Interpretive Review of the Potential Adverse Effects of Chlorinated Organic Chemicals on Human Health and the Environment

Report of an Expert Panel

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Overview

This report provides an assessment of the potential adverse effects of past, present, and expected future ambient concentrations of chlorine and chlorinated organic chemicals on the health of humans and aquatic and terrestrial wildlife. The assessment is based on a comparison between exposure limits known not to cause adverse effects and exposures resulting from estimated environmental concentrations of chlorinated organic chemicals, integrating information on anthropogenic and natural sources, physical/chemical properties, environmental fate, and toxicology/epidemiology. Evaluations were conducted on chlorinated organic chemicals representing eight product or process categories including chlorine, polyvinyl chloride (PVC) and vinyl chloride monomer (VCM), pesticides, polychlorinated biphenyls (PCBs), pulp and paper, drinking water and wastewater, incineration, and solvents.

CHAPTER 1: INTRODUCTION AND METHODS

Chemicals and chemical groups were selected from a comprehensive list for detailed assessment. A detailed review of the literature was conducted with emphasis on contributions of sources related to human activities and to natural production to total concentrations in the environment; physical/chemical properties; environmental fate and bioaccumulation; toxicology in mammalian, aquatic, and avian species; human and wildlife epidemiology. Using temporal data on ambient concentrations of these representative chemicals, hazard/exposure analyses were conducted for humans and aquatic and terrestrial wildlife. Estimated historical and present exposures were compared with exposure limits for human health or no-observed-adverse-effect levels for wildlife. An assessment also was made of the potential for adverse effects in humans and wildlife related to projected reductions in future ambient concentrations of chlorinated organic chemicals due to the implementation of best-available technologies (BAT). These assessments were based on the following fundamental scientific principles: (i) dose-response relationships exist; the magnitude of the biological response is proportional to the dose, and chemicals have exposure thresholds below which adverse effects do not occur; (ii) the biological significance of a response is related to the nature, degree, and severity of the response, and the toxicological mechanisms involved; (iii) intrinsic

metabolic processes allow organisms to accommodate low doses of chemicals; (iv) dose is proportional to the extent of exposure resulting from the concentrations in environmental media for which exposure pathways exist; (v) chemical concentrations in environmental media represent the net difference between quantities and rates of release of chemicals into the environment from all sources and the rates of elimination or degradation of the chemicals from the environment; (vi) the environmental fate and bioaccumulative potential of organic chemicals are determined by their physical/chemical properties; organic chemicals with high log Kow values, low water solubilities, low vapor pressures, and slow degradation characteristics tend to be more persistent in the environment and have a greater potential for bioaccumulation in food chains; (vii) structure-activity relationships exist and can be useful for identifying chemicals for which further toxicological and environmental fate information should be gathered; and (viii) statistical associations cannot be used in isolation to prove cause-effect relationships. The conclusions of the chapters on specific products or process categories were as follows.

CHAPTER 2: CHLORINE

Chlorine is used in the manufacture of many industrial and consumer products and also plays an important role in the disinfection of drinking water and wastewater. Volcanic eruptions and the photolysis of sea salt are two major natural sources of chlorine. Estimates of the relative contributions to the total environmental load of chlorine indicate that natural sources exceed the total quantities released from anthropogenic sources by at least 10 times. Ambient concentrations of chlorine and hydrochloric acid, are several fold less than concentrations associated with adverse effects on human health and the environment, except under emergency conditions during accidental releases.

CHAPTER 3: POLYVINYL CHLORIDE/VINYL CHLORIDE MONOMER

PVC is a solid, stable, and environmentally inert polymer of VCM subunits. PVC is used in the production of numerous household and industrial products. Historically, the potential health concern regarding PVC polymer was residual VCM in PVC products. Today, residual concentrations of VCM in PVC products are extremely low and present no hazard to the general population. VCM exposures in manufacturing facilities, prior to the 1970s, resulted in hepatic angiosarcoma in some workers. Through improved technology and manufacturing practices, the concentrations of VCM in the workplace are now below those that cause adverse effects. At no time were ambient environmental concentrations of VCM sufficiently high to cause adverse effects in humans or wildlife.

CHAPTER 4: PESTICIDES

The toxicity of a pesticide depends on specific molecular configurations that affect the physical/chemical properties and reactivity, not on the presence of chlorine. Accordingly, certain chlorinated pesticides are less toxic than their nonchlorinated counterparts. Regulatory control of pesticides now involves comprehensive and effective risk/benefit analysis and risk management. New pesticides are being developed with the objective of increasing specificity to target organisms, and eliminating the potential for food chain accumulation.

CHAPTER 5: POLYCHLORINATED BIPHENYLS

PCBs are members of a subgroup of chlorinated organic chemicals that have high log KO_w values, low solubility in water, low vapor pressures, and are slowly degraded and metabolized. Chemicals with these properties can persist and bioaccumulate in the environment. Reports of possible adverse human health effects from ambient environmental exposures to PCBs do not show dose-responses and may be confounded by exposures to other chemicals and inadequate study design. The available data indicate that ambient concentrations of PCBs would not be expected to produce adverse effects in humans. Due to the extensive past use of these chemicals, tissue concentrations of PCBs and other persistent and bioaccumulative chemicals increased dramatically in fish and in piscivorous wildlife during the 1960s. The concentrations of these chemicals were cumulatively sufficient to cause adverse effects and declines in wildlife populations, notably among piscivorous birds. A direct causal link to specific chlorinated organic chemicals cannot be established. Changes in habitat quality may also have an impact on wildlife population density. Coincident with the introduction of controls over release, the environmental concentrations of PCBs and other chemicals decreased substantially during the 1970s and 1980s, and affected wildlife populations are recovering. Evidence of adverse effects remains in areas of continuing high concentrations of these chemicals, though environmental releases of PCBs are expected to decrease further as remaining sources of PCBs (e.g., waste storage facilities) are eliminated and quantities currently in the environment gradually dissipate.

CHAPTER 6: PULP AND PAPER

The use of chlorine to bleach wood pulp used in the production of paper results in the formation of a variety of chlorinated organic chemicals. Concentrations of chlorinated dioxins and chlorinated furans in fish downstream of mills not employing the best available technology could result in exposures to piscivorous wildlife above the threshold for adverse reproductive effects. Concentrations of pentachlorophenol in fish near mill outfalls, measured during the 1970s, could have led to exposures, through fish consumption, that would have exceeded the current exposure limit for human health. Today, improvements in pulping and bleaching technologies, and primary and secondary treatments of effluents by North American mills result in much lower concentrations of chlorinated organic chemicals in receiving waters, of at least 100-fold in concentrations of total chlorinated dioxins and furans in effluents. This human exposure through consumption of fish would not exceed exposure limits and concentrations would not be expected to cause adverse effects in fish or piscivorous wildlife. In keeping with historical findings that lethality in fish occurred at mills employing both chlorine and nonchlorine technologies, recent research efforts, focused on measuring enzyme activity in fish, have demonstrated that hepatic enzyme induction is not restricted to mills that use chlorine.

CHAPTER 7: DRINKING WATER AND WASTEWATER

Chlorine is used to disinfect water for drinking and to treat wastewater prior to release to the environment. Disinfection of drinking water and wastewater with chlorine continues to be the treatment method of choice. No other proposed method of disinfection is as effective as chlorine in achieving the main objectives of drinking water treatment: (i) biocidal activity; (ii) improved taste and odor; and (iii) residual disinfection within the distribution system. Greater knowledge of the chemistry of chlorine disinfection/oxidation has resulted in alterations in water treatment procedures

that remove precursors of chlorinated organics prior to chlorination, minimize the chlorine contact time, and remove a significant proportion of the chlorinated byproducts that are formed. Consequently, chlorination by-products in drinking water are generally several fold less than those reported for the 1960s and 1970s. No adverse human health effects are expected from consumption of drinking water disinfected with chlorine. Similarly, no adverse effects on aquatic or terrestrial wildlife are expected from the disinfection of wastewaters with chlorine.

CHAPTER 8: INCINERATION

Emission rates of products of incomplete combustion (PICs), including chlorine and chlorinated chemicals, vary among incinerators. Operation of an incinerator at a high combustion efficiency with appropriate use of air emission control systems reduces the potential for the formation of PICs. The results of a case study assessment of a hazardous waste incinerator operating with best-available technology (BAT) indicated that hazardous waste incinerators using such technologies will not produce adverse effects on human health.

CHAPTER 9: SOLVENTS

Chlorinated solvents are used to dissolve or disperse other chemicals and are common household and industrial chemicals. There are many natural sources of some of these chemicals that contribute to ambient environmental concentrations. Improvements in industrial containment, based on greater scientific understanding of potential environmental fate and effects, have substantially reduced total releases to the environment of chlorinated solvents from production and manufacturing facilities in the past decade. Current ambient concentrations of chlorinated solvents are not associated with adverse effects on human health or the environment.

CONCLUSIONS

The major conclusions of the report are: (i) the presence of chlorine in a molecule does not necessarily confer unique toxic properties or bioaccumulative potential; (ii) chlorinated chemicals span a wide range of physical/chemical properties and molecular structures, consequently display a wide range of environmental fate characteristics and biological activities, and thus cannot be considered as a single group for the purposes of health or environmental risk assessment; (iii) chlorinated organic chemicals that have a high log KoW, low solubility in water, and a low vapor pressure can persist and bioaccumulate when released into the environment; (iv) many chlorinated chemicals are produced from natural sources and, in some cases, the contribution to ambient concentrations from natural sources exceeds that from human activities; and (v) technological improvements leading to reductions in the formation of chlorine-containing by-products, decreased emissions, and a reduced likelihood of accidental releases are expected to further reduce the concentrations in the ambient environment. In general, the review has shown that chlorine and chlorinated organic chemicals have, in the past, been used and discharged to the environment without a full appreciation of their fate in the environment and potential to cause adverse effects. In response to ecological and toxicological concerns, appropriate controls and technological advances

have been implemented to reduce environmental concentrations. Although there is a need to continue to learn more about these chemicals, the principal factors that affect their fate and toxicity are now reasonably well understood and provide assurance that most chlorinated organic chemicals can now, and in the future, be used without adverse effects.

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