

# Environmental and Toxicological Planning in Polymer Production and Disposal

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There is neither a prescribed format nor a rigid sequence of testing to follow for the assessment of health and environmental effects of chemicals. Conventional animal toxicity tests plus medical surveillance and monitoring of exposed human populations will provide knowledge of the biological effects of chemicals and assurance that they can be handled safely. Useful information also can be derived from other test procedures. These include extraction studies to measure the amounts of additives which can leach from polymers, toxicity tests using aquatic organisms and birds, and determination of the biodegradability of materials and their potential for accumulation and magnification in biological systems. Current concern over pyrolysis products of polymers points up the need for defining the variables involved and development of test procedures by which meaningful evaluations of potential health hazards can be made.

The preceding speakers at the conference have covered a variety of topics embracing animal and human studies and dealing with the toxicity of materials involved in the manufacture and use of plastics. It should be noted that, in general, their remarks also apply to any chemical, to the process by which it is manufactured, and to the effluents resulting therefrom. After I say all of these studies are necessary, and all of them should be conducted, I am faced with a dilemma of what else to add to this broad and comprehensive coverage of toxicity.

As a start, I would like to refer to words that were written before the current concern about environmental effects of chemicals. "Despite an infinite amount of animal work upon a new chemical the tolerable human intake will remain only tentatively defined until human observations have been made" (1). If expanded to include the environment, the amended statement could serve as a concise abstract of this presentation. Conventional toxicity testing and some new approaches can be utilized to develop information from which judgements can be

made regarding the safe use and disposal of materials.

Animal studies may be classified as either predictive or confirmatory on the basis of their intended aim. Predictive studies are those performed before a material is introduced into commerce. They are done to anticipate possible harmful effects so that adequate safeguards can be instituted to protect the health of persons making and using the product. Confirmatory studies are conducted to confirm suspicions of injury to man. They usually are done only after a substance has been produced for a long period in large quantities. By contrast, only confirmatory studies are performed on humans exposed to industrial chemicals. This is the proper procedure, since there generally is no justification, and scant opportunity, for testing industrial chemicals on man before they are used. Regrettably, human confirmatory tests too often are long delayed and are undertaken only after there are indications of injury to man. Herein lies the problem. How can we better utilize animal studies for predictive testing, and how can we institute earlier monitoring of human populations so that we can be alerted to potentially harmful exposures as soon as

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possible? A parallel situation exists in the area of environmental effects. There is a need for more predictive testing to decrease the probability of adverse effects in the future. In both man and the environment, adequate testing coupled with subsequent surveillance, should enable us to build a body of knowledge about the possible biological effects of substances. With such knowledge, we would have more reassurance of safety and less alarm about possible unknown effects.

There is neither a panacea nor a cookbook solution to this problem. I would like to review some of the things that have been done, to share some of our current thoughts in this area, and to indicate why and when we do certain studies.

Any new component of a plastic will be tested for its acute toxicity and irritant effects so that it can be handled safely—at least with respect to short-term health hazards. If it becomes part of a material which will have a high probability of direct dermal exposure, repeated insult patch tests on humans will be conducted. This is one of the few tests of any industrial chemical prior to marketing which can be justified on man, because the results of animal experiments are not a reliable indicator of the sensitization potential of a material to humans. Finally, if its use is subject to regulatory action, the material will be tested for safety in such use according to the requirements of the regulatory agency. These toxicity tests are so obvious that they deserve mention lest they be overlooked. At present, unfortunately, there is no substitute for long-term animal studies to evaluate carcinogenic potential of a material. All of us who have conducted lifetime studies in the laboratory are aware of the difficulties encountered in such tests. In spite of debates over the route of exposure, the arguments which can result over the interpretation of results, and our uncertainties of how to make meaningful evaluations of the actual hazards to man, somewhere along the line these studies will have to be done, and they must be done much earlier. Another obvious fact is that these traditional toxicity tests are quite adequate to detect potential injury resulting from the use of chemicals. These tests have served, and continue to serve, us well in this respect. It appears that a greater number of human health hazards have resulted from

failure to perform these tests rather than from failure of the test procedures themselves.

In addition to the customary animal toxicity tests, there are other procedures we are exploring. Extraction studies, using simulated food solvents, have been done on polymers intended for food contact applications. The results have been used to determine whether or not the proposed use was safe in light of available toxicity data. Similar studies can be done by use of water and either real or simulated body fluids such as saliva, gastric juice, and urine. The degree of extractability of components of the polymer system will enable a judgment as to whether or not there will be leaching of harmful amounts of them from a material disposed of in a landfill, whether harmful amounts of additives could be ingested by a child chewing on a synthetic material, or whether a bed-wetting child will develop a rash from the amounts of additives leached out of a fire-retarded fabric. These tests are relatively simple to perform if there is an analytical method of adequate sensitivity for the substances under study.

The acute toxicity of materials for fish can be determined. This information is useful in assessing the potential environmental impact of accidental and other discharges of the materials near or into waterways. The biodegradability of materials can be determined by using river die-away or semicontinuous activated sludge procedures. The former test will estimate the persistence of the material in a flowing body of water. The latter test will determine the ability of conventional sewage treatment facilities to remove contaminants from waste waters. There are some cautions which should be kept in mind when performing semicontinuous activated sludge measurements. Many organic chemicals may not be decomposed by microbial action until after the sludge has been acclimatized, i.e., it may be necessary for enzyme systems to be induced to metabolize a previously unavailable substrate. This may be regarded as nothing more than an extension of the evolutionary process. In addition to monitoring the disappearance of the parent compound, the likely metabolites will have to be followed if one is to determine the ultimate fate of the compound. Interpretation of data from mixtures requires special attention. Since the components may have different rates or degrees

of biodegradability, a small proportion of a resistant material could be overlooked despite an overall apparently favorable rate of biodegradability. A material which biodegrades readily, which has no appreciable acute toxicity to aquatic organisms, and which does not bioaccumulate will not become a long-term environmental hazard. A persistent substance which has high toxicity or bioaccumulates is a potential threat to the environment. Resistance to biodegradation, of itself, is not necessarily a basis for condemning a chemical. It is an indicator that additional studies must be done to evaluate possible long-term changes which it might produce in the environment. The degree of analytical sophistication required for biodegradation testing is considerably greater than that involved in extraction studies.

Currently, some of the best fire retardants for plastics are halogenated materials. Since they may accumulate in organisms and may build up in tissues to levels many times beyond their actual concentrations in the environment, their potential biological impact must be determined. Initially, the accumulation and retention of these materials in the tissues of animals should be determined. Subsequently, similar studies should be done in fish, and perhaps birds. As we develop a better understanding of the behavior of compounds in these species, we may be able to reduce the amount of analytical work involved without sacrificing our ability to assess the environmental effects of a compound. Tissue accumulation and retention studies require the analysis of larger numbers of samples and a considerably greater degree of analytical sophistication than extraction or biodegradation studies. One is seeking relatively small amounts of the parent compound and its metabolites among the great array of natural chemicals which occur in living tissues. Among our projects is the development of a model sampling system which will yield the optimum amount of information without overwhelming our analytical capabilities. Extension of this type of study to organic materials which lack halogens or other substituents by which they can be traced poses even greater analytical difficulties.

Years ago, Dr. Henry F. Smyth remarked to a group of students that one chemist could develop enough compounds in a year to keep a toxicologist busy for a lifetime. On assuming

a productive career of 30 to 40 years, and since there are considerably more chemists than toxicologists, it soon becomes apparent that the toxicologist will never lack for work. Fortunately, most of the chemicals never get beyond the stage of laboratory items. However, the increasing amount of analytical chemical support that safety evaluations require suggests that the toxicologists may yet redress this long-standing inequity.

Increasing concern is being expressed about the flammability of plastics and the health hazards associated with their pyrolysis products. We are cooperating with others and developing our own program which should enable us to make meaningful assessment of the hazards involved in fire situations. As in many other situations with emotional overtones, certain unpleasant facts tend to be overlooked. People died in fires long before plastics were as widely used as they are today. In fact, since the annual death toll from fires has been relatively constant in this country for about 20 years (Fig. 1) and since our population has increased, the actual death rate from fires has been declining (2). To credit the use of plastics for this decreasing death rate from fires would be as illogical as the counterclaim that plastics are increasing the death toll. A fire is an exceedingly complicated, dynamic system which changes from moment to moment. Some of the variables involved are free-burning conditions, smoldering situations, temperature, rate of heat release, total fuel load and its composition, oxygen supply, and the rate of formation and

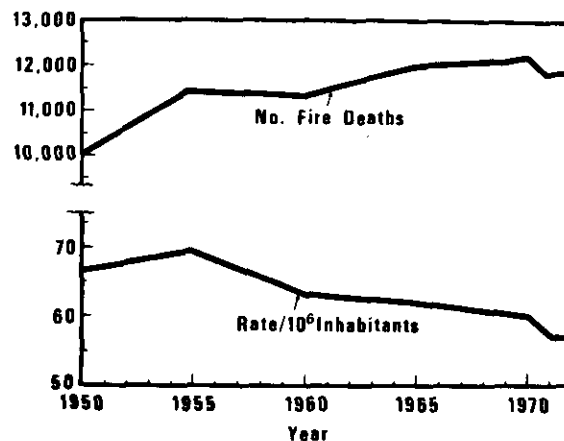


FIGURE 1. U.S. fire deaths, 1950-1972.

the air concentrations of gaseous and particulate contaminants. Changes in these factors can result in death or survival even with natural materials such as wood, leather, and wool. Unless these variables are controlled or there is a better understanding of their influence on the observed results, it will be virtually impossible to make meaningful comparisons of the health hazards posed by pyrolysis products of different materials. In support of that comment, let us assume that a fire retardant is developed which does, in fact, give off highly toxic gases when burned. Assume also that when added to a plastic, it makes the polymer considerably more difficult to ignite. In the overall assessment of the health hazards—the risks of introducing that product into the market—how do you balance benefits from fires that might be prevented against the increased risks that would arise only on occasion, since no one tabulates figures on prevented fires while somebody takes note of every fire.

These are some of the approaches which we are taking to develop information from which judgements can be made regarding the safe use and disposal of materials such as those used in the manufacture of plastics. One of the first decisions that has to be made is which tests should be performed on a given material. A close second is a decision as to when during the development of the compound these studies should be undertaken. While the overall outline is similar, there is no fixed pattern by which these decisions can be made. In general, animal tests which mimic the routes of potential exposure will be conducted relatively early in the development of a product. If the structure of a material is closely related to another compound known to produce adverse health or environmental effects or if its metabolism could result in suspect compounds, it is important to determine whether the new substance produces a similar effect. As the complexity of a test procedure increases, its cost also will increase. Thus, projects may be dropped because their economic potential does not justify the costs of toxicity testing. However, the economic potential cannot always be determined without making and using the material to at least a limited degree.

Thus we are faced with the classical chicken-and-the-egg question: which comes first—toxicity testing or use? In most instances, a balance

is struck, in that some toxicity testing is done and some trial marketing is undertaken. This is followed by more extensive toxicity testing and further evaluation of the utility of the product. Concurrently, surveillance of the health of employees and monitoring of their potential exposures should begin. Every possible source of information should be exploited to develop knowledge about, and an understanding of, the biological effects of compounds. This should be an incessant process in which available information is continuously reassessed in the light of subsequent information.

Questions concerning the effects of chemicals on man have been with us for a long time. Since these are old questions, the answers to them have been sought in a series of procedures which have evolved over the years, the combination of alternate testing and monitoring which was just mentioned.

This is not a new concept, since it was described by Smyth over 20 years ago (1): “. . . new chemicals are studied by screening methods before any amount is sold. . . . As it becomes certain that a chemical will be a regular item of commerce more advanced work is performed. . . . Despite an infinite amount of animal work upon a new chemical, the tolerable human intake will remain only tentatively defined until human observations have been made. A pressing need is for the publication of workroom analyses and clinical examination of the workmen in order to validate more fully or to correct the commonly used hygienic standards for inhalation. At present most detected human injuries are likely to be reported in the literature but instances where no injury results are not published. It is understandable that authors hesitate to write, and editors hesitate to accept, articles which simply reassure. The sensational is more attractive, but we badly need more studies like that of Sterner et al. (3) on butyl alcohol where air concentrations were followed for 10 years and clinical studies of the workmen involved showed no injuries. We are neglecting our duty if we do not collect and publish such data. Toxicologists properly discharge their duty to use animals to establish probable safety before human use begins, but after a material is an article of commerce we rely too much on rare accidents to authenticate or to correct the animal predictions. Many files

are loaded with pertinent data. How can they be dragged out and published?"

Questions concerning the effects of chemicals on the environment have gained prominence relatively recently. Since these are new questions, they may require development of a different type of toxicity data upon which answers can be based. It has been remarked that many issues affecting the environment and man's health are not "buttressed by adequate scientific data" (4). Some of the directions in which we are seeking such data have been indicated.

In closing, it should be noted that planning involves making decisions. Decisions are based on judgements. Judgements can be criticized after they have been made. As scientists, trained to be critical, we should examine our decisions objectively and expect similar scrutiny of them by our peers. In addition to objectivity,

however, as our host Dr. David P. Rall has remarked, "We also need reason, and I am not sure we can achieve that. The scientific community, as we all know very well indeed, is very diverse and heterogenous and contains within its continuum many honest differences of opinion" (4). Let us recognize these honest differences as opinion and strive to resolve them by an objective collection and appraisal of facts.

#### REFERENCES

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