valdez environment (see section 7.4). It is important to note that the average concentrations were derived by averaging the concentrations reported by the monitoring stations (section 5.1). Given the uncertainty in the monitored concentrations and the expected spatial variability of the concentration fields, the calculations of the emission rates using the SMCM model should only be regarded as approximations. Nonetheless, as discussed in section 7, such analysis does portray potential incompatibilities between the reported emission rates and the monitored concentrations.

7. THE DISTRIBUTION OF BETX AND N-HEXANE IN THE PORT VALDEZ REGION

7.1 Overview

The concentrations of BETX and *n*-hexane in the air compartments were evaluated based on both the monitoring data and a simple mass balance approach (see section 6.2.2.1). Based on the average monitored concentration data, the partitioning of the study chemicals into the soil, water, suspended solids, and sediment compartments was determined using the SMCN model (see section 6 and Appendix B). The effect of various assumed model parameters on the calculated concentrations in the various compartments and in relation to the estimated sources are presented in sections 7.2 - 7.5. Finally, the distributions of the BETX and *n*-hexane in the Port Valdez environment and the ~~intermedia~~ fluxes are presented in section 7.6.

7.2 Atmospheric Compartment

Several test cases have shown that for the study chemicals and the range of environmental conditions at Port Valdez, the transfer of airborne hydrocarbons to the water and soil environment has a negligible effect on the air phase concentration. This conclusion is supported by the recent study of Cohen et al. (1990, 1991) on the multimedia distribution of refinery emitted hydrocarbons. Given the above findings it is instructive to explore the mass balance on the emitted BETX and *n*-hexane using the simple box-model given by Eq. 6.3. At steady state (i.e., the case representing annual averaged basin-wide concentrations) one can determine from Eq. 6.3 the atmospheric chemical concentrations for a given volume and the mean convective residence time for the basin. The resulting concentrations relative to the averaged monitored concentration (for the sites excluding East Gate; see Tables 5.1), using the approximate reported convective residence time of 13.3 hours (see section 6.2.2.2) and the average atmospheric degradation rate constants (see Table 6.12), are shown in Table 7.1 and Figure 7.1. The results given in Table 7.1 which were obtained based on the estimated emission rates for BETX (see Table 4.2) indicate that the estimated concentrations for benzene and *n*-hexane are higher by about a factor of two relative to the averaged reported concentrations. The predicted concentrations for xylenes and ethylbenzene are lower by factors of about 2.4 and 3.8, respectively, than the average of the reported concentrations. Finally, the predicted concentrations for toluene are only 11% higher than the average of the reported concentrations,

Using Eq. 6.3 one can also estimate the source strength for each of the chemicals that would be required to yield the average of the monitored concentrations. As shown in Figure 7.2 (see also Table 7.2), the calculated sources are different from the reported estimated emissions (see Table 4.2). It is noted that the emission rate estimate for *n*-hexane was not available from the Alyeska Tanker Loading Emission Study (Alyeska, 1988, 1990). Thus, the emission rate for *n*-hexane was estimated based on vapor phase analysis data for Prudhoe Bay Crude oil (see

Table 4.2). The above analysis, although approximate, does suggest that there is a need for a detailed modeling effort to determine the suitability of the monitoring data to provide a representative view of the distribution of released hydrocarbons in the Port Valdez basin.

TABLE 7.1
PREDICTED VERSUS OBSERVED CONCENTRATIONS
AT PORT VALDEZ^(a)

Chemical	<i>Predicted Concentration</i> <i>Measured Concentration</i>
Benzene	2.13
Ethylbenzene	0.26
Toluene	1.11
Xylenes	0.41
<i>n</i> -Hexane ^(b)	1.85

^(a) $Q/V = 0.075 \text{ hr}^{-1}$; The measured concentrations represent the average of the monitored concentrations (excluding the East Gate site).

^(b) based on estimated source emission of 623 tons/year (see Table 4.2)

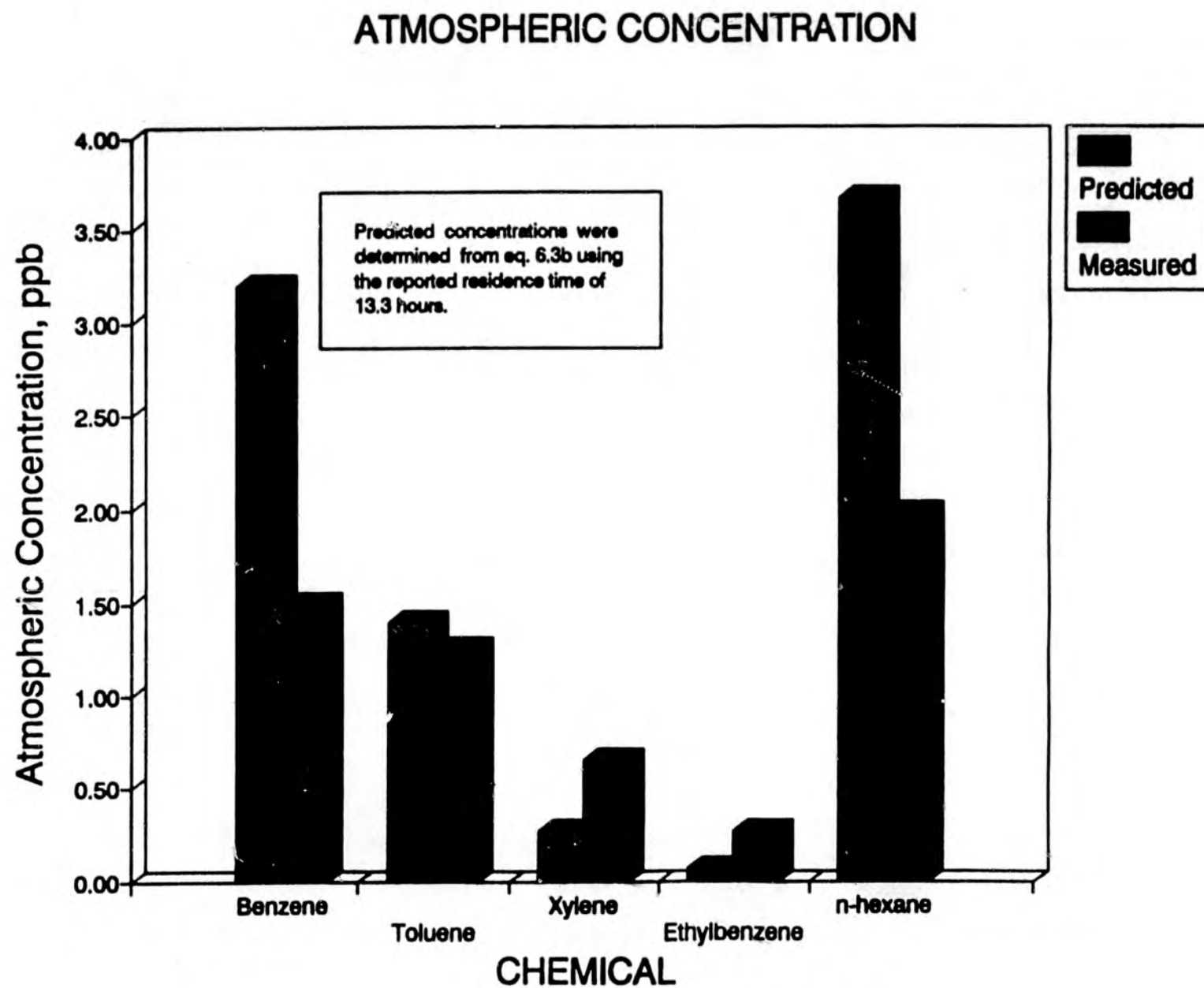
TABLE 7.2
Emissions Calculated From Eq. 6.3 Compared with Emissions Estimated
from the Alyeska Tanker Loading Emission Study

Chemical	Average Monitored Concentrations (Excluding East Gate) (ppb)	Calculated Emission Rate (Tons/Year) (Based on Eq. 6.3)	Emission Rate Estimated by Alyeska (Table 4.2) (Tons/Year)
Benzene	1.5	211	450
Ethylbenzene	0.27	58.7	16
Toluene	1.26	237	262
Xylenes	0.66	57	69
<i>n</i> -Hexane	1.98	336	623 ^(a)

^(a) Estimated based on vapor phase composition (see Table 4.2).

^(b) Emission rates determined based on the average monitored concentrations (excluding East Gate).

FIGURE 7.1



EMISSION RATES (Based on Reported Concentration Data)

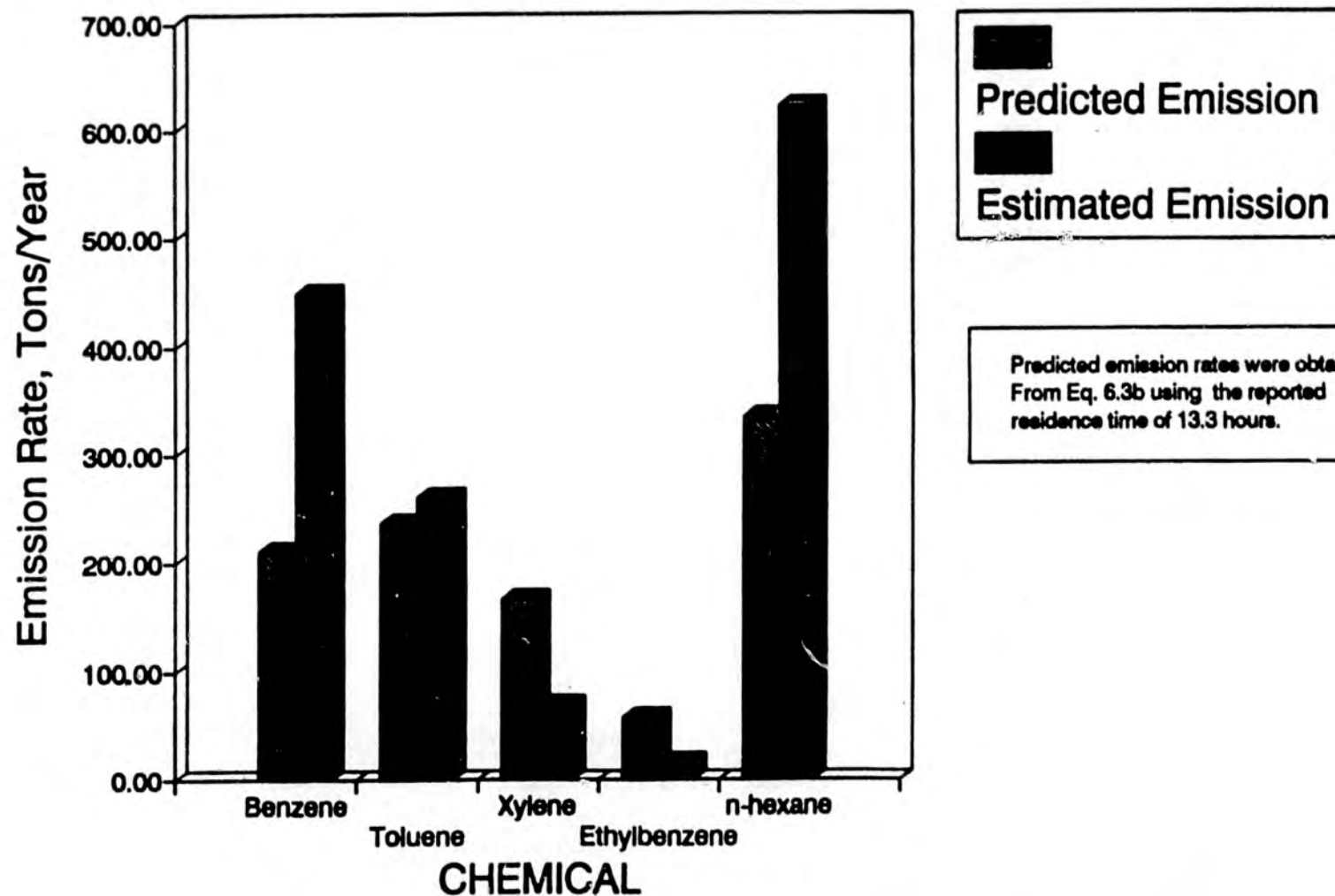


FIGURE 7.2

Wind dispersion leads to the spreading of the emitted pollutants in the region and generally higher wind speeds lead to a greater degree of dilution and consequently lower observed concentrations. The degree of wind mixing on a basin-wide scale can be approximated by the convective residence time (see eq. 6.3) the higher the convective residence time, for a given air basin volume, the lower the observed concentrations. One would expect that if equation 6.3 is used as an empirical equation to calculate the convective residence (i.e., using the monitored concentrations) then a single convective residence time should be expected for the air basin. The results of such an analysis is presented in Figure 7.3. Clearly, in order to match the predicted and average reported concentrations different convective residence times must be used for each chemical. This representation of the simple mass balance approach suggests that a closure of the mass balance must be sought in order to assure that the monitored concentrations can indeed be quantitatively related to the estimated emissions from the marine terminal and other sources at Port Valdez.

The mixing height has a direct influence on the predicted atmospheric concentrations. A higher mixing height leads to a larger mixing volume for the air basin and thus a lower concentration for the released pollutants (i.e., the pollutants are dispersed in a larger volume). Similarly, as mentioned above a higher wind speed will lead to increased dispersion (or dilution) and thus a lower concentration. As an illustration the change in the atmospheric concentration of benzene relative to the base case (mixing height=350 m, wind speed = 2.68 m/s) as a function of the mixing height and wind speed is depicted in Figure 7.4. Clearly, the mixing height can have a significant effect on the atmospheric concentration and as a result also on the concentration in the water column in the bay (due to atmospheric input; see section 7.4.3). The mixing height does change diurnally (and seasonally) and thus fluctuations in the air-basin concentrations of the emitted chemicals are to be expected. Real-time data for the mixing height at Port Valdez were not available⁷, but it is believed that the range of average mixing heights depicted in Figure 7.4 is representative of typical mixing heights expected for the Port Valdez area (see "Summary Report: Air Quality for the Trans Alaska Pipeline System: Terminal", Alyeska Pile Services Company, April 1974).

⁷ Mixing height monitoring data were obtained by Alyeska but these data were not available at the time of preparation of this report.

ATMOSPHERIC CONVECTIVE RESIDENCE TIME (Based on Reported Concentration Data)

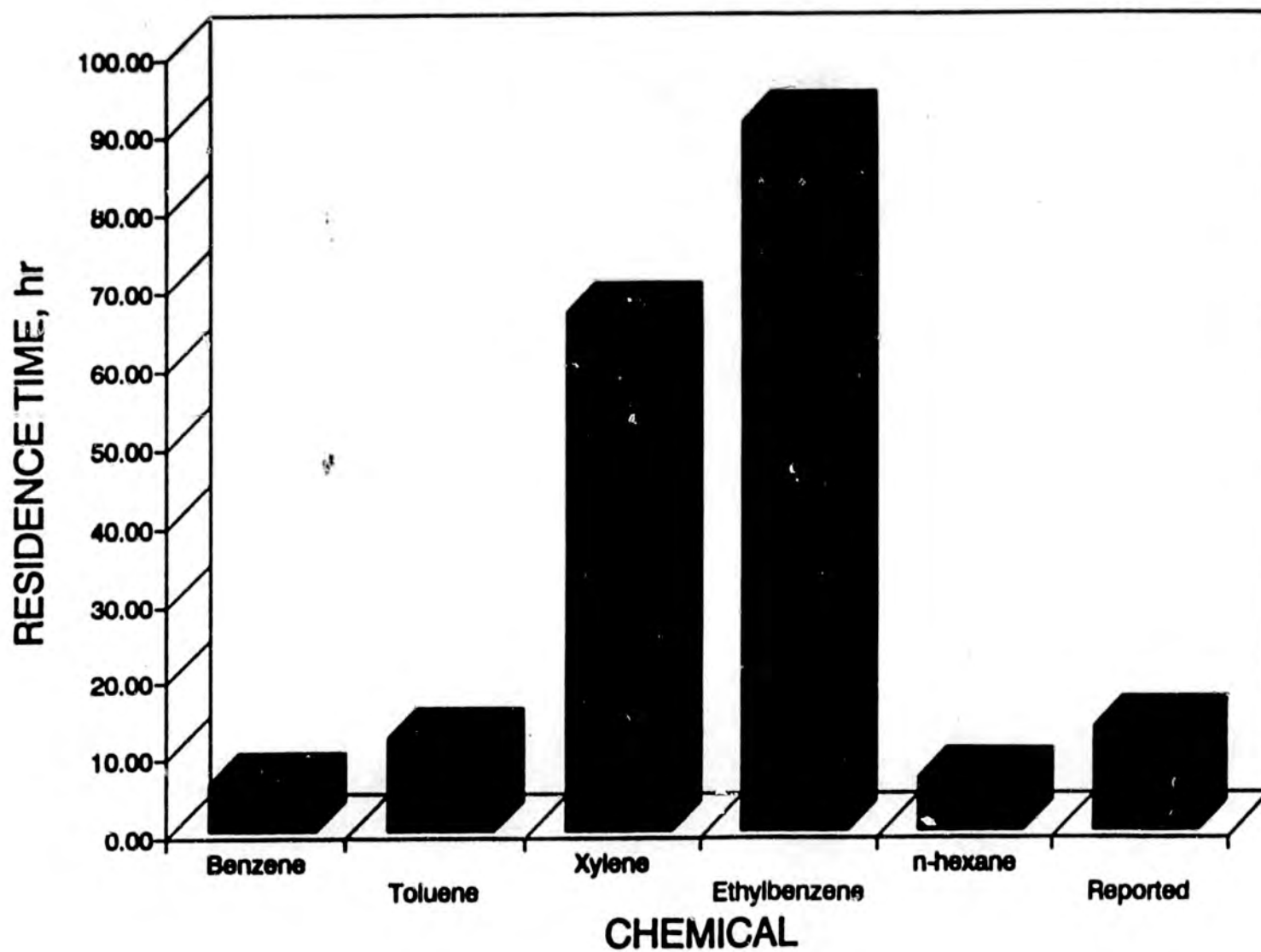


FIGURE 7.3

EFFECT OF WIND SPEED AND MIXING HEIGHT ON BENZENE CONCENTRATION IN ATMOSPHERE

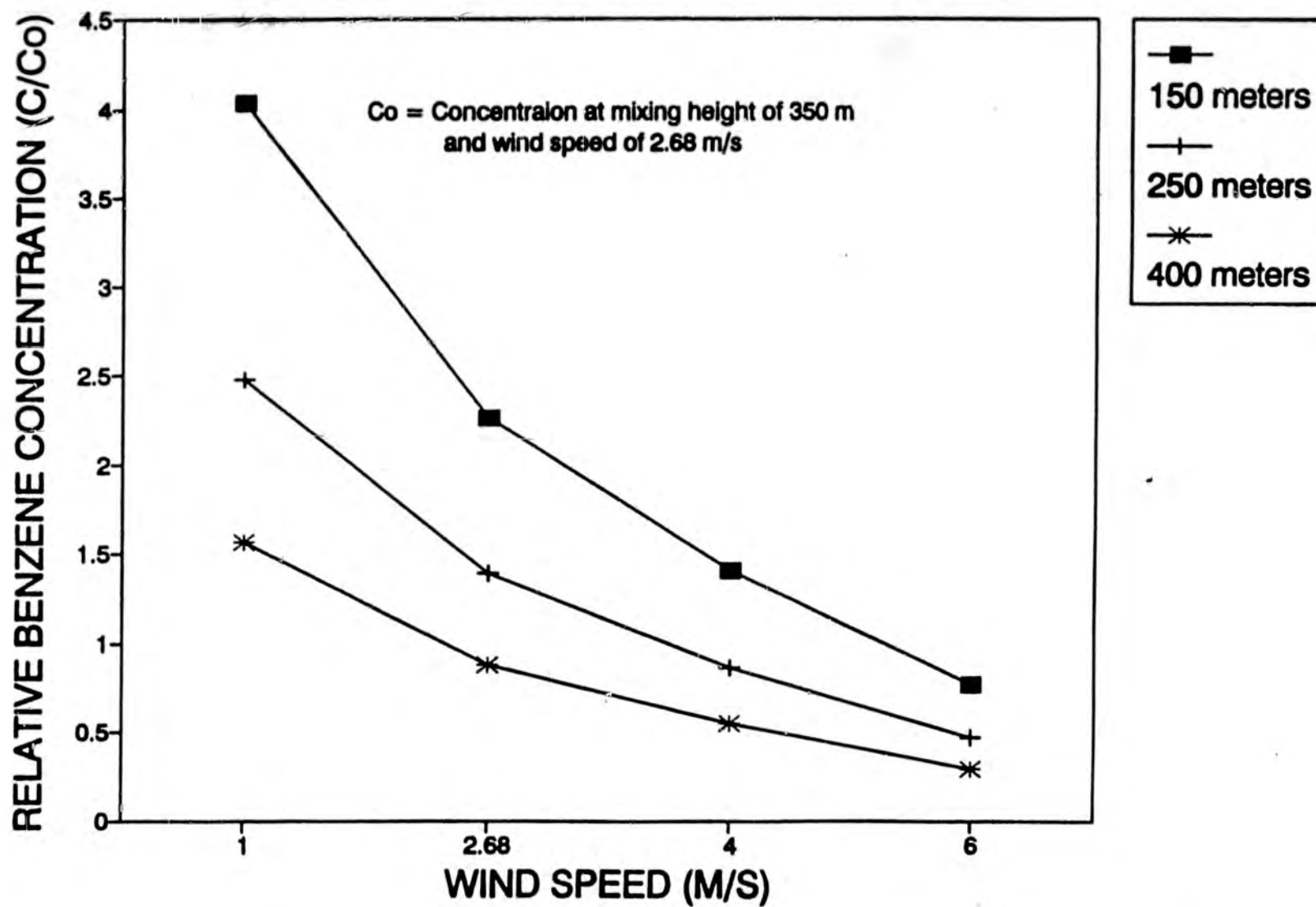


FIGURE 7.4

7.3 Monitored Atmospheric Concentrations at Port Valdez Relative to Urban Regions

It is instructive to compare the monitored concentrations to those reported in urban atmospheres as indicated in Table 7.3. The monitored concentrations at Port Valdez for benzene, toluene, xylenes, and *n*-hexane are within the range of the concentrations reported for Boston and at the lower limits of the concentrations reported for Los Angeles and Denver for benzene and *n*-hexane. Clearly, with respect to the atmospheric concentrations of BETX and *n*-hexane, Port Valdez cannot be considered to be a pristine or rural area (see also Table 3.3).

TABLE 7.3
COMPARISON OF MONITORED CONCENTRATION AT PORT VALDEZ
AND TYPICAL CONCENTRATIONS REPORTED FOR URBAN ATMOSPHERES^(a)

Urban Regions/Monitor Locations, and Year Sampled	Range of Monitored Atmospheric Concentrations (ppb)				
	Benzene	Ethylbenzene	Toluene	Xylenes ^(a)	<i>n</i> -Hexane
Port Valdez, Alaska ⁽¹⁾ , 1991	1.2-7.8	0.19-0.6	1.07-5.78	0.34-1.67	1.11-20.72
Batton Rouge, LA, 1989	0.62-2.98	0.12-1.5	0.61-4.35	0.55-8.61	
Camden, NJ, 1989 ⁽²⁾	0.53-8.24	0.11-2.57	1.10-22.36	0.68-15.25	
Chicago, IL, 1989	0.43-10.59	0.10-3.24	0.54-31.98	0.36-22.35	
Dallas, TX, 1989	0.32-2.07	0.03-0.42	0.26-3.4	0.13-2.77	
Ft. Lauderdale, FL, 1989	0.05-4.18	0.04-1.2	0.08-10.53	0.04-1.2	
Houston, TX, 1989	0.57-7.56	0.02-1.61	0.45-11.36	0.35-6.38	
Miami, FL, 1989	0.05-4.15	0.02-1.38	0.21-12.15	0.14-10.26	
St. Louis, MO, 1989	0.60-27.7	0.18-1.71	1.71-41.69	1.1-50.5	
Washington, DC, 1989	0.58-7.88	0.11-2.52	0.83-18.4	0.58-14.48	
Wichita, KS, 1989	0.35-3.31	0.05-0.85	0.32-5.24	0.20-4.86	
San Francisco, CA, 1986 ⁽³⁾	0.8-5.2				
Batton Rouge, LA, 1985					0.64-6.6
Boston, MA, 1985					0.35-1.88
Cleveland, OH, 1985					0.58-4.78
El Paso, TX, 1985					0.91-7.23
Kansas City, MO, 1985					0.51-3.41
Lake Charles, LA, 1985					0.55-5.71
Las Vegas, NV, 1985					0.5-3.8

Urban Regions/Monitor Locations, and Year Sampled	Range of Monitored Atmospheric Concentrations (ppb)				
	Benzene	Ethylbenzene	Toluene	Xylenes ^(a)	n-Hexane
Port Valdez, Alaska ⁽¹⁾ , 1991	1.2-7.8	0.19-0.6	1.07-5.78	0.34-1.67	1.11-20.72
Philadelphia, PA, 1985					0.67-9.81
Portland, ME, 1985					0.27-4.31
Richmond, VA, 1985					0.51-2.54
St. Louis, MO, 1985					0.72-6.63
Washington, DC, 1985 ⁽²⁾					0.73-2.3
Boston, MA (1981, 1984) ⁽³⁾	1.3		4.7	2	1.1
Chicago, IL (1984-1986) ⁽⁴⁾	3.8-30.3				
San Francisco, CA, 1984 ⁽⁵⁾	0.8-5.2				
Stinson Beach, CA, 1984 ⁽⁵⁾	0.38 ± 0.39 (weighted average)				
Los Angeles, CA, 1984 ⁽⁶⁾	5	2.23			8.06
Los Angeles, CA, 1984 ⁽⁶⁾	1.12	0.69			2.78

(a) Data are from references 2 and 3 unless otherwise indicated.

¹ Range of Average Monitored Concentrations at Port Valdez (Excluding East Gate Monitoring Station), 1991 (see Tables 5.1-5.6).

² All data for sampling date of 1989 are from EPA, 1990, 1989 Urban Air Toxics monitoring Program, EPA OAQPS, Research Triangle Park, NC (EPA-450/4-91-001).

³ All data for sampling date of 1985 are from EPA, 1988, National Ambient Volatile Organic Compounds (VOCs) Database Update, EPA OR&D, Research Triangle Park, NC (EPA/600/3-88-010A).

⁴ Category "Xylenes" in EPA, 1990 data is m/p-xylene. Data also available for o-xylene, but was aggregated with styrene.

⁵ Wester, R.C., H. I. Maibach and L. D. Gruenke, "Benzene Levels in Ambient Air and Breadth of Smokers and non-Smokers in Urban and Pristine Environments", J.Toxicol.Environ.Health, 18, 567-573 (1986).

⁶ EPA, "June-September, 6-9 a.m., Ambient Air Benzene Concentrations in 39 U.S. Cities, 1984-1986". Research Triangle Park, NC, EPA/600/D-87/160 (1987).

⁷ Finlayson-Pitts, B. J. and J. N. Pitts, Jr., "Atmospheric Chemistry: Fundamentals and Experimental Techniques", John Wiley and Sons, New York (1986), Pages 350-351.

⁸ Wallace, L., E. Pellizzari, L. Sheldon, T. Harwell, C. Sparacino, and H. Zelon, "Total Exposure Assessment Methodology (TEAM) Study: Direct Measurement of Personal Exposure through Air and Water for 600 Residents of Several U.S. Cities", in Pollutants in a Multimedia Environment, Cohen, Y. (Editor), Plenum Press, New York (1986); (8a) Average of 48 samples for February 1984; (8b) Average of 48 samples for May 1984.

7.4 Accumulation of BETX and *n*-Hexane in the Soil, Water, Sediment and Suspended Solids Compartments

7.4.1 Overview

The concentrations of BETX and *n*-hexane in the soil, water, sediment, and suspended solids compartments, as determined based on the monitoring data (see section 6.4.4) and the SMCM model, are given in Tables 7.4 and 7.5. Table 7.4 presents the calculated concentrations that would occur for basin-wide concentrations that are taken to be equivalent to the average of the monitoring data for three sites (Old Valdez, High School, and Spit), while Table 7.5 provides the concentrations in the media in the vicinity of the East Gate monitoring site.

The results given in Tables 7.4 and 7.5 are also illustrated in Figures 7.5 and 7.6. The concentration at the East Gate location are higher in all media. This result is expected due to the higher concentrations in the East Gate site relative to the other monitoring sites.

TABLE 7.4
Multimedia Concentrations
Based on Atmospheric Concentrations
Monitored at Port Valdez (Excluding East Gate)

Chemical	Air (ppb)	Water (ng/l)	Soil (ng/kg)	Sediment (ng/kg)	Suspended Solids (ng/kg)
Benzene	1.5	0.901	3.78	0.131	0.181
Ethylbenzene	0.27	0.093	1.39	0.025	0.0823
Toluene	1.26	0.831	10.1	0.246	0.997
Xylenes	0.66	0.663	14.5	0.33	2.0
<i>n</i> -Hexane	1.98	0.0157	2.26	0.0366	0.329

TABLE 7.5
Multimedia Concentrations
Based on Atmospheric Concentrations
Monitored at the East Gate Site at Port Valdez^(a)

Chemical	Air (ppb)	Water (ng/l)	Soil (ng/kg)	Sediment (ng/kg)	Suspended Solids (ng/kg)
Benzene	3.2	1.92	8.06	0.280	0.385
Ethylbenzene	0.36	0.125	1.86	0.033	0.11
Toluene	2.5	1.65	20.1	0.49	1.98
Xylenes	0.81	0.814	17.8	0.405	2.46
<i>n</i> -Hexane	6.58	0.522	7.5	0.122	1.09

^(a) Estimates using basin-average concentrations equivalent to the concentration levels monitored at the East Gate site.

CONCENTRATION IN WATER COMPARTMENT
(MODEL RESULTS)
(Excluding Eastgate)

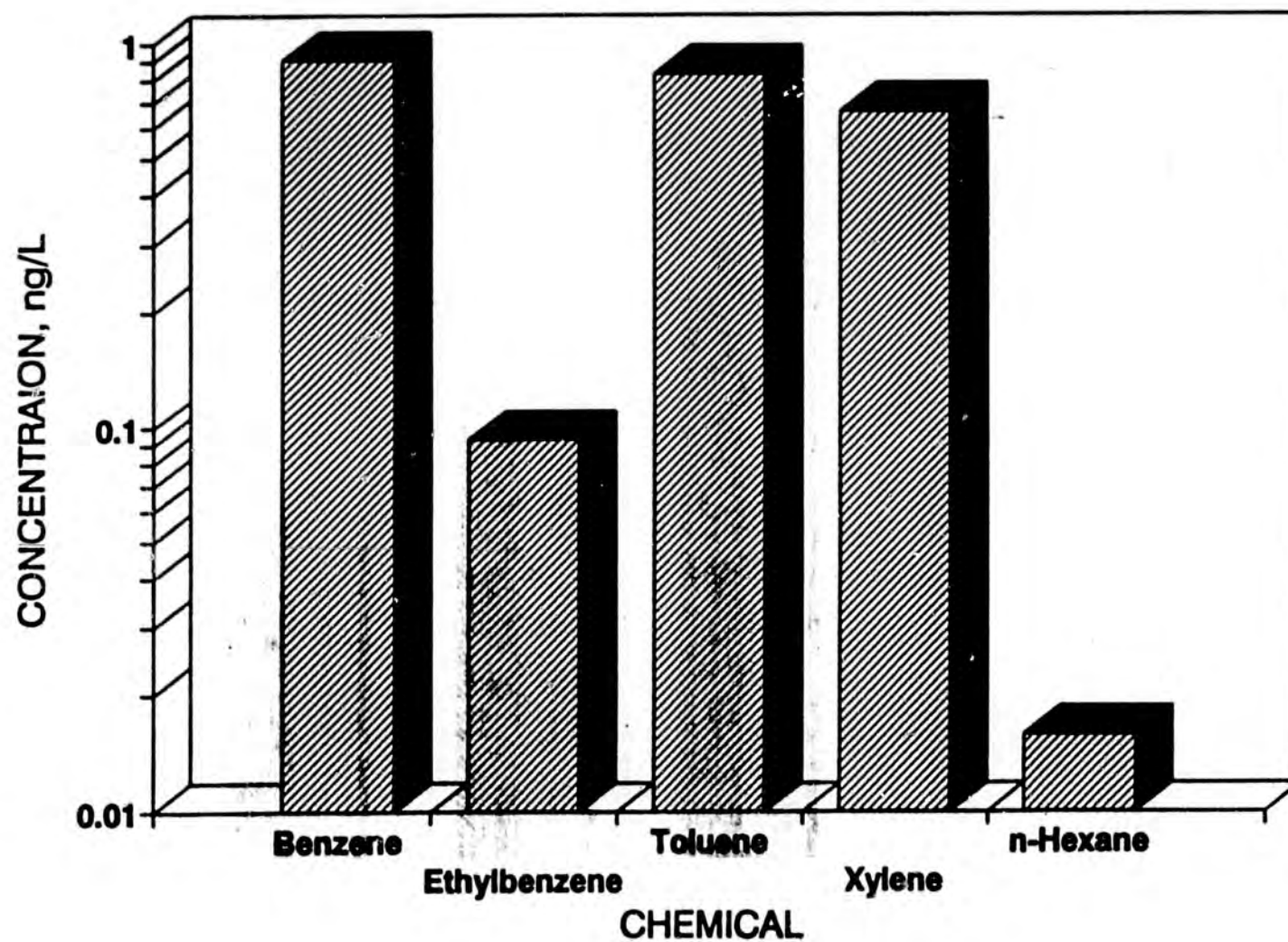


FIGURE 7.5

**COMPARTMENTAL CONCENTRATIONS
(MODEL RESULTS)
(Excluding Eastgate)**

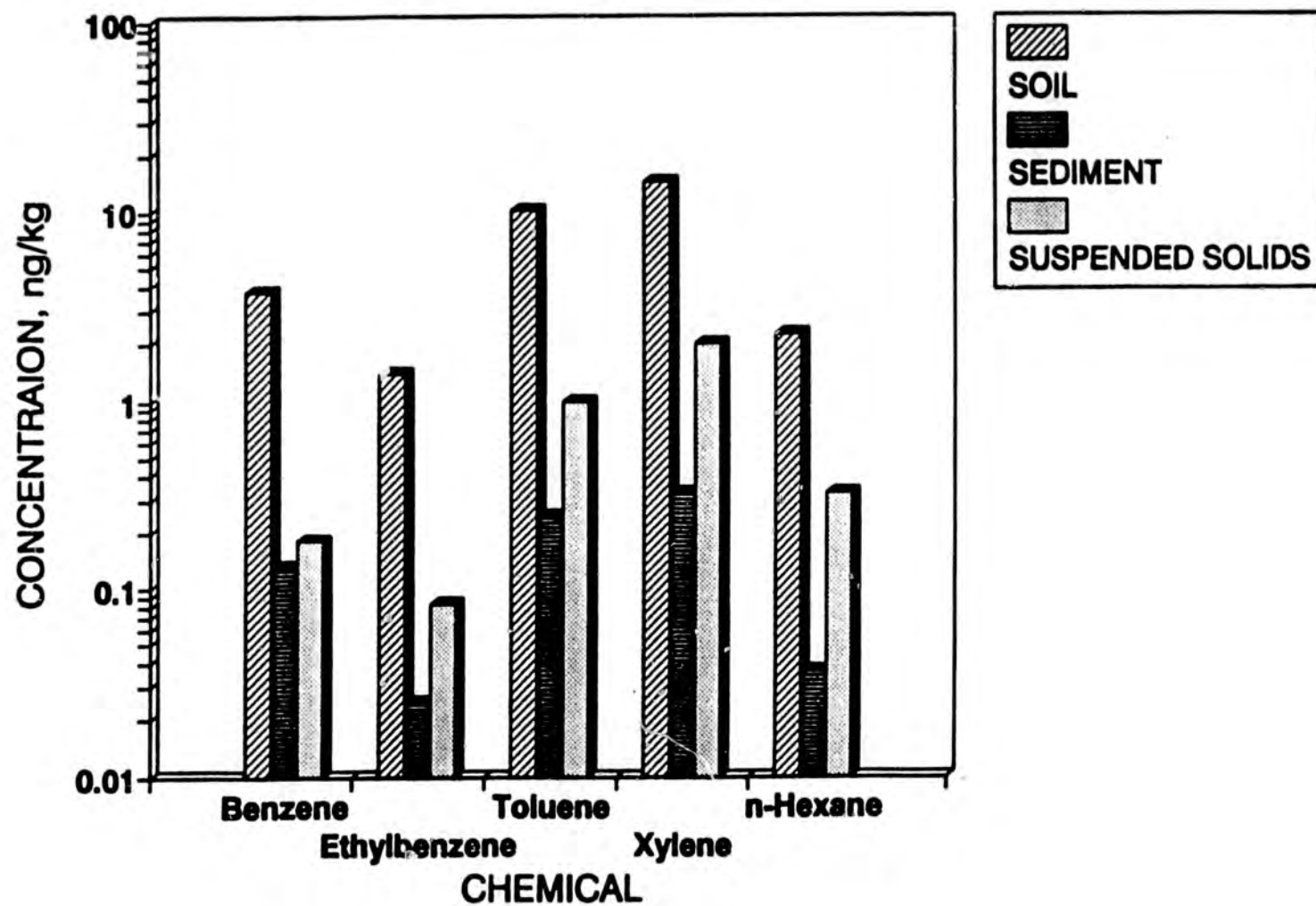


FIGURE 7.6

7.4.2 Soil Compartment

The predicted concentrations of ethylbenzene, *n*-hexane, and benzene in the soil environment, for the base case simulations were in the range of about 1.4 ng/kg to 3.8 ng/kg. Higher concentrations of 10.1 ng/kg and 14.5 ng/kg were calculated for toluene and xylenes, respectively, based on the concentrations monitored at the East Gate site. The above concentrations are low relative to typical concentration observed for soils (see Table 3.3). As evident from Table 7.6 the soil concentrations are in the ng/kg range even for a soil organic carbon content of 4%. Even a ten fold increase in the organic content of the soil to 40% would only results in an increase in xylenes and benzene accumulation in the soil to concentrations of about 0.85 $\mu\text{g/kg}$ and 33 $\mu\text{g/kg}$, respectively. These concentrations are extremely low and monitoring data for typical soils in urban areas, at these expected comparable concentration levels, have not been found for comparison.

TABLE 7.6
EFFECT OF ORGANIC CARBON ON THE CONCENTRATION
OF BENZENE IN THE SOIL MATRIX^(a)

Percent Organic Carbon	Concentration
	Concentration for 0.6% Organic Carbon Content
0.1	0.62
1	1.26
4	1.43

^(a) Average concentration calculated for the top ten centimeters of the soil matrix.

7.4.3 Water Compartment

Chemicals that are released to the atmosphere can be transferred to the water column by absorption. The rate of mass transfer from the atmosphere to the water column is a function of the air phase concentration, the Henry's law constant for the chemical, and the wind speed across the water surface (Cohen, 1983, 1985). As indicated in Tables 7.4 and 7.5, the water phase concentrations (calculated for the averaged monitoring data) for BETX and *n*-hexane range from about 0.01 ng/l to 1.9 ng/l. These concentrations are within or below the range of concentrations reported for pristine regions.

Direct discharge of hydrocarbons to the water column is possible via the BWT diffuser (see section 4.4). Figure 7.7 illustrates the change in the water concentrations for benzene (relative to the base case simulation, i.e., no diffuser discharge) as a function of the discharge of benzene through the diffuser. Real-time data for discharge concentrations in the diffuser effluent were not available, however, the estimates provided in Table 4.9 indicate that the discharge rate for benzene is probably in the range of less than 0.4 tons/year to about 8 tons/year. The above results provide a basin-wide average value. In reality, however, dispersion studies in Port Valdez revealed that the ballast effluent is "trapped as a plume under a pycnocline between 50 and 70 m depth (Redburn, 1988). Thus, the actual local concentrations near the diffuser region are likely to be significantly higher than the concentrations predicted in the current study. The study of Yearsley (1987) suggests that BETX concentrations as high as 2.7 $\mu\text{g/l}$ can be reached at the mixing zone boundary of the diffuser discharge during conditions of maximum stratification.

Over the water temperature range of 2°C to 8°C the water phase concentration for benzene was found to increase by about 17 percent. Thus, for Port Valdez it is not expected that the water temperature will significantly affect the water phase concentration. The air temperature has a more significant impact on the rate of transfer of hydrocarbons from the air phase to the water phase and the effect of the air temperature was taken into account in the model simulations. It is worth noting that the accumulation of hydrocarbons in fish will be proportional to the water concentration as indicated by the BCF values (see section 6.3.1). Thus, the concentration of the study chemicals in biota relative to the base case follows the same trend as the concentration in the water compartment.

7.4.4 Sediment and Suspended Solids

The accumulation of airborne hydrocarbons in the sediment is via diffusion from the water column to the sediment. Similarly hydrocarbons absorbed from the atmosphere by the water column are adsorbed by solid hydrosols suspended in the water column. The concentrations of BETX and *n*-hexane in the sediment ranged from 0.025 ng/kg to 0.49 ng/kg and the concentrations in the suspended solids phase range from 0.08 ng/kg to 2.46 ng/kg for the suspended solids (see Tables 7.4 and 7.5). The concentration in the water, sediment, suspended solids and biota can also increase as the result of discharge through the diffuser pipe from the BWT facility as illustrated in Figure 7.8. It should be noted that as the case of the soil compartment the concentration of BETX and *n*-hexane in the sediment is expected to increase relative to the base case of 0.4 % organic content in the sediment matrix. For all of the conditions studied, the calculated concentrations in the sediment and suspended solids were found to be below or within the concentration range reported for pristine regions (see Table 3.3). Thus, it can be concluded that airborne volatile hydrocarbons such as BETX and *n*-hexane do not significantly accumulate in the sediment and in suspended solids.

EFFECT OF WIND SPEED AND MIXING HEIGHT ON BENZENE WATER CONCENTRATION

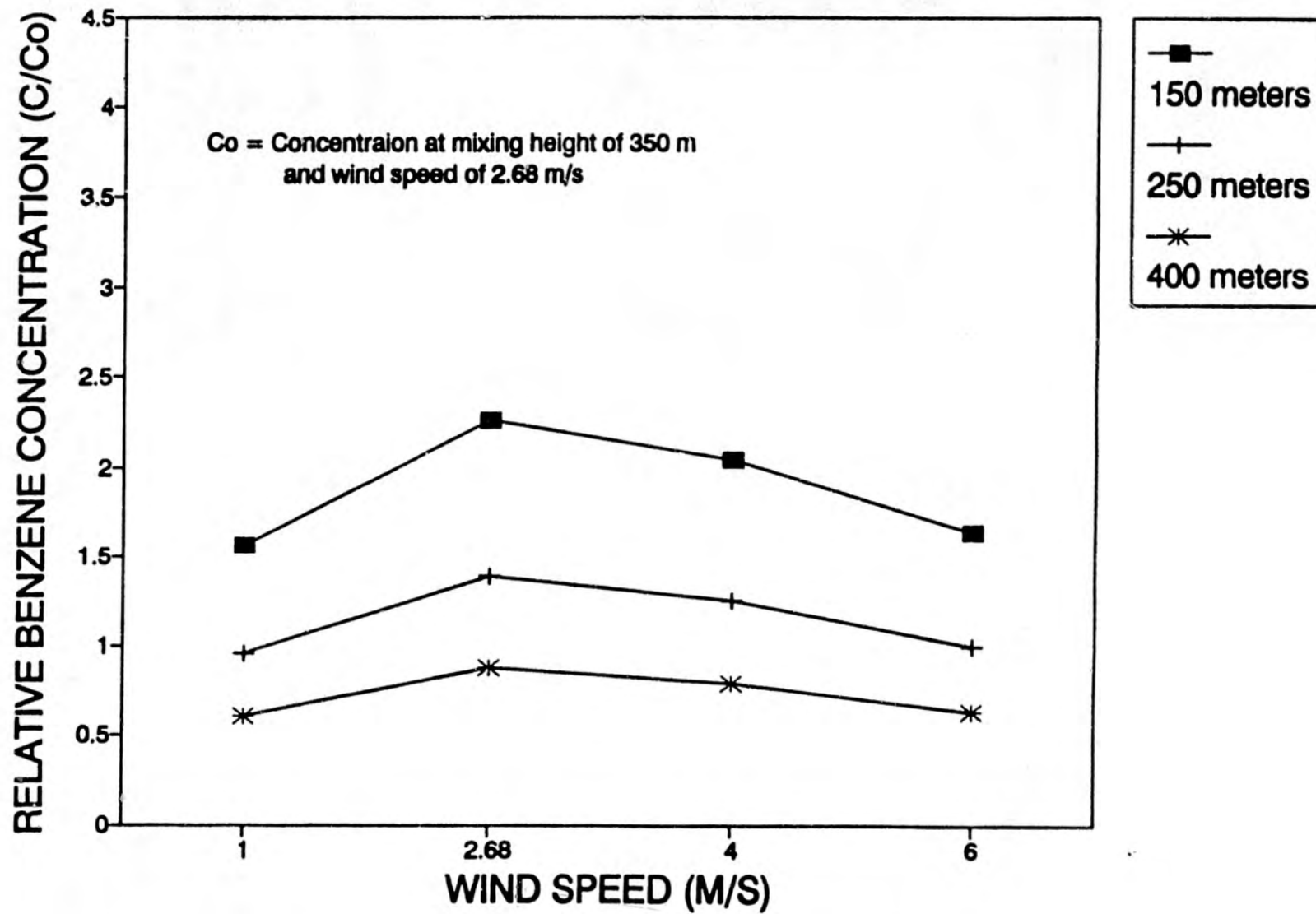


FIGURE 7.7

EFFECT OF DIFFUSER DISCHARGE OF BENZENE ON COMPARTMENTAL CONCENTRATIONS

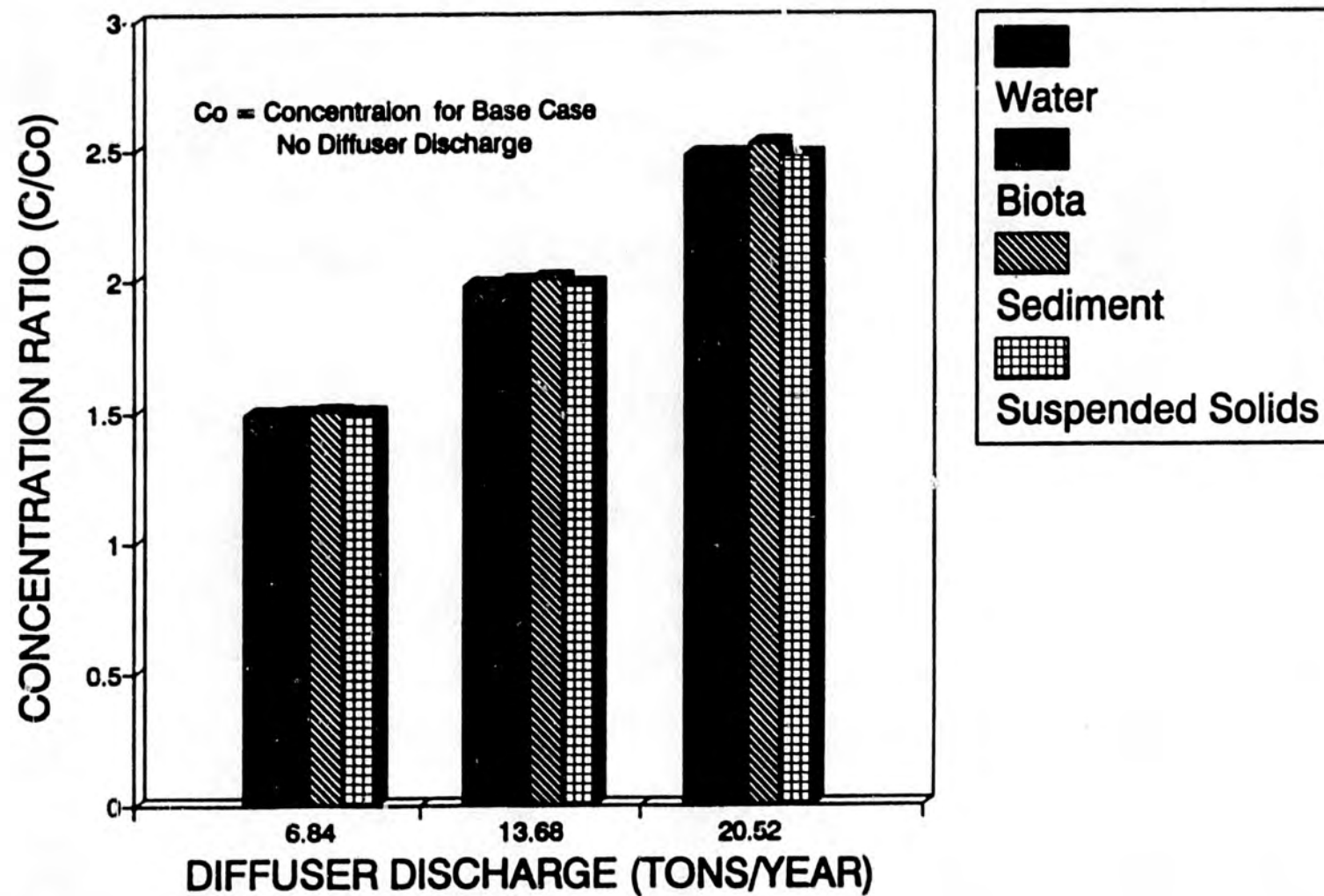


FIGURE 7.8

7.5 Distribution of BETX and *n*-Hexane in the Port Valdez Environment

The hydrocarbons emitted to the environment follow a variety of pathways among the different environmental media. Figures 7.9 -7.13 illustrate the amount of the chemical retained in each of the environmental compartments expressed as a percentage of the total amount present in the Port Valdez environment. The above information is also displayed in Tables 7.7 and 7.8. *n*-Hexane is the most volatile chemical of the group studied and correspondingly about 99.9% of the total *n*-hexane in the environment is present in the air phase compared to 95% for xylenes which has the lowest Henry's law constant for the group of chemicals studied. The percentage of benzene, ethylbenzene, toluene, and xylenes which partitions to the water compartment varies from about 1.7% to 4.8%. In contrast only about 0.05% of *n*-hexane partitions to the water compartment. For BETX and *n*-hexane the percentage of the chemical partitioned to the sediment, suspended solids, soil and the biota compartments is negligible compared with the amount present in the air and water compartment.

TABLE 7.7
PERCENT DISTRIBUTION OF THE STUDY CHEMICALS
IN THE PORT VALDEZ ENVIRONMENT ^(a)

	Air	Water	Soil	Sediment	Suspended Solids (in Water)	Biota
Benzene	96.02	3.92	0.064	3×10^{-4}	5.9×10^{-6}	6.9×10^{-6}
Ethylbenzene	98.25	1.7	0.048	2.4×10^{-4}	1.1×10^{-6}	1.3×10^{-5}
Toluene	96.27	3.65	0.083	5.5×10^{-4}	3.3×10^{-5}	2.0×10^{-5}
Xylenes	95.05	4.78	0.16	1.1×10^{-3}	1.1×10^{-4}	2.1×10^{-4}
<i>n</i> -Hexane	99.92	0.049	0.035	4.6×10^{-5}	7.7×10^{-6}	1.5×10^{-5}

TABLE 7.8
ACCUMULATION OF THE STUDY CHEMICALS
IN THE PORT VALDEZ ENVIRONMENT

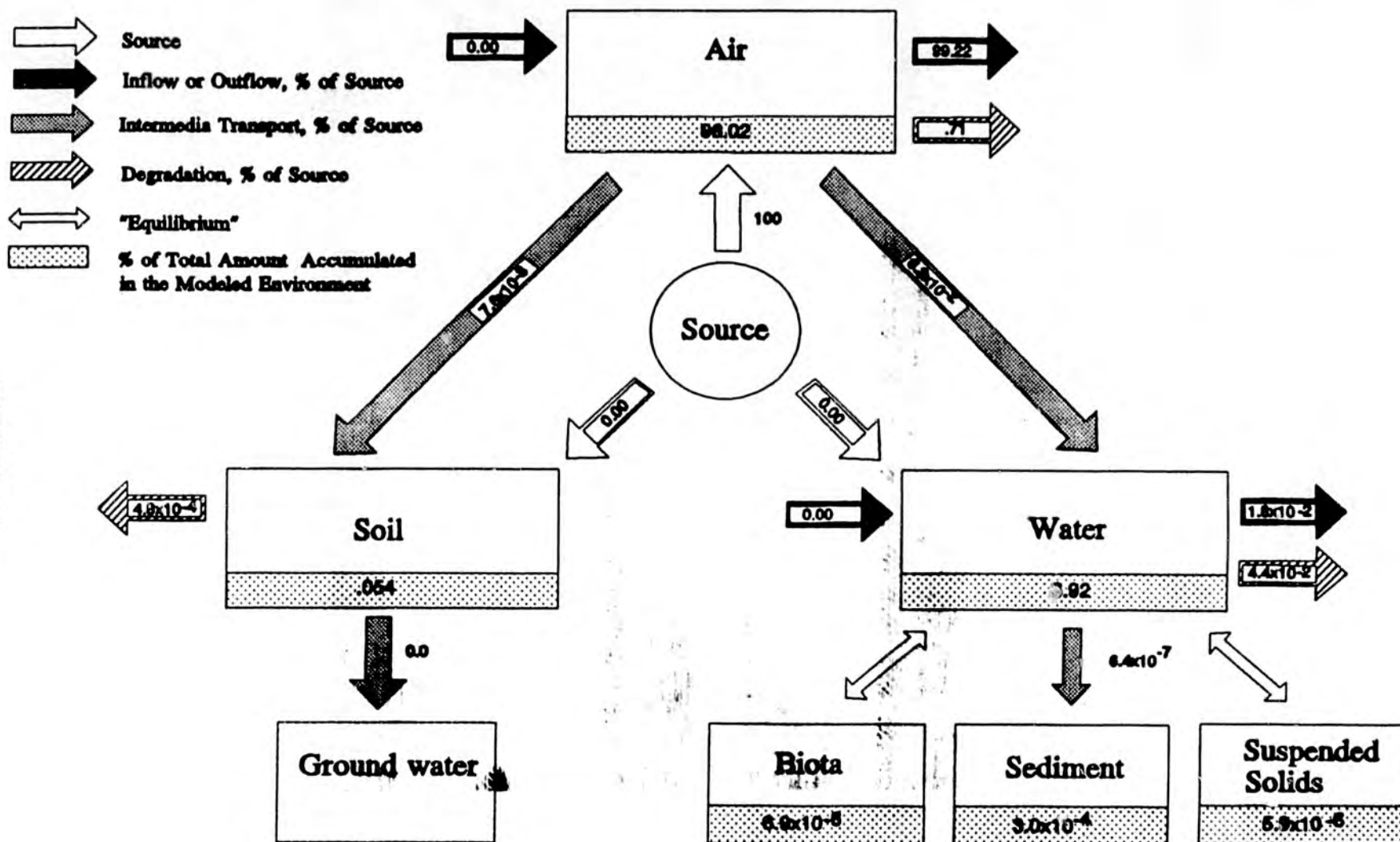
	Total Mass Present in the Full-Port Region (Kg)	Total Mass Present in the Half-Port Region (Kg)
Benzene	329.13	178.1
Ethylbenzene	78.03	42.6
Toluene	326.98	177
Xylenes	198.2	107
<i>n</i> -hexane	455.94	249

^(a) This table presents the total mass of the chemical present in the multimedia environment.

An illustration of the transfers of the study chemicals among the various compartments is also provided in Figures 7.9-7.13 for the half-port region (see section 6.4.2). In these figures the transfer rates between any two compartments, the rate of degradation, and the convective transport away from the half-port region are given in terms of the percentage of the annual emission rate from the marine terminal. It is interesting to note that the percent of the chemical degraded in the atmosphere ranges from about 0.7% to 30%. Also, the rate at which the study chemicals are convected away from the Valdez Port area range from about 63% to 99% (assuming an average wind speed of 2.68 m/s). In order to obtain the transfer rates for the full-port region, the transfer rates between compartments as given in Figures 7.9-7.13 (given in terms of percentages of the total emission rate) should be multiplied by a factor of 2.56 for exchange between the atmosphere and the water compartment, and also for exchange between the water and suspended solids, sediment, or biota compartments. The transfer rates between the atmosphere and the soil compartment for the full-port region are larger by a factor of 1.27 than for the half-port region. The rate of degradation in the atmosphere for the full port region is a factor of 1.82 larger than for the half-port region and the rate of degradation for the soil and water compartments are larger by factors of 1.27 and 2.56, respectively, than the results for the half-port region. The mass of BETX and n-hexane present in the Port Valdez environment is illustrated in Figure 7.14. It is worth noting that since these chemicals are volatile their presence in the environment is directly proportional to their respective concentrations in the atmospheric compartment. The bulk of the chemicals that are emitted to the atmosphere are either degraded in the atmosphere or they are convected by wind away from the Port Valdez region.

The various compartments with the exception of the sediment and soil reach equilibrium or "steady state" rapidly while the concentrations in the sediment compartments continue to increase at a slow rate. Figure 7.15 illustrate the rise in the concentrations of benzene in the Port Valdez area, assuming an initially pristine area. The concentrations increase rapidly to their "annual average" value except for the sediment and soil compartments in which the migration of the hydrocarbons is diffusion controlled. Finally, it is noted that precipitation scavenging is not a sufficient process for the removal of BETX and n-hexane. Precipitation scavenging, however, is expected to be an important process of input of airborne particle-bound contaminants (e.g., Benzo(a)Pyrene) and highly water soluble chemicals (e.g., SO_2) to the soil and water compartment.

Multimedia Fluxes and Partitioning of Benzene in Valdez, Alaska



Total Amount Accumulated in the Modeled Environment = 178.1 kg
 Total Source = 50.77 kg/hour

FIGURE 7.9

Multimedia Fluxes and Partitioning of Ethylbenzene in Valdez, Alaska

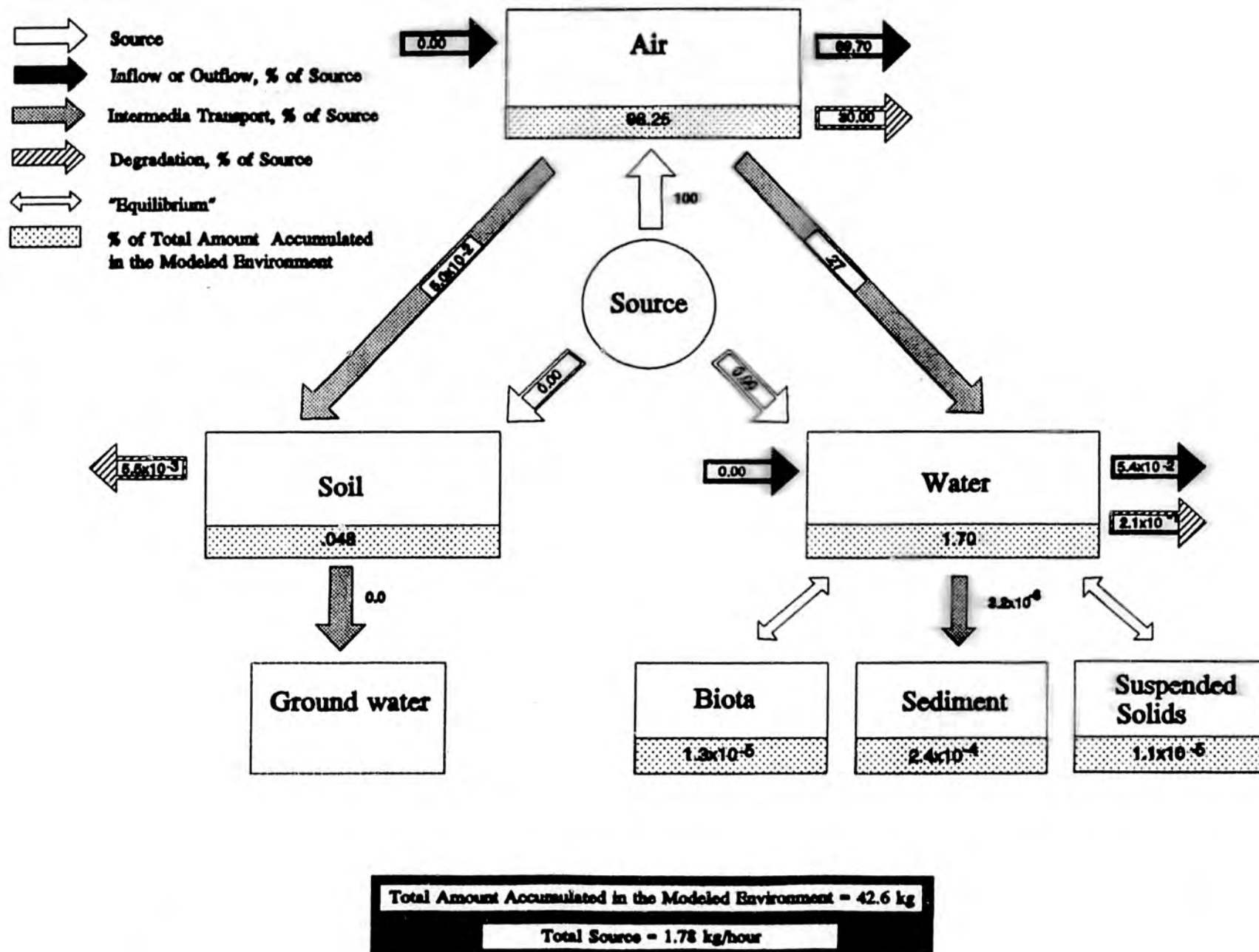
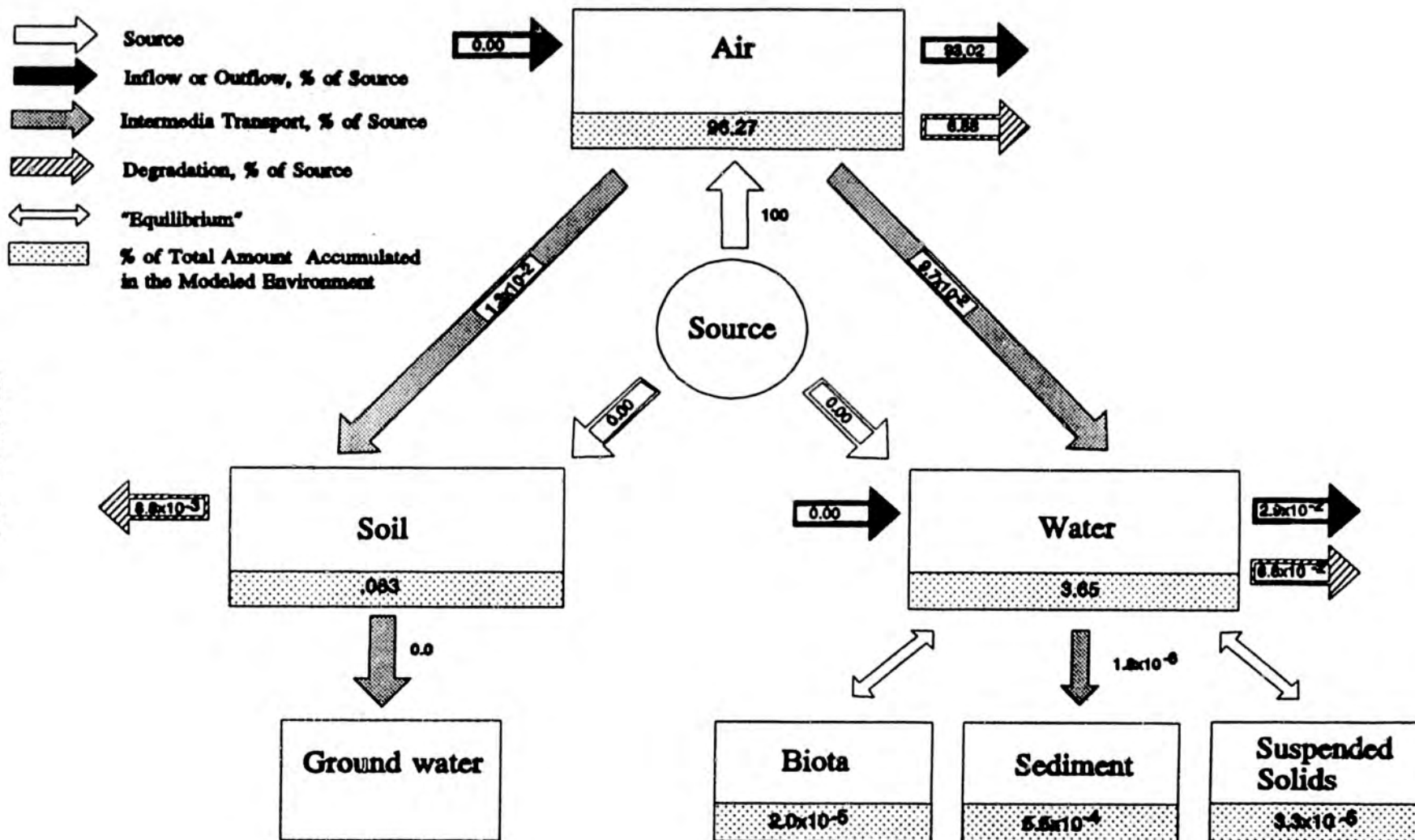


FIGURE 7.10

Multimedia Fluxes and Partitioning of Toluene in Valdez, Alaska

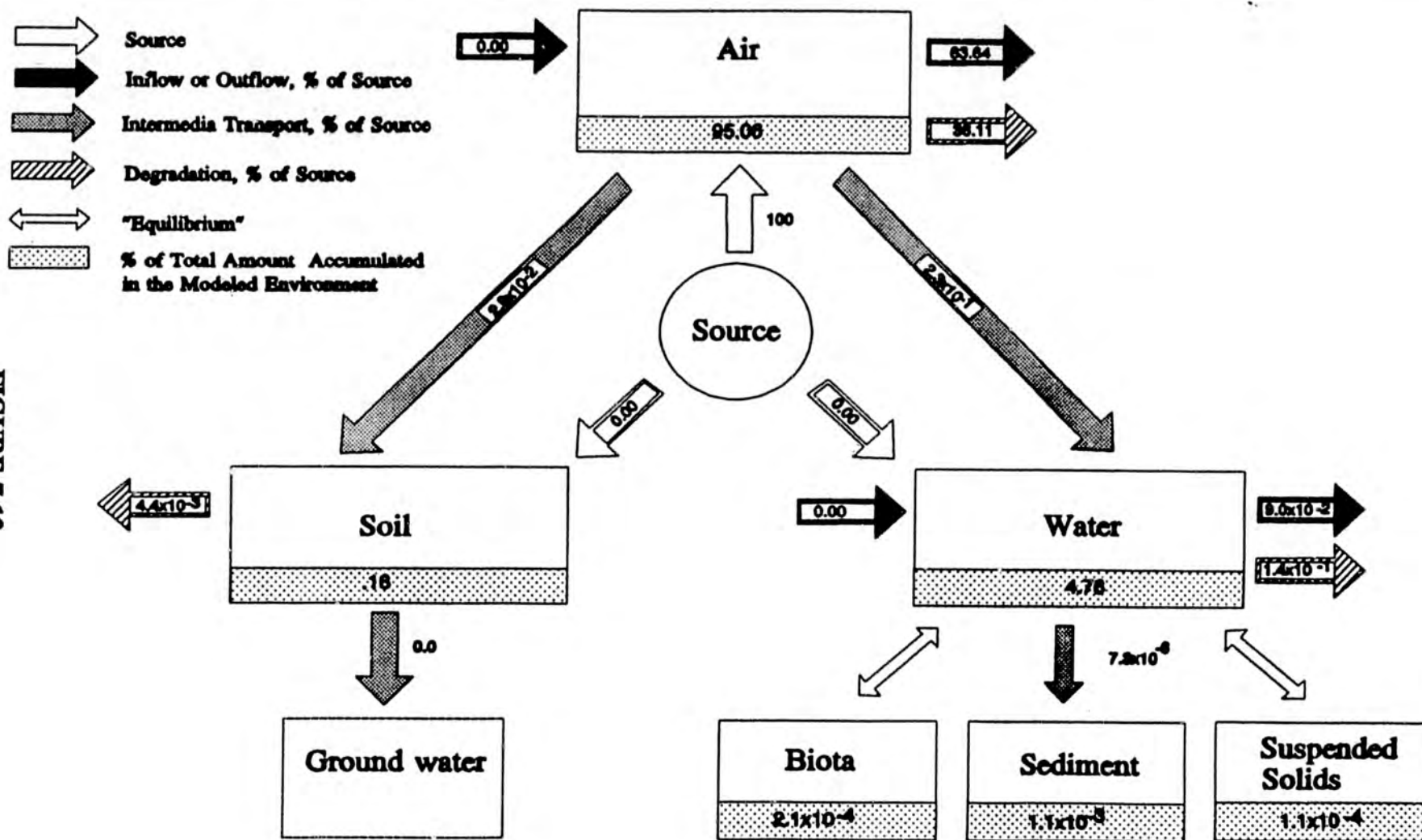


Total Amount Accumulated in the Modeled Environment = 177 kg

Total Source = 29.3 kg/hour

FIGURE 7.11

Multimedia Fluxes and Partitioning of Mixed Xylenes in Valdez, Alaska



Total Amount Accumulated in the Modeled Environment = 107 kg

Total Source = 7.65 kg/hour

FIGURE 7.12

Multimedia Fluxes and Partitioning of n-Hexane in Valdez, Alaska

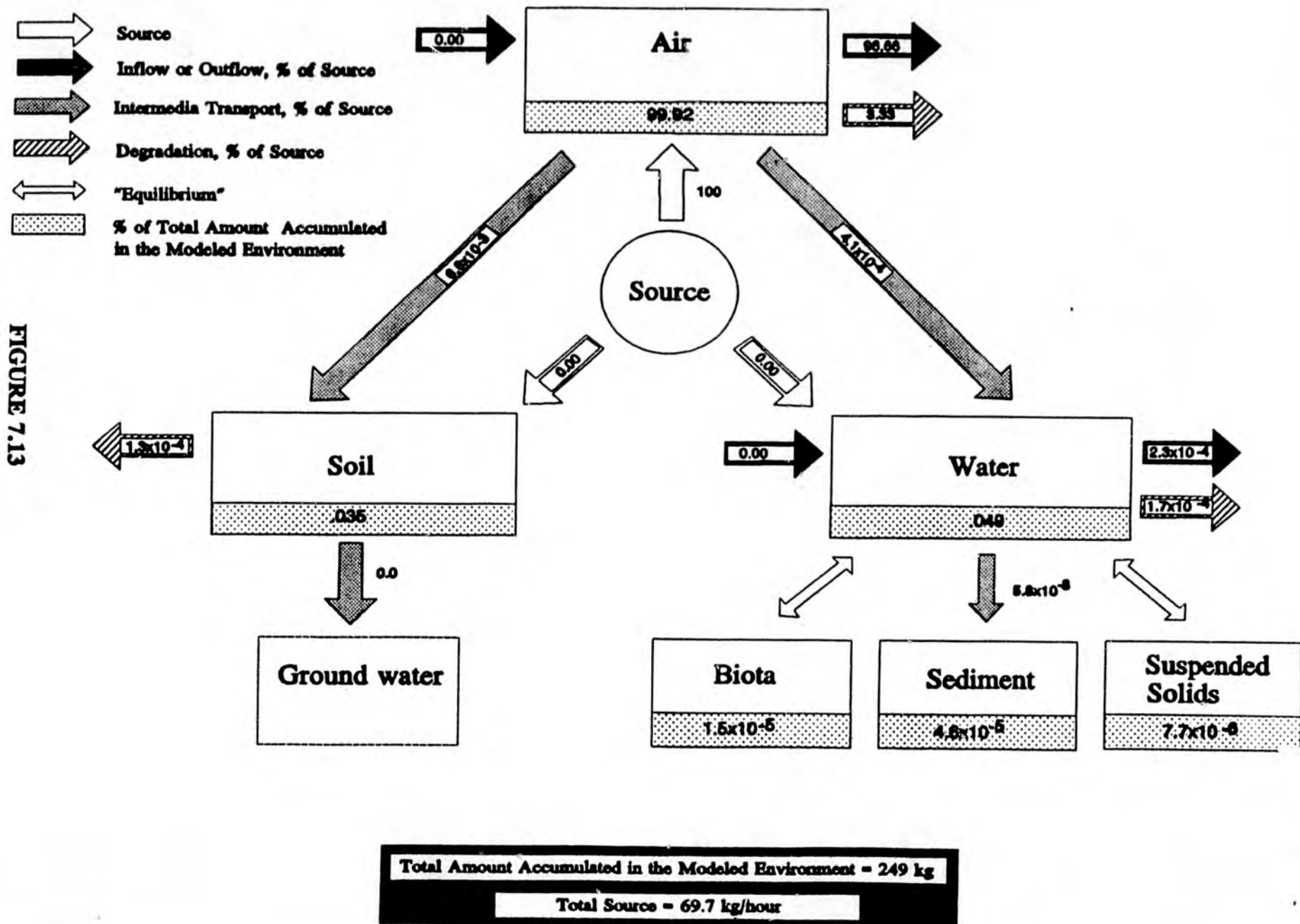


FIGURE 7.13

ACCUMULATION OF BETX AND n-HEXANE IN PORT VALDEZ

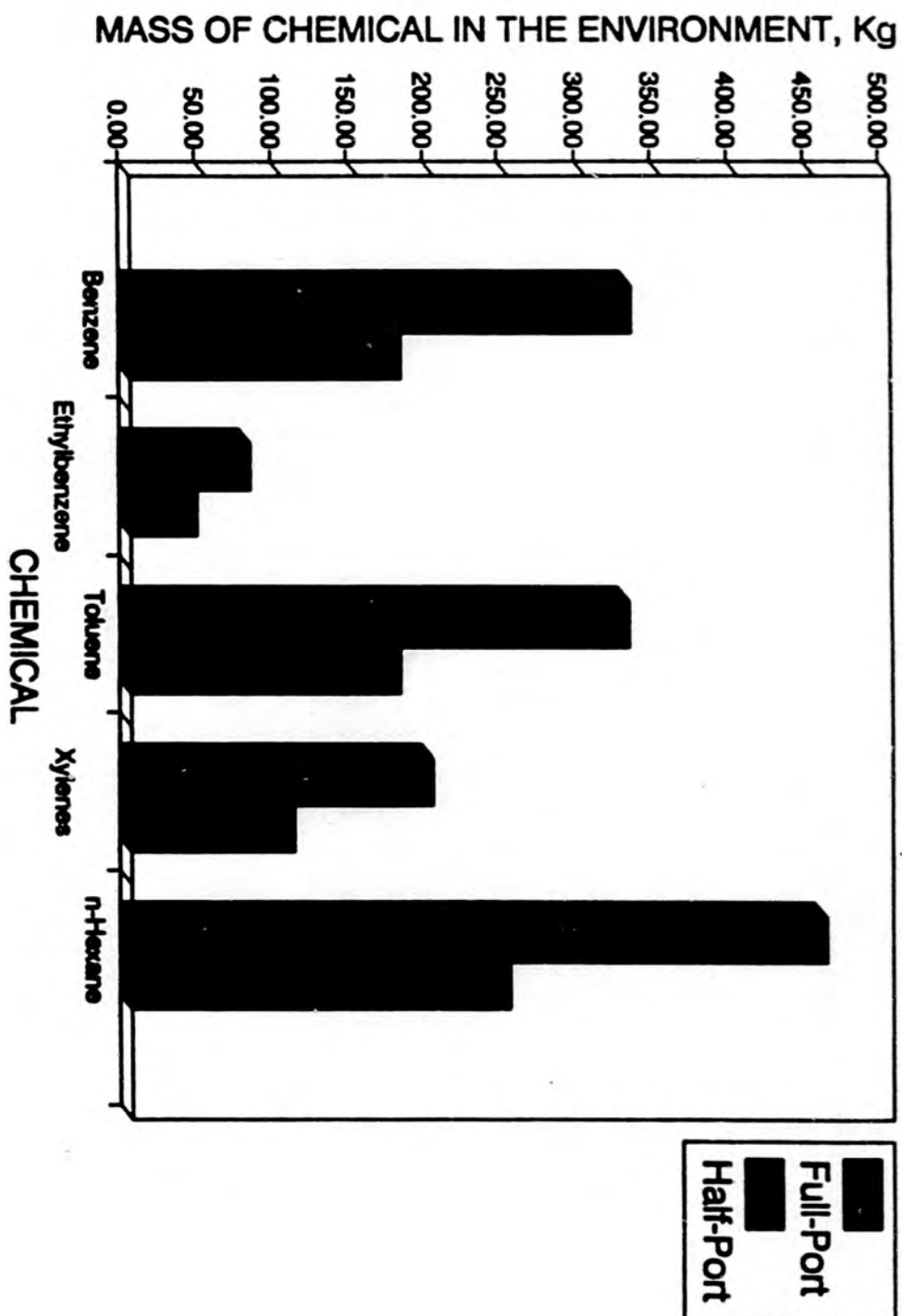


FIGURE 7.14

BENZENE CONCENTRATIONS IN PORT VALDEZ
(Based On Reported Atmospheric Data)

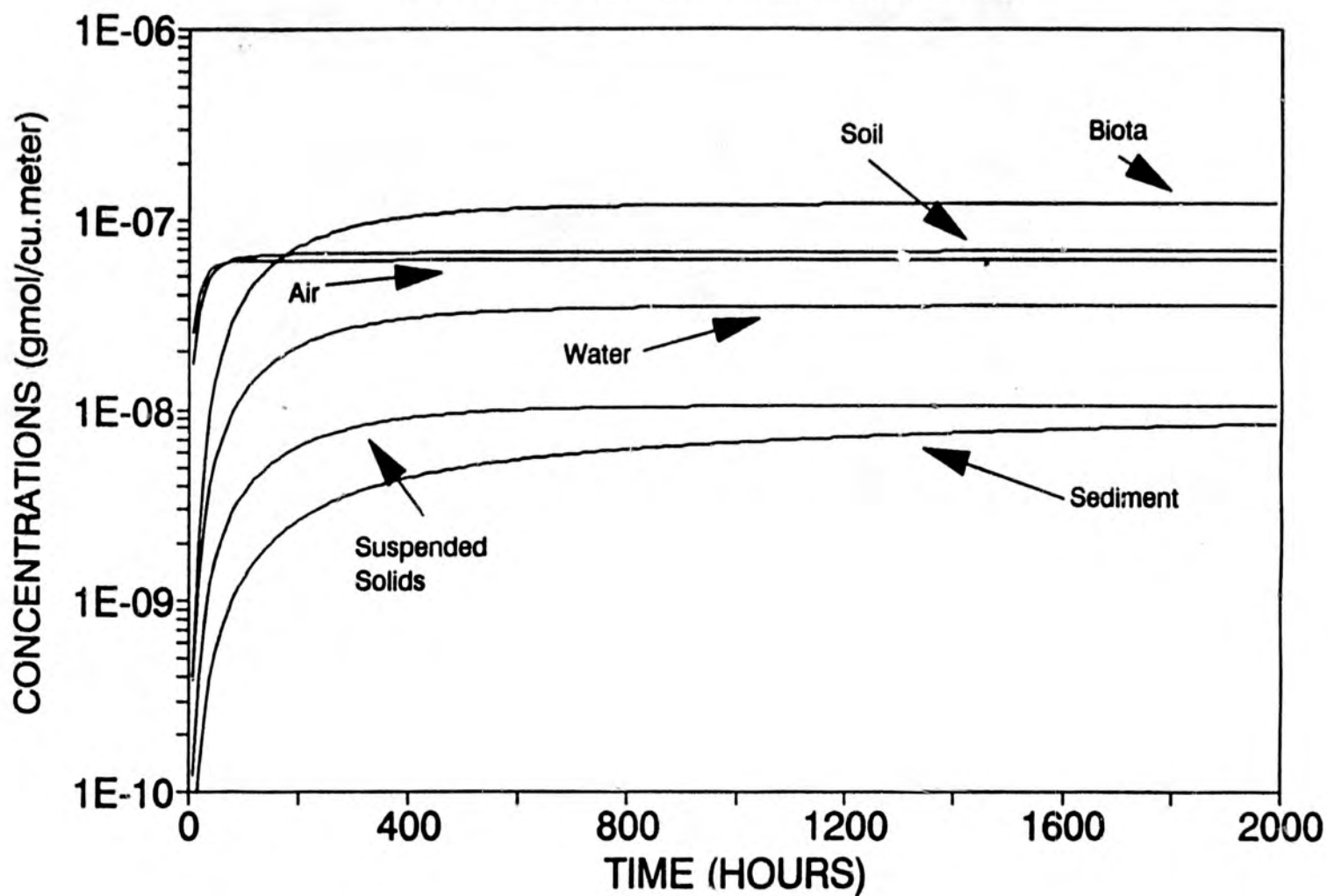


FIGURE 7.15

8. SCREENING-LEVEL EXPOSURE ANALYSIS

8.1 Overview

The assessment of health risk requires the determination of exposure from multiple pathways (Ott, 1985; Liou, 1990; NRC, 1987, 1991; Cohen, 1989). As an illustration, the exposure of the human receptor to chemical pollutants via multiple pathways is shown in Figure 8.1. The major exposure pathways pertinent to human health risk assessment of toxic air pollutants include:

- Inhalation of released contaminants
- Inadvertent and intentional ingestion of crops contaminated by deposition and/or translocation of pollutants
- Ingestion of contaminated soil or soil containing adsorbed pollutants
- Ingestion of fish and other aquatic species contaminated by pollutants present in surface water
- Dermal absorption due to contact with contaminated air, soil and water
- Infant exposure to contaminants in mother's milk
- Drinking water exposure (surface or groundwater)
- Ingestion of dairy products (e.g., ingestion of cow's milk affected by consumption of contaminated feedstock)
- Ingestion of meat and other animal products from game and domestic livestock

The movement of chemicals throughout the food chain may be particularly important to the overall assessment of the exposure of the human receptor to pollutants that tend to bioaccumulate. The determination of exposure of human and ecological receptors to chemical pollutants requires knowledge of pollutant concentrations in all media through which significant exposure can occur. Exposure, in turn, is a function of contaminant concentrations in various environmental media that affect both the receptor directly, as well as various components of the food chain.

EXPOSURE PATHWAYS

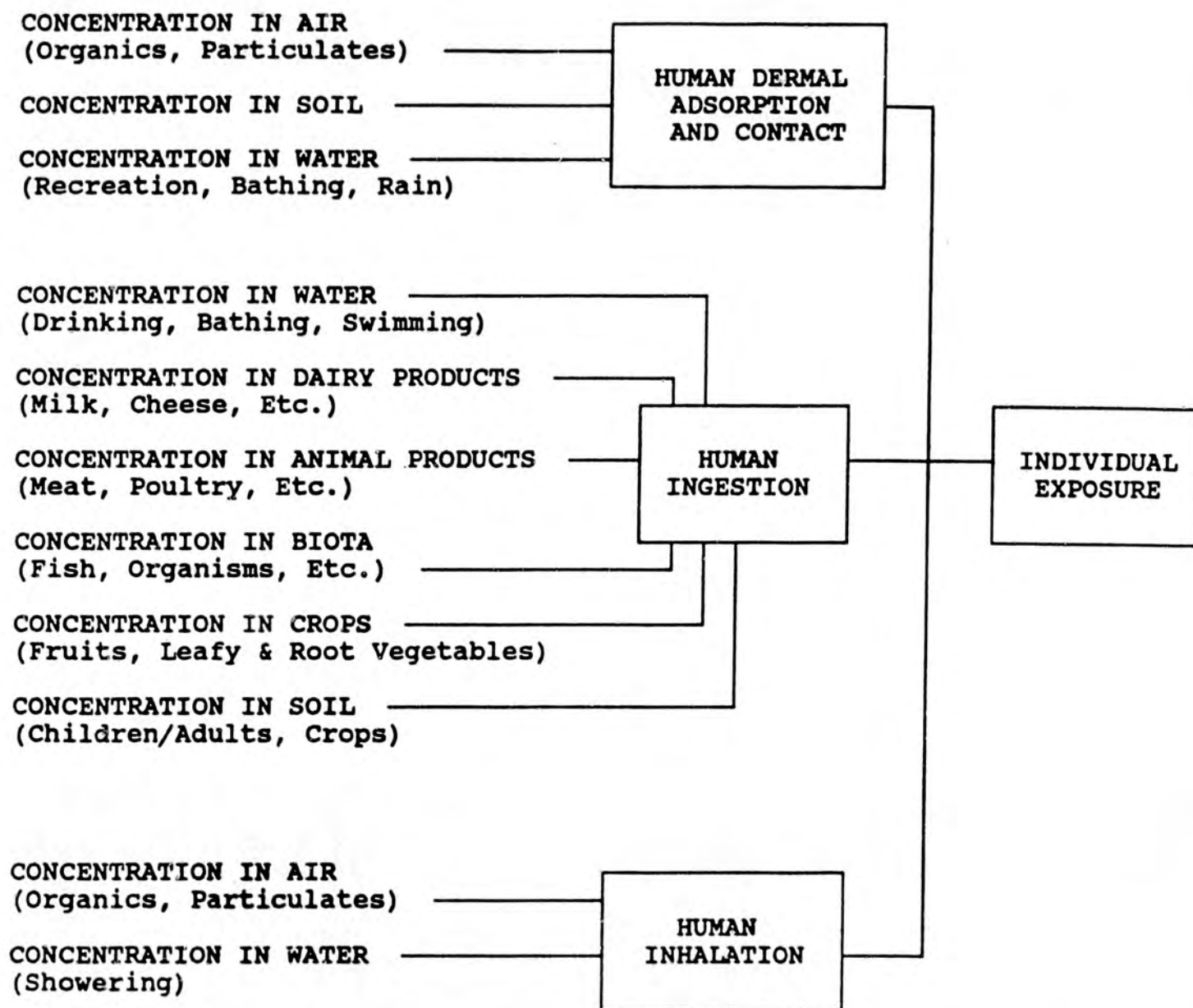


FIGURE 8.1

8.2 General Description of the Modeling Approach

Exposure assessment can be carried out by either direct exposure monitoring, modeling, or combined modeling and monitoring (Wallace, 1987, 1989; NAS, 1991; Liroy, 1990; Sexton and Ryan, 1988; Winer, et al., 1989; Thomas et al., 1989). In this study an approximate exposure assessment for chronic exposures was carried out using the multimedia concentrations determined for the Port Valdez area (see section 7) and the multimedia total dose (MTD) model (Chetty, 1991). The major pathways of the MTD model are illustrated in Figure 8.1. Some of the major features of the MTD model are:

- Dynamic (i.e., time dependent) analysis of dose and dose rate
- Time and age dependent human physiological and anatomical parameters (e.g., receptor's mass, inhalation rate)
- Theoretical model for absorption/desorption via the lungs
- Sub-models for dermal absorption
- Dynamic sub-models to predict pollutant accumulation in the food chain (e.g., vegetation, fish, beef)
- Inclusion of agent metabolism within the human body

The MTD model is more comprehensive than the standard EPA approach to estimating contaminant intake. However, in the present approach the model was run in a mode compatible with the EPA methodology (EPA, 1986a-1986d, 1988a). Chetty (1991) demonstrated that the MTD model can be used to duplicate the EPA guidelines for exposure assessment and other similar models (e.g., McKone and Kastenber, 1986; McKone and Ryan, 1989; McKone and Layton, 1986; McKone and Daniels, 1990) by neglecting metabolism within the human body and other elimination pathways (e.g., urination). The significance of including metabolism through pharmacokinetics models was recently illustrated for benzene by Hattemer-Frey and Travis (1990) and Travis et al. (1990). In this study, however, a conservative estimate of the dose rate (mg/kg/day) was obtained following the recommended EPA approach. It is recognized that such an approach is likely to overestimate the actual exposure and thus the calculated risk. However, this screening-level approach can be used to provide a ranking of expected environmental problems among the various chemicals of concern. Also, it is often the case in risk management that a conservative estimate of risk is utilized in order to provide a safety margin designed to protect the public.

A conservative estimate of dose rate is given by the following equation (Chetty, 1991)

$$\frac{dD}{dt} = \sum_{l=1}^{N_p} \sum_{z=1}^X L_{lz}(t) C_{lz} f_{lz} W_{lz} + \sum_{l=1}^{N_v} \sum_{z=1}^X N_{lz} A_{lz} f_{lz} \quad (8.1)$$

In the current application of the MTD model the first term on the right hand side of Eq. 8.1 represents contaminant intake due to inhalation and ingestion while the second term represents intake due to dermal absorption. The total mass of agent uptake by the receptor is designated by D (μg), f_l is the fraction of time during which exposure occurs for each pathway (dimensionless), and W_l is the absorption or agent uptake factor for pathway l (dimensionless), X is the total number of macro/micro-environments, L_k is the extent of contact of receptor with a given medium designated by the subscript i (e.g. air, water, soil, etc.) via a specific exposure pathway (e.g., inhalation, etc.) (m^3/day , or g/day), and C_k is the concentration ($\mu\text{g}/\text{m}^3$, or $\mu\text{g}/\text{g}$) of the chemical in environmental media i (soil, water, food, etc.) in contact with the receptor. N_k is the flux ($\mu\text{g}/(\text{day})(\text{m}^2)$) of the chemical agent across an exchange boundary (as in dermal absorption), N_v is the total number of exposure pathways where agent exchange is by interfacial transport, A_k is the surface area of the exchange boundary involved in the interfacial transport of agent into the body (m^2), z designates the macro or microenvironment where exposure occurs, and l designates the exposure pathway where agent exchange is by interfacial transport in the absence of a control volume, i.e., soil on exposed skin. It is important to note that Eq. (8.1) leads to a conservative estimate of dose since it neglects agent outflow from the receptor, and production and/or degradation/metabolism of the agent within the receptor.

Equation 8.1 specifies the time rate of change of the total mass of agent in the body during a specific time period. Frequently however, the agent dose rate for the receptor per kg of receptor body mass is desired (i.e., specific dose rate). If one expresses the dose rate as

$$\frac{dD}{dt} = \alpha \quad (8.2)$$

in which α represents the left hand side of Eq. 8.1. If one defines the specific dose as

$$D_s = \frac{D}{M_m} \quad \text{for } m=1,2 \quad (8.3)$$

where D_s is the specific dose (μg of agent/kg of receptor), and M_m is the mass of receptor (kg), then the specific dose rate, $\dot{D}_s$, can be expressed as

$$\begin{aligned}\dot{D}_m &= \frac{dD_m}{dt} = \frac{d(D/M_m)}{dt} = \frac{1}{M_m} \frac{dD}{dt} + D \frac{dM_m^{-1}}{dt} \\ &= \frac{\alpha}{M_m} - \frac{D}{M_m^2} \frac{dM_m}{dt} \quad \text{for } m = 1, 2\end{aligned} \quad (8.4)$$

Equation 8.4 indicates that the specific dose rate is a function of the change of mass of the receptor. The dose rate is also reported to vary with time as other characteristics of the receptor change with time (e.g., inhalation rate, dietary intake).

Frequently, in health risk analysis, knowledge of the average specific dose rate is needed, in order to determine the corresponding health risk. The time averaged specific dose rate can be obtained by integrating Eq. 8.4 with respect to t and dividing by the time period $(t_f - t_o)$,

$$\bar{D}_m = \frac{1}{t_f - t_o} \int_{t_o}^{t_f} \left[\frac{d\dot{D}_m}{dt} \right] dt = \frac{1}{t_f - t_o} \int_{t_o}^{t_f} \left[\frac{\alpha}{M_m} - \frac{D}{M_m^2} \frac{dM_m}{dt} \right] dt \quad (8.5)$$

Thus, Eq. 8.5 specifies that the average specific dose rate is a function of the receptor's growth rate (i.e., the rate of change in body mass).

The prediction of the average dose and average dose rate, via Eq. 8.1 require a knowledge of the various model parameters. It is beyond the scope of this report to review the various exposure parameters that are used in standard exposure assessment and the interested reader is referred elsewhere (EPA, 1986a-1986d, 1984; CAPCOA, 1990; Vaughan, 1984; Liroy, 1990; Travis and Arms, 1988; McKone, 1986, 1990; Chetty, 1991; and references therein). In the MTD approach as described by Eqs. 8.1-8.5 the specific dose, and average specific dose rate are calculated as a function of the age of the receptor.

8.3 Estimation of Health Risks

Once the dose rate from the various pathways is determined, health risk analysis can be carried out given the appropriate dose-response information. In general, however, one should recognize that the response can be a function of incidence, intensity and severity (Hartung, 1986). The incidence variable is a measure of the fraction (or percentage) of the studied population that exhibits a given response (e.g., presence of tumors). The intensity of the response is a graded or continuous measurement of changes in the individual such as change in growth rate or blood pressure. The severity of responses is a subjective measure which reflects the levels of public concern. For example, one may assign a high severity scale value to birth defects and a relatively lower rating to insomnia or occasional mild headaches. Generally, we expect that the percent incidence will increase with increasing dose rate and that such increase

will be more pronounced as the duration of exposure increases. Toxic chemicals can lead to a variety of health effects including cancer, genetic damage in reproductive cells, affect offsprings in the fetal development stage, or cause a multitude of non-cancer effects. Specific information regarding the study chemicals can be found in the Toxicological Profiles published by the ATSDR and also in the IRIS database.

A simple and often a conservative approach for determining the risk associated with exposure to chemical carcinogens is based on the one-hit model (Bailar, 1988). This model is a standard model used in screening-level risk assessment and it is generally believed to be a conservative model of cancer health risk. Accordingly, the risk of developing cancer is determined from the following relation:

$$R_{ij} = 1 - e^{-(a + q_{ij}D_{ij})} \quad (8.6)$$

where R_{ij} is the health risk for exposure to chemical carcinogen i for exposure pathway j (dimensionless), D_{ij} is the average daily dose rate of chemical carcinogen i (mg/kg.day), and q_{ij} is the cancer potency factor for chemical carcinogen i [(mg/kg.day)⁻¹] via intake pathway j , and a represents the background cancer risk. Since the health risk above background is generally of interest Eq. 8.7 is often used with a set to zero. The cancer potency factors (q_{ij}) which are recommended by the USEPA have been published by the EPA⁸ and they are also available through the computerized IRIS data base. At low specific dose rates eq. 8.6 can be simplified to yield

$$R_{ij} = q_{ij}D_{ij} \quad (8.7)$$

In contrast to carcinogens, the probabilistic risk associated with non-carcinogens is difficult to quantify. However, the regulatory approach to establishing guidelines such as with the reference dose (RfD) method have been discussed in the toxicology literature. The reference dose is the average life-time daily dose below which adverse health effects are not expected. A hazard index can be calculated as the ratio of the specific dose rate to the RfD value. Thus, a hazard index below unity indicates that the environmental concentrations are at the acceptable levels.

The above approaches represent approximate screening-level estimates that lead to conservative life-time estimates of health risks. Risk analysis is complex and it is subject to many uncertainties and varying degrees of interpretation (Glickman et al., 1990). Nevertheless, the simple screening-level approach described above serves as a first order analysis to identify potential environmental problems.

⁸ EPA, Health Effects Assessment Summary Tables, OERR-9200.6-303 (91-1), NTIS #PB91-921199.

8.4 Results and Discussion of Exposure Analysis

8.4.1 Summary of Results

Two scenarios were analyzed in which the human dose rates and resulting risks and the accumulation of the study chemicals in aquatic biota and vegetation were evaluated based on the multimedia concentrations given in Table 7.4. In the first scenario, ingestion values of contaminated food for a reference individual were based on statistical information on the population of the continental United States (EPA, 1984). In the second scenario ingestion rates of contaminated food were used based on a statistical information specifically determined for coastal areas (EPA, 1989). The consumption of fish and shell fish are given in Table 8.1. It was assumed, in both scenarios, that the Valdez population is at the upper 95% and that 90% of its consumption of seafood is from the bay area. Such an approximation believed to provide an upper limit estimate of the contribution of fish ingestion to the overall dose rate. As part of the exposure analysis the accumulation of BETX and *n*-hexane in biota and vegetable were estimated as and the results are given in Table 8.4.

TABLE 8.1
INGESTION RATE VALUES FOR A REFERENCE INDIVIDUAL

Reference Individual Age (yrs)	Ingestion Rate for a Reference Individual in the U.S.		Ingestion Rate for a Reference Individual in Coastal Areas	
	Fin Fish (g/day)	Shell Fish (g/day)	Fin Fish (g/day)	Shell Fish (g/day)
Under 1	0.6	0.5	0.6	0.5
1 to 4	7.0	0.3	7.0	0.3
5 to 9	10.3	1.1	14.9	1.6
10 to 14	12.5	0.9	24.2	2.6
15 to 19	14.0	2.0	24.2	2.6
20 to 24	17.2	3.0	32.7	5.6
25 to 29	20.6	3.5	32.7	5.6
30 to 39	16.2	3.8	34.7	5.8
40 to 59	18.3	3.9	41.8	8.9
60 and over	17.2	2.4	48.6	6.8

The results of the two simulations are given in Tables 8.2-8.3 and Figure 8.2. Table 8.2 provides the overall lifetime average specific dose rate, the lifetime average specific dose rate due to inhalation, the lifetime average specific dose rate due to ingestion, and the lifetime average specific dose rate due to dermal absorption based on the average monitored concentrations (see Table 7.4). The lifetime average specific dose rates are the average dose rates calculated up to the length of a reference individual's lifetime, which was set to seventy years. The overall lifetime average specific dose rates in the tables accounts for the uptake of the chemical from the major exposure pathways (excluding indoor exposure). Indoor exposure to hydrocarbons can be significant indoors and it is well documented that significant exposure to benzene can occur due to both active and passive cigarette smoking (Webster, 1986; ATSDR, Toxicological Profile for Benzene, 1991).

TABLE 8.2
LIFETIME AVERAGE SPECIFIC DOSE RATES
FOR MULTIMEDIA CONCENTRATIONS
BASED ON THE AVERAGED MONITORED AIR CONCENTRATIONS

Chemical	Overall (mg/kg/day)	Inhalation (mg/kg/day)	Ingestion (mg/kg/day)	Dermal Absorption (mg/kg/day)
Ingestion Intake Values Based on a Reference Individual in the U.S. (USEPA, 1984)				
Benzene	2.10E-03	2.10E-03	9.66E-07	9.61E-10
Ethylbenzene	3.08E-04	3.08E-04	1.51E-07	1.48E-10
<i>n</i> -Hexane	4.69E-03	4.69E-03	2.45E-06	2.18E-09
Toluene	1.88E-03	1.88E-03	9.03E-07	8.84E-10
Xylenes	6.90E-04	6.90E-04	3.69E-07	3.33E-10
Ingestion Intake Values Based on a Reference Individual in Coastal Areas (USEPA, 1989)				
Benzene	2.10E-03	2.10E-03	1.03E-06	9.61E-10
Ethylbenzene	3.08E-04	3.08E-04	2.47E-07	1.48E-10
<i>n</i> -Hexane	4.70E-03	4.69E-03	8.22E-06	2.18E-09
Toluene	1.88E-03	1.88E-03	1.29E-06	8.84E-10
Xylenes	6.91E-04	6.90E-04	1.03E-06	3.33E-10

LIFETIME AVERAGE SPECIFIC DOSE RATE
(Based on Reported Concentration Data)

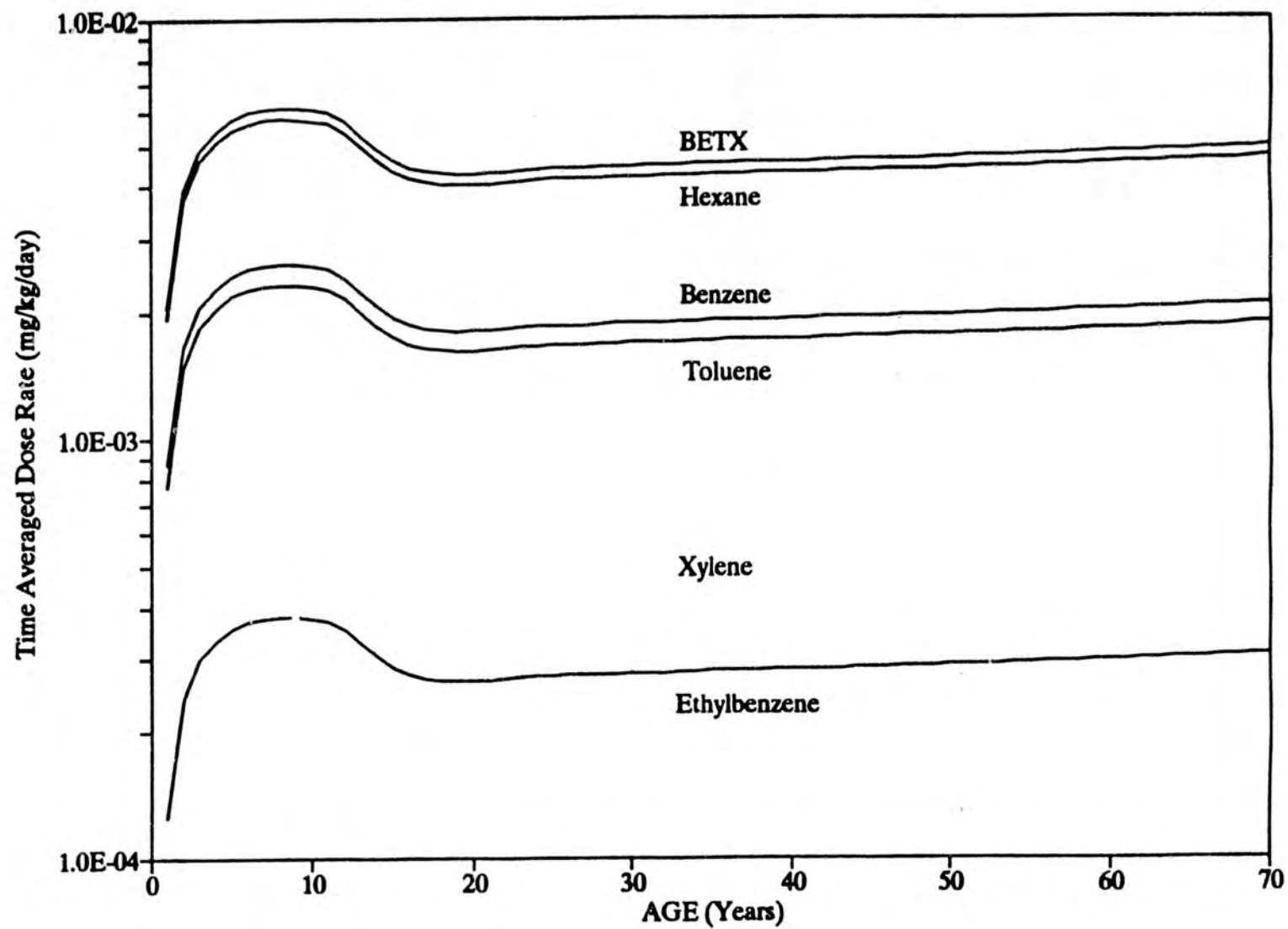


FIGURE 8.2

The overall specific dose rates for the individual chemicals and the cumulative average specific dose rate for BETX as a function of the age of the reference individual are depicted in Figure 8.2. For example, the average dose rate of the chemical corresponding to twenty years in the figures indicates the overall lifetime average specific dose rate if an individual lived in the region from birth to an age of twenty years. The specific average dose rate increases rapidly in the early years as the receptors' rate of change of mass and rate of inhalation increases rapidly. Past the age of about eight years the specific dose rate decreases towards the nearly constant value which is reached at the age of about eighteen years. Thus, for an individual born and raised at Port Valdez, the average dose rate equal in value to the lifetime-average specific dose rate is reached at the age of about eighteen years. The results in Figure 8.2 present only one possibility, one can carry out the analysis for different scenarios in order to obtain the dose rate for individuals who have moved to or away from Port Valdez at different stages of their life.

The toxicological information used for determining the hazard indices or carcinogenic risk for the study chemicals are shown in Table 8.3 along with the corresponding values of the hazard index and incremental lifetime cancer risk for the above case studies. Finally the level of accumulation (in units of $\mu\text{g/kg}$) of the five study chemicals in fish and vegetation are given in Table 8.3. These results are demonstrative of expected level of accumulation of BETX and *n*-hexane in biological receptors.

8.4.2 Inhalation Pathway

The inhalation pathway is the dominant mode of human to BETX and *n*-hexane. It is obvious from Tables 8.2-8.3 that the inhalation dose rate is directly proportional to the atmospheric concentration of the inhaled chemical

The five study chemicals have available toxicological information (see Table 8.3) that can be used to estimate the potential health risks. Only benzene is considered to be a carcinogen with a potency factor of $.029 (\text{mg/kg/d})^{-1}$ for inhalation uptake. For the other four chemicals the dose rates must be compared to the reference dose (RfD). With the above factors (see Table 3.1 and 8.3) the upper estimate of the risk from exposure at the average air concentrations is estimated to be 6.09×10^{-5} . These risk estimates correspond to a life-time cancer risk due to exposure to benzene 1 person in 16,420. Given the approximate nature of this conservative analysis it is more appropriate to report this risk rounded to a risk of 1 person in 20,000.

Comparison of the other four study chemicals shows that the inhalation pathway represents the major contribution to the hazard index. Again, the air concentration has the major influence on the contaminant intake via inhalation and hence the resulting value of the hazard index. The highest hazard index of 0.024 was calculated for *n*-hexane, which also had the highest estimated air concentration. Thus, the exposure *n*-hexane is approximately 2.4% of the

reference dose (RfD). For ethylbenzene, toluene, and xylenes the hazard indices were found to be in the range of 10^{-3} - 10^{-5} ; It appears that, from the viewpoint of human health, the concentrations of these chemicals in the Port Valdez atmosphere are within the acceptable levels. The above results are approximate basin-average values and they do not reflect actual or site-specific health risks. A more detailed analysis, has been conducted by Alyeska, to account for activity-time patterns for the targeted population through personal exposure monitoring (Yocom et al., 1991). This study is currently under review by the Valdez Air Study Review Committee, recently formed by the Regional Citizens' Advisory Council.

8.4.3 Ingestion and Dermal Absorption Pathways

Contaminant intake via the ingestion pathway was found to be significantly less than the inhalation pathway. The chemical concentration in the water compartment has the major influence on the accumulation of the study chemicals in fish with uptake by plants being most influenced by the air phase concentration. The comparison between the ingestion values based on a reference individual in the United States and from coastal area reveals that the increased consumption of local biota has a negligible influence on the overall lifetime average specific dose rate. However, the increase in consumption of local fish does significantly affect contaminant intake via ingestion.

Contaminant intake via the dermal absorption pathway is also insignificant when compared to the inhalation and ingestion pathways. The contribution of dermal absorption to the lifetime average specific dose rate is approximately six orders of magnitude less than that of inhalation and three to four orders of magnitude less than the contribution of ingestion. The main factor influencing the amount of chemical dermally absorbed is the magnitude of the air concentrations; as the atmospheric concentration increases, for a given chemical, contaminant intake by the human receptor due to dermal absorption is also expected to increase.

8.4.4 Accumulation of the Study Chemicals in Biota and Vegetation

The accumulation of the chemicals in aquatic fauna (biota) are given in Table 8.4. The results for fin fish are based on the model of Thomann (1989) which describes the uptake of the chemical accounting for growth of the fish and excretion of the chemical. From Table 8.4 it is clear that *n*-hexane displays the highest degree of bioaccumulation followed toluene, benzene, xylenes, and ethylbenzene, respectively. The major parameters affecting the predicted concentration in fin fish are the water concentrations and the octanol-water coefficient. It is worth noting that even though benzene displays a higher environmental concentration in water than toluene, the predictions for bioaccumulation of toluene are slightly higher; this trend is consistent with the higher BCF value for toluene.

TABLE 8.3

**TOXICOLOGY INFORMATION AND THE HAZARD POTENTIAL
FOR PREDICTED OVERALL LIFETIME AVERAGE SPECIFIC DOSE RATES**

Chemical	Inhalation Reference Dose ^a (mg/kg/day)	Oral Reference Dose ^a (mg/kg/day)	Potency Factor Inhalation ^a (mg/kg/day) ⁻¹	Potency Factors Oral ^a (mg/kg/day) ⁻¹	Hazard Index (HI) or Cancer Risk (CR)
					Average Air Concentration
Ingestion Intake Values Based on a Reference Individual in the U.S. (USEPA, 1984)					
Benzene	---	---	2.9E-2	2.9E-2	6.09E-05 (CR)
Ethylbenzene	1.0	1.0	---	---	3.08E-04 (HI)
n-Hexane	2.0E-01	6E-2	---	---	2.35E-02 (HI)
Toluene	2.0	2.0E-1	---	---	9.44E-04 (HI)
Xylenes	3.0E-01	2.0	---	---	2.30E-03 (HI)
Ingestion Intake Values Based on a Reference Individual in Coastal Areas (USEPA, 1989)					
Benzene	---	---	2.9E-2	2.9E-2	6.09E-05 (CR)
Ethylbenzene	1.0	1.0	---	---	3.08E-04 (HI)
n-Hexane	2.0E-01	6E-2	---	---	2.36E-02 (HI)
Toluene	2.0	2.0E-1	---	---	9.46E-04 (HI)
Xylenes	3.0E-01	2.0	---	---	2.30E-03 (HI)

The shell fish concentrations were predicted from the experimental data for accumulation of the chemical by both water and food uptake (Southworth et al., 1978). The correlation was based on the octanol-water coefficient of the chemical and the concentrations predicted for these organisms are dependent on the magnitude of the water concentrations and the octanol-water partition coefficient.

The predicted chemical concentrations in leafy vegetables and root vegetables grown in the study area are given in Table 8.4. The predicted concentrations were estimated from the predicted soil concentrations and octanol-water coefficient (Briggs et al., 1982; Chetty, 1991; and references therein). Benzene displays the highest accumulation in leafy vegetables followed by toluene, *n*-hexane, xylenes, and ethylbenzene. For root vegetables, *n*-hexane exhibits the highest accumulation followed by toluene, benzene, xylenes, and ethylbenzene. The above order of accumulation is expected consistent with the higher soil and air concentrations and bioconcentration factors for the chemicals exhibiting greater bioaccumulation.

Although the accumulation of BETX and *n*-hexane (originating from the marine terminal) in biota and vegetation appears to be at low level, data on toxicological and ecological impacts at such low concentration levels are unavailable. Obviously more work is needed to establish the effect of chronic exposure of aquatic organisms and plants exposed to low contaminant concentration levels.

TABLE 8.4
ACCUMULATION OF STUDY CHEMICALS
IN BIOTA AND VEGETATION PREDICTED BY THE MTD MODEL

Chemical	Fin Fish ($\mu\text{g/kg}$)	Shell Fish ($\mu\text{g/kg}$)	Leafy Vegetables ($\mu\text{g/kg}$)	Root Vegetables ($\mu\text{g/kg}$)
Predictions Based on Average Air Concentrations				
Benzene	1.38E-01	4.56E-03	3.69E-03	3.91E-09
Ethylbenzene	2.21E-01	4.09E-03	1.31E-04	5.56E-09
<i>n</i> -Hexane	1.33E+01	1.76E-01	2.13E-03	1.22E-06
Toluene	8.80E-01	2.02E-02	2.82E-03	2.69E-08
Xylenes	1.52E-00	2.79E-02	2.27E-03	9.96E-08

9. CONCLUSIONS

Based on the basin-wide analysis conducted in this study the following conclusions can be stated:

1. The concentrations of BETX and *n*-hexane monitored by Alyeska at Port Valdez are typical of the concentration levels observed in other urban areas. The concentrations at Port Valdez, on the average, are typical of the average or the low end of the concentration range observed in urban atmospheres. Peak concentrations higher by up to one to two orders of magnitude relative to the average concentrations have been measured. Clearly, with respect to the atmospheric concentrations of BETX and *n*-hexane, Port Valdez cannot be considered to be either a pristine or a rural area.
2. Human exposure to ethylbenzene, toluene, xylenes, and *n*-hexane leads to a lifetime average contaminant intake rate ranging from about 3.1×10^{-4} mg/kg/day to 1.8×10^{-3} mg/kg/day. The dose rates, for the above non-carcinogens, are significantly below the EPA reference dose (RfD) at which adverse health effects may occur. However, it must be noted that higher average daily intake, by a factor ranging from 2 to 10, can result from occupational exposure near and at the terminal as suggested by the higher concentrations of BETX and *n*-hexane reported from the East Gate monitoring station.
3. Human exposure to benzene leads to a lifetime average benzene intake rate estimated to be about 2.1×10^{-3} mg/kg/day. At this exposure level a conservative analysis of human health risk due to exposure to benzene, based on a basin-wide average concentration revealed that the expected lifetime cancer health risk is about 1 in 20,000. The risk to terminal workers may be greater since their daily dose of benzene, due to occupational exposure, may be significantly higher relative to non-terminal workers. It is important to note, however, that the daily dose of benzene for cigarette smokers (and those exposed to benzene through passive smoking) may be significantly higher compared to the dose received due to exposure to ambient levels of benzene. Obviously, a detailed analysis of exposure is required in order to assess the detailed health risks from all sources (see section 10).
4. The estimation of BETX emissions from the BWT facility indicates that the biological treatment units may be a major source of BETX emissions if they are not as efficient in biodegrading BETX as claimed by Alyeska.

5. Accumulation of BETX and *n*-hexane in biota is in the range of 0.14 $\mu\text{g/kg}$ to 13.3 $\mu\text{g/kg}$. It is not known if such low levels of accumulation in fish can lead to adverse effects (on fish and other aquatic organisms) as the result of chronic exposure.
6. Accumulation of BETX and *n*-hexane in vegetation is in the range of 1.3×10^{-4} $\mu\text{g/kg}$ to 3.7×10^{-3} $\mu\text{g/kg}$. No documented adverse effects on vegetation due to low concentrations of BETX or *n*-hexane have been documented in the literature. Adverse effects can occur when hydrocarbon emissions also affect ozone formation. However, this is not believed to be the case at Port Valdez.
7. The monitored concentrations reported by Alyeska and upon which part of the analysis in this study was based represent an incomplete set. For the 8/90 - 9/91 sampling period the average percentage of data not reported ranged from about 39.8% to 48.6%. Thus, presently there is an undetermined degree of uncertainty in the adequacy of the monitored data for obtaining meaningful average concentrations.

10. RECOMMENDATIONS

1. There is a need to establish the level of confidence in the Alyeska ambient air monitoring data for specific hydrocarbons (e.g., BETX and *n*-hexane) in order to determine the appropriate error bounds on the reported monitoring data. As part of the above task, the correlation between the reported data, missing data, and the tanker loading activity logs must be established.
2. There is a need to reconcile the estimated emissions with the monitoring data in order to determine the contribution of the terminal operations to the ambient levels of hydrocarbons in the Port Valdez area. This task will require that appropriate air dispersion models are used using the rich meteorological data base accumulated for Port Valdez and the available emission estimates.
3. There is a need to conduct a careful review of the tanker loading emission study in order to establish the uncertainty in the emission estimates reported by Alyeska. Such information is crucial if these emission estimates are to be used by Alyeska to establish the contribution of emissions from the terminal to the exposure of the residents of Valdez to petroleum hydrocarbons.

4. There is a need to establish the effectiveness of the biological treatment units (BTU) in the BWT facility. Convincing evidence should be presented that the BTU are indeed biodegrading BETX at the rate implied by Alyeska. If biotreatment is not as effective as it is claimed to be then the BTU can contribute significantly to the air emissions from the BWT facility.
5. Realistic exposure assessment that encompasses the actual exposed population including Alyeska employees should be conducted. In fact, a detailed personal exposure monitoring study was undertaken by Alyeska and a review of this study was recently undertaken by the Valdez Air Study Review (VASR) Committee convened by the Regional Citizens' Advisory Council (RCAC). It is hoped that the Alyeska study will provide the additional information required to assess the potential human health risks associated with the operation of the marine terminal at Port Valdez.
6. Although polyaromatic hydrocarbons of crude oil origin have been identified in the Port Valdez sediment their sources have not been clearly identified. Since polyaromatic hydrocarbons tend to bioaccumulate, it is essential that their origin and potential impact on the marine environment is clarified.
7. There is a need for a systematic program focused on the evaluation of ecological risks to the Port Valdez marine environment as the result of chronic exposures to low concentrations of hydrocarbons (both VOCs and polycyclic hydrocarbons).

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APPENDIX A

OVERVIEW OF THE SMCM MODEL

A.1 Model Equations

The SMCM model consist of both uniform compartments and non-uniform compartments. The chemical mass balance equation for each type of compartment are given below along with a brief description of the parameter estimation methods used in the SMCM model.

A.1.1 Uniform Compartments

The material balance equations for the uniform well-mixed compartments in the SMCM model (air, water, biota and suspended solids) are given by

$$\frac{d(V_i C_i)}{dt} = \sum_{j=1}^N A_{ij} K_{oi} C_j - C_i + \sum_{j=1}^N \Omega_{ij} + \sum_{j=1}^N (Q_{ji} C_j - Q_{ij} C_i) + R_i + S_i \quad i=1, \dots, N-J, \quad i \neq j \quad (1)$$

with the initial conditions

$$C_i = C_i(0) \quad \text{at } t = 0 \quad (2)$$

where V_i is the volume of compartment i (m^3), C_i is the concentration of the species of interest in compartment i ($gmol/m^3$), N is the total number of compartments, J is the total number of non-uniform compartments, A_{ij} is the interfacial area between compartments i and j (m^2), K_{oi} is the i^{th} side overall mass transfer coefficient between compartments i and j (m/hr), C_j^* is the pollutant concentration in compartment i which would be in equilibrium with compartment j and it can be expressed as $C_j^* = C_j H_j$ (refer to Eq. 19), R_i is the production or degradation rate of chemical ($gmol/hr$), S_i is the source strength ($gmol/hr$), Q_{ij} and Q_{ji} are the volumetric flow rate (m^3/hr) from compartment i to compartment j , and compartment j to compartment i , respectively. The term on the left hand side represents the rate of accumulation of chemical in compartment i . The first term on the right hand side of Eq. 1 represents the rate of the chemical mass entering or exiting compartment i by interfacial mass transfer. The second term, $\sum_{j=1}^N \Omega_{ij}$ accounts for additional intermedia transport processes between compartments i and j such as dry deposition of particle-bound organics and rain scavenging. The third term accounts for the net convective flow of the chemical into compartment i . The volumetric flow rate associated with the air compartment and its surrounding environment is evaluated based on the concept of air recirculation, accounting for non-ideal mixing. The fourth term represents the production/degradation by chemical reaction. Although this term is modeled in this work as a

pseudo first order process, the inclusion of more complex kinetic expressions can be incorporated without a loss of generality. Finally, the last term is the net input into the compartment from source emissions.

The loss of pollutant mass in the air compartment resulting from rain scavenging can be incorporated via the second term of Eq. 1, e.g.,

$$\Omega_{aw} + \Omega_a = -R^*(A_{aw} + A_{as}) \lambda_g^* C_a H_{wa} \quad (3)$$

where the subscripts a, w, and s represent the air, water and soil compartments, respectively; R^* is the precipitation rate (e.g., mm/hr); A_{as} and A_{aw} are the air/soil and air/water interfacial areas, respectively; C_a is the pollutant concentration in the air compartment, and H_{wa} is the dimensionless chemical water/air partition coefficient (i.e., $H_{wa} = C_w/C_a$, at equilibrium). λ_g^* is a dimensionless gaseous rain scavenging ratio; it describes the efficiency by which rain drops can remove contaminants from the air, and varies between 0 and 1 for chemicals which are nonreactive in the aqueous phase. Contaminants entering to the water compartment due to rainfall are also incorporated by using the second term of Eq. 1, e.g.,

$$\Omega_{aw} = R^* A_{aw} \lambda_g^* C_a H_{wa} + f_{ro} (R_o) L_{ro} H_{as} \lambda_g^* C_a H_{wa} \quad (4)$$

The terms on the right hand side of Eq. (4) account for the amount of pollutant added to the water compartment by wet deposition and surface runoff, respectively. R_o is the runoff rate (m/hr), f_{ro} is the fraction of runoff which will reach surface waters, L_{ro} is the length perpendicular (m) to the direction of runoff flow, and H_{as} is the height of the sheet of runoff water (m).

A.1.2 Non-uniform Compartments

The soil and sediment are treated as non-uniform compartments in the SMCM model. The pollutant transport processes in these compartments are dominated by molecular diffusion which leads to significant concentration gradients in these compartments.

Pollutant transport in the three-phase (air, water, and solids) soil matrix can be approximated, assuming the soil phases to be in local equilibrium (Cohen and Ryan, 1990), by a one-dimensional diffusion equation with convection and chemical reaction.

$$\frac{\partial C_m}{\partial t} = \frac{\partial}{\partial z} \left(D_m \frac{\partial C_m}{\partial z} \right) - V_m \frac{\partial C_m}{\partial z} + R_m + S_m \quad (5)$$

with the initial condition

$$C_m = C_m(0, z) \quad \text{at } t=0 \quad (6)$$

and the flux boundary conditions

$$V_m C_m - D_m \left(\frac{\partial C_m}{\partial z} \right) = R^* \lambda_g^* C_a H_{m,a} + k_{a,m} (C_a - C_m / H_{m,a}) \quad \text{at } z=0 \quad (7)$$

$$-D_m \left(\frac{\partial C_m}{\partial z} \right) = k_{gw,m} (C_m / H_{m,gw} - C_{gw}) \quad \text{at } z=L \quad (8)$$

or

$$\left(\frac{\partial C_m}{\partial z} \right) = 0 \quad \text{at } z=L \quad (9)$$

where the depth from the soil-atmosphere surface is designated by z , C_m is the pollutant concentration in the soil matrix, and V_m is the effective water infiltration rate in the soil matrix (m/hr) (Jury et al., 1983) as defined below.

$$C_m = (1 - \epsilon_m - \epsilon_{rw}) C_{sp} + \epsilon_{rw} C_{rw} + \epsilon_m C_{sa} \quad (10)$$

$$V_m = \frac{V_w}{H_{m,rw}} \quad (11)$$

in which C_{sp} , C_{rw} and C_{sa} are the concentrations in the soil-solids, soil-water, and soil-air phases, respectively, ϵ_m , ϵ_{rw} are the volume fractions of the soil-air and soil-water, respectively, and V_w is the interstitial velocity of water in the soil matrix (m/hr) which is determined from a detailed submodel for water infiltration and evaporation. $H_{m,a}$ and $H_{m,rw}$ are the soil matrix/soil-air and the soil matrix/soil-water partition coefficients, respectively (defined in Eqns. 21 and 22). D_m is the effective diffusion coefficient (m^2/hr) that can be estimated as discussed later in the paper. $k_{a,m}$ is the air-side mass transfer coefficient at the soil/atmosphere interface, and $k_{gw,m}$ is the water-side mass transfer coefficient at the soil/groundwater interface. R_m is the rate of production or degradation per unit volume of soil matrix ($gmol/hr.m^3$), and S_m is the source strength of pollutant per unit volume of soil matrix ($gmol/hr.m^3$). This source strength can in principle be a function of time and position. However, the above approach for the soil matrix with a buried chemical layer may be unreasonable. Therefore, for the case of buried chemical simulation, an alternative approach is applied as described in the following paragraph. Through the use of the boundary conditions (Eqns. 7-9), it is recognized that the uniform compartments and non-uniform compartments are not necessarily in dynamic equilibrium at the boundaries, and

thus more appropriate flux boundary conditions are applied at the top and bottom boundaries of the soil compartment (Eqns. 7-9). Specifically, the deposition of water-borne pollutant, the infiltration of rain water, and the interfacial mass transfer constrained by equilibrium are incorporated to the top flux boundary condition (Eq. 7). Furthermore, two different flux boundary conditions are provided in the SMCM model for the bottom boundary. One accounts for the chemical transport to groundwater (Eq. 8); although groundwater is not treated as a compartment in the current work, a flux condition at the bottom boundary of the soil compartment is incorporated to account for chemical transport to groundwater. It is worth noting that, as a first approximation, the pollutant concentration in the bulk groundwater (i.e., C_{gw} in Eq. 8) is simply assumed to be zero, i.e. equivalent to assuming an initially uncontaminated groundwater. A modification of the above approach can be made by incorporating a simple groundwater model into the SMCM approach to account for the time variations of C_{gw} . The other flux condition (Eq. 9) allows the setting of the flux of the chemical through the bottom of the compartment to be zero. This is valid so long as the concentration front has not reached the bottom boundary at $z = L$, or if the bottom boundary is indeed impermeable to the solute.

The material balance of pollutant transport in the sediment compartment is also treated by a one-dimensional diffusion equation similar to Eq. 5. In the current screening approach, convection due to water infiltration into the sediment compartment is neglected, and the sediment matrix is assumed to be a two-phase system (water and solids). The flux boundary conditions for the sediment compartment are

$$-D_{sed} \left(\frac{\partial C_{sed}}{\partial z} \right) = K_{w,sed} (C_w - C_{sed}/H_{sed,sdw}) \quad \text{at } z=0 \quad (12)$$

$$\left(\frac{\partial C_{sed}}{\partial z} \right) = 0 \quad \text{at } z=L \quad (13)$$

where C_{sed} is the pollutant concentration in the sediment matrix as defined below

$$C_{sed} = (1 - \epsilon_{sdw}) C_{sdp} + \epsilon_{sdw} C_{sdw} \quad (14)$$

in which C_{sdp} and C_{sdw} are the pollutant concentrations in the sediment-solids and sediment-water phases, respectively. The volume fraction of water in the sediment is denoted by ϵ_{sdw} , and $K_{w,sed}$ is the water-side mass transfer coefficient at the water/sediment interface. D_{sed} is the effective diffusion coefficient in the sediment, and it can be estimated as discussed later in the paper. Finally, $H_{sed,sdw}$ is the sediment matrix/sediment-water partition coefficient as defined in Eq. (20).

A.2 Parameter Estimation Methods

In the SMC model, various theoretical and empirical parameter estimation methods are used (as shown in Table A.1) such that the required input data are substantially reduced, and the temperature variations of diffusivities, partition coefficients and mass transfer coefficients are taken into account. Also, the temperature dependence of the reaction rate constants can be incorporated via user input for parameters in the Arrhenius-type equation for the rate constants. The estimations of major model parameters such as partition coefficients, mass transfer coefficients, diffusion coefficients, transport parameters associated with rainfall, and meteorological parameters are briefly described in sections 2.1 -2.5.

A.2.1 Partition Coefficients

The partition coefficients, H_i , which appear in the model equations are defined using the fugacity approach (Mackay and Paterson, 1981), i.e.,

$$H_i = \frac{C_i}{C_j} = \frac{Z_i}{Z_j} \quad (15)$$

where Z_i is the fugacity capacity (gmols/m³-Pa) of compartment i. Thus, using the fugacity approach, one needs only to calculate the fugacity capacity for each compartment, and all the partition coefficients are defined. The fugacity capacities for the air and water are given by

$$\text{Air} \quad Z_a = \frac{1}{RT} \quad (16)$$

$$\text{Water} \quad Z_w = \frac{1}{H} \quad (17)$$

where H is the Henry's law constant for the solute (Pa.m³/gmol). The partitioning between soil/air, sediment/water, and suspended solids/water partition coefficients can be correlated with the organic carbon content of the solid phase, and the solute octanol/water partition coefficient. For example, the fugacity capacity of the sorbed phase Z_{sp} can be evaluated as

$$Z_{sp} = \frac{K_p \rho_{sp}}{H} \quad (18)$$

where ρ_p is the density of the solid particles (g/cm^3), and K_p is the sorption coefficient with units of $\text{m}^3 \text{ water}/10^6 \text{ g sorbent}$ given by

$$K_p = K_{oc} X_{oc} \quad (19)$$

in which K_{oc} is the organic carbon/water partition coefficient which has units of $\text{ml solution/g organic carbon}$, and X_{oc} is the mass fraction of organic carbon contained in the solid phase (dry weight basis). Various correlations of K_{oc} with the octanol/water partition coefficient (K_{ow}) have been proposed in the literature (Lyman et al., 1990), and K_{ow} has been experimentally determined for many substances (Lyman et al., 1990). These values are well established and should be used whenever possible.

The fugacity capacities of sorbed phases can be calculated given Eqs. 18-19, and the densities and the organic carbon contents of the solid particles in the sediment, soil and suspended solids compartments. Subsequently, the dimensionless sediment matrix/sediment-water partition coefficient ($H_{\text{sedm},\text{sdw}}$) is estimated from a mass balance over the water and solid phases contained in the sediment

$$H_{\text{sedm},\text{sdw}} = C_{\text{sedm}}/C_{\text{sdw}} = (1 - \epsilon_{\text{sdw}}) H_{\text{sdp},\text{sdw}} + \epsilon_{\text{sdw}} \quad (20)$$

where ϵ_{sdw} is the volume fraction of water in the sediment, and $H_{\text{sdp},\text{sdw}}$ is the sediment solid particle/sediment-water partition coefficient evaluated by taking the ratio of Z_p for sediment to Z_w . Similarly, the soil matrix/soil-air partition coefficient ($H_{\text{sm},\text{sa}}$) and soil matrix/soil-water partition coefficients ($H_{\text{sm},\text{sw}}$) can be estimated from a mass balance over the soil-air, soil-solids and soil-water phases. The resulting expressions for $H_{\text{sm},\text{sa}}$ and $H_{\text{sm},\text{sw}}$ are given by

$$H_{\text{sm},\text{sa}} = C_{\text{sm}}/C_{\text{sa}} = (1 - \epsilon_{\text{sw}} - \epsilon_{\text{sa}}) H_{\text{sp},\text{sa}} + \epsilon_{\text{sw}} H_{\text{rw},\text{sa}} + \epsilon_{\text{sa}} \quad (21)$$

$$H_{\text{sm},\text{sw}} = C_{\text{sm}}/C_{\text{sw}} = (1 - \epsilon_{\text{sw}} - \epsilon_{\text{sa}}) H_{\text{sp},\text{sw}} + \epsilon_{\text{sw}} + \frac{\epsilon_{\text{sa}}}{H_{\text{rw},\text{sa}}} \quad (22)$$

where ϵ_{sw} is the volumetric soil water content, ϵ_{sa} is the volumetric soil air content, $H_{\text{sp},\text{sa}}$ is the soil solid particle/soil-air partition coefficient, and $H_{\text{sp},\text{sw}}$ is the soil solid particle/soil-water partition coefficient. Finally, the partitioning between biota and water is estimated by the use of a bioconcentration factor (BCF).

$$\text{BCF} = C_p/C_w \quad (23)$$

where C_b is the pollutant concentration in biota. If BCF data are not available, then an appropriate correlation of BCF with K_{ow} should be utilized (Lyman et al., 1990).

A.2.2 Mass Transfer Coefficients

The overall mass transfer coefficients, K_{oi} , from compartment i to compartment j can be estimated using the two-film resistance theory

$$1/K_{oi} = 1/k_i + H_j/k_j \quad (24)$$

where k_i and k_j are the i^{th} and j^{th} side individual mass transfer coefficients. The estimation of each individual mass transfer coefficient is briefly described below.

The gas-side mass transfer coefficient at the atmosphere-soil interface ($k_{a,m}$) can be determined from the deposition velocity to a fully rough surface for a reference chemical. Accordingly,

$$k_{a,m1} = k_{a,m2} (D_{a1}/D_{a2})^{2/3} \quad (25)$$

where D_a is the molecular diffusivity of the pollutant in air, subscript 1 denotes the pollutant species under study and subscript 2 defines a reference species. It should be noted that Eq. 25 is based on the observation that the gas-side mass transfer coefficient at the atmosphere-soil interface is correlated with the Schmidt number $Sc^{2/3}$ (Fernandez de la Mora and Friedlander, 1982). Experimental data on the gas-side mass transfer coefficient for a variety of chemicals have been reported by Sehmel (1980), and these data can be applied for the reference species in Eq. 29. In addition, the correlation of Brutsaert (1975) can also be used to evaluate the air-side mass transfer coefficient at the atmosphere-soil interface.

The volumetric mass transfer coefficient for water/biota exchange can be estimated from either experimental data (Neely et al., 1974) or an appropriate empirical kinetic model such as the recent model proposed by Barber et al. (1988) for a variety of fish species. For the biota compartment, it is often more convenient to use a volumetric water/biota mass transfer coefficient, which is preferred since it is difficult to quantify the surface area for water/biota interfacial mass transfer.

In the SMC model, the sediment-water mass transfer coefficient (water side) is determined using the correlation of Thibodeaux and Becker (1982) which expresses the mass transfer coefficient as a function of wind speed, the depth and fetch of the lake. The water/suspended solid mass transfer coefficient (water side) is estimated from the correlation of Rowe et al. (1965). The air-side mass transfer coefficient is evaluated from the set of correlations of Brutsaert (1975), which is recommended for the gas-side mass transfer coefficient

to a smooth or rough water-air interface. Finally, the liquid-side mass transfer coefficient at the water-air interface is determined from the correlation developed by Cohen and Ryan (1985) which is a predictive momentum-mass transfer analogy for the liquid-side mass transfer coefficient.

A.2.3 Diffusion Coefficients

The effective diffusivity of the chemical of interest, D_m , in the soil matrix is calculated by using the method proposed by Jury et al. (1983), which assumes local chemical equilibrium between the soil phases,

$$D_m = \frac{\epsilon_m D_a / \tau_a + \epsilon_{rw} H_{rw,m} D_w / \tau_w}{\epsilon_m + \epsilon_{rw} H_{rw,m} + (1 - \epsilon_m - \epsilon_{rw}) H_{sp,rw}} \quad (26)$$

where ϵ_m is the volumetric soil air content, ϵ_{rw} is the volumetric soil water content, $H_{rw,m}$ is the water/air partition coefficient, $H_{sp,rw}$ is the soil-sorbed phase/soil-water partition coefficient, and D_a and D_w are the air and water molecular diffusivities, respectively. The air and water phase tortuosities, τ_a and τ_w , respectively, can be approximated by using the following empirical correlations (1984),

$$\tau_a = [(\epsilon_m + \epsilon_{rw}) / \epsilon_m]^{2.13} \quad (27)$$

$$\tau_w = [(\epsilon_m + \epsilon_{rw}) / \epsilon_{rw}]^{2.13} \quad (28)$$

The air phase and water phase diffusion coefficients are calculated using the Chapman-Enskog method and the Wilke-Chang correlation (1979), respectively. Finally, the effective diffusivity in the sediment is determined from an equation similar to Eq. 26 with D_m replaced by D_{sd} , and the subscript s in Eqs. 30-32 replaced by sd .

A.2.5 Meteorological Parameters

Temporal variations in weather conditions such as changes in temperature and changes in precipitation are incorporated in the SMCM model. For example, the daily ambient temperature in the region under consideration is approximated from the average monthly ambient temperatures using the method of Jamison (1982). The required input data are thus reduced to 12 monthly values for each year of simulation.

The SMCM model has a rain generation module which can generate rainfall events randomly distributed for each month with specified levels of rainfall intensity, duration and total monthly rainfall throughout the simulation time. The required input data for rainfall simulations are therefore reduced to the amount of total rainfall (mm) for each month and the number of events of a given intensity for each month. In the SMCM approach, since data for a particular year or monthly averages for multiple years can be used, rainfall distributions which are characteristic of the region but with a degree of randomness from year to year, can be handled.

A.3 Source Types and Other Simulation Scenarios

In order to provide for a variety of scenario simulations, four types of uniformly distributed (UD) sources (non-repetitious constant, non-repetitious sinusoidal, constant repetitious, and sinusoidal repetitious) were considered for the air and water compartments, whereas only a non-repetitious constant UD source was applied for the soil and sediment compartments. The non-repetitious constant source is applicable for scenarios where the pollutant is released with a constant source strength, and it allows the source strength to be turned on at any given time and turned off at any time before the end of simulation. The non-repetitious sinusoidal source can be applied for scenarios where chemical emission follows the pattern of sinusoidal variation such as chemicals emitted from industrial plumes. In such a case, the SMCM application would only be appropriate if multiple plumes exist over an area of sufficient size to treat the point sources as distributed sources. The constant repetitious source allows the source strength to be turned on and turned off sequentially. Finally, the sinusoidal repetitious source provides for modeling of diurnal or seasonal variation such as the emissions of pollutants from automobile traffic. In this latter example, the average source strength may represent the average daily pollutant emission rate from traffic, whereas the source amplitude represents the maximum (or minimum) variation from the average source strength.

The SMCM model can also be used to estimate the source strength given spatial-averaged monitored concentrations. The SMCM model can also simulate scenarios without source emissions by setting the source strength to zero. Such scenarios may be of interest in modeling the distribution of pollutants in areas that are initially polluted. For such scenarios, sufficiently high initial concentrations (above background) are required as input for the appropriate SMCM compartments. The SMCM model output include the concentrations in the various compartments as a function of time, the percent of the total mass of the chemical present in each compartment, and the chemical transfer rates from one medium to another. Details of the numerical algorithms of the SMCM model can be found elsewhere (Cohen et al., 1990).

APPENDIX B
EMISSION INDEX AND EMISSION HAZARD INDEX
FOR SELECTED PETROLEUM HYDROCARBONS

Spreadsheet for Prioritizing the Study Chemicals.

status: yes indicates that no RfD has been assigned but ill health effects have been observed

inc missing vapor pressure data

* used very approximate vapor pressure, need to revise if compound is included on list

NOTE: A volatility index of unity indicates that the compound exists as a gas under normal ambient conditions.

The values listed for the volatility index, emission index, and the emission hazard index are approximate values.

The indices should be used only for ranking petroleum hydrocarbons with respect to air emissions.

Formula	Status	Compound	Concentration mg/L	MW, g/mol	Volatility Index	Emission Index	Emission Hazard Index = Emission Index times		Potency Factor, kg-day/mg high	RfD, mg/kg/day low
							High PF	Inv Low RfD		
	inc	(2-Methylbutyl)benzene	183.4							
C H4		Methane	75.3	16	1.0E+00	8.36E-02				
C2 H6		Ethane	432.3	30	1.0E+00	4.80E-01				
C3 H8		Propane	2474.9	44	1.0E+00	2.75E+00				
C4 H10		n-Butane	3395.3	58	1.0E+00	3.77E+00				
C4 H10		isobutane	3123.3	58	1.0E+00	3.47E+00				
C5 H10		Cyclopentane	1293.1	70	3.9E-01	5.67E-01				
C5 H12		isopentane (2-Methylbutane)	7232.9	72	7.9E-01	6.34E+00				
C5 H12		n-Pentane	8486.9	72	5.5E-01	5.21E+00				
C6 H6		Benzene	2990.0	78	9.7E-02	3.23E-01	9.38E-03	yes	0.029	APP A
C6 H12		Cyclohexane	4801.5	84	1.1E-01	5.97E-01				
C6 H12		Methylcyclopentane	4304.0	84	1.7E-01	7.93E-01				
C6 H14		Dimethylbutane	1.4	86	3.5E-01	5.27E-04				
C6 H14		n-Hexane	2756.0	86	1.6E-01	4.79E-01		7.99E+00		0.08
C6 H14		2-Methylpentane	37.9	86	2.7E-01	1.15E-02				
C6 H14		3-Methylpentane	13.5	86	2.4E-01	3.65E-03				
C7 H8		Toluene	6395.8	92	3.4E-02	2.43E-01		1.22E+00		0.2
C7 H14		1,1-Dimethylcyclopentane	386.0	98	4.5E-02	1.92E-02				
C7 H14		cis-1,2-Dimethylcyclopentane	6.7	98	4.5E-02	3.35E-04				
C7 H14		trans-1,2-Dimethylcyclopentane	1737.0	98	4.5E-02	6.63E-02				

Formula	Status	Compound	Concentration, mg/L	MW, g/mol	Volatility Index	Emission Index	Emission Hazard Index = Emission Index times		Potency Factor, kg-day/mg high	RfD, mg/kg/day low
							High PF	Inv Low RfD		
C7 H14		Ethylcyclopentane	791.9	98	4.5E-02	3.94E-02				
C7 H14		Methylcyclohexane	8521.0	98	5.0E-02	4.73E-01				
C7 H16		2,2-Dimethylpentane	0.2	100	7.8E-02	1.95E-05				
C7 H16		n-Heptane	20.1	100	5.3E-02	1.18E-03				
C8 H16		cis-1,2-Dimethylcyclohexane	492.2	112	1.8E-02	8.63E-03				
C8 H16		trans-1,2-Dimethylcyclohexane	1138.7	112	2.4E-02	3.00E-02				
C8 H16		cis-1,3-Dimethylcyclohexane	2354.6	112	2.6E-02	6.88E-02				
C8 H16		trans-1,4-Dimethylcyclohexane	791.3	112	2.8E-02	2.43E-02				
C8 H16		1-Ethyl-1-methylcyclopentane	57.9	112	2.1E-02	1.35E-03				
C8 H16		cis-1-Ethyl-2-methylcyclopentane	86.9	112	2.1E-02	2.03E-03				
C8 H16		trans-1-Ethyl-2-methylcyclopentane	781.7	112	2.1E-02	1.83E-02				
C8 H16		cis-1-Ethyl-3-methylcyclopentane	260.6	112	2.1E-02	6.09E-03				
C8 H16		trans-1-Ethyl-3-methylcyclopentane	270.2	112	2.1E-02	6.32E-03				
C8 H16		Isopropylcyclopentane	125.5	112	2.1E-02	2.93E-03				
C8 H16		n-Propylcyclopentane	2422.2	112	2.1E-02	5.67E-02				
C8 H16		3-Trimethylcyclopentane	0.4	112	2.1E-02	8.87E-06				
C8 H16		4-Trimethylcyclopentane	0.4	112	2.1E-02	8.87E-06				
C8 H16		trans,cis-1,2,3-Trimethylcyclopentane	656.2	112	2.1E-02	1.53E-02				
C8 H16		trans,cis-1,2,4-Trimethylcyclopentane	511.5	112	2.1E-02	1.20E-02				
C8 H18		Methylheptane	1.3	114	4.2E-02	6.02E-05				
C8 H18		n-Octane	3.0	114	1.4E-02	4.78E-05				
C9 H8		Indene	19.3	116	2.0E-03	4.23E-06				
C9 H12		meta-Ethyltoluene	1100.1	120	5.4E-03	6.59E-03				
C9 H12		ortho-Ethyltoluene	1215.9	120	4.6E-03	6.22E-03				
C9 H12		para-Ethyltoluene	617.6	120	5.3E-03	3.61E-03				
C9 H12		Isopropylbenzene	269.5	120	5.7E-03	1.82E-03				
C9 H12		n-Propylbenzene	704.5	120	5.7E-03	4.43E-03				
C9 H12		1,2,3-Trimethylbenzene	984.3	120	2.2E-03	2.45E-03				
C9 H12		1,2,4-Trimethylbenzene	1756.3	120	3.4E-03	6.68E-03				
C9 H12		1,3,5-Trimethylbenzene	1426.2	120	4.6E-03	7.31E-03				
C9 H18		n-Butylcyclopentane	415.0	126	4.7E-03	2.18E-03				
C9 H18		sec-Butylcyclopentane	665.9	126	4.7E-03	3.50E-03				
C9 H18		cis-1-Ethyl-3-methylcyclohexane	658.9	126	4.7E-03	4.52E-03				
C9 H18		trans-1-Ethyl-3-methylcyclohexane	627.3	126	4.7E-03	3.30E-03				

Formula	Status	Compound	Concentration, mg/L	MW, g/mol	Volatility Index	Emission Index	Emission Hazard Index = Emission Index times		Potency Factor, kg-day/mg mg/kg/day	RID, low
							High PF	Inv Low RID		
C9 H18		trans-1-Ethyl-4-methylcyclohexane	530.8	128	4.7E-03	2.79E-03				
C9 H18		isobutylcyclohexane	96.5	128	4.7E-03	5.08E-04				
C9 H18		isopropylcyclohexane	357.1	128	4.7E-03	1.88E-03				
C9 H18		1-Methyl-1-ethylcyclohexane	173.7	128	4.7E-03	9.14E-04				
C9 H18		1-Methyl-3-propylcyclopentane	521.1	128	4.7E-03	2.74E-03				
C9 H18		n-Propylcyclohexane	1235.2	128	4.7E-03	6.50E-03				
C9 H20		n-Nonane	0.7	128	7.4E-03	5.92E-06				
C10 H8		Naphthalene	791.3	128	6.6E-05	5.78E-05	0.00E+00	1.45E-02		0.004
C10 H14		n-Butylbenzene	241.3	134	1.1E-03	2.82E-04				
C10 H14		1,2-Diethylbenzene	115.6	134	9.2E-04	1.19E-04				
C10 H14		1,3-Diethylbenzene	193.0	134	1.2E-03	2.94E-04				
C10 H14		1,2-Dimethyl-3-ethylbenzene	154.4	134	1.1E-03	1.81E-04				
C10 H14		1,2-Dimethyl-4-ethylbenzene	453.6	134	1.2E-03	5.97E-04				
C10 H14		1,3-Dimethyl-2-ethylbenzene	144.8	134	1.1E-03	1.69E-04				
C10 H14		1,3-Dimethyl-4-ethylbenzene	530.8	134	1.2E-03	6.98E-04				
C10 H14		1,3-Dimethyl-5-ethylbenzene	453.6	134	1.2E-03	5.97E-04				
C10 H14		1,4-Dimethyl-2-ethylbenzene	299.2	134	1.2E-03	3.94E-04				
C10 H14		isobutylbenzene	241.3	134	3.0E-03	8.11E-04				
C10 H14		1-Methyl-2-isopropylbenzene	67.6	134	9.2E-04	6.91E-05				
C10 H14		1-Methyl-4-isopropylbenzene	164.1	134	1.3E-03	2.40E-04				
C10 H14		1-Methyl-2-propylbenzene	207.1	134	9.2E-04	9.28E-04				
C10 H14		1-Methyl-3-propylbenzene	897.5	134	1.2E-03	1.18E-03				
C10 H14		1-Methyl-4-propylbenzene	289.5	134	1.3E-03	4.23E-04				
C10 H14		1,2,3,4-Tetraethylbenzene	638.9	134	2.6E-04	1.86E-04				
C10 H14		1,2,3,5-Tetramethylbenzene	366.7	134	2.6E-04	1.07E-04				
C10 H14		1,2,4,5-Tetramethylbenzene	212.3	134	1.3E-04	3.10E-05				
C10 H20		sec-Butylcyclohexane	1022.9	140	6.6E-03	7.48E-03				
C10 H20		tert-Butylcyclohexane	415.0	140	6.6E-03	3.03E-03				
C10 H20		1,3-Dimethyl-2-ethylcyclohexane	675.5	140	6.6E-03	4.94E-03				
C10 H20		1-Ethyl-2,3-dimethylcyclohexane	125.5	140	6.6E-03	9.17E-04				
C10 H20		isobutylcyclohexane	443.9	140	6.6E-03	3.24E-03				
C10 H20		cis-1-Methyl-4-isopropylcyclohexane	202.7	140	6.6E-03	1.48E-03				
C10 H20		trans-1-Methyl-4-isopropylcyclohexane	212.3	140	6.6E-03	1.55E-03				
C10 H20		cis-1-Methyl-3-propylcyclohexane	395.7	140	6.6E-03	2.89E-03				

Formula	Status	Compound	Concentration, mg/L	MW, g/mol	Volatility Index	Emission Index	Emission Hazard Index = Emission Index times High PF	Low PF	Potency Factor, kg-day/mg mg/kg/day	RD, mg/kg/day
C10 H22		Decane	32436.5	142	2.4E-03	8.54E-02				
C11 H10		1-Methylnaphthalene	678.2	142	3.9E-04	3.65E-04				
C11 H10		2-Methylnaphthalene	1234.5	142	3.9E-04	5.50E-04				
C11 H16		1-Methyl-8-ethylbenzene	86.9	146	7.9E-04	7.62E-05				
C11 H16		1-Methyl-4-ethylbenzene	87.9	146	6.6E-04	4.23E-05				
C11 H24		Heptadecane	30173.6	156	5.3E-04	1.76E-02				
C12 H6	no	Acenaphthylene	9.7	152		0.00E+00		yes	APP A	
C12 H6 O	no	Dibenzofuran	67.6	166		0.00E+00				
C12 H18		1,3,5-Trimethylbenzene (mesitylene)	135.1	162	2.6E-04	3.95E-05				
C12 H24	no	trans-1-Methyl-2-(4-methylpentan-2-yl)pentane	212.3	168		0.00E+00				
C12 H26		Dodecane	35678.0	170	2.6E-04	1.64E-02				
C13 H10		Fluorene	86.9	166	1.1E-05	1.82E-06		2.54E-05	0.04	
C13 H14		C3 alkyl Naphthalenes	2219.5	170	3.9E-05	9.72E-05				
C13 H26		Tridecane	42775.6	184	1.1E-04	5.00E-03				
C14 H10		Anthracene	9.7	178	2.6E-06	2.62E-10		9.41E-10	0.3	
C14 H10		Phenanthrene	183.0	178	2.6E-06	5.94E-07		yes	APP A	
C14 H16		C4 alkyl Naphthalenes	1061.5	184	3.9E-05	4.86E-05				
C14 H30		Tetradecane	46566.3	198	2.6E-05	1.45E-03				
C15 H12		Methyl phenanthrenes	772.0	182	2.6E-06	2.26E-06				
C15 H32		Pentadecane	49757.6	212	6.6E-06	3.56E-04				
C16 H10		Fluoranthene	9.7	202	2.6E-06	2.82E-08		7.05E-07	0.04	
C16 H10		Pyrene	9.7	202	2.6E-06	2.82E-08		9.41E-07	0.03	
C16 H34		Hexadecane	39637.1	226	2.6E-06	1.16E-04				
C17 H36		Heptadecane	62902.3	240	9.2E-07	5.41E-05				
C18 H12		Benz[a]anthracene (1,2-Benzanthracene)	9.7	228	2.6E-06	2.82E-10	B2	yes	B2	APP A
C18 H12		Chrysene	36.6	228	2.6E-06	1.13E-07	B2	yes	B2	APP A
C18 H36		Octadecane	59804.2	254	1.3E-06	6.80E-05				
C19 H14		Methyl chrysene	36.6	242	2.6E-06	1.13E-07				
C19 H40		Nonadecane	66302.4	268	3.9E-07	2.89E-05				
C20 H12		Benzo[b]fluoranthene (3,4-Benzofluoranthene)	36.6	262	2.6E-06	1.13E-07	B2		B2	
C20 H12		Benzo[k]fluoranthene (10,11-Benzofluoranthene)	19.3	262	2.6E-06	6.94E-08	B2	yes	B2	APP A
C20 H12		Benzo[j]fluoranthene (11,12-Benzofluoranthene)	48.3	258	2.6E-06	1.41E-07				
C20 H12		Benzo[e]pyrene	9.7	262	2.6E-06	2.82E-08	3.24E-07	yes	11.5	APP A
C20 H167		7,12-Dimethylbenz[a]anthracene	29.0	266	2.6E-06	6.46E-10	B2	yes	B2	APP A

Formula	Status	Compound	Concentration, mg/L	MW, g/mol	Volatility Index	Emission Index	Emission Hazard Index = Emission Index times		Potency Factor, kg-day/mg high	RfD, mg/kg/day low
							High PF	Inv Low RfD		
C21 H16	ino	3-Methylcholanthrene	29.0	268		0.00E+00	B2	yes	B2	APP A
C22 H12	*	Benzo[ghi]perylene	38.6	276	2.6E-06	1.13E-07		yes		APP A
C22 H12	*	Indeno[1,2,3-cd]pyrene	135.1	277	2.6E-06	3.95E-07	B2	yes	B2	APP A
C22 H14	*	Dibenz[a,h]anthracene (1,2:5,6-Dibenzanthracene)	212.3	278	2.6E-06	6.21E-09	B2	yes	B2	APP A
C22 H14	*	Dibenzo[a,e]pyrene (1,2:4,5-Dibenzopyrene)	96.5	278	2.6E-06	2.82E-07				
C22 H14	*	Dibenzo[a,h]pyrene	96.5	278	2.6E-06	2.82E-07				
C22 H14	*	Dibenzo[a,i]pyrene	96.5	278	2.6E-06	2.82E-07				
C22 H14	*	Dibenzo[a,j]pyrene	96.5	278	2.6E-06	2.82E-07				

Study says Valdez at risk

By Susan Price
Valdez Vanguard

People kept piling in, scrambling for chairs in a council chambers packed wall-to-wall with people a week ago. After a Regional Citizens' Advisory Council board member recited the UCLA professor's extensive academic background, the professor joked:

"You've heard about my life.

Now I'm going to tell you about yours."

Yoram Cohen — whose past includes a doctorate, more than 60 articles, numerous reports, serving on various professional journal editorial boards, developing pollution software that's used in 20 universities, plus writing a textbook — began to talk about airborne hydrocarbons, specifically benzene, in Valdez.

He explained that his six-month project — commissioned by RCAC's Terminal and Environmental Monitoring Committee for \$42,200 — was only an overview of existing literature and data on the airborne chemicals from the Alyeska terminal. He was to outline the pollution issues, estimate the exposure to Valdez residents, identify where the gaps in information are, and recommend what needs to be done.

After a cautious preface, Cohen said a number of things in his Thursday afternoon presentation that kept some people on the edge of their chairs.

He said people in Valdez have a 1-in-20,000 risk of getting cancer in a 70-year life span. He explained how the U.S. Environmental Protection Agency uses 1-in-a-million as an acceptable level.

He explained the chances of obtaining cancer from benzene is highest for babies and young children. The risk tends to level off on a slightly downward slope. He said in his 3/4-inch report the chances for cancer from benzene are greater for

smokers and those that breathe passive smoke.

Cohen explained how when benzene enters the air in Valdez, 99 percent of it leaves Valdez, and that from what's left, 96 percent of goes into the air, 3.9 percent goes into the water and .05 percent goes into the soil.

It's like filling a swimming pool, he said later. A certain amount will keep flowing over. But then a specific amount stays in the pool. Of what's left in the pool, 96 percent of it goes into the air. Cohen said either the swimming pool is very small, or more likely, it's a "very large flow" into the pool.

The professor explained how Valdez compares with other cities. Not Cordova, or Seward, or Anchorage, but places like Los Angeles; Washington, D.C.; Miami; Boston and St. Louis.

He showed graphs to pinpoint the Valdez highs and lows of the BETX chemicals, focusing on benzene. (BETX is comprised of benzene, ethylbenzene, toluene, xylenes and normal-hexane. The latter four are not carcinogens and fall significantly below the level the EPA says adverse health affects may occur.)

Some people said later they found the graphs a bit startling. For benzene, the Valdez high was above the Los Angeles and Miami highs and Boston average, the same as the Washington high and below the St. Louis high.

The Valdez low estimates came in slightly above the Los Angeles low and above the Washington, St. Louis and Miami low. It fell slightly under the Boston average.

The Valdez high for normal-hex-

ane, which is not a carcinogen, came in clear above the numbers for Washington, Los Angeles, St. Louis, Miami and Boston.

The researcher said the main issue is benzene in the air; hydrocarbons in fish and vegetable are minuscule by comparison.

Cohen's report is particularly interesting because Alyeska subcontractors are working on the company's own studies.

One is based on the data collected from four air monitoring stations throughout Valdez to determine the level of benzene and other volatile organic compounds, as well as criteria pollutants (ozone, carbon monoxide, oxides of sulfur and nitrogen and others).

Right now, the VOCs, including benzene, from the terminal aren't

regulated. But the EPA is working to formulate those regulations and should be finished by November, an Alyeska spokeswoman said.

A second health risk study also being done by Alyeska contractors examines Valdez residents' exposure to benzene. It's sometimes called the "vest study" because 60 residents were fitted with vests that had sampling tubes on the lapel to siphon air for two 24-hour periods, one in August 1990 and another last February.

But to make it more interesting, the EPA is in the midst of deciding whether or not Alyeska will need to install a \$200 million hard piping vapor recovery system, which would cut hydrocarbon emissions from tanker loading by at least 95 percent, a TOEM official said.

Hard piping — called "hard" because it's fixed in place and is permanent — captures toxic vapors that normally escape into the atmosphere while tankers take on crude. If the EPA requires it in November, the system would have to be in place within two years. An Alyeska spokeswoman said the company is working on the engineering design work now.

He said if the treatment facility is not biodegrading BETX to the extent Alyeska claims, then it could be a major source of additional emissions.

The next day, an article that appeared in the Anchorage Times quoted Marnie Isaacs, Alyeska's spokeswoman, as saying the report's risk assessment was "unprofessional." That started things rolling.

Valdez called major air polluter

Alaska port blamed for 46% of oil tanker emissions in US

By William P. Coughlin
GLOBE STAFF

The loading of huge tankers with Alaskan crude oil at Valdez may be responsible for 46 percent of all airborne petroleum hydrocarbons emitted at oil tanker terminals nationwide, an Alaskan watchdog committee says.

The group and other studies found air pollution at Valdez close to that in heavily polluted urban areas and much higher than in Boston.

The Valdez citizen group, the Terminal Operations and Environmental Monitoring Committee, was set up under the 1990 Oil Pollution Act to monitor oil transportation and operations of Alyeska Pipeline Service Co.

Alyeska, the oil industry consortium that runs the terminal, has been under congressional scrutiny for reported environmental violations since the 1989 Exxon Valdez spill.

On Friday, the Valdez citizens

panel revealed findings of two American Petroleum Institute-sponsored conclaves in January, along with an independent study on effects of toxic airborne hydrocarbons at Valdez by Yoram Cohen, a member of the National Research Council and a specialist on pollutants.

Joe Bridgeman, the Valdez committee coordinator, said the citizens group also reported that Alyeska unleashes 94.7 million pounds of volatile organic compounds, including 900,000 pounds of carcinogenic benzene, into the air each year.

The group said Alyeska asked the Environmental Protection Agency in August to exempt the tanker terminal from expected federal regulations under the Clean Air Act that would require costly vapor controls at tanker terminals.

The American Petroleum Institute conferees were told by the EPA's David Markwood, an environmental engineer in Durham, N.C., that, "of a nationwide total of 98,000 metric tons," or 202,972,000 pounds, "emitted from all marine oil loading docks each year, Alyeska releases about 48,000 metric tons. That's 46 percent of the total. It's a big number," he said.

Two Alyeska representatives told the Petroleum Institute meeting that the problems are manageable and that a suggested \$125 million vapor control system can be installed, Bridgeman said.

But Bridgeman and Greg Winter, a member of the citizens group who attended the institute sessions, said company officials have said in recent interviews that the emissions pose no health problem.

In his separate study of atmospheric pollutants conducted for the Valdez group, Cohen found that concentrations of certain hydrocarbon toxins released into the air over tiny, isolated Valdez — population, 4,068 — is comparable to that found in urban areas such as Los Angeles.

Cohen said average benzene concentrations at Valdez measure between 1.2 and 7.8 parts per billion, compared with 5 parts per billion in Los Angeles and 1 to 2 in Boston.

Cohen's report also challenged the trustworthiness of industry data. "There is a need to establish confidence in Alyeska's ambient air monitoring data for hydrocarbons," the report said.

"The major statement here," Cohen said in an interview, "is that as far as hydrocarbons are concerned ... it is surprising to find atmospheric levels of chemicals at Valdez are in the range of levels found in numerous urban atmospheres. ... It is not a pristine place."

But, he said, unlike in urban areas, "people at Valdez have an opportunity to control it."

*certificates
Peer Review*



Expert says Benzene levels very high

Valdez is comparable with Lower 48 cities

By Pat Lynn

Editor, *The Pioneer*

CITY HALL -- A pollution expert from the University of Los Angeles, California, says the benzene levels in Valdez are comparable and often higher than found in Lower 48 cities, including his hometown of Los Angeles which is notorious for its air pollution.

Dr. Yoram Cohen's study suggests that Valdez residents are subject to high levels of health-threatening pollution, most of it generated from the loading of oil tankers at the Alyeska terminal and from the terminal's ballast water treatment plant.

Much of the study focuses on the annual release of 450 tons of benzene, a cancer-causing agent, that poses a cancer risk of 1-in-

20,000 or five times higher than the 1-in-100,000 viewed as acceptable risk from any single chemical by the U.S. Environmental Protection Agency.

"The conclusion is that concentration of BETX (compounds) are typical of what would find in other rural areas. So the notion is that the Port of Valdez, as far as BETX is concerned, is neither rural area nor pristine," Dr. Cohen told the audience.

"What does it mean to you?" he asked the audience. "It's up to the residents of Valdez to determine whether that is acceptable or unacceptable."

"What does it mean for me in Los Angeles. It means I don't have to go all the way to Valdez to breathe clean air," he told his audience in the City Council Chambers.

Benzene levels in Valdez, he said, are comparable and sometimes exceed those in Los Angeles, Boston, Miami and Washington, D.C.

(See: *Benzene*, page 7)



(Photo by PATTY GINSBERG)

DR. YORAM COHEN gives his benzene report at the RCAC Annual Meeting. City Attorney Bill Walker listens attentively.

Benzene, contd.

(from page 1)

Dr. Cohen's conclusions with respect to terminal pollutants may be difficult for Valdez residents to assess since benzene emissions are among the compounds not regulated by the U.S. Environmental Protection Agency at the terminal in the absence of a health-risk study to determine their impact on Valdez residents.

Dr. Cohen is an Associate Professor in Chemical Engineering at UCLA. He was contracted for \$40,000 to conduct the air quality study in Valdez. His report was released here last Thursday to coincide with the annual meeting of the RCAC -- the Regional Citi-

zens Advisory Committee which provides oversight of Alyeska's operations.

His study is based on existing data largely supplied by Alyeska which is conducting its own air quality study, the results of which are expected by this June. Dr. Cohen did not conduct any independent field tests in Valdez.

Dr. Cohen's conclusions drew a skeptical response from Alyeska spokeswoman Marnie Isaacs. She termed the study "unprofessional" and said Dr. Cohen's claim of a 1-in-20,000 cancer risk factor "an extraordinarily unprofessional statement without the

data."

Alyeska is under pressure from the state Department of Environmental Commission to bring its tanker-loading pollution emissions under control. It's now estimated that as many as 43,000 tons of hydrocarbons are emitted into the air annually from tanker loadings.

One suggestion, albeit a very costly one, is to construct a vapor recovery system that would, in effect, capture the hydrocarbons during tanker loadings and pipe them to Alyeska incinerators for burning.

Alyeska has estimated the cost of a vapor recovery system at \$200 million. Alyeska officials say they have misgivings about such a system not only on the grounds of cost but because they have a high potential for explosion.

SCOMM

78:17

Sam-

I think his statement
is a bit apples & oranges.

The amount going in
might be sufficient

that removal of 98-99 %
might still be insufficient.

The point is that:

- 1) "bugs" were clearly
documented to not be

The best available
technology which Alyeska
had promised as part of
its permit

- 2) effluent monitoring studies are
inconclusive according to
Alyeska, so how do they
know their facility is 99%
efficient?
giving

Sam- you should ask
Aljesta if the 98-99%
efficiency is based on
actual studies measuring
what goes in & what
comes out or if its based
on a model of how the
system is supposed to
work. jmk

in addition; without a
mass balance study
that statement cannot
be relied upon. direct
that question to
darr
lawn or riki ott

would some of
this debate be
resolved if
DEC was in charge
of monitoring?

question:

Harold Gerew just said
ballast transferred from
tankers is illegal but

industry has stated that
they are routine:

sanctioned under the

NPDES permit. would be
a good point to clarify.

That's what

SOATRAC does
for Sullivan

(monitoring) -

maybe ~~TRAC~~ TRAC

or the Citizen's
Oversight Council

s/b in charge.

3). isn't it cumbersome to
have to judge each
Case? will they
try to replace the
current process w/
a more routine
practice?

i think a main point
that needs to be
brought out is that
if the Ballast water
treatment can handle
the transfers, washings, &
sludge, it doesn't matter
if they save money

not disposing in
portland or wherever.
if the facility is
inadequate or not
sufficiently monitored,
then it is a problem.