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PLASTICISERS: A CONSIDERATION OF THEIR IMPACT ON HEALTH AND THE ENVIRONMENT

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SUMMARY

Plasticisers have been used for centuries to improve the processability and flexibility of a variety of materials.

At the dawn of civilisation water was used to plasticise clay for the production of pottery and clay tablets and the Ark was reputedly waterproofed with pitch plasticised with oil.

Today the most common plasticisers are phthalates, adipates and similar esters the majority of which are used to produce flexible PVC products.

The widespread use of plasticisers in these applications over the last forty years has resulted in their toxicology being extensively researched and understood. As a consequence of these investigations many official bodies and legislative authorities have concluded that plasticisers pose no significant hazard to man or the environment.

Plasticisers will therefore continue to be used to enhance all our lives through the production of a wide variety of PVC items ranging from medical components to waterproof clothing and floor coverings.

1 INTRODUCTION

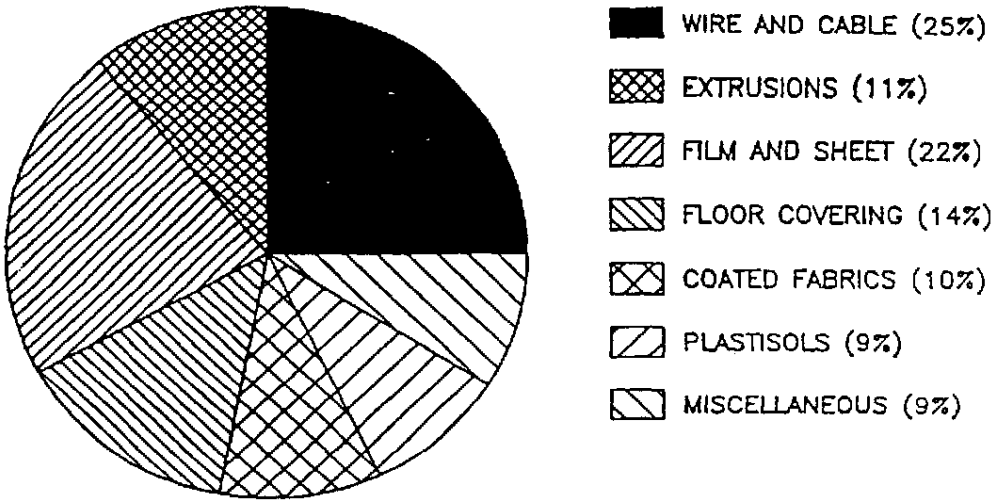
Plasticisers are in general colourless, odourless liquids which are relatively non-volatile and have a very low solubility in water.

The vast majority of plasticisers are esters of phthalic acid (phthalates) with a wide variety of long chain alcohols containing up to 13 carbon atoms. The remainder are also esters or polyesters and include those based on adipic, trimellitic, phosphoric, sebacic or azelaic acids.

In Western Europe about 90% of all plasticisers are used to convert PVC, which is a rigid plastic, into a soft, flexible, elastic material. The remainder is used in other plastics, dispersions, coating systems and lubricants. Plasticisers have been used in this way for many years to produce flexible PVC for a wide variety of everyday applications. The level and type of plasticiser used is selected to meet the required performance of each application.

The major uses of flexible PVC vary somewhat from one country to another, however the typical split between the various applications in Western Europe is shown in the diagram. The proportion of plasticiser used in each application sector may be assumed to be similar to that given for flexible PVC.

APPLICATIONS OF FLEXIBLE PVC IN EUROPE



2 HEALTH ASPECTS OF PLASTICISERS

The toxicity of a substance is a measure of its effects on living organisms. It is not possible to state simply whether plasticisers or any other materials are toxic because this is determined by the dose level. This was expressed by Paracelsus as early as the 16th century as the basic tenet of toxicology:

'All substances are poisons; there is none which is not a poison. The right dose differentiates a poison and a remedy'.
(Paracelsus 1493-1541)

Acute toxicity

The acute toxicity of a substance is an assessment of the effect that a single dose will have on a living organism. The relevant parameter is the dose which is lethal for 50% of the test animals referred to their body weight (LD_{50}).

The acute toxicity of plasticisers is extremely low. In order to put this into perspective, the table below shows a range of substances and their poison class. As can be seen plasticisers are classed as having negligible toxicity. In fact the toxicity of plasticisers is lower than that of other everyday substances such as common salt.

In addition to their low acute toxicity many years of practical use coupled with animal tests show that plasticisers do not irritate the skin or mucous membranes.

ACUTE TOXICITY OF VARIOUS SUBSTANCES		
CATEGORY*	EXAMPLES OF TOXIC SUBSTANCES	LETHAL DOSE IN MG/KG (FOR ORAL APPLICATION)
VERY TOXIC (LESS THAN 25 MG/KG BODY WEIGHT)	BOTULINUS TOXIN	0.00000003
	HYDROCYANIC ACID	0.7 – 1.0
	ARSENIC (ARSENIC OXIDE)	1.4 – 4.3
TOXIC (25–200 MG/KG BODY WEIGHT)	SODIUM NITRITE	57 – 86
	BARBITURATES	47 – 143
HARMFUL (200–2000 MG/KG BODY WEIGHT)	OXALIC ACID	375
	CARBON TETRACHLORIDE	457 – 686
NOT CLASSIFIED AS HARMFUL (MORE THAN 2000 MG/KG BODY WEIGHT)	ETHANOL	3300
	COMMON SALT	7150 – 14300
	PLASTICISERS (eg DOP)	MORE THAN 30000

* BASED ON THE EEC CLASSIFICATION LEVELS FOR ACUTE TOXICITY

Chronic toxicity

The chronic toxicity of a substance describes the effects which it has on a living organism as a consequence of long term or lifetime exposure. In general chronic toxicity is assessed by administering the test substance either by feeding or by inhalation to rats or mice every day over a period of up to two years and then examining the effect on the animal. Chronic toxicity studies are invariably carried out at multiple dose levels (usually a minimum of three). The top dose level is not usually related to any anticipated normal exposure but rather is selected to be as high as possible in order to produce signs of toxicity without shortening the animals lives. The bottom dose is normally selected to be a clear no observed effect level (NOEL). The latter dose is usually selected with reference to expected human exposure (a safety factor of 100 is considered desirable).

In the case of plasticisers numerous long term feeding trials have been carried out. The majority of these studies have been on di-2-ethylhexyl phthalate (DEHP,commonly called DOP) because it accounts for around 50% of the plasticiser usage in Europe and has been considered as a model for the other phthalates.

Prior to 1980 such studies showed no adverse effects. However in 1980 the results of a two year feeding study carried out as part of the NTP/NCI[1] Bioassay Programme in the USA indicated that DOP caused

1 NTP/NCI - National Toxicology Programme/National Cancer Institute

increased incidence of liver tumours in rats and mice and that di-2-ethylhexyl adipate (DEHA,commonly called DOA) had a similar effect in mice but not rats. In these studies the levels of plasticisers fed were very high, this being only possible because of their low acute toxicity. Their diets contained up to 12,000 ppm[1] of DOP and 25,000 ppm of DOA (this is comparable with a human consuming half a litre of DOA every day).

A large number of more recent investigations carried out in both Europe and the USA on a variety of plasticisers and different types of animals clearly show :

Plasticisers are not genotoxic. That is to say that, contrary to the behaviour of most chemicals which cause tumours in humans and animals, plasticisers do not interact with genetic material in cells (DNA)[2].

Oral administration of plasticisers,fats and other chemicals (such as hypolipidaemic drugs) to rodents causes a large increase of microbodies in the liver called peroxisomes. This "peroxisome proliferation" is considered by some authors to be linked to the formation of liver tumours.

However the administration of plasticisers,fats or hypolipidaemic drugs to non-rodent species such as the marmoset (a primate considered to be metabolically closer to humans) does not lead to peroxisome proliferation and liver damage. Some commonly used hypolipidaemic drugs (eg clofibrate), which cause peroxisome proliferation in rodents have been used by humans for many years with no ill effects.

These species differences have also been observed in test tube studies on the liver cells of rats, mice, guinea pigs, marmosets and humans.Peroxisome proliferation was observed in the rat and mouse cells but not in those of the human, marmoset or guinea pig.

On the basis of these differences in species response (especially if we also take into consideration the extremely high exposure in the animal tests) it is concluded that plasticisers pose no significant hazard to man.

The level of human exposure to plasticisers

Experimental investigations and assessments in the USA and Europe have shown that the average human intake of plasticisers amounts to only 2 g per person per year. This is mainly due to traces of DOA migrating from food packaging. The level of exposure is considerably below the dose at which toxic effects are to be expected. The so called "No Observed Effect Level" (NOEL) for DOA and DOP is around 40 mg per kg body weight per day, or higher depending on the kind of effect, ie at least 1000 g per year for an average adult. There is thus a 500 fold safety factor between the estimated plasticiser intake of 2 g per person per year and the NOEL. Taking into consideration the difference in response between rodents and primates the safety factor is in fact even greater.

1 ppm - Parts per million or mg plasticiser per kg diet
2 DNA - Deoxyribonucleic acid

The opinion of official experts and legislative authorities.

The International Agency for Research into Cancer (IARC), a body forming part of the World Health Organisation, classified DOP as 'an agent possibly carcinogenic to humans', largely because of the NTP/NCI rodent studies. It is very important to understand that IARC have not classified DOP as a carcinogen for regulatory purposes. Their responsibility is to screen materials on the basis of available data. By their classifications they indicate those materials requiring full quantitative risk assessment by appropriate experts acting for national or international regulatory bodies.

The EC Working Group 'Classification and Labelling of Dangerous Substances' have recently examined all the toxicological data and have concluded that DOP should not be labelled as a human carcinogen.

In Germany the Advisory Body for Environmentally Relevant Existing Substances (BUA) has summed up the situation in their report No 4 (1986) as follows :

'Chronic damages have been noticed in rodents exposed to high DOP concentrations (rat: over 40-70 mg per kg bodyweight per day). The rat because of a characteristic feature in its DOP metabolism - being different from the human metabolism - is especially sensitive to this substance. Thus, data obtained via tests with these animal species have no relevance for man. Tests with primates - having a metabolism comparable to that of man - showed that DOP was rather ineffective. According to these findings there is no basis to suspect chronic damages due to DOP exposure at environmentally relevant concentrations.'

Similarly the German Health Authority (BGA) has concluded that the carcinogenic effect of DOP in rats and mice is specific to this species and is not relevant to man.

In the USA the Food and Drug Administration (FDA) have not introduced any new regulations following the results of the NTP/NCI studies.

3 PLASTICISERS IN THE ENVIRONMENT

The release of plasticisers to the environment may occur during their production and distribution, during incorporation into PVC and by loss from the finished article during its use or after its final disposal.

The controlled nature of modern manufacturing processes make it unlikely that any significant loss of plasticiser to the environment occurs during its production (measurements of total emission from a modern plasticiser plant have given values of less than 0.01%).

The extremly low solubility of plasticisers in water means that little is lost by leaching from flexible PVC either during use or after disposal. The increasing use of modern incineration techniques to dispose of domestic waste results in complete combustion of plasticisers to carbon dioxide and water.

The main way in which plasticisers enter the environment is therefore by evaporation during processing with PVC. The extent to which such loses occur depends on the process and plasticiser used and has been estimated to vary from 0.03% for injection moulding up to 2% for coating processes. However these levels are being continually reduced by the installation of incineration, scrubbing and filtration systems on processing plants.

Plasticisers can be detected in the environment in the ultratrace (parts per billion) range. This detection is now possible as a result of the extreme refinement of analytical detection methods over recent years.

There are no indications of an accumulation of plasticisers in water, soil or air because they are biologically and photochemically degraded. Degradation is particularly rapid under aerobic conditions(in the presence of air) to produce carbon dioxide and water as for other organic substances.

The occurence and effects of phthalates in the environment has been reviewed in detail in ECETOC[1] Technical Report No 19 (1985). It is clear from this report that in laboratory tests microorganisms and fish can take up dialkyl phthalates however they are rapidly excreted and no toxic effects have been seen. The report concludes that, at the levels corresponding to current use and disposal practices, phthalates do not represent a hazard to the environment.

4 HEALTH ASPECTS OF FLEXIBLE PVC

Small quantities of plasticisers may be lost from PVC by evaporation and extraction or by migration into other materials.

Plasticiser evaporation from flexible PVC

The use of plasticisers in the production of vinyl wall and floor covering can lead to plasticiser vapour being present in room air. However the plasticisers used have extremly low vapour pressures and thus at 25°C the maximum level of DOP which could possibly be present in 1 m^3 of air is only approximately 0.01 mg. The levels of the higher molecular weight plasticisers are even lower still. Also if we take into consideration the comparatively slow plasticiser release rate and normal ventilation then the plasticiser concentration in reality is extremely low. The high concentrations sometimes reported must therefore be attributed to analytical errors. This is demonstrated by the fact that recent measurements of the air in an emission chamber containing 1 m^2 of PVC flooring for 96 hours showed no detectable levels of plasticiser; the detection limit was 4 parts per billion.

Flexible PVC toys

In the USA the Consumer Products Safety Commission (CPSC) has expressed its concern that children might ingest plasticisers by sucking teething rings and pacifiers.The estimated intake of plasticisers by infants in this way varies over several orders of magnitude up to a maximum of 0.07

1 ECETOC - European Chemical Industry Ecology and Toxicology Centre

mg per kg per day. On the basis of the toxicological evidence this does not represent a health risk. For other toys such as balls, dolls, etc the intake of plasticisers is negligible.The use of plasticisers in PVC toys for infants is regulated in some countries.

Medical uses of plasticised PVC

Flexible PVC has been established for many years as one of the most important materials used in the manufacture of a wide variety of medical products. The main advantages of PVC are its low toxicity, flexibility, clarity and sealing properties. These permit the manufacture of lightweight, breakage-resistant medical devices which can be supplied ready for use in sterile packages. After single use the devices can be safely disposed of without the need for cleaning and resterilisation, thereby avoiding problems of cross contamination and infection which could occur with previously used materials such as glass and rubber.

It is known that low levels of DOP migrate from flexible PVC blood bags into blood. There is published evidence showing that this has a beneficial effect in that it significantly reduces the level of destruction of red cell walls compared to that which occurs on storage in other plastic or glass systems.

DOP is the only plasticiser authorised by the European Pharmacopoeia for use in the manufacture of PVC blood bags.

Plasticised PVC in food packaging

Flexible PVC is used to produce food wrap film, cap seals for bottles and jars and tubing for beverages. DOP, DINP and DIDP are used in caps and seals whereas DOA and polymeric adipates are used in the production of food wrap film. DOA is used in this application because it gives a film with a high degree of cling which remains flexible at low temperatures. It also provides the high permeability to oxygen and water vapour which is necessary to ensure good food storage.

The level of plasticiser migration from these packaging materials into foodstuffs has been measured in the UK by the Ministry of Agriculture Fisheries and Food (MAFF) both for domestic and retail packaging of food. These measurements together with a knowledge of the typical diet has enabled MAFF to assess the maximum possible intake of plasticisers as 0.02 mg per person per day of phthalates and 16 mg per person per day of DOA[1].

The UK Committee on Toxicity of Chemicals in Food, Consumer Products and the Environment (COT) has examined this data together with the relevent toxicological information and has concluded :

'Toxic effects have been demonstrated for some plasticisers, but the safety margins between toxic doses and human intakes are large and we consider it very unlikely that there are any adverse health effects from the current or past use of plasticisers in food packaging materials.'

1 These estimates are based on a worst case situation which assumes that all solid foodstuffs are purchased wrapped in cling film and that 50% of these are subsequently rewrapped in the home.

5 THE LEGAL REGULATIONS AND PROVISIONS

In terms of handling and storage plasticisers are in general classified as non hazardous.

In different countries the recommended limit for occupational exposure varies between 2 and 10 mg/m^3 (time weighted average over an 8 hour period).

These recommended exposure limits have been reviewed by the Health and Safety Authorities in the UK and Germany and in the light of recent toxicological findings they have confirmed that the current limits of 5 and 10 mg/m^3 respectively are entirely satisfactory.

The regulations controlling the use of plasticisers in food contact applications differ from country to country. However a common feature of the regulations is that the level of plasticiser which migrates into foodstuffs should not have any adverse effects on their taste or smell and in general must not exceed 60 ppm. Because of the large volume of

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6 ...and in general must not exceed 60 ppm. Because of the large volume of toxicological data indicating that phthalates and adipates pose no health risk to man, regulatory authorities in most countries allow their use in caps, seals, tubing and wrapping films.

In the near future the situation in the EEC will be harmonised by the publication of a list of additives including plasticisers which may be used in plastics for food contact applications.

CEFIC has, as Corporate Associate Members, most of the major world companies with headquarters in Europe. CEFIC represents an industry which employs two million people and accounts for about 30% of world production.

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