DIOXIN AND PAPER PRODUCTS: THE UNNECESSARY RISK

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Dioxins are rapidly becoming one of the most notorious of the xenobiotic pollutants and human exposure through a variety of environmental pathways is of increasing concern to the scientific community, legislators and the public alike. In the United States by 1985 spending on dioxin research had topped 150 million dollars.

The term "dioxin" refers to a group of 75 chemicals correctly termed polychlorinated dibenzo-p-dioxins (PCDDs) consisting of a three-ring structure of carbon and oxygen, with between one and eight chlorine atoms arranged around the two carbon rings. Also of grave environmental concern, though less well-known, are the 135 polychlorinated dibenzofurans (furans or PCDFs). They are similar in structure to the dioxins. (see Figure 1) They frequently occur simultaneously with the dioxins, since they are formed under similar conditions. These compounds, which have no direct industrial use, are formed predominantly as byproducts of industrial processes using chlorine or chlorinated materials. Research has shown that this by-production is not limited to the synthesis of chlorinated organic chemicals but is also associated with the destruction of chlorinated materials in hazardous and municipal waste incinerators and some inorganic chlorine chemical processes. Studies of lake sediment records show that this group of compounds first appeared in significant quantities at the same time as chlorinated organic compounds came into use in the late 1920s, and levels have continued to increase with time.

Dioxins and furans behave in the environment in much the same way as other notorious organochlorine compounds such as DDT and the PCBs. They are highly bioaccumulative since they dissolve readily in fat but not in water, and are very resistant to breakdown either in biological systems or the environment. This means that they can accumulate in an animals' fatty tissues over a lifetime and concentrations will increase greatly towards the top of the food chain. They can also be passed from mother to young transplacentally and through the mothers milk. Evidence is mounting that dioxin levels in human fatty tissues and breast milk are rising.

Toxicological problems associated with PCDDs and PCDFs came under scrutiny due to chronic and acute exposure of humans in a variety of incidents. Some of the more significant episodes are: the Yusho outbreak in Japan caused by contaminated rice oil in 1968; the use of contaminated phenoxy herbicides (Agent Orange) in the Vietnam war; the Seveso chemical plant explosion in Italy in 1976 and the spraying of dioxin contaminated oils for dust control in Missouri in the United States.

The whole group of compounds has been subject to a great deal of research and this has led to identification of the 2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) and the 2,3,7,8-tetrachlorodibenzofuran (TCDF) as the most toxic members of each group, with dioxins being approximately ten times more toxic than the corresponding furan congeners (see Figure 1). In guinea pigs, the LD50 for 2,3,7,8-TCDD has been determined at 1.75 ug/kg body weight. Moreover, it has been shown to be a carcinogenic initiator and to have a potent immunosuppressive effect at cumulative doses as low as 0.32ug/kg body weight in animals. Induction of liver enzymes by the dioxins is also thought to lead to the breakdown of the steroid sex hormones with a subsequent impairment of reproductive capacity.

In humans, it seems that long term exposure to dioxins is associated with depressed cell mediated immunity, although not resulting in overt expression of clinical illness. Research into this aspect continues, but it is hampered by the difficulties of assessing the effects of a single compound when subjects have invariably been exposed to a variety of them. Human response to toxic insult is also a great deal more variable than that of animals in closely controlled test systems. Consideration of data from animal models suggests that children are likely to be most susceptible since these compounds exert a particularly marked effect upon the developing immune system.

Concern about these compounds in the environment eventually resulted in a series of studies in the United States to identify the sources and background levels in order to attempt human exposure analysis and risk assessment. Sophisticated sample preparation was developed to allow determination of these compounds at the ppt (part per trillion) level. In 1983 the Environmental Protection Agency established a surprising link between the pulp and paper industry and elevated levels of dioxin in water and sediments outside the factories. These compounds were found also to occur in the finished products. Levels of 14 ppt have been reported from food packaging, 10ppt in nappies and 6-8ppt in tissues and paper towels. Recent analyses of paper products in the UK have shown a range of 2,3,7,8-TCDF of 0.3-40ppt and a range of 2,3,7,8-TCDD of 0.2-13ppt.

The pulp and paper industry was already under a great deal of scrutiny due to its many environmental problems. These revelations served to intensify the attention. While the precise way in which PCDDs and PCDFs are formed in the papermaking process remains unresolved, there are methods available which reduce their production. The use of chlorine dioxide rather than chlorine as a bleach reduces the production of total chlorinated organics by up to 80%.

Oxygen delignification of pulp is another process option for pulp mills which stops the formation of chlorinated compounds. Ultimately, however, the use of mechanical/chemical pulping with hydrogen peroxide or sulphide bleaching could solve not only the dioxin problem but a number of the other environmental problems associated with the industry. Governments have begun to take the initiative: In Sweden the government is in the process of tightening regulations applying to this sector of industry, notably those concerning by-production of chlorinated compounds such as the dioxins.

In the meantime, a complex analytical and regulatory problem remains with respect to PCDDs and PCDFs in paper products. Since the precise human toxicity is not established and nor are the toxicological mechanisms, assessments of the overall risks vary widely. A West German study estimated that about 40% of the PCDD consumed with food originated from bleached paper wrapping and containers and that consumption of all dioxins exceeded the "one in a million" threshold level for cancer induction.

In contrast a level of 230000 ppt has been calculated by the Paper Industry Research Association for a one in a million cancer risk for personal care paper products contacting the skin. This figure, based upon EPA data, is rather optimistic since it considers whole body application factors rather than site specific effects. Some of the variables which do not appear to have been considered and which are particularly relevant to medical/sanitary applications might include.

1) Variable sensitivity. Toxicological theory predicts that response to a toxicant will conform to a spectrum of sensitivity. What then becomes important is not the highest likely dose per se, but the highest dose in relation to the the most sensitive individual exposed to it. For example, the skin of small children is known to be more sensitive than that of adults.

2) The application milieu: Medical paper products are used to apply substances, to remove them or to hold them in place. The solubility of dioxins in these substances and the extent to which this then allows passage across the skin may be important. Childrens nappies may be particularly prone to such effects since oil based creams are often applied to the covered area to protect against nappy rash. This is potentially a perfect system to effect percutaneous absorbtion of dioxins contained in the paper. Further consideration under these circumstances is the higher dose received by skin in the treated covered areas as opposed to untreated skin. The same observations apply to incontinence products.

3) Differential area effects: Areas of the body may differ markedly in sensitivity. Hence the lifetime use of sanitary towels and tampons may be a greater toxicological risk than a lifetimes use of paper tissues.

4) Possible synergy: It is possible that dioxins may interact in unpredictable ways with pharmaceutical preparations applied using medical paper products particularly where these are applied in an oil based medium thus facilitating potential transfer.

None of these factors has been adequately considered in any risk assessment so far reported for paper products. The whole topic, then, is dogged by uncertainty throughout. This stems from a lack of understanding of the fundamental toxicology of the compounds concerned which then translates obviously into uncertainty concerning dose/effect/risk level evaluation. Attempts at such evaluation must be regarded as flawed if they only consider dose in whole body terms. Finally, the assignment of risk factors is rendered impossible by the fact that a "no effect" level has not been demonstrated for dioxins.

It may be concluded, therefore, that the issue of dioxins in paper is a highly complicated one, but in this case the solution to all the problems both real and potential is simply to stop using chlorine bleached pulp and to substitute pulp derived from another process. The use of chlorine bleached white paper products is essentially an industry driven phenomenon. Industry has neither informed its customers about the contamination of its products nor until recently has it offered an alternative. Responding to marketing strategies, the public retains its perception of white as "clean". In reality, the cream coloured alternatives to nappies, tampons and medical wipes are both environmentally and toxicologically more desirable. Human exposure to these compounds through the use of medical and other paper products is completely unnecessary. Under the circumstances, precaution should prevail and users of these products should start to enquire about the available alternatives.

LEGEND TO: Figure 1

a) Chemical structure of one of the 75 chlorinated dioxins. 2,3,7,8-tetrachlorodibenzo-p-dioxin is one of the most toxic compounds ever isolated. It can also act as a carcinogen and is known to suppress immune function at low levels. It is found in paper products as a result of chlorine bleaching used in the production process.

b) Chemical structure of 2,3,7,8-tetrachlorodibenzofuran. one of a group of 135 such compounds. These are closely related to the chlorinated dioxins and exert similar toxicological effects.