Chapter 2. Risk Concepts

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Risk: the probability that a substance or situation will produce harm under specific conditions. Risk is a combination of two factors: the probability that an adverse even will o ccur and the consequences of the adverse event.

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Risk is a concept that used in the chemical industry and by practicing chemical engineers. The term risk is mult ifaceted and is used in many disciplines such as: finance (rate of return for a new plant or capitol project, process improvement, etc), raw materials supply (single source, back integration), plant design and process change (new design, impact on bottom l ine), and site selection (foreign, political stability). Though the term risk used in these disciplines can be discussed either qualitatively or quantitatively, it should be obvious that these qualitative or quantitative analyses are not fields (financial risk $\neq$ process change risk). This chapter will focus on the basic concept of environmental risk and risk assessment as applied to a chemical's manufacturing, processing, or use, and the impact of exposure to these chemicals on human health or the environme nt.

Risk assessment is a systematic, analytical method used to determine the probability of adverse effects. A common application of risk assessment methods is to evaluate human health and ecological impacts of chemical releases to the environment. Information collected from environmental monitoring or modeling is incorporated into models of human or worker activity and exposure, and conclusions on the likelihood of adverse effects are formulated. As such, risk assessment is an important tool for making deisions with environmental consequences. Almost always, when the results from environmental risk assessment are used, they are incorporated into the decision-making process along with economic, societal, technological, and political consequences of a prop osed action.

Chapter 2 Example Problem

Example 2.6-3: Reference-Dose

Reference doses are used to evaluate noncarcinogenic effects resulting from exposure to chemical substances. The reference dose (RfD) is the threshold of exposure below which protective mechanisms are believed to guard an oganism from adverse effects resulting from exposure over a substantial period of time. When valid human toxicological data are available, it forms the basis for the reference dose. When human exposure data are not available, the animal species believed to be most sensitive to the chemical of concern is used to determine the lowest level at which an adverse effect is detected, often called the LOAEL. Similarly the NOAEL is the greatest test-dose level at which no adverse effect is noted. When animal dat a are used the reference dose for human populations is

adjusted by extrapolation factors to convert the NOAEL or LOAEL into a human subthreshold or reference dose.

$$RfD = \frac{NOAEL}{F_A F_H F_S F_L F_D}$$

where F_A is an adjustment factor to extrapolate from animal to human populations;
F_H is an adjustment factor for differences in human susceptibility;
F_S is an adjustment factor used when data are obtained from subchronic studies;
F_L is an adjustment factor applied when the LOAEL is used instead of the NOAEL; and,
F_D is an adjustment factor applied when the data set is dubious or incomplete.

Each adjustment factor should account for the systematic difference between the two measures bridged by the extrapolation and incorporate a margin of safety in accordance with the uncertainty associated with the extrapolation. For example, in a 3-month subchronic study in mice, the NOAEL for tris(1,3-dichloro-2-propyl) phosphate was 15.3 mg/kg body weight per day; the LOAEL was 62 mg/kg at which dose abnormal liver effects were noted. *See* Kamata E. et al., Acute and subacute toxicity studies of tris(1,3 - dichloro-2-propyl) phosphate on mice. *Bull Natl Inst Hyg Sci*, 107:36-43 (1989). If each of the adjustment factors is equal to 10, the reference dose for this chemical is:

Using the NOAEL:

$$RfD = \frac{NOAEL}{F_A F_H F_S} = \frac{15.3 mg/kg-day}{10x10x10} = 0.015 mg/kg-day$$

Using the LOAEL:

$$RfD = \frac{LOAEL}{F_A F_H F_L F_S} = \frac{62 mg/kg-day}{10x10x10x10} = 0.0062 mg/kg-day$$

The lesser of the two values, 0.0062 mg/kg -day, would be selected as the reference dose for humans in this instance.

Chapter 2 Sample Homework Problem

1. A colleague has requested your advice on selection of a safe solvent for a photoresist. A photoresist consists of an acrylate monomer, polymeric binder, and photoinitiator applied to the surface of a copper-clad laminate or silicon wafer. After the solvent

evaporates, the photoresist is exposed to ultraviolet light through a mask containing the pattern to be etched on the circuit board or silicon wafer. When exposed, the resist polymerizes and becomes insoluble to the developer. The circuit board or silicon wafer is subsequently washed with the developer solution to remove unpolymerized photoresist exposing the pattern to be etched with acid into the copper metal or the silicon wafer. Your colleague has identified the following solvents as suitable for formulation of the photoresist.

Solvent	CAS Number	Vapor Pressure kPa at 25°C	OSHA Concentration Limit (parts per million)
Furfuryl alcohol	98-00-0	0.1	50
Diethylamine	109-89-7	30.1	25
Ethyl acetate	141-78-6	12.6	400
Monomethyl ether	109-86-4	1.3	25
Methyl ethyl ketone	79-93-3	12.1	200
n-butyl acetate	123-86-4	1.3	150

a. Using the OSHA Permissible Exposure Limit as a surrogate for relative hazard, a higher OSHA PEL connoting a lower hazard, rank these solvents from highest hazard to lowest.
b. Using the vapor pressure as a surrogate for the magnitude of worker exposure to the solvent vapors, rank these solvents from highest exposure potential to lowest.
c. Considering both hazard and exposure potential, which of these solvents would you recommend to your colleague for the photoresist solution?
d. What alternatives can be used to reduce the risk associated with solvents even further?