MASTER

Environmental, Health, and Safety Considerations

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Environmental, Health, and Safety Considerations*

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Most photovoltaic (PV) cells under consideration contain at least one chemical element either known to be toxic (e.g. Cd, As) or about which only little health-effects information exists (e.g. In, Te, Ga, Ge). The concentrations of these types of elements in PV cells may vary from a few ppm (e.g. when As is used as a dopant in Si cells) to major fractions of the matrix (e.g. the As in GaAs cells). The absence of health-effects information on an element may arise from the relative absence of the element from natural ecosystems. For example, indium was not discovered until early in this century, and as late as 1924 the world's supply of the isolated metal was approximately one gram; even today it is regarded as rare. Such absences or low abundances are themselves reason for attention because organisms (e.g. those in man's food chain or man himself) may lack the ability to eliminate an element with which they have had no evolutionary experience. This mechanism could increase otherwise insignificant traces in soil or water to a toxic level in a higher organism whose ultimate source of food derives at least partly from this soil or water. For example, the average Cd intake of most people is about 25% of that required for producing toxic effects; nearly 80% of this comes from food, especially grains and cereals which, in turn, derive their Cd from the soil, which gets its Cd from fertilizers, leachings from Cd-containing pigments used in paints and plastics, and rain-assisted fallout from atmospheric releases from the combustion of coal and the smelting of Zn. High average intakes such as this need not be increased very much before toxic symptoms could be expected in a significant fraction of the population.

Another factor worth consideration is the synergistic interaction between trace elements. Micronutrients, i.e. essential elements usually operate as part of a hormone or enzyme system, and in this manner a minute trace of the element can exert a disproportionately large effect on the whole organism. For example, one of the several elements recognized as essential in trace amounts is Se and another for which traces may be essential is Cd, although both are also suspected of being carcinogenic in larger amounts. For some metals, the body has homeostatic control mechanisms which tend to keep the concentration in the body from getting too high or too low. However, interactions between trace elements have been demonstrated for several pairs of elements including Cd/Zn and Cd/Se. Thus, too much Cd can cause a deficiency of Zn, another essential element. With so many possible pairs of essential elements that might be expected to interact with each other, science has only just begun to gather the information with which to predict the consequences of, say, a ten-fold increase in the level of a given metal. This is one of the reasons why so-called "new" or exotic elements should not be dismissed lightly by simply noting that their concentrations or total amounts in a new technology are too small to be of concern. Whether such materials will cause problems or not is a question that cannot be answered without considerable study and a great deal more information than we now have.

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Potential problems presented by these elements may appear at any stage in the handling of the particular element and may affect either the workers or the public living near (downwind of) any of the sites (e.g. the mine or smelter from which the raw material is obtained and purified, the factory where the cells are manufactured, or the incinerator or landfill in which the cells are discarded).

I hasten to point out several mitigating effects: (1) The semiconductor industry is already a clean one, and there is no reason for the PV industry not to continue to be clean. (2) The PV industry may actually reduce certain environmental pollutants (like Cd) by requiring more efficient recovery from smelters in order to increase supply to meet the demand; (Cd is produced as a by-product, and if the demand is lower than the supply the amount allowed to escape into the atmosphere may be higher than necessary).

In trying to maintain proper perspective it is useful to compare the amounts of an environmental pollutant which might be contributed by the PV industry with amounts contributed by other accepted (or at least unregulated) sources. A case in point is Cd. On a nation-wide average, the amount of Cd which the PV industry would ever contribute to environmental pollution is probably only a very small fraction of the total Cd environmental pollution, most of which comes from sources noted above, from electroplating operations, from solder, batteries, etc. On this basis, it is tempting to argue that the PV industry should not be held accountable for an environmental problem to which it may contribute only insignificantly. However, the other side of the coin is that with average intakes of Cd already so close to the toxic level, it would not be surprising if all industries involving Cd became much more tightly regulated, thus adding to the cost of working with Cd. Ironically, this logic suggests that an emerging clean industry that wishes to use a given toxic material may have to bear the price of the sins of other dirty industries that have been the principal cause of the release of this material -- a factor which need not prevent use of the material but which should be factored into cost estimates for using it. Cadmium is used here as an example, but it may turn out that the same reasoning will be found to apply to other elements relevant to the PV industry.

One issue which is not likely to be important technically, although it may be important from an emotional (public perception) or political (legislative/regulatory) standpoint, is that of carcinogenicity. Some of the elements (e.g. As, Ba, Cd, Sb) relevant to the PV industry are suspected in varying degrees of being environmental carcinogens. It would be easy to note that the 40-year latency period for most carcinogens exacerbates the problem of acquiring data on humans because much of such data is from retrospective epidemiological studies, and this implies that many people will have been exposed before the first symptoms are noted; consequently, one might argue that until a given element or compound is shown not to be carcinogenic it should not be used. This view, however, is an extreme one which does not adequately take into account benefits from the use and risks of using alternatives. I believe that if one were to assess the weight of expert opinion as objectively as possible, one would find that carcinogenicity is not

now nor likely to become a serious problem to the PV industry either for industrial workers or the public at large.

Nevertheless, because of other problems to which I have alluded, it is important to maintain perspective by comparing expected future usage with present usage, to develop health-effects information where little or none exists and large future expansion is expected, and to monitor the development and utilization of PV technology to assure compliance with recommended procedures and concentration limits and to identify new problems that may arise in the future.

As implied above, the disposal of PV cells must be viewed as a potential problem because the large planned-for residential usage and the finite life-times of cells imply a certain rate of disposal of defective or worn-out cells and there can be little or no control over how a consumer discards a product: Any real or artificial economic incentive to recycle (e.g. a deposit refund) may be impractical (by being too low to be effective) or may cause consumer resistance (from fear, nuisance, etc.) to the development of the industry. I believe that no technical or legal mechanism exists now, nor is any likely to be developed, which will guarantee that a device containing a toxic element can be disposed of in a general municipal collection/disposal system with absolute safety.

Even standard fire-fighting techniques may have to be altered to protect firemen and minimize property loss. When one mentions the fact that a fire in a PV array could release toxic oxides of Cd, As, or other components of a PV cell, a common reply is that the damage from the fire itself would far outweigh any likely toxic effect to the homeowner from the fumes released. Such an answer overlooks two points: (1) Once-in-a-lifetime exposure to toxic fumes may be unimportant to a homeowner, but weekly or perhaps daily exposures to a fireman could be quite a different matter, requiring the use of supplied-air masks while fighting roof fires. (2) Present fire-fighting techniques sometimes call for deliberately allowing a hole to burn through the roof in order to create a chimney effect to confine the fire by reducing its tendency to spread laterally throughout the building or to other structures; this technique would surely have to be re-evaluated if rooftops became fitted with costly PV arrays.

The solution to these potential problems is to anticipate which chemical elements might be considered likely candidates for PV development and to generate needed toxicity information now, for input into planning decisions that will be required for PV development and the promotion of its utilization.

Before outlining briefly what DOE is doing to provide this information, I would like to mention the difference between toxicity and hazard. It is the exposure of a material to a human being that makes the difference between toxicity and hazard. A highly toxic substance can be handled with complete safety (albeit at some expense) if this is done in such a way that human exposure to the material is well controlled so that it never exceeds some safe level (which may be zero in some cases). A toxic substance becomes a hazard when its method of handling or containment is such that one no longer is sure

that exposure to it is indeed acceptably low. The point of this is that the mere fact that a material may be toxic is no reason to refuse to use it -- especially if there are other reasons such as efficiency or economics that make it attractive in spite of its handling costs; what one should do in such a case is simply to ensure that any hazard from the use of such a material is either zero or acceptably low.

That happens to be what DOE is doing to assist the PV industry. DOE recently selected Brookhaven National Laboratory to be its field center for environmental, health, and safety effects of PV technology. The relationship of BNL to other parts of DOE's PV program is shown in Figure 1.

Thus, whenever DOE needs information or advice on this subject it will turn to BNL for guidance. It means also that one single laboratory (BNL) now has the responsibility for ensuring that issues involving environmental, health, and safety effects of PV technology are not overlooked but are properly identified and considered and that where information is lacking or research needs to be done to gather necessary data, this lack and these needs will be brought to the attention of the appropriate planners so that, when it is both desirable (or necessary) and feasible, appropriate research can be implemented to fill the gaps. I include feasibility here because it is neither possible nor necessary to do all of the toxicological research that would be necessary to fill in all of the gaps in our knowledge about the possible health effects of materials that are relevant to PV technology (or at least to do so in the next 20 or 30 years, much less to do so within the time period available before planning decisions have to be made). Laboratory resources and available funds are simply insufficient to do everything that one might like to do for maximum assurance. On the other hand, doing everything is unnecessary if we can maintain our perspective and if we do the best we can to evaluate both risks and benefits. This is what we are trying to do.

This program of surveillance, advice, and action has begun, and our first task was to convene a workshop on the health effects of PV technology. This was a very successful affair, attended by experts representing a very wide variety of disciplines and fields of expertise, including chemical engineers, chemists, electronics specialists, physicists, and plant managers from industry and biologists, toxicologists, industrial hygienists, environmental health scientists, doctors engaged in medical research and public health protection, and government planners. The purpose of the workshop was to provide the basis for determining where information was lacking and what research needs to be done on what time schedule. This it did very well, and we are now in the process of analyzing the results. The Proceedings of this meeting are also in the final stage of publication, so this information can be made widely available.

A somewhat smaller workshop to deal with strictly environmental effects of PV development and utilization is being planned for June 1980. We are also actively involved in the task of quantitative evaluation and analytical assessment of the environmental, health, and safety impacts of the PV energy cycle in order to develop systematic overviews of the biomedical and environmental costs of energy production by PV systems in a way that will permit

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Figure 1.

these costs to be compared with the same types of costs involved in other energy technologies.

In a few weeks, after we have fully digested the results of our recent workshop, some specific health-effects research will be recommended. Although it is too early to be very specific about what will be recommended, one task that is ready to be implemented as soon as funding becomes available is to organize a sampling program for the collection and chemical characterization of wastes generated by representative PV technologies.

In summary, developing PV cells without regard to possible health effects could lead to potential problems in the not-too-distant future. Some specific points of concern have been identified regarding the possibility of introducing into general use some uncommon chemicals for which we may have insufficient health-effects information to permit making the best decisions. DOE is on top of these concerns, working to prevent them from becoming problems.