Question 8:
Can the lead, mercury, and liquid crystals in computer displays pose health risks?

In addition to the environmental life-cycle assessment of desktop computer displays, a more detailed analysis was conducted for a few select materials of interest to EPA, industry, and others who participated in the project. This additional analysis provides more detailed information on the potential exposures and chemical risks of these materials to both human and ecological populations. The materials selected for further analysis were lead, mercury, and liquid crystals. Having chosen these three materials a *priori* does not presume that these are the only materials worthy of additional analyses.

LEAD

Lead is found in glass components of CRTs and in electronics components (e.g., printed wiring boards and their components) of both CRTs and LCDs. It is also a top priority toxic material at EPA and the subject of electronics industry efforts to reduce or eliminate its future use. The following section summarizes the conclusions drawn from a focused look at lead's role in the life cycle of the computer display, and its affects on human health and the environment.

CRTs contain over 25 times more lead than LCDs. Lead is a significant material in current CRTs, accounting for up to eight percent of the overall composition of the CRT by weight. As shown in Table 8.1, lead is used in the CRT glass parts (funnel, panel, and neck glass), the sealing frit, and the solder on the printed wiring boards within the CRT. Lead is not as prevalent in LCDs, being found only on printed wiring boards.

Table 8.1. Computer display parts that contain lead

Part	Display type	Quantity (kg)[a]	% lead content of part (by weight)
Funnel	CRT	0.91	22-28% [b, c]
Front panel	CRT	0.18	0-4 [b, c]
Neck	CRT	0.012	26-32 [b, c]
Frit	CRT	0.026	70-80 [b, c, d]
Printed wiring boards (total)	CRT	0.051	NA
Printed wiring boards (total)	LCD	0.043	NA

[a] Quantity of lead in a 17" monitor (Monchamp et. al., 2001).
[b] Menad,1999.
[c] Lee *et. al.*, 2000.
[d] Busio and Steigelmann, 2000.
NA= Not applicable

Lead-based impacts were greater in CRTs than in LCDs. Impacts from lead were found in the following eight categories: non-renewable resources, hazardous waste landfill use, solid waste landfill use, radioactivity, chronic public health effects, chronic occupational health effects, aquatic toxicity, and terrestrial toxicity. Lead-based impacts from the CRT ranged from moderately to significantly greater than those from the LCD in every category, with the exception of solid waste landfill use. The most significant difference was in non-renewable resource consumption, resulting primarily from the lead (a non-renewable resource) used in manufacturing the CRT glass. In this impact category, the CRT (989 grams) used over 40 thousand times more lead over the course of its life cycle than LCD (0.025 grams). Other categories where CRTs had notably greater differences in impacts were in hazardous waste landfill use, chronic public health effects, and terrestrial toxicity.

Even in CRTs, lead-based impacts are low relative to impacts from other materials. While the use of lead in a computer display life cycle does contribute to several impact categories, in relation to other materials used in computer displays, such as glass and copper wire, lead's impacts are relatively low. For example, the lead impacts for CRTs in the non-renewable resources category account for only 0.2 percent of the overall impact score in the category.

For workers, inhalation is the most likely route of exposure to lead. Many of the processes required to manufacture computer displays use lead in the workplace; correspondingly, there is the potential for worker exposure. Exposure occurs through inhalation, dermal contact (when lead or materials containing lead come into contact with workers' skin), or through ingestion (e.g., ingestion of lead-bearing dust). The greatest potential for high-level occupational exposure occurs in lead smelting and refining operations, where lead is vaporized during high-temperature heating. This heating releases lead fumes and small respirable lead particles. Existing studies of smelting and refining operations have found mean concentrations of lead in the air nearly 90 times higher than the OSHA recommended safety levels for worker exposure. Exposures to lead dust may also occur during lead mining, frit manufacturing, CRT glass manufacturing, or processes in which metallic lead is heated in the presence of air.

Many occupational exposures can be minimized or avoided. The presence of lead in the workplace does not mean that occupational exposures are unavoidable. Worker exposures to lead can be reduced or even eliminated through the use of personal protective equipment, sound operating practices, or advanced machinery that protects workers from exposure (e.g., an enclosed and vented wave solder machine). To determine actual worker exposures to lead, a complete exposure assessment specific to each manufacturing process would be required. Additionally, alternatives are being developed, such as lead-free solders and glass components, that will potentially minimize the future lead content in both CRTs and LCDs.

MERCURY

Mercury is contained within the fluorescent tubes that provide the source of light in the LCD. Mercury is also emitted from some fuel combustion processes, such as coal-fired power plants, which contribute to the life-cycle impacts of both CRTs and LCDs. Because of mercury's toxicity to both humans and the environment, a more detailed analysis of mercury in this study was warranted. The following conclusions were drawn from a focused look at mercury's role in the life cycle of the computer display, and its effects on human health and the environment.

Life-cycle mercury emissions are similar for CRTs and LCDs. The mercury emitted from the generation of power consumed by the CRT during manufacturing and use (7.75 mg), is slightly greater than the entire amount of mercury emissions from the LCD, including both the mercury used in LCD backlights (3.99 mg) and the mercury emissions from electricity generation (3.22 mg). Although this was not expected because mercury is intentionally incorporated into LCDs, but not in CRTs, the results are not surprising because mercury emissions from coal-fired power plants are known to be one of the largest anthropogenic sources of mercury in the United States.

Mercury outputs from LCDs had a broader effect on the environment than those from CRTs. The life-cycle mercury-based outputs from LCDs affected six impact categories, while those from CRTs showed impacts in three categories, as shown in Table 8.2. LCD impacts to both solid and hazardous waste landfill use, as well as to the chronic health effects of workers, all result directly from the use of mercury in the LCD backlights. No mercury is required in CRT fabrication. Although the quantities of mercury are not large, they cannot be discounted given the toxicity of mercury to both human health and the environment.

Table 8.2. Mercury-based impact categories for CRTs and LCDs

Impact category	Impact calculated for CRT life-cycle	Impact calculated for LCD life-cycle
Hazardous Waste Landfill Use (m^3)	0	7.73E-15
Solid Waste Landfill Use (m^3)	0	1.98E-11
Chronic Health Effects-Public (tox-kg)	5.22E-04	3.11E-04
Chronic Health Effects-Occupational (tox-kg)	0	3.99E-06
Aquatic Toxicity (tox-kg)	9.02E-04	5.43E-04
Terrestrial Toxicity (tox-kg)	5.21E-04	3.11E-04

Overall, mercury-based impacts are low relative to impacts from other materials. Contributions from mercury-based impacts are not significant relative to the total life-cycle impacts from other materials (e.g., glass, copper wire), with the greatest contribution of mercury-based outputs occurring in the aquatic toxicity category (contributing 0.4 percent for CRTs, 0.01 percent for LCDs).

Worker exposure may occur during backlight fabrication for LCDs. About 4 mg of elemental mercury is used to manufacture the fluorescent backlight for the LCD. Possible pathways of worker exposure during backlight fabrication include inhalation of mercury vapors, dermal exposure, or ingestion. Occupational chronic health effect scores from mercury exposures (3.99e-06 tox-kg for LCD, none for CRT) likely underestimate the chronic occupational impacts for mercury, because they are based on inputs only and do not consider chronic occupational impacts from outputs in other processes, such as aluminum production or fluorescent lamp recycling, which may result in emissions of mercury that originate within the workplace.

The most likely pathway for general population exposure to mercury is inhalation. Per functional unit, LCDs are responsible for approximately 4 mg of mercury releases to the air and CRTs are responsible for approximately 12 mg. Mercury is naturally present in coal and becomes airborne when coal is burned to generate electricity for the manufacturing and use of the computer displays. Airborne mercury can stay in the atmosphere for up to a year and can travel thousands of miles, potentially resulting in general population exposures.

Alternative backlights could reduce the mercury impacts of LCDs. Alternative backlights have been developed that not only eliminate mercury from the light, but also improve many of the optical characteristics of the displays. Current development is focused on improving the energy efficiency of the alternative lights.

Liquid Crystals

Liquid crystals are organic compounds responsible for generating an image for the LCD. The toxicity of the liquid crystals in LCDs has been alluded to in the literature, yet there is very little known about the toxicity of these materials. The following conclusions were drawn from a focused look at the role of liquid crystals in the life cycle of the computer display, and its effects on human health and the environment.

Liquid crystals are not used in CRTs. Liquid crystals are not used to fabricate CRTs and so have no environmental impacts in the CRT life cycle.

Toxicological data on liquid crystals are limited. There are several hundred liquid crystal substances that may be used in an LCD; therefore, comprehensive toxicological data are not available. However, limited tests that have been conducted by manufacturers indicate that few liquid crystals have acute toxic potential to humans. The study also reviewed toxicological data from eight liquid crystal compounds identified as part of the life-cycle inventory. The review failed to identify toxicological thresholds, indicating that the testing of these chemicals is probably insufficient to determine their potential for chronic human effects.

Liquid crystals do not appear to contribute significantly to any of the impact categories for LCDs. When no toxicity data were available, the study used a default average toxicity value. This practice prevents the study from assuming there are no toxic impacts just because there are no data. Of the 20 impact categories designed for this study, liquid crystals contribute only to the category of "chronic occupational health effects." Relative to other materials used in LCDs, however, the impact of liquid crystals on this impact category is very small. Specifically, the impacts from liquid crystals on overall chronic occupational health effects represent less than 0.01 percent of the total impact for the functional unit of one LCD. Impacts were not calculated for liquid crystal *releases* because data regarding liquid crystal outputs were not available to the project.