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Consumer Hazards of Plastics

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The modern consumer is exposed to a wide variety of plastic and rubber products in his day to day life: at home, work, school, shopping, recreation and play, and transport. A large variety of toxic sequellae have resulted from untoward exposures by many different routes: oral, dermal, inhalation, and parenteral. Toxic change may result from the plastic itself, migration of unbound components and additives, chemical decomposition or toxic pyrolysis products. The type of damage may involve acute poisoning, chronic organ damage, reproductive disorders, and carcinogenic, mutagenic and teratogenic episodes. Typical examples for all routes are cited along with the activities of Canadian regulatory agencies to reduce both the incidence and severity of plastic-induced disease.

After the final manufacturing and processing steps, a considerable portion of the plastic industries' products are sold as consumer or household items. Other plastic articles may appear in public places (schools, theaters, stores, transport vehicles), or they could be widely dispersed throughout the work force and thus come into frequent contact with the population. Thus, man in his modern existence is inextricably linked and exposed to the many products of the polymer and rubber industries.

One can cite toys, clothing, furniture, medical devices, food containers, paints, sporting equipment, recreational articles, pens, pencils, construction materials such as water pipes, insulation, electrical wiring; the list is endless, but all may incorporate modern plastics.

The routes of exposure to polymers include oral ingestion, dermal adsorption, inhalation, and contact with skin and eye. We may have exposure to heavy metals, plasticizers, stabilizers, fillers, dyes, residual monomers, antioxidants, fire retardants, and in cases of fire, a large number of thermal decomposition products.

Hazards include acute poisoning and chronic toxicity, sensitization and corrosive damage to skin and eye. Carcinogenicity, mutagenicity, and teratogenicity have also been implicated; these latter responses have been reported following exposure to a wide variety plastic products.

In the Health Protection Branch of the Department of National Health and Welfare our task is not only to eliminate or minimize potential health hazards from polymer exposure through application of the Food and Drugs Act and the Hazardous Products Act, but also to spend considerable time dispelling erroneous ideas on the alleged toxic consequences of various plastic products in daily use. Considerable publicity of the latter type appears in newspapers, magazine, radio, and TV and great public anxiety and even panic can follow rational or irrational claims of this nature.

This paper will discuss a few examples of the various problems encountered and their ultimate resolution; some have yet to be fully resolved.

Oral Exposures

The intentional oral ingestion of plastic materials is rarely encountered other than in young children. The latter of course indulge in oral exploration of many articles, including those fabricated from synthetic polymers and rubber. This activity is enhanced during periods of teething. For this very reason the Canadian Hazardous Products (Toys) Regula-

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tions have set stringent standards for those toys intended for children 3 years of age and under. For example, the use of lead pigments or the deliberate introduction of mercury in decorative coatings of such toys is specifically prohibited. Compounds of antimony, arsenic, cadmius, selenium, or barium must not be eluted under prescribed test conditions in excess of 0.1% of the product or decorative coating. More general regulations stipulate that no toxic substance should be available for ingestion, inhalation, or absorption through the skin and that the total quantity of the available toxic substances shall not exceed 1/100 of the acute oral or dermal median lethal dose calculated for a child have a body weight of 10 kg.

A far more common oral ingestion hazard involves food containers and packaging materials derived from plastics and possible migration of some of the ingredients into the food. The Canadian Food and Drugs Act regulates articles coming into contact with food: Section B 23.001 states: "No person shall sell any food in a package that may yield to its contents any substance that may be injurious to the health of the consumer of the foods. Thus in the case of polyvinyl chloride, the free monomer must not be released;" the current limit of detection is 50 parts per billion.

Similar regulations exist for pharmaceutical products dispensed in plastic containers and standards are being drafted for medical devices such as dentures to ensure that potentially dangerous susbstances are not released in toxic amounts.

A special examination was made of all PVC pacifiers sold in Canada. Chemical examination failed to find any pacifier releasing the monomer; as mentioned earlier, the method employed was sensitive to 50 ppb.

Formaldehyde–urea or formaldehyde–melamine plastics have occasionally been incriminated in ingestion problems. Some years ago a group of Japanese scientists approached our Department for an opinion as to whether an increased incidence of peripheral vision defects could be attributed to increased use of urea–melamine dinner ware. Seemingly they related the release of formaldehyde from such dinner ware to an increased incidence of decreased peripheral vision. Ophthamologists advised that it was not possible to state whether there was or was not an increase in peripheral vision defects, since measurement of such defects received very little attention in most routine eye examination unless there was some reason to suspect glaucoma. It would be virtually impossible to establish a base line. Fortunately, our laboratories had already looked at the elution of formaldehyde from melamine dinner ware. Under normal conditions, about 0.2 ppm was removed. Although higher amounts could be removed under extreme conditions (broken dishes or hot 24-hr soaks in acetic acid) it was concluded that under ordinary or normal conditions of use only insignificant amounts of formaldehyde would be released into food or drink from this type of plastic tableware (*1*).

The possibility of visual defects resulting from formaldehyde ingestion at this level is remote. Episodes of acute poisoning from formaldehyde ingestion have been reported in detail, and eye damage has never been mentioned (*2*). Methanol does produce visual damage, and it is believed by some that the methanol is converted to formaldehyde *in situ* by an alcohol dehydrogenase; however the likelihood of ingested formaldehyde reaching the retina is remote (*3*). Indeed, even this contention is still theoretical and final proof is lacking (*4, 5*).

Certain ball point pens presented a problem a few years ago. A group of senior civil servants were attending a workshop at a remote conference center. After a coffee break, one of them mentioned that his tongue felt numb. Others reported similar responses. Being of analytical bent they soon came to the probable cause. They had all been sucking the end of their ball point pens! Each had used the same type of pen—one supplied by the conference center. Did this phenomenon present a toxic hazard?

The Federal Government purchases annually large numbers of ball point pens, and they had massive numbers of this particular product in stock—hundreds of thousands. Could they be released to staff or was there an element of danger? The first approach was to contact the manufacturer and determine the composition of the plastic, secondly, to carry out elution tests. The manufacturer's answer supplied the main clue; the pen barrels were made of cellulose acetate. Chemical analysis revealed that acetic acid was being released in small amounts. While the amount released was not substantial, it was noteworthy that it was released in those sucking or chewing the pens in very close proximity to the acid-taste receptors in the tongue, and obviously for a sufficient period of time to anethesize the tongue, as it were. This conjecture was confirmed by employing a "pen-sucking panel" in which eight different pens were investigated, including three different types of the suspect cellulose acetate manufacture. There were five of each type in a double-blind study, and, interestingly enough, only the cellulose acetate pens produced the phenomenon of a numb tongue. Almost all participants sucking those pens reported a tingling or numb tongue.

Since there was no hazard involved the pens were released; however, the pen manufacturer has reformulated his product and now uses a polypropylene barrel in place of cellulose acetate.

Dermal Exposure

In consumer products, dermal exposures may involve percutaneous absorption of some loosely bound ingredient, such as a plasticizer, although direct cutaneous reactions are far more common. Frequently, such reactions represent allergic responses or skin sensitization. Clothing, furniture fabrics, watch straps, and jewelry are common offenders. Naturally, it requires skilled dermatological investigation and co-operation of the manufacturer in providing a list of ingredients to isolate and determine the actual allergenic substance. However, certain strong sensitizers have had a notorious history of producing allergic reactions and to not require such involved detective work.

Many episodes with formaldehyde-type plastics have developed from clothing and sheets. Some years ago, there were instances of dermatitis arising from the wearing of permanent press trousers and shirts. The permanent crease was achieved by using a formaldehyde-type resin. Residual formaldehyde produced sensitization (*6*). Although newer processes have largely eliminated this problem of free formaldehyde, there was a major recrudescence a few years ago when a manufacturer changed his process for making permanent press sheets. There was a substantial amount of residual formaldehyde in these products and very widespread reports of dermatitis followed the sale of these sheets. Washing, of course, removed the problem, and the manufacturer redesigned his process to eliminate the likelihood of free formaldehyde.

In addition to primary dermal irritation and sensitization, actual corrosive effects have been noted. The home craftsman makes frequent use of polymer processes—for example, in resin-casting kits and glass fiber repair kits for cars and boats. One of the ingredients in these kits is an organic peroxide, such as methyl ethyl ketone peroxide. This product, frequently supplied in fairly high concentrations, can produce very serious damage if accidentally splashed in the eye (*3*). Amine hardners present in some of these kits may also be strongly corrosive.

The relatively new methacrylate glues undergo rapid polymerization in the presence of hydroxyl ions in water. In the hands of children or the careless or unwary adult, the polymerization can lead to such distressing events such as the sticking together of fingers or eyelids. We have studied a number of these glues and have yet to find a simple, widely available innoccuous solvent that can dissolve the reaction product. Although their use for children in model toys is not sanctioned and their retail cost is relatively high, in our affluent society, children may well get hold of them. The extremely rapid speed of reaction is disturbing, since there is not enough time to take remedial countermeasures. Hence, their continued sale and use is closely monitored for some indication of accident frequency.

Inhalation

Inhalation risks from exposure to plastics are not nearly so common for the consumer as for workers in the plastics industry. Frequently a "brand new" manufactured plastic article may give off or release a malodorous ingredient. This strong odor may invite consumer inquiries but it is seldom possible to provide a definitive answer to the actual degree of hazard. Small squeeze toys in particular seem to be perennial offenders in this regard. The release of phthalate plasticizers from the interior plastic finishings in automobiles has generated much comment, but little actual study of exposure conditions has been undertaken.

The cutting, grinding and polishing of plastics have produced many instances of allergic respiratory manifestations in the industry. There is every reason to suppose that the home craftsmen could be at similar risk.

Unquestionably, however, the greatest inhalation risks arise from fires. In Canada, the annual number of fire-related deaths exceeds 700. The majority of these fatalities are related to inhalation of toxic gases and smoke containing thermal decomposition products.

The flammability of plastics is becoming a major problem which we will not, however, discuss in detail. Most fire-related deaths it appears, result from inhalation of toxic pyrolysis products. The identity of such pyrolysis products is currently receiving a great deal of attenion. It is a most difficult area for legislation. One cannot by legislation prohibit a certain toxic decomposition product—say, hydrocyanic acid or phosgene. The more logical route is the use of fire retardants. However, the widespread use of fire retardants itself needs critical evaluation, for example in the case of the cyclic phosphate esters or polybrominated biphenyls.

There is great concern over the environmental consequences of polychlorinated biphenyls, the PCBs. Recent studies have indicated that they are carcinogenic and that they produce reproductive disorders in birds, mink, and monkeys (*7*). Polybrominated biphenyls have had wide usage as flame retardants—do they pose similar hazards? Does vinyl bromide, a starting material for certain fire retardants, emulate vinyl chloride? Is it a possible carcinogen?

It is hoped that fire retardants can arrest fires with polymers and prevent the release of the highly toxic gases. Nevertheless, some of the current methods for assessing flammability may not simulate the very high temperatures found in a typical apartment or residence fire. Indeed, the supposed protection of a fire retardant may be illusory, since at high temperatures the fire retardant itself may break down and release toxic components. New tests for flammability are urgently needed. Fortunately, this need is well known and it is being studied intensively.

There are also strict regulations about highly flammable plush toys such as teddy bears, since they can lead to tragic accidents. One manufacturer purchased his skins in the Orient since they were less costly. They were made of rayon and extremely flammable. When told these toys could not be sold in Canada the manufacturer proposed to treat them with a flame retardant, in order to pass the test. The flame retardant he posed to use was borax, but boric acid and its salts have produced many fatalities in infants, and its use is specifically prohibited in children's toys by our Toy Regulations. These toys were not released for sale in Canada.

In recent years, the economic climate has favored the retention of plastic building materials and furnishings for longer periods. Here we run into another problem—the aging of plastics. Thus an antioxidant or a fire retardant may lose its effectiveness, particularly in buildings maintained at elevated temperatures. The stability of such additives requires more study (*8*).

Parenteral Exposures

One does not usually think of parenteral exposure to plastics as posing a hazard to consumers. Nevertheless, this route of administration does occur.

Medical devices encompass a great many plastic products—some of which may be implanted for long periods, e.g., bone cements or plastic tubing. Obviously, such products should not elicit sensitization reactions, induce carcinogenic or mutagenic responses, or release toxic products. One area receiving attention at present is a standard for plastic bags for storing whole blood, blood plasma, and for other solutions used in intravenous medication. Some of these bags have been shown to release diethylhexyl phthalate (DEHP). There is some indication that DEHP may be converted to monoethylhexyl phthalate (MEHP) in the liver. MEHP, it is claimed, is more toxic than DEHP. This is a field where more study is indicated using the intravenous route in experimental animals.

Summary

The above brief overview indicates that man in his modern existence is exposed to a wide variety of polymers by every conceivable route of administration: oral, percutaneous, dermal, ocular, inhalation and parenteral (subcutaneous, intraperitoneal, and intravenous). Although one thinks primarily of acute exposures, chronic long-term exposures are by no means uncommon. Particularly good examples of the latter would be migration to foods, elution of chemicals from plastic water pipes, and indwelling medical devices.

The plastic industry uses an extremely wide variety of chemicals, and therefore the possibility for toxic sequellae in consumers resulting from short- or long-term exposure is great. The challenge to the plastic industry and to the toxicologist is obvious. They must ensure that the products of the plastic industry are safe for consumer use. The toxicologist must design simple rapid tests to assess potential hazards, and the manufacturer must produce products that are stable and release little if any of the ingredients. This will permit man to continue to enjoy the benefits accruing from the many developments in the plastics industry.

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