

**DESIGNATION OF NAPHTHALENE AS A CARCINOGEN:  
RISK ASSESSMENT FOR INHALATION EXPOSURE PATHWAYS  
AT HAZARDOUS WASTE SITES**

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Vapor Intrusion to Indoor Air ", February 2005

[http://www.dtsc.ca.gov/ScienceTechnology/HERD\\_POL\\_Eval\\_Subsurface\\_Vapor\\_Intrusion\\_interim\\_final.pdf](http://www.dtsc.ca.gov/ScienceTechnology/HERD_POL_Eval_Subsurface_Vapor_Intrusion_interim_final.pdf)

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## **ABSTRACT**

California EPA has designated naphthalene as a carcinogenic toxic air contaminant with a unit risk factor of  $3.4 \text{ E-}5 \text{ (}\mu\text{g/m}^3\text{)}^{-1}$ . Naphthalene is a common pollutant in urban outdoor air. It is found in a number of products, notably diesel and other petroleum-based fuels. We present here a comparison of the impacts of naphthalene and benzene at a hazardous waste site (Site A) in California, where shallow groundwater is contaminated with wastes from refining petroleum and producing manufactured gas. Groundwater at 6-8 ft below ground surface contains benzene and naphthalene at concentrations up to 300 and 3,000  $\mu\text{g/L}$ , respectively. The Johnson & Ettinger vapor intrusion screening model, using groundwater as a source and assuming a vadose zone of coarse sandy soil, predicts indoor air concentrations of 30  $\mu\text{g/m}^3$  for benzene and 17.4  $\mu\text{g/m}^3$  for naphthalene. The Cal/EPA unit risk factor for benzene is  $2.9 \text{ E-}5 \text{ (}\mu\text{g/m}^3\text{)}^{-1}$ , similar to that of naphthalene. Thus, concentrations of naphthalene ten times those of benzene in shallow groundwater yield similar estimates of cancer risk in indoor air in a residential setting ( $2.4 \text{ E-}4$  vs.  $3.6 \text{ E-}4$ ). The U.S. EPA Reference Concentration (RfC) for benzene is ten times higher than that of naphthalene ( $30 \mu\text{g/m}^3$  vs.  $3 \mu\text{g/m}^3$ ), which yields hazard quotients for non-carcinogenic toxicity of 1 for benzene and 6 for naphthalene for exposures to modeled concentrations in indoor air above Site A. Although naphthalene is less easily mobilized than benzene into indoor air than monoaromatic compounds such as benzene, the relatively high unit risk factor and low RfC for naphthalene will probably increase its significance as a groundwater contaminant.

## **INTRODUCTION**

Naphthalene is a common pollutant in urban outdoor air and is found in a number of products, including diesel and certain other petroleum-based fuels. Naphthalene is also present as a contaminant at refineries and former manufactured gas plants (MGP) that utilized either petroleum or coal as a feedstock. The Office of Environmental Health Hazard Assessment of California EPA recently designated naphthalene as a toxic air contaminant with a unit risk factor of  $3.4 \text{ E-}5 \text{ (}\mu\text{g/m}^3\text{)}^{-1}$ . Since naphthalene is commonly found at fuel sites and is moderately volatile, we investigated what impact the designation as a carcinogen would have on risk assessment at sites with naphthalene contamination where intrusion into indoor air is a consideration. Here we present a comparison of the impacts of naphthalene and benzene on indoor air risks at a hazardous waste site (Site A) in California, where shallow ground water is contaminated with refining petroleum and producing manufactured gas. Naphthalene is less water soluble and less volatile than benzene and other mono-aromatic compounds; however the common occurrence of naphthalene in fuels and MGP wastes, and its relatively high unit risk factor and low reference concentration will likely make it a significant soil and groundwater contaminant.

## **DISCLAIMER**

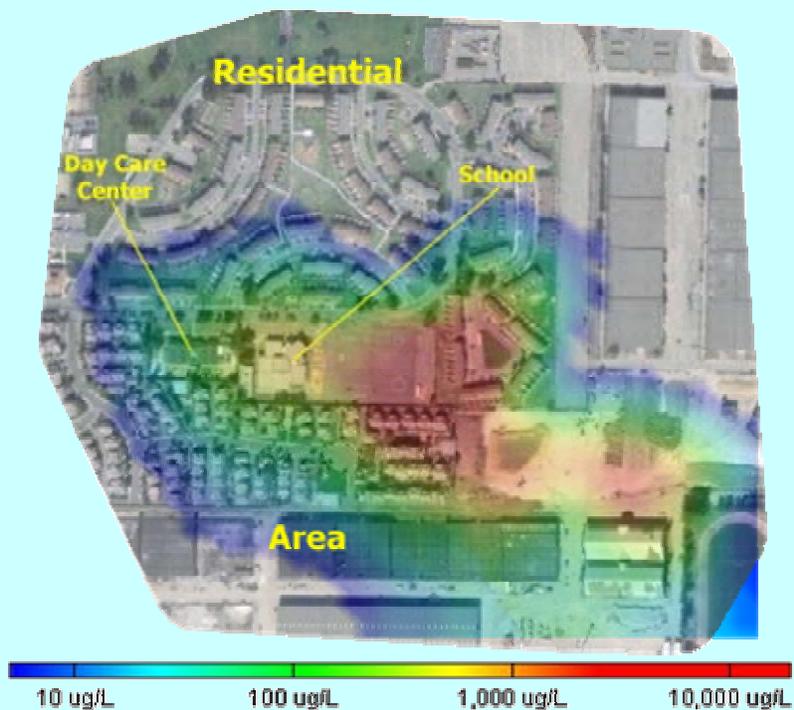
*The opinions and findings in this paper are those of the authors. They do not represent guidance or policy of the California Department of Toxic Substances Control or California Environmental Protection Agency.*

**PHYSICAL, CHEMICAL, AND TOXICOLOGICAL PROPERTIES****Benzene****Naphthalene**

<b>Molecular Weight MW (g/mol)</b>	<b>78</b>	<b>128</b>
<b>Boiling Point T<sub>b</sub> (°K)</b>	<b>353</b>	<b>491</b>
<b>Vapor Pressure at 25° C mm Hg</b>	<b>75</b>	<b>0.02</b>
<b>Water Solubility S (mg/L)</b>	<b>1,790</b>	<b>31</b>
<b>Henry's Law Constant H' (unitless)</b>	<b>0.227</b>	<b>0.0198</b>
<b>Organic Carbon Partition Coefficient K<sub>oc</sub> (cm<sup>3</sup>/g)</b>	<b>58.9</b>	<b>2,000</b>
<b>Reference Concentration RfC (mg/m<sup>3</sup>)</b>	<b>3 E -02</b>	<b>3 E -03</b>
<b>Unit Risk Factor URF (µg/m<sup>3</sup>)<sup>-1</sup></b>	<b>2.9 E -05</b>	<b>3.4 E -05</b>

## BENZENE PLUME

- Source concentration in groundwater = 300  $\mu\text{g/L}$
- Modeled indoor air concentration = 30  $\mu\text{g/m}^3$
- Indoor air risk = 3.6 E-4

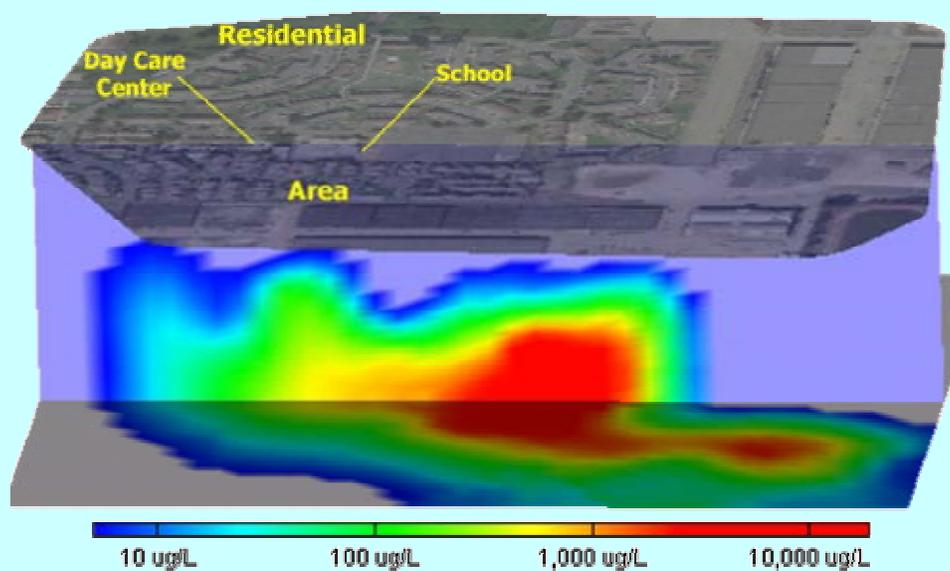


**Above:**

The horizontal slice through the benzene plume is taken at approximately 20 feet below ground surface.

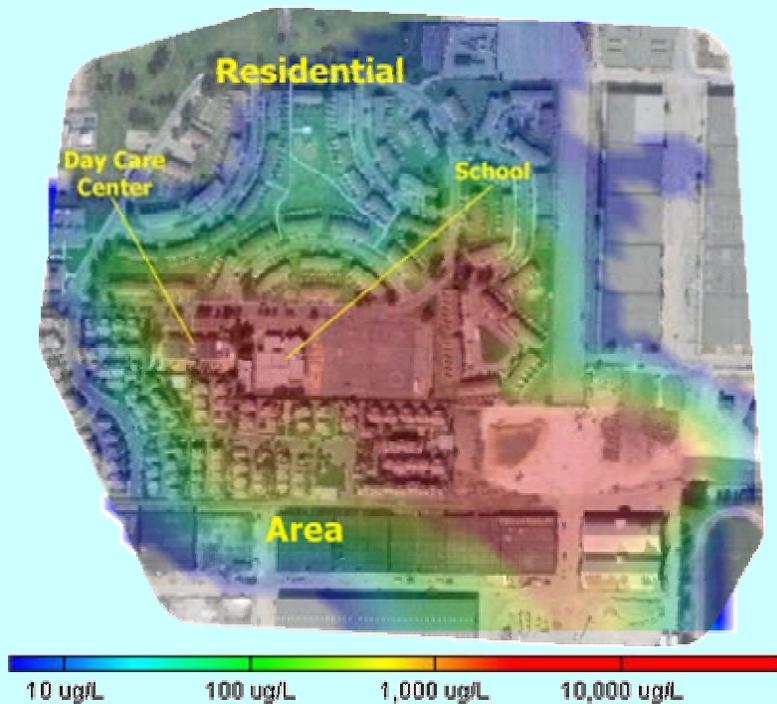
**Below:**

Vertical slice through the benzene plume taken at the school and day care facility. The horizontal slice is taken at approximately 20 feet below ground surface.



## NAPHTHALENE PLUME

- Source concentration in groundwater = 3,000  $\mu\text{g/L}$
- Modeled indoor air concentration = 17.4  $\mu\text{g/m}^3$
- Indoor air risk = 2.4 E-4

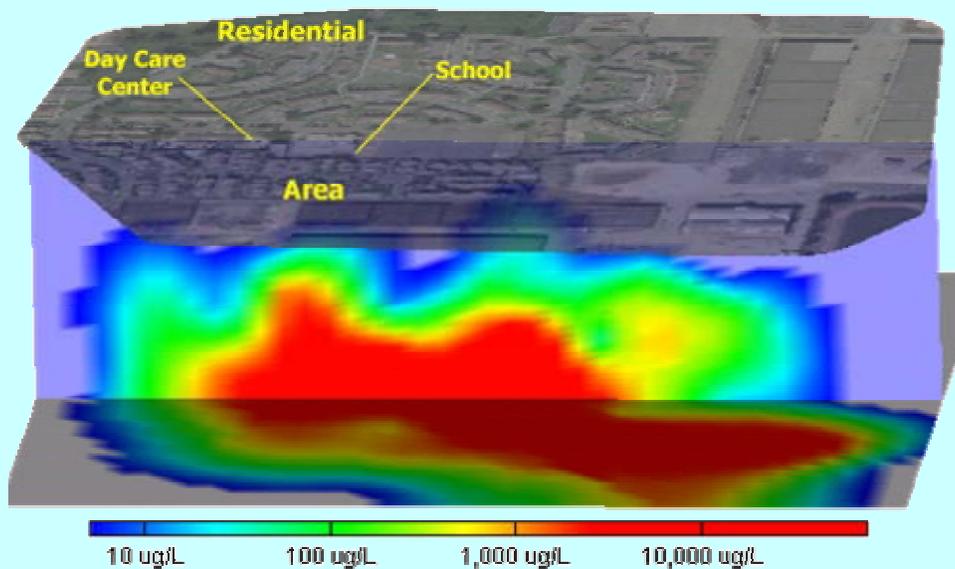


**Above:**

*The horizontal slice through the naphthalene plume is taken at approximately 20 feet below ground surface.*

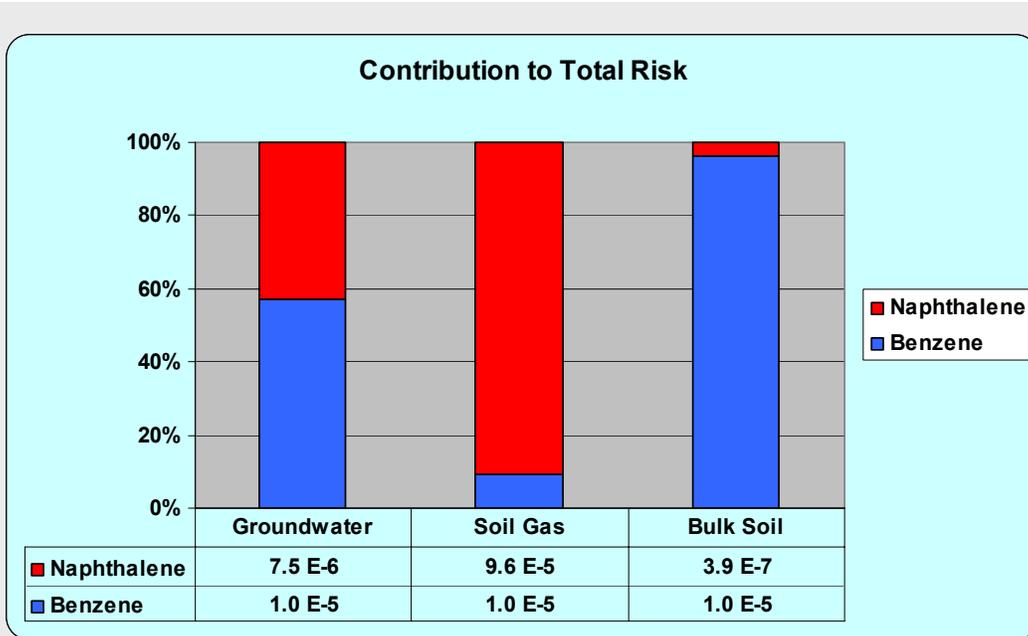
**Below:**

*Vertical slice through the naphthalene plume taken at the school and day care facility. The horizontal slice is taken at approximately 20 feet below ground surface.*



## JOHNSON & ETTINGER MODELING OF VAPOR INTRUSION

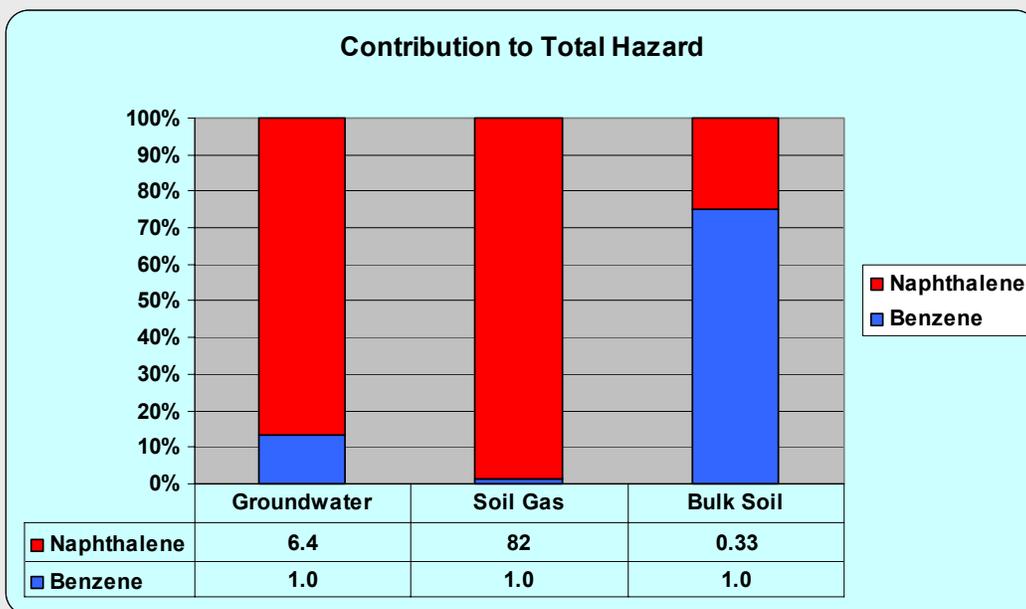
J&E model handles chemicals differently depending on the medium where the source term is located. Below we solve for the benzene concentrations yielding 1 E-5 risk or HQ = 1.0 in the indoor air pathway. Then we estimate risk and HQ for naphthalene at 10x the concentrations of benzene.



**Goundwater:** Naphthalene at 10x the concentration of benzene yields roughly equal risk.

**Soil Gas:** When soil gas is source term, J&E models diffusion and advection but not partitioning to soil organic carbon. Hence, higher concentrations of naphthalene move directly to indoor air.

**Bulk Soil:** Benzene dominates here because naphthalene binds more tightly to soil organic carbon.



**Goundwater:** Different from cancer risk because RfC for naphthalene is 1/10 that of benzene.

**Soil Gas:** Naphthalene dominates due to lower RfC and model not including binding to soil organic carbon.

**Bulk Soil:** Benzene dominates because naphthalene binds more tightly to soil organic carbon.

RESULTS OF JOHNSON & ETTINGER MODELLING OF VAPOR INTRUSION						
Source Term	RISK					
	Benzene			Naphthalene		
	Concentration	Units	Risk	Concentration	Units	Risk
Groundwater 200 cm bgs	7.1	µg/L	1.0 E-5	71	µg/L	7.5 E-6
Soil Gas 152.4 cm bgs	616	µg/m <sup>3</sup>	1.0 E-5	6,160	µg/m <sup>3</sup>	9.6 E-5
Bulk Soil 152.4 cm bgs	0.27	µg/kg	1.0 E-5	2.7	µg/kg	3.9 E-7
Source Term	HAZARD					
	Benzene			Naphthalene		
	Concentration	Units	Hazard	Concentration	Units	Hazard
Groundwater 200 cm bgs	265	µg/L	1.0	2,650	µg/L	6.4
Soil Gas 152.4 cm bgs	23,000	µg/m <sup>3</sup>	1.0	230,000	µg/m <sup>3</sup>	82
Bulk Soil 152.4 cm bgs	10.2	µg/kg	1.0	102	µg/kg	0.33

*NOTE: On the plume maps for Site A, indoor air concentrations, cancer risks, and non-cancer hazards for benzene and naphthalene were modeled at a soil temperature of 20° C. Results presented in the table above were modeled at 24° C.*

## CONCLUSIONS

1. Naphthalene can be a significant contaminant at some hazardous waste sites.
2. Naphthalene must be evaluated as a carcinogen at sites with subsurface aromatic contamination.
3. Tenfold lower RfC of naphthalene can dominate effects of benzene for non-carcinogenic effects.
4. Interactions of source medium with physical, chemical, and toxicological properties of benzene and naphthalene produce surprising outcomes when modeling the indoor air pathway with the Johnson and Ettinger equations.

## REFERENCES

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