National Network on Environments and Women's Health
Réseau pancanadien sur la santé des femmes et le milieu

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CHEMICAL EXPOSURE AND PLASTICS PRODUCTION: ISSUES FOR WOMEN'S HEALTH | A REVIEW OF LITERATURE

INTRODUCTION

This booklet is a brief overview of the major occupational health hazards found in the plastics industry and what can be done to control them. It is a resource guide to help plastics workers and their unions understand the nature and extent of toxic exposures in the production of plastics, and what measures can be taken for a cleaner and healthier workplace.

Can work in the plastics industry affect women's health?

The plastics industry in Canada has the highest concentration of women than any other industry in the manufacturing sector constituting 37 percent of the total plastics workforce.[1, 2] In the Windsor-Essex County area women make up the majority of the area's plastics workforce.[3] During the course of their work these women are exposed to a large number of toxic chemicals. Several of these substances have been identified as breast (or mammary) carcinogens. Workers are also exposed to substances that may contribute to the development of breast cancer and reproductive problems by disrupting the normal functioning of the body's endocrine system. These hormone-disrupting substances are referred to as 'endocrine disrupting chemicals' (EDCs). Some materials used in the manufacturing of plastics have been identified as both breast carcinogens and endocrine disrupters. The endocrine system is a complex system of glands which produce hormones that regulate body growth, metabolism, sexual development and reproduction. Some EDCs mimic the hormone estrogen or trigger the production of estrogen. Estrogen is a powerful tumor promoter and is known to contribute to the development of breast cancer. For this reason, the nature of EDCs is such that even very low levels of exposure may cause problems with endocrine or reproductive functions.

A recent study found that most plastics products release estrogenic chemicals[4]. In fact, the environment inside plastics plants has been described as a "toxic soup" containing a complex mixture of these chemicals. This is disturbing because the effects of several different EDCs in combination may be greater than their individual effects.

MATERIALS AND PROCESSES

What are plastics?

Plastics are synthetic polymers that are made up of long chains of repeating molecular units called monomers. Monomers are the building blocks of polymers. Monomers such as vinyl chloride, styrene, and acrylonitrile are produced by the petrochemical industry through crude oil distillation at refineries.These raw materials are then sent to resin producers where monomers are polymerized into final polymer products such as polyvinyl chloride (PVC), polystyrene (PS), and acrylonitrile-butadiene-styrene (ABS). After the addition of additives such as plasticizers and fire retardants, resins are then shipped to plastics manufacturers in the form of powders, liquids or pellets where they are transformed into a whole host of plastics products.

The processing of plastics is divided into two main classes. Thermoplastic materials are polymers that can be repeatedly softened and reshaped with the application of heat and pressure. Thermoset materials undergo a chemical reaction that results in a permanent product that cannot be softened or reshaped. Refer to **Table 1** listing thermoplastic and thermosets.

TABLE I | MOST COMMONLY USED PLASTIC POLYMERS

Thermoplastic Resins	Thermosetting Resins
Polyethylene—PE | (40%)	Epoxy
Polyvinyl Chloride—PVC | (20%)	Polyester
Polypropylene—PP | (19%)	Urea
Polystyrene—PS | (9%)	Melamine
Polyethlene Terephthalate—PET | (6%)	Phenolics
Acrylonitrile-buadiene-styrene—ABS	Polyurethane
Styrene-Acrylonitrile—SA	
Acrylic—PMMA	
Polyamide—PA (Nylon)	
Styrene-Acrylonitrile—SAN	
Polycarbonate—PC	

Using one of these classes of processing, the resins are formed into various products such as PVC fabrics, steering wheels, bumpers, light lenses, fuel tanks, foams, insulation, adhesives, and sealants.

How are workers exposed to chemicals during plastics production?

" We do plastic injection moulding, we smell a lot of smells, a lot of fumes, stuff like that so I'd like to see actually more local exhaust, is what I'd like to see in our facilities...I've been there about 23 years."

Plastics processing involves the conversion of resin to a soft state through heat and pressure. Several different methods are used to form resin into the final end product. The main methods are injection moulding, extrusion, blow moulding, calendaring and compression moulding. High temperatures and pressures applied to resins result in the release of various emissions from resin melt. The overheating of plastic materials during processing, cleaning, purging and maintenance operations can expose workers to a complex mixture of combustion by-products. Some of these contaminants include: hydrogen chloride from PVC, styrene from polystyrene, nitrogen compounds from nylon and acrylonitrile, and cyanide from urethanes. Finishing operations can expose workers to a variety of other chemical compounds, such as those found in paints, solvents and adhesives. Refer to **Table II** listing job tasks and exposures in thermalplastics processing.

Injection moulding: Pellets or granules are loaded into a hopper and heated in a barrel. The melted plastic is injected into a metal mould by a reciprocating screw. The parts are held under pressure until cool, then removed and trimmed. In this process, workers may be exposed to heated resins, release agents and cleaning solvents. Workers may additionally be exposed when the dies open releasing smoke and vapours from the plastic part and mould.

Extrusion: This method is similar to injection moulding, but instead of forcing the melted resin into a mould, the screw forces a continuous melted resin through a metal die of a desired shape. This method can be used in the fabrication of pipes, tubing, or sheets, or during resin production where extruded material is chopped into pellets. Workers may be exposed to heated resins and cleaning agents.

Blow Moulding: A hollow tube of heated plastic is formed, usually by extrusion, and placed in a mould of desired shape. The tube is then filled with air under high pressure to push the plastic against the walls of the mould. The process is used to form bottles and fuel tanks. Workers may be exposed to heated resins and various blowing agents.

Compression Moulding: Heat and pressure are applied to resin granules with a mould, forcing resins to conform to the mould shape. Workers may be exposed during the venting and ejection of the part, when various gases are released from the moulding compound.

Calendering: Heated resin is run through heated rollers to form sheets and coatings. Because this is an open process with a large surface area, workers can be highly exposed to resin fumes and gases.

"I don't know if it's from the smoke or if it's from the fumes, you smell a fume, you taste in your mouth and then you get, it's like a — light-headedness, dizziness."

Finishing processes involve the use of paints, adhesives, and solvents. The moulded plastics often need to be trimmed, drilled and sanded before packaging and shipping. Some products may also need to be assembled. Workers can be exposed to polymer dust from sanding and grinding operations as well as paint and solvent vapours during finishing operations. Scrap plastic materials are usually recycled after being ground

Purging and maintenance: Finally, moulding machines need to be purged of the previous resins to change colour or polymer type. This involves forcing resins and purging agents through the presses at very high temperatures. Because of the high heat, the purging process produces high levels of polymer fumes, smoke and gases and various by-products to which workers can be exposed.

"...we've had quite a few women, one woman, actually right now is actually going through her treatment for breast cancer started last week... and we've had four within the last ten years I would say. So yeah, it's always in the background of your mind when they're purging the machines...we'll yell over at another co-worker and say I wonder what this smell, if it can affect us."

Other activities: Handling resins, intermediaries and additives can also result in worker exposures. Activities such as opening bags and drums, manual handling and blending, pouring resin pellets and powders into hoppers can expose workers to significant levels of resin dusts.

What are the principal contaminants released during plastics processing and fabricating?

The plastics processing work environment is potentially contaminated by residual monomers, polymers, and various additives including plasticizers, stabilizers, pigments/colourants, flame retardants, activators, lubricants and fillers. There also may be contamination from various solvents, paints and finishing agents used in the decorative process.

The following are specific contaminants of concern:

Monomers

Hazardous monomers such as styrene are frequently present in common polymers.[5] A recent study ranked fifty-five polymers used in plastics production with respect to their degree of toxicity and seriousness of health impact. The highest ranking of these identified fifteen substances that were carcinogenic and/or mutagenic including polyvinyl chloride, styrene–acrylonitrile, and acrylonitrile-butadiene-styrene (ABS).[6]

Vinyl Chloride: Vinyl Chloride is used essentially to produce polyvinyl chloride (PVC) resins used for the manufacture of various plastics products such as pipes, tubing, fabrics, and auto parts. Vinyl chloride monomer can be released during PVC resin production as well as during thermal processing of the resin. Vinyl chloride is classified by the International Agency for the Research on Cancer (IARC) as carcinogenic to humans (Group 1)[7]. It is also shown to be a mammary carcinogen in animals.[8]

Styrene: Styrene is used in the production of various plastics, resins and vulcanizers such as styrene butadiene rubber, acrylonitrile-butadiene- styrene (ABS), and styrene-acrylonitrile resins. Styrene is classified by IARC as possibly carcinogenic to humans (Group 2B)[9] and is shown to cause mammary gland tumours in animal studies.[10] It also acts as an endocrine disrupter.[11]

Acrylonitrile: Acrylonitrile is used in the production of acrylic and modacrylic resins and rubbers. Acrylics and ABS polymers are used in production of pipes, auto parts, and windows. Thermal degradation of acrylonitrile-butadiene-styrene (ABS) during normal plastics processing results in the release of acrylonitrile monomer into the air. Acrylonitrile is classified by IARC as possibly carcinogenic to humans[12] and is shown to be a mammary carcinogen in animals.[13] In addition, it is linked to genital abnormalities in children born to exposed mothers and may have endocrine-disrupting effects.[14] Acrylonitrile is also linked to an increase in lymphocyte counts, severe liver damage, lung cancer, and increased chromosomal aberrations in exposed workers.[15, 16]

Bisphenol A (BPA): BPA is a monomer used to manufacture polycarbonate plastic, the resin used in linings for most food and beverage cans, dental sealants, and as an additive in many other consumer products including automotive parts. Animal studies show a number of negative effects in offspring of BPA-exposed mice such as abnormal development of mammary end buds.[17] Human BPA studies identify adverse effects in women with a high BPA body burden such as: recurrent miscarriages, ovarian cysts, obesity, and endometriosis.[18, 19, 20, 21] Concern over its endocrine disrupting qualities led the Canadian government to restrict its use in the manufacture of baby bottles. However, it continues to be allowed in many other products.

Formaldehyde: 80 percent of all formaldehyde is used for plastic resin production such as urea-formaldehyde resins, phenolic resins, epoxy and melamine resins. IARC has classified formaldehyde as a human carcinogen (Group 1).[22] It was linked to an increase in breast cancer risk in a 1995 study of industrial workers; similar results were found in other international studies.[23] Formaldehyde is released during thermal processing, and is most likely present during over-heating events such as machine malfunctions, purging or maintenance operations.[24]

"Well I know firsthand when you go and you're first diagnosed with cancer, they never asked where you worked. They wanna know if you smoked, if you had stress in your life, if you drink... they didn't ask me where I live...they never asked me where I worked all those years."

ADDITIVES

Numerous additives are used in the production of plastics. The following are of concern due to their potential link to cancer and endocrine disruption:

Plasticizers: Phthalates are a broad class of substances used to make plastics soft and pliable. They can be released into the air during thermal processing. The potential estrogenic action of di-(2-ethylhexyl) phthalate (DEHP) used to plasticize PVC may have a role in the development of male breast cancer, testicular cancer, and adverse pregnancy outcomes among those who work in PVC fabricating.[25, 26, 27] A recent study of male PVC workers in Taiwan found an adverse effect on the semen quality among the men with the highest concentrations of DEHP.[28] A study of a phthalate-exposed population in Northern Mexico found an elevated breast cancer risk among women.[29]

Metals: Various metal compounds are used as stabilizers and colourants in polymers. These can include: inorganic lead compounds, cadmium, organic tin compounds, barium, calcium, zinc carboxylates, and antimony compounds. Lead compounds that are used in PVC stabilization are classified by IARC as possibly carcinogenic to humans (Group 2B).[30] Lead is also considered to be an endocrine disrupter,[31] and can have reproductive effects in men and women. When cadmium is used as a pigment in thermoplastics, the injection moulding process can result in measurable air concentrations.[32] Cadmium is classified by IARC as a human carcinogen (Group 1).[33] It also functions as an estrogen mimic (xenoestrogen).[34]

Flame Retardants: The primary flame retardants that have been used in plastics production are organohalogen and organophosphorus-containing compounds.[35] Polybrominated biphenyls (PBB) and polybrominated diphenyl ethers (PBDE) have been shown to be strongly estrogenic and in some instances have been classified by IARC as possibly carcinogenic to humans (Group 2B).[36] (Tris(2-chloroethyl) phosphate (TCEP), a phosphororganic compound, has been shown to be potentially "toxic to reproduction." Antimony trioxide, used as a flame retardant, has been shown to cause respiratory cancer in female rats and negative reproductive effects in humans.[37] It has been classified by IARC as possibly carcinogenic to humans (Group 2B).[38] Several jurisdictions (including the European Union and several U.S. States) have either banned or restricted the use or manufacture of a number of PBDE flame retardants as well as TCEP. Some manufacturers have voluntarily ceased producing some of these or have committed to phasing these out. Despite these measures, there is evidence that these chemicals continue to be in widespread use.[39]

Solvents

In addition to the many carcinogenic and/or EDCs that are found primarily in plastics production, there are several other cancer causing and hormone disrupting substances used in the plastics industry that are common to most manufacturing jobs. They include:

Polycyclic aromatic hydrocarbons (PAHs): PAHs are emitted by machining, fuel combustion, and other decomposition processes. PAHs have been identified as mammary carcinogens in animal testing.[40] Benzo(a)pyrene, one of the PAHs produced when combustion is incomplete, has been identified by IARC as carcinogenic to humans (Group 1).[41]

Benzene, methyl ethyl ketone (MEK) and toluene are used in the painting, gluing, and decorating of plastics products. Benzene, methylene chloride, toluene, and several other organic solvents have been found to cause mammary tumours in animals.[42] Researchers have suggested that organic solvents may initiate or promote breast cancer.[43] Many of these solvents are also considered to be endocrine disrupters.[44]

Exposure to Complex Mixtures

Plastics workers are rarely exposed to these substances one-at-a time. Instead, they are exposed to complex mixtures of chemicals used and produced during the production process. Workers are also exposed to a multitude of combustion products released when plastics are overheated. Additional exposures also occur outside the plant setting (at home, outdoors, etc.) and also add to the combination. Such mixtures can have additive and synergistic effects in which the combined effect is far greater than the individual effect of each single chemical. Some studies that have investigated the link between endocrine disrupters and breast cancer were inconclusive when exposure to only one chemical at a time was measured, but showed adverse effects when exposures to complex mixtures were tested.[45, 46]

Other Work Conditions That May Affect The Endocrine System

Shift Work: Night shift workers were found to have elevated levels of breast cancer in several studies.[47,48,49] Exposure to light at night is thought to suppress the hormone melatonin which regulates circadian rhythms and normally supresses the production of estrogen.[50] IARC has concluded that, "[s]hift work that involves circadian disruption is probably carcinogenic to humans"[51] The Danish workers' compensation system now recognizes the association between work at night and breast cancer.[52]

To what extent are workers exposed to toxic substances in plastics processing?

"Committees have had the ministry come in and do testing and it's never over the exposure limits … We would run ABS [acrylonitrile-butadiene-styrene] … and there were a lot of issues with people suffering from symptoms and the test results always came back under what was allowed."

Workers seldom have their health symptoms and complaints validated by meter readings taken through government or company air sampling. Typically, readings come in below the occupational exposure limit and, without question, the workplace is given a clean bill of health.

"...even though our plant got tested and everything turned out perfect, people are still getting, you know, side-effects."

Critics of our current occupational exposure limits have challenged the legitimacy of those limits and would argue that they are not health-protective.[53, 54] Furthermore, air monitoring can underestimate the true body burden. Several studies that used biological monitoring methods to study the biological accumulation of plastics substances in workers found that while levels measured in air were below occupational exposure limits, the blood and urine concentrations were significantly higher in the exposed workers than were found in the general population or in a control group. These studies included measure of:

acrylonitrile[55], styrene[56,57,58], phthalates[59], brominated fire retardants[60,61,62], and bisphenol A [63]. Two other studies on off-gassing of fire retardants and phthalates in car interiors found relatively high concentrations of phthalates and halogenated fire retardants, raising question about potential exposures of autoworkers to these substances during automobile assembly.[64,65]

What can be done to control or eliminate exposure to these toxic substances?

Effective control measures in the plastics industry must be based on the fundamental industrial hygiene principles of control. We consider these measures on the basis of 'where' the control measure is exerted: at the source; along the path to the worker; and, at the worker.

Controlling at the source

Controlling hazards at the source of production is the most effective method. This can be achieved by substitution with less hazardous substances, isolating the hazard by enclosing the hazardous process or re-engineering the process to eliminate the hazardous steps in the production process. A combination of these methods were used in the Japanese steel industry to eliminate exposures to coke oven emissions.

Substitution: Researchers have suggested full-scale substitution of plastic additives shown to be estrogenically active.[66] It is argued that it is possible to substitute relatively inexpensive monomers and additives that do not exhibit estrogenic activity at minimal additional cost. For example, some manufacturers have re-engineered the use of blowing agents that both minimize exposures and improve quality control.

Isolation: Contamination can be controlled by enclosing the process at every step where exposure would be possible. For example, closed vat or closed-loop systems have reduced exposures to such carcinogens as vinyl chloride and bis chloromethyl ether (BCME) to minimal levels.

Re-engineering: Re-designing the production process can eliminate the potential for the release of contaminants. In the case of plastics injection moulding, for example, automating such procedures as part retrieval from the mould can minimize exposures during injection moulding operations.

Controlling along the path

There are several ways in which hazards can be controlled between where they are released and where the worker is located.

For example, when local exhaust ventilation is installed close to the source, it interrupts the flow of hazardous fumes by extracting them along the path before they can reach the worker. Local exhaust ventilation includes fixed hoods, soldering benches, moveable hoods and ducts in welding operations and spray booths. Properly designed and maintained local exhaust systems can be an extremely effective means of controlling exposures. General ventilation or dilution ventilation, on the other hand, is not considered to be an acceptable control method. In a toxic environment such as that which can be found in plastics plants, it is little more than a technical term for the complete absence of controls.

Another example of controlling hazards along the path is the use of wet methods to control dust in grinding, drilling and sanding operations.

Finally, good housekeeping measures can be considered controls along the path. These include proper clean-up, disposal of waste, dust and spills, and the use of vacuum cleaners instead of brooms or mops.

Control at the Worker

The use of personal protective equipment (PPE) and administrative controls are generally found to be the least effective methods of controlling hazards. Examples of controls at the worker include such devices as respirators, ear muffs or plugs, protective gloves, safety glasses or eye shields. These types of controls offer very limited protection, are often uncomfortable for the worker, and can be hazardous themselves. For example, respiratory protection may leak because of improper fit, particularly in the case of women. It can also cause breathing difficulties and put stress on the cardio-vascular system particularly where these are worn for long periods and by workers who may have pre-existing cardio-pulmonary problems. Finally, some studies reviewed also indicated that respiratory protection did not decrease the body's uptake of the chemicals involved in the production of plastics. In some instance, body uptake increased on days that respiratory protection was worn.[67]

Administratively-imposed controls such as pre-screening workers who may be abnormally susceptible; rotating shifts in hazardous areas; and hiring workers who have been sterilized where there are hazards to reproduction may have short-term impact but do not get at the source of the problem (or, do not further health and safety for all workers).

THE COST OF CONTROLS

Companies typically stress that safety measures and controls can be too costly to the organization, and predict that plant closures and unemployment will result if stronger standards are enforced. While these scare tactics have been barriers to more effective controls and stringent standards in the past, in reality these claims are not always well founded. A well documented example of this is the case of the vinyl chloride industry that initially protested that a more stringent standard would result in the demise of the vinyl chloride industry in the United States, yet was able to comply with the new standard at a relatively minor cost.[68, 69]

"It is very scary because I noticed a lot of new feeder plants... out there, they're still working for minimum protection and we need to get everyone up to the same scale that they should be and get rid of those chemicals, there are substitutions out there for them..."

CONCLUSION

Acting on growing evidence that various plastic additives and monomers can cause adverse health effects –cancer, hormone disruption, birth defects, neurological problems —governments in several jurisdictions have taken measures to limit, restrict or ban the use of many of these substances. Many individual companies have voluntarily discontinued the use or production of these compounds and initiated efforts to find safer substitutes. Witness the Canadian government's restriction on the use of BPA in baby bottles, the restricted use of certain plasticizers such a DEHP, and the banning of certain halogenated flame retardants. While these developments make an important contribution to the health of workers and the general public, we still have a difficult task in front of us.

The number of chemicals that continue to come into use is astronomical, while the amount of toxicological data is relatively small. It is estimated that we have toxicological data for less than one fifth of the commercial chemicals on the list of substances compiled under the U.S. Toxic Substance Control Act. Adding to this difficulty there is little to require the pre-testing of chemicals introduced into the workplace. And for the most part, the burden of proving harm is placed on the worker and the public in general.

We need to strongly reinforce a system which reverses the onus of proof and requires the pretesting of all substances. With so many women being employed in the plastics industry we also need improvements to the regulating system that recognize sex and gender-based implications of chemical exposures.

Quotations contained within the text are taken from focus groups of Windsor, Ontario (Canada) plastics workers in 2011.

A glossary of terms appears at the end of the text.

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TABLE II | JOB TASKS AND EXPOSURES IN THERMOPLASTIC PROCESSING

Process	Job Tasks	Activities	Exposure Factors	Substances	Probably Exposure
Resin Preparation	• Compouding • Blending/Mixing/ • Drying	• Manual Handling of Resins • Open/closing drums • Scooping powders/pellets • Supplying mold operator with resins, tending dryers	• Direct contact with resins: dusts, vapour, liquids • Inhalation and dermal routes	• Various resin formulation and additives: PVC, PP, PE, PS, ABS, SAN PC + Addictives	• High if process is manual and in batches
Molding Machine Operations	• Monitoring and tending mold machine	• Pouring resins onto hopper • Monitoring/ controlling temperature and pressure • Retrieving product • Triming product • Purging • Cleaning and maintenance	• Direct contact with resins • Venting and melt degassing from mold machine • Off gassing from ejected and extruded plastic product • Dust from trimming product • Inhalation and dermal routes	• Thermal decomposition products in form of gases and vapours: VC, AN, Styrene, PAHs, phthalates, metals, flame, retardants, release agents, blowing agents	• High depends on molding process
Molding Processes					
Injection			• Enclosed thermal process (venting and melt degassing)		Medium
Extrusion			• Hot plastic continuously extruded in open in addition to venting		High
Blow Mold			• Enclosed thermal process (venting and egassing)		Medium
Calendering			• Open thermal process and large surface area		High

Process	Job Tasks	Activities	Exposure Factors	Substances	Probably Exposure
Finishing	• Triming excess plastic	• Drilling, grinding, cutting, sanding and buffing plastic product	• Direct contact with plastic • Vapour from fresh product • Inhalation of fine particulate from drilling, grinding, sanding and buffing • Dermal absorption	• Inhalation and absorption of • Particulate containing residues of monomers, additives, plasticizers, metals, pigments, stabilizers	• High to medium
Fabricating	• Manually fashioning plastic product	• This involve activities that include: Bonding, carving and shaping, turning on lathes, grinding, sanding, welding and sewing or stitching	• Vapours from bonding and gluing agents, fine dust particulate from grinding/sanding • Fumes from welding • EMF from induction welding • Fine particulate, oil mist and EMF from sewing operations • Sewing plastic fabric involves work with fresh plastic sheets with large surface area	• Inhalation of vapour from bonding and gluing agents Inhalation and skin absorption of fine plastic dusts from sanding, grinding and sewing operations. • Sewers exposed to dust and vapours • Proximity to EMF from machine motors and induction heaters	• High
Painting and Decorating	• Manually painting and decorating plastic product	• Spray painting, electrostatic spraying, dip coating, filling in, screen painting, roller painting • Preping product for decorating and painting	• Inhalation and absorption of vapour and mists substances with high volatility	• Preparatory solvents such as acetone, toluene, trichloroethylene, MEK, ether, isopropanol, priming with chlorinated polyolefins • Acrylic paints and lacquers containing	• High to medium

Process	Job Tasks	Activities	Exposure Factors	Substances	Probably Exposure
Painting and Decorating				solvents and enamels • Urethane, epoxy, polyester, acrylic lacquer, enamel, enamels	
Plastic recycling	• Plastic regrinding	• Plastic regrinders operate machines that grind up scrap plastic to be recycled	• Inhalation and dermal absorption of plastic particulate	• Exposure to fillers (silica, talc), pigments, metals, stabilizers	• High
Purging/Cleaning Operations	• Removing resins in preparation for new resins	• Running resins or purging agents through molding machines at high heat to remove old resins • Followed by cleaning with solvents	• Inhalation and dermal absorption of vapour, fumes and gases from intense thermal degradation products	• Exposure to a large variety of thermal degradation products • Benzene, bensopyrene, 1,4 Dioxane, formaldehyde, acetaldehyde, butadiene, acrolein, acrylonitrile	• High

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GLOSSARY

Aberration: abnormal content in the *chromosome* of a cell. These can be passed down from ones parents, even if they showed no signs of genetic abnormality. Others occur as mistakes when cells are dividing or are exposed to *genotoxic* substances. Not all aberrations cause disease in humans, but they are the major cause of genetic conditions such as Down Syndrome.

Additives: additional agents blended and mixed into commercial plastics to change the chemical properties of the final product. Some of these additives have been identified as *mammary carcinogens* and *endocrine disruptors*, such as plasticizers and *flame-retardants*.

Body Burden: concentration of the chemicals in the body at any given moment. Body burden can be measured by the concentration of chemicals in urine, blood, fat tissue, breast milk and semen.

By-products: secondary products or chemicals created through the manufacturing process. In plastics, numerous by-products are detected through air sampling in the plant.

Carcinogens (mammary): any type of *toxic agent* that is involved in causing and in promoting the progression of cancer in mammals. Only some chemicals can by themselves cause cancer, but when chemicals are combined (*concomitant exposure*), such as those found in a plastics plant, they can act together as carcinogens to meet the check-list of requirements to, not only initiated cancer cells but, cause the disease.

Case-control study: a study design where those who have a condition (“cases”) are compared with similar people who do not have the condition (“controls”). This allows the researchers to assess for differences, such as occupational exposure, which may be a risk factor in the cases but not in the controls.

Chromosome: well-organized structures of genetic material (DNA and proteins) within the nucleus of every cell. Each chromosome has two identical strands of genetic material, known as chromatids, joined at the centre by a centromere.

Circadian rhythm: the body’s built-in biological clock. Taking cues from the environment, such as daylight, the system helps the body establish a regular sleep/rest and active/wake cycle. Artificial environments, such as light at night, can also have an effect on circadian rhythm. Circadian disruptions are thought to be carcinogenic (see *carcinogens*) to humans.

Cohort: a group of research subjects who share a common characteristic (e.g. male/female) or experience (e.g. plastics workers), who are studied in a defined period of time. A cohort may then be compared to the general population or to another cohort for a risk factor, such as breast cancer or chemical exposure.

Concomitant exposure: when different chemical exposures occur simultaneously (e.g. several different purges at one time) to create additive or *synergistic* harmful health effects. Because much research in *endocrine disruption* is done in laboratories, the effect of concomitant exposure has not been fully replicated in epidemiological studies (see *epidemiology*).

Endocrine disruption: interference with the synthesis, secretion, transport, activity, or elimination of natural hormones. This interference can block or mimic hormone action, causing a wide range of effects.

Endocrine system: consists of the cells, tissues, organs, and glands (such as the pituitary, the pancreas, the adrenals, and the testes) that secrete hormones, to regulate development, reproduction, metabolism, behavior and homeostasis in the body. The endocrine system controls maturation, development, growth, and regulation within the body.

Epidemiology: the study of the distribution and determinants of health and disease. It makes use of a range of both *qualitative* and *quantitative* methods to gain a well-rounded understanding of the relationship between exposure and outcome. It is difficult for this type of research to account for all the real-life, day-to-day *concomitant exposures*.

Estrogens: the primary female sex hormones (see *hormones*). Though they are found in both men and women, they are usually found in much larger quantities in women of reproductive age, as they play an important role in the reproductive system but are nonetheless important elsewhere in the body.

Flame-retardants: additives that block or slow the spread of fire. They are used in commercial plastics and are required by law to be included in automotive parts. Many are recognized as *mammary carcinogens* and *endocrine disruptors.* There are two categories of flame-retardants: organic (phosphate esters and halogenated materials, particularly organobromine compounds) and inorganic (metal oxides, hydroxide and basic carbonates). Organic halogen and phosphorus compounds are the most commonly used in the plastics industry. Some important plastics production examples of flame retardants that have been shown to have negative health and environmental effects are: polybrominated biphenyls (PBB), Tris(2-chloroethyl) phosphate (TCEP), and antimony trioxide.

Foetus: developing mammal after the embryonic stage, from the 9th week after conception until birth. This is a period of immense growth in a short amount of time, and different periods of time in fetal development cause vulnerability to different growing organs. The placenta, the organ that connects the foetus to the mother, offers some protection for the foetus although not as much as was once believed. In fact, some substances tend to accumulate and concentrate in the fetal blood circulation more than in the mother's.

Genotoxicity: property possessed by some substances that makes them harmful to the genetic information contained in organisms. For example, cancer results when genotoxic substances interfere with a cell's genetics, which can cause problems for natural cell death, cell replication and cell function. As a result, when cancer occurs there is an uncontrolled growth and division of cells that cannot accomplish the task they were set out to do.

Gland: an organ that synthesizes a substance for release of substances, such as hormones or breast milk.

Hazard mapping: mapping out an environment (e.g. workplace) and identifying all the sources of exposure (e.g. chemicals) so that action can be taken to prevent or contain that exposure (e.g. installing ventilation).

Hormones: messenger molecules that are released from a cell/*gland* to signal a cell or gland to act or to block an action. Hormones and the *glands*/cells from which they originate form the basis of the endocrine signalling system (see *endocrine system*), which is vital to life. There are many hormones in the body, though *estrogen* hormones and chemicals that mimic or change their effects (see *endocrine disruption*, *xenoestrogen*) are of particular concern in the plastics industry. *Melatonin* is another hormone, which is involved in regulation of *circadian rhythm*.

Hyperplasia: growth in the number of cells in response to a stimulus (usually *estrogen* or hormone-related), which may take the shape of a benign (non-cancerous) tumour. It is considered an important risk factor for the development of cancer.

International Agency for Research on Cancer (IARC): a branch of the World Health Organization (WHO), created to coordinate and conduct research on the causes of human cancer and develop strategies to prevent and control cancer. They also classify chemicals based on the level of *carcinogenicity* to humans into.

Agents Classified by the IARC Monographs

Group 1: Carcinogenic to humans

Group 2A: Probably carcinogenic to humans

Group 2B: Possibly carcinogenic to humans

Group 3: Not classifiable as to its carcinogenicity to humans

Group 4: Probably not carcinogenic to humans

Lymphocyte: a type of white blood cell which is important in the immune system. There are three types of lymphocytes: T cells, B cells and Natural Killer cells. When their numbers are increased in circulation, this indicates that the body is having a heightened immune response to something it has tagged as damaged or foreign to the body.

Mammary (terminal) end buds: growing fringe of the mammary gland, with lateral buds branching dichotomously to form branches towards the nipple. In pre-puberty, when the mammary glands are greatly developing, the terminal end buds move through the fat pads of the mammary tissue and develop, in puberty, into the ducts needed for milk release.

Mammary gland: the breast, found in mammals. A gland is an organ responsible for releasing a substance into the body; in this case, the purpose of the mammary gland is to produce milk to feed infants. In puberty, *estrogen* promotes breast development in women, with the help of *mammary end* buds. Breast tissue has been found to be particularly vulnerable when exposures to harmful chemicals (such as plasticizers and *flame retardants*) occur before the age of thirty-six when it has fully developed.

Material Safety Data Sheets (MSDS): forms that provide information on the properties of particular substances. The purpose is to provide workers the information needed to handle, store and dispose of materials safely as well as offer spill-handling procedures. MSDSs are required by law to be provided for all the materials that are currently in use. However, older MSDSs for chemicals that are no longer in use are often discarded, making it difficult for researchers to trace back exposures, given the *latency period* for cancer.

Mean age: average age.

Melatonin: hormone that causes drowsiness and lowers the body temperature to prepare for and sustain sleep. This hormone is one aspect of the *circadian rhythm* of the body.

Monomers: single atom or small molecule that binds to other monomers to form *polymers*. There can be harmful monomers found in commonly used polymers in the plastics industry. These hazardous monomers can be released during production, such as acrylonitrile release into the air during *thermal degradation* of acrylonitrile-butadiene-styrene (ABS).

Mutagens: *toxic agents* that cause mutations or mistakes in the genetic material of a cell. Mutagens that cause cancerous mutations are called *carcinogens*, but not all mutations cause cancer.

Paradigms: framework containing all of the commonly accepted views about a subject. For example, there are two paradigms in the argument of how occupational exposures to plastics cause breast cancer. There is the traditional toxicology theory (increased dose, higher effect) and the endocrine disruptor theory (lower dose, higher effect).

Polymer: larger molecules built of monomers that have different (often improved) chemical properties than their monomer components. Plastics and resins are typically made of polymers.

Thermosetting polymers: polymers that irreversibly harden (cure) at a set temperature.

Qualitative research: method of research that draws data from exploratory oral or written interviews in an attempt to answer questions. This method often focuses on a smaller sample of people in order to gain a deeper, richer understanding of their experiences. Unlike *quantitative research,* qualitative research does not aim for *statistical significance* but tries to gain a thoughtful understanding of the different layers of interests at stake in an issue to capture data that may not be apparent in the statistics alone.

Quantitative research: method of research that attempts to quantify data. This method aims to achieve *statistical significance*, in order to draw links and answer questions. Though this type of data is useful in quantifying a problem, it sometimes lacks depth in its understanding of the underlying problems and the individual experiences behind the numbers. However, the statistical analysis and use of larger samples in quantitative research allows the researchers to make hypotheses that can be generalized to the larger population.

Sample size: number of subjects/observations included in a study.

Statistically significant: indication that a finding is probably true and not just happening by chance. This is accomplished through a numerical analysis, which usually requires a fairly large *sample size*. Notably, just because a finding is statistically significant does not mean that it is particularly important, nor does it tell you what other factors are coming into play. There is also always a percentage of error and the only way to truly confirm that a finding is statistically significant is to repeat the research and see whether the results are consistent.

Synergistic: when factors act together to amplify each other. In *toxicology*, a growing field of study is how chemicals can act synergistically to be detrimental to health, knowing that most people are exposed to more than one chemical on a regular basis.

Thermal degradation: when *polymers* are overheated, such as in purging in polymer manufacturing. This causes the polymers to separate into *monomers* and react with other polymers to form new ones. This can add to the concentration of *toxic agents* in the environment.

Thermal molding techniques: method of heating plastic to a temperature at which it is soft enough to be molded into the desired shape (e.g. injection-molding).

Thermoplastics: polymers that, when heated, turn to liquid, and, when cooled sufficiently, become glassy. This allows them to be whatever shape is desired with a smooth finish.

Toxic agent: This is a physical or chemical substance that is harmful to health and/or the environment.

Toxicology: the study of *toxic agents*. Traditionally, toxins are studied in a dose-dependent manner, where it is assumed that the higher the dose or exposure, the greater the toxicity (known as the dose-response curve). At a high enough dose, almost all consumable things have a level at which they are toxic to the human body. In contrast, *endocrine disruptor* theory believes that some chemicals can also have toxic properties at extremely low levels.

Xenoestrogen: a xenohormone that acts like *estrogen* in the body.

Xenoestrogenic potential: the possibility of a compound to be able to act as a *xenoestrogen* that could be evaluated through further research.

Xenohormone: naturally occurring or artificially created compounds showing hormone-like properties. These compounds disrupt the normal balance of hormones, which is particularly relevant to hormone related cancers and reproductive health.