5. POTENTIAL FOR HUMAN EXPOSURE

5.1 OVERVIEW

2,3-Benzofuran is a colorless organic liquid with an aromatic odor. It is produced by the destructive distillation of coal, and may also be formed during processing of fossil fuels, such as coke production and coal gasification. Limited data indicate that 2,3-benzofuran may partition to soils and sediments from water, but the information available is insufficient to predict the environmental fate of this compound. Substantial bioconcentration in aquatic organisms is not expected based on the physical/chemical properties of 2,3-benzofuran.

Monitoring data on 2,3-benzofuran in environmental media are scarce. Potential human exposure to 2,3-benzofuran may occur by ingestion of foods treated with coumarone-indene resin; however, migration of 2,3-benzofuran from this resin has not been confirmed. Occupational exposure to 2,3-benzofuran may occur in several energy-related industries, and individuals living in the vicinity of hazardous waste sites at which this compound has been detected may also be exposed. The EPA has identified 1,177 NPL sites. 2,3-Benzofuran has been found at 5 of the sites evaluated for the presence of this chemical (View 1989). However, it is not known how many of the 1,177 NPL sites have been evaluated for 2,3-benzofuran. As more sites are evaluated by the EPA, the number may change. The frequency of the sites in the United States at which 2,3-benzofuran was found can be seen in Figure 5-1.

5.2 RELEASES TO THE ENVIRONMENT

2,3-Benzofuran may be released to the environment from production and use of 2,3-benzofuran-containing products, and from coke production, coal gasification, and oil-shale facilities. 2,3-Benzofuran is not listed on the SARA Section 313 Toxics Release Inventory (TRI).

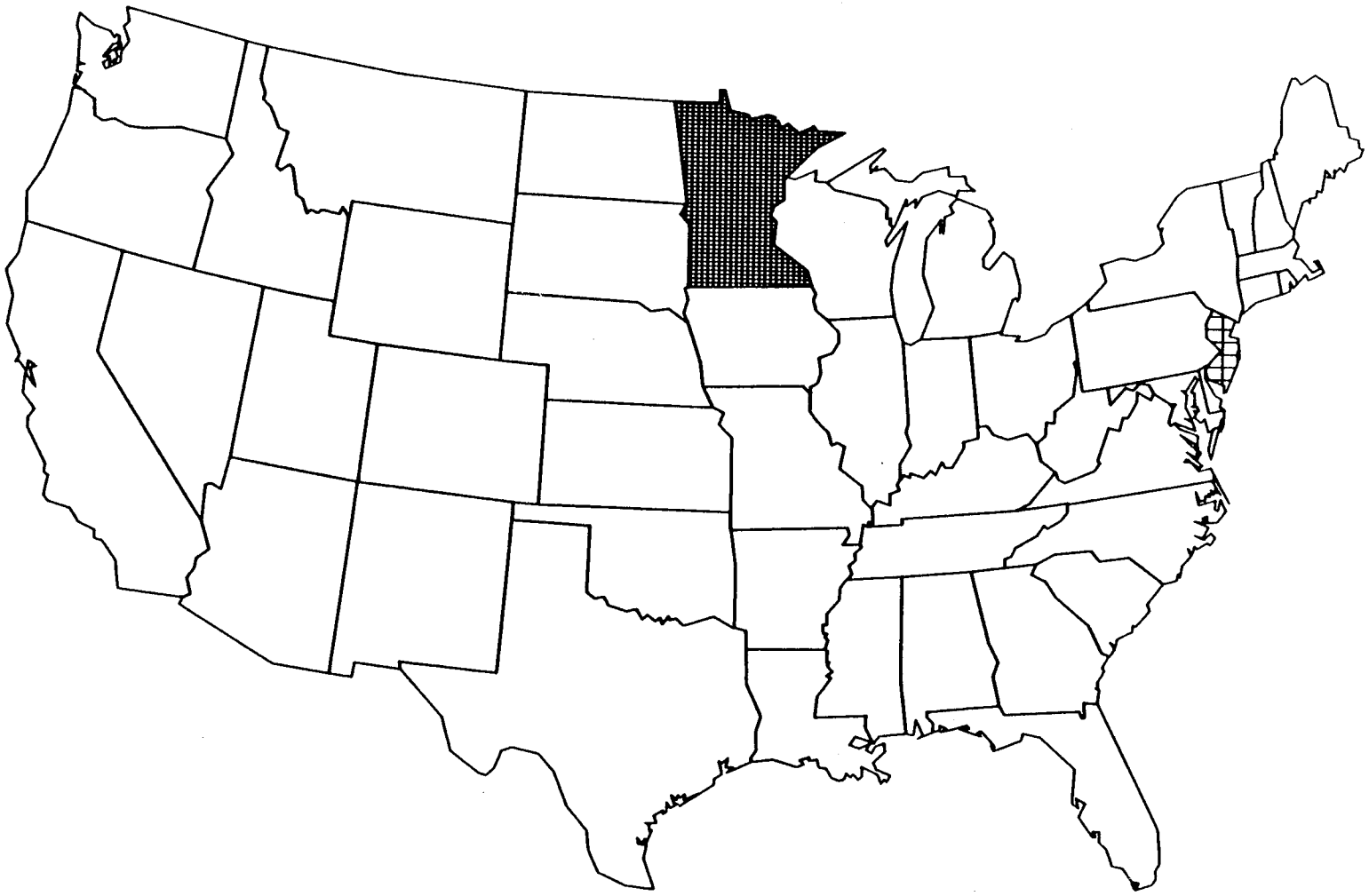
5.2.1 Air

Data on 2,3-benzofuran air emissions are sparse. No information was located regarding 2,3-benzofuran releases from production facilities. However, 2,3-benzofuran was detected in emissions from a Swedish floor finish used on domestic flooring (van Netten et al. 1988), and in emissions from the pyrolysis of silk (Junk and Ford 1980), and in combustor flue gas emissions from fluidized-bed coal combustion at a concentration of 900 ng/g (Hunt et al. 1982). Exhaust produced by an automobile burning simple hydrocarbon fuels contained 2,3-benzofuran at concentrations ranging from less than 0.1 to 2.8 ppm (Seizinger and Dimitriades 1972), but an analysis of air in a highway tunnel in use by both diesel- and gasoline-powered vehicles indicated no 2,3-benzofuran (Hampton et al. 1982).

5.2.2 Water

2,3-Benzofuran may be released to water from coal gasification facilities. 2,3-Benzofuran was detected in coal gasification facility effluents at concentrations ranging from 6 to 267 ppb, but was not detected

FIGURE 5-1. FREQUENCY OF NPL SITES WITH 2,3-BENZOFURAN CONTAMINATION *



* Derived from View 1989

(detection limit 0.1 ppb) in effluents from oil shale processing facilities (Pellizzari et al. 1979). 2,3-Benzofuran was also detected in 1 of 18 waste water concentrates (Lucas 1984). Data from the Contract Laboratory Program (CLP) Statistical Database indicate that 2,3-benzofuran was found at a concentration of 770 ppb in a groundwater sample, but was not found in any surface water samples, taken at one hazardous waste site (CLPSD 1990). It is not known how many hazardous waste sites have been evaluated for 2,3-benzofuran. Note that these data from the CLP Statistical Database represent frequency of occurrence and concentration information for NPL sites only.

5.2.3 Soil

2,3-Benzofuran was found at a concentration of 60 ppb in one soil/sediment sample taken at one hazardous waste site (CLPSD 1990). It is not known how many hazardous waste sites have been evaluated for 2,3-benzofuran. Note that these data from the CLP Statistical Database represent frequency of occurrence and concentration information for NPL sites only.

5.3 ENVIRONMENTAL FATE

5.3.1 Transport and Partitioning

No information was located on the transport and partitioning of 2,3-benzofuran in the atmosphere. Based on the high boiling point of 2,3-benzofuran, volatilization would be expected to be slow, but because the vapor pressure of the chemical is unknown, it is not possible to predict how 2,3-benzofuran will partition in the atmosphere.

2,3-Benzofuran is reported not to be soluble in water (Windholz et al. 1983). However, based on its octanol/water partition coefficient (Table 3-2), the solubility of 2,3-benzofuran may be on the order of 200 mg/L, using the empirical regressions of Hassett et al. (1983) for hydrophobic organic chemicals.

2,3-Benzofuran may partition from water to soils and sediments. The extent of adsorption of neutral organic compounds by soils is often correlated with the organic-carbon content of the soil (Hassett et al. 1983). When adsorption is expressed as a function of organic-carbon content, an organic carbon/water partition coefficient (K_{oc}) is generated, and may be used to classify the relative mobility of the chemical in soil. Based on its octanol/water partition coefficient, an estimated K_{oc} for 2,3-benzofuran is about 330, using the empirical regression of Hassett et al. (1983). This K_{oc} implies that 2,3-benzofuran has a medium mobility in soil, using the mobility classifications of Roy and Griffin (1985), and would be most mobile in soils and groundwater where the organic-carbon content is low. No soil adsorption studies on 2,3-benzofuran were located. A coal-tar/water partition coefficient of 912 for 2,3-benzofuran was derived that was similar in magnitude to the octanol/water partition coefficient (Rostad et al. 1985).

Lignite coal is able to adsorb 2,3-benzofuran from aqueous solution (Humenick et al. 1982), which indirectly confirms the expectation that the mobility of the chemical will be influenced by the distribution of organic carbon.

The potential for 2,3-benzofuran to be bioconcentrated by aquatic organisms is likely to be moderate. A bioconcentration factor (BCF) is the ratio of the concentration of a chemical in the tissues of aquatic animals to the concentration of the chemical in the water in which they live. No experimentally measured value for the BCF of 2,3-benzofuran was located, but the octanol-water partition coefficient (K_{OW}) of 2,3-benzofuran has been measured as 468 (Leo et al. 1971). The empirical regressions of Neeley et al. (1974) relate the values of K_{OW}, and BCF for other compounds, and can be used to estimate that the BCF of 2,3-benzofuran is approximately 40. If this estimate is correct, substantial bioconcentration of 2,3-benzofuran by aquatic organisms would not be expected.

5.3.2 Transformation and Degradation

5.3.2.1 Air

No information was located on the transformation or degradation of 2,3-benzofuran in the atmosphere.

5.3.2.2 Water

No information was located on the transformation or degradation of 2,3-benzofuran in water.

5.3.2.3 Soil

No information was located on the transformation or degradation of 2,3-benzofuran in soils, sediments, or waste water treatment processes.

5.4 LEVELS MONITORED OR ESTIMATED IN THE ENVIRONMENT

5.4.1 Air

2,3-Benzofuran was detected, but not quantitated, in 1 of 10 samples of ambient air taken in an industrial area in the Kanawha Valley, West Virginia (Erickson and Pellizzari 1978). No other monitoring data for 2,3-benzofuran in the United States were located. However, one study identified 2,3-benzofuran among pollutants in the air of the Southern Black Forest in Germany (Juttner 1986).

5.4.2 Water

No information was located regarding 2,3-benzofuran in surface water in the United States. 2,3-Benzofuran was detected in contaminated groundwater at a coal-tar distillation and wood-preserving facility in Minnesota (Rostad et al. 1985).

5.4.3 Soil

No studies were located regarding occurrence of 2,3-benzofuran in soils. 2,3-Benzofuran was among those chemicals selected as representative compounds of waste chemicals from energy production for, subsurface transport research (Zachara et al. 1984).

5.4.4 Other Environmental Media

2,3-Benzofuran has not generally been reported in foods. However, 2,3-benzofuran was detected among the volatile constituents of freeze-dried whey powder subjected to accelerated browning (Ferretti and Flanagan 1971). It was also detected in three samples of human milk (Pellizzari et al. 1982) and is reportedly a constituent of cigarette smoke (Curvall et al. 1984; Florin et al. 1980; Schlotzhauer and Chortyk 1987).

Although 2,3-benzofuran is a component of coumarone-indene resin and this resin has been approved by the FDA for use as a coating on citrus fruits, as a component of food-preparation utensils, and as an adhesive in food packages (see Table 7-1), no information was located confirming that coumarone-indene resin is currently used on food in the United States. Furthermore, no data were located to indicate that 2,3-benzofuran migrates from the resin into foodstuffs.

5.5 GENERAL POPULATION AND OCCUPATIONAL EXPOSURE

Humans may be exposed to 2,3-benzofuran by inhalation, ingestion, or dermal absorption. Based on the limited data available, exposure of the general population to 2,3-benzofuran does not appear to be substantial. However, since this compound has been detected at hazardous waste sites, is reported to be a component of cigarette smoke, and is one monomer in a resin which may be used as a coating on citrus fruits and in packaging materials for foods, human exposure may be possible from these sources. People in Britain who had died in fires had 2,3-benzofuran in some blood samples, but no source of exposure was identified (Anderson and Harland 1980). 2,3-Benzofuran was detected in human milk (Pellizzari et al. 1982); this indicates possible exposure of the mother and is an exposure source for the infant.

Occupational exposure to 2,3-benzofuran may occur in several energy-related industries. 2,3-Benzofuran is part of the naphtha fraction of coal distillates and exposure is possible in coke production and coal gasification facilities (see Chapter 4). Exposure may also occur during the polymerization process used to produce coumarone-indene resin. 2,3-Benzofuran was not included in the NIOSH National Occupational Hazard Survey or the National Occupational Exposure Survey. However, the naphtha fraction of coal tar is considered in the NIOSH (1978) evaluation of occupational hazards associated with coal gasification.

5.6 POPULATIONS WITH POTENTIALLY HIGH EXPOSURES

Individuals occupationally exposed to coal tars or the naphtha fraction of coal-tar distillate have potentially high exposure to 2,3-benzofuran. Persons living near industrial sources or hazardous waste sites contaminated with 2,3-benzofuran may be exposed to 2,3-benzofuran. There are insufficient data to identify any other populations with potentially high exposure to this compound.

5.7 ADEQUACY OF THE DATABASE

Section 104(i)(5) of CERCLA, as amended, directs the Administrator of ATSDR (in consultation with the Administrator of EPA and agencies and programs of the Public Health Service) to assess whether adequate information on the health effects of 2,3-benzofuran is available. Where adequate information is not available, ATSDR, in conjunction with the NTP, is required to assure the initiation of a program of research designed to determine the health effects (and techniques for developing methods to determine such health effects) of 2,3-benzofuran.

The following categories of possible data needs have been identified by a joint team of scientists from ATSDR, NTP, and EPA. They are defined as substance-specific informational needs that, if met, would reduce or eliminate the uncertainties of human health assessment. In the future, the identified data needs will be evaluated and prioritized, and a substance-specific research agenda will be proposed.

5.7.1 Data Needs

Physical and Chemical Properties. Measured values of the physical and chemical properties of 2,3-benzofuran necessary to predict the environmental fate and transport of this chemical are not available. Reliable measurements of the vapor pressure, solubility in water, Henry's law constant, and K_{oc} would be useful for more accurate prediction of the behavior of 2,3-benzofuran in environmental media.

Production, Import/Export, Use, and Disposal. No recent quantitative data were located on the production, import/export, use, or disposal of 2,3-benzofuran. Virtually all of the 2,3-benzofuran produced by the destructive distillation of coal is reportedly used in the production of coumarone-indene resin (Powers 1980), but no information was located detailing the current uses of this resin, the composition of this resin, the amount of 2,3-benzofuran emitted from the resin, or the current production volume of the resin. 2,3-Benzofuran is not listed as a hazardous waste by the EPA; therefore, no regulations restricting land disposal apply to this chemical. Data required to assess potential human exposure to this chemical include the amount of production and import/export of 2,3-benzofuran and coumarone-indene resin, and emission rates of 2,3-benzofuran from the resin. If the data indicate that 2,3-benzofuran is emitted from the resin, then current information on the nature and extent of use of the resin will also be

necessary. Data on environmental releases of 2,3-benzofuran from production facilities and disposal methods employed for wastes containing this chemical would also be helpful to assess potential human exposure.

Environmental Fate. The available data on partitioning, transport, and transformation are insufficient to predict the environmental fate of 2,3-benzofuran. Measurements of the rate of photodegradation of 2,3-benzofuran in the atmosphere and determination of the composition and fate of the decay products would be useful to predict the atmospheric fate of this compound. Information regarding the potential for 2,3-benzofuran to photodegrade or oxidize in water or to biodegrade in water or soil, and the rates at which these reactions occur, would be useful in predicting the fate of the compound in these media. Physical/chemical properties suggest that 2,3-benzofuran can partition to soils (Hassett et al. 1983; Roy and Griffin 1985). Verification of this prediction by measurements of the adsorption and desorption of 2,3-benzofuran by soils and sediments, and measurement of the rate of volatilization of the compound from water, would be useful in predicting the transport and partitioning of 2,3-benzofuran among environmental media.

Bioavailability from Environmental Media. The available data are insufficient to assess the bioavailability of 2,3-benzofuran from environmental media. In vitro evidence suggests that 2,3-benzofuran would be less available from organic-rich particles than from organic-poor particles (Sehnert and Risby 1988), but confirmation of this prediction with in vivo studies would be useful. Animal studies have used gavage in oil for exposure to 2,3-benzofuran (NTP 1989) but no quantitative information concerning absorption is available. Additional information on the bioavailability of 2,3-benzofuran would be useful to assess the extent of absorption of 2,3-benzofuran from environmental media.

Food Chain Bioaccumulation. No data were located regarding the bioconcentration of 2,3-benzofuran in plants, aquatic organisms, or animals. Based on physical/chemical properties, substantial bioconcentration of 2,3-benzofuran is not expected (Leo et al. 1971; Neeley et al. 1974). No data on biomagnification in terrestrial or aquatic food chains are available. Data on bioconcentration of this compound in aquatic species would be useful in confirming the predicted low bioconcentration potential of this compound.

Exposure Levels in Environmental Media. Monitoring data for 2,3-benzofuran are sparse and are insufficient to assess the potential for human exposure to this compound, so no estimates of human intake of this substance are available. Since 2,3-benzofuran is a coal-tar product (Powers 1980), monitoring data for this compound in all environmental media in the vicinity of fossil fuel facilities would help to determine the potential for both general population and occupational exposure. In addition, monitoring foods which come in contact with coumarone-indene resin for 2,3-benzofuran would be useful to assess the potential for human exposure from food.

Remedial investigations and feasibility studies at hazardous waste sites are potential sources of information on possible exposures of populations surrounding hazardous waste sites.

Exposure Levels in Humans. 2,3-Benzofuran has been detected in several samples of breast milk (Pellizzari et al. 1982). It is unknown whether the presence of this compound in milk is a result of exposure to 2,3-benzofuran itself, or whether it is a metabolite of other compounds. Biological monitoring of workers in coal gasification or related facilities and of c populations surrounding hazardous waste sites would be useful to evaluate human exposure to this compound.

Exposure Registries. No exposure registries for 2,3-benzofuran were located. This compound is not currently one of the compounds for which a subregistry has been established in the National Exposure Registry. The compound will be considered in the future when chemical selection is made for subregistries to be established. The information that is amassed in the National Exposure Registry facilitates the epidemiological research needed to assess adverse health outcomes that may be related to the exposure to this compound.

5.7.2 On-going Studies

No information was located on any on-going studies on the fate, transport, or potential for human exposure to 2,3-benzofuran. Remedial investigations and feasibility studies at hazardous waste sites may provide information on environmental levels, transport, and transformation of 2,3-benzofuran.