TOXIC CHEMICAL REDUCTION AND SUBSTITUTION

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ABSTRACT

The process of toxic use reduction offers many advantages over traditional pollution control. This process can also be applied to reduce the emissions of indoor air pollutants such as VOCs and formaldehyde. A policy of toxic use reduction has been developed and is being considered by the Environmental Advisory Committee of Murdoch University. The Process of toxic use reduction is described and the process is applied to three case studies at the University to reduce the exposure of building occupants to elevated levels of indoor air pollutants.

INTRODUCTION

There has been an increasing use of chemicals over the past 40 years. As a result, an increasing number of toxic chemicals have been released into the environment. Volatile organic compounds (VOCs) and formaldehyde are released into indoor environments and have commonly been linked with sick building syndrome and poor indoor air quality in new and renovated buildings. Nearly every home and place of business contains common materials that may cause elevated levels of chemical exposure. Little is known about the possible adverse health effects of exposure to the complex mixtures of chemicals found in buildings. However, VOC's have been reported to impair cognitive function, irritate mucosal membranes in the eyes, nose and throat, cause headaches, mental fatigue respiratory distress and mental confusion and fatigue.

Although many studies of indoor air quality have been reported in scientific publications and proceedings, little information on indoor air has been targeted at facility managers and Health and Safety representatives who are the people in a good position to prevent and resolve indoor air problems. Policies to reduce indoor air quality problems often become reactive once complaints have been received from the building occupants making it more difficult to find a solution to the problem.

While ventilation has often been used to reduce levels of toxic gases in buildings the best solution is to reduce the introduction of materials which emit these chemicals into the building. As a result a policy paper was developed on toxic use reduction to identify areas where Murdoch University could reduce their use and consequent expose of toxic chemicals to individuals from indoor pollutants.

In recent years a new approach to dealing with toxic chemicals has been initiated. Conventional approaches to toxic chemical and waste management have been called pollution control policies because they attempt to control releases into the environment (TURI, 1993). The focus of pollution control has been end of pipe, end of stack solutions (TURI, 1993), relating to indoor air quality it has been pollution control by ventilation. Pollution prevention policies on the other hand focus on preventing the release of chemical contaminants.

Toxic use reduction differs from conventional pollution control in that it is about;

- reducing or eliminating the use of toxic chemicals or the generation of hazardous by-products at the point of production;
- planning and goal setting with a view toward the efficient use of materials in production;
- continuous improvement, the setting of reasonable goals and the resetting of new goals once they have been met;
- real reductions of toxic chemical use and toxic chemical waste; and
- the process can be adopted at any stage of the product/chemicals life.

METHOD

Toxic use reduction involves changes to the production process or raw materials to reduce or eliminate the use and generation of toxic or hazardous substances and by-products. This reduction can be achieved by one of many methods including changes to in plant operating procedures or product formulation, recycling of by-products and waste, chemical substitution and improved in-house management and house keeping. Any of these can be used to reduce toxic waste.

A general approach to toxic chemical reduction for Universities was devised for application to most situations.

1) Identify areas/ products where toxic chemicals or emissions are involved.

2) Determine the types of toxins present; material safety data sheets can be obtained for many products on request from the manufacturer.

3) Decide whether the situation is a high enough priority to warrant further steps at this stage.

4) Research alternatives; identify different brands of the same product that are formulated with less toxic constituents.

5) Install or implement the less toxic alternative; professionals may need to -be consulted for the removal of some toxic areas such as asbestos.

The problem with many toxic use reduction strategies lies in the lack of information on the available methods (TURI, 1993). Very few studies on material emissions have been undertaken in Australia and in many cases material safety data sheets, and product labelling do not list the entire chemical constituents of their products. As a result very little information is available. Even if the chemicals were all well known the toxicity of many of these products has likely not been accurately determined. In the absence of information on the the toxicity of certain products the case studies will rely on the theory that any situation can be improved and therefore the toxic use reduction techniques suggested are valid.

RESULTS AND DISCUSSION

Areas/ products where toxic chemicals or emissions have been identified are listed below;

- asbestos roofs
- ply board, particleboard in portable buildings
- wood floor polishes and waxes
- white board marker pens
- correction fluid ('liquid paper')
- disinfectants and cleaners used in the veterinary school
- laboratory chemical
- pesticides
- toilet cleaning agents
- new lecture theatres
- printers and photocopiers
- carpets and adhesives
- paints

The list is by no means complete but is designed to provide a general overview of the widespread uses of toxic chemicals on campus, and the areas where toxic use reduction strategies can be implemented. The following 3 case studies are based on the process identified earlier and involve steps 2,3 and 4 in the process of toxic chemical reduction in Universities

CASE STUDY 1: PRINTERS AND PHOTOCOPIERS.

In the print room the offset lithographic printing process used by the university utilises many potentially toxic chemicals including;

blankrola solvent; 1,1,1-trichloroethane, napthas, and liquid hydrocarbons which have been identified as upper respiratory tract irritants (Sittig, 1991):
electrostatic solution; potassium ferrocyanide:
deglazing fluid; methylene chloride which have been identified as animal positive and suspected human carcinogen (Sittig, 1991):
silicon spray; 1,1,2-Trichloro 1,2,2-Trifluoroethane, n- hexane, hydrocarbons:

high yield toner; styrene identified as animal positive carcinogen and upper respiratory tract irritant (Sittig, 1991): and
various other toners and printing inks and organic solvents.

The safety directions labelling these containers advised the user to avoid breathing the vapours and to only use the chemicals in a well ventilated area. The majority of these chemicals volatilize or evaporate into the print room air during the process. Wolkoff et al (1993) found that a total of 61 volatile organic chemicals (VOCs) were emitted from various toner powders, and 31 VOCs were emitted from paper that had been processed by a printer or photocopier. Some of these chemicals are known or suspected human carcinogens (benzene, styrene etc) and the majority are respiratory irritants (Sittig, 1991).

As well as process chemicals the inks used in lithographic printing also contain toxic chemicals including naphthenic fractions of a petroleum distillate. The use of these chemicals may result in skin irritation, dizziness or drowsiness. VOCs emitted by these petroleum based inks are also precursors to ground level ozone formation which may cause irritation of mucous membranes found in the eyes or lungs (Tellus Institute, 1993a).

In response to environmental concern many ink manufacturers are turning back to using natural vegetable oils as substitutes for the potentially toxic petroleum based oils in their printing inks. The type of paper to be printed and it's intended use will determine to what extent toxic chemical use can be reduced by this substitution (Tellus Institute, 1993a). In many cases these less toxic inks can be substituted with little effort or cost to the printing process.

Photocopiers are present and frequently used in the majority of buildings. A number of toxic chemicals are used in photocopiers as well as emissions of ozone from the high temperatures obtained in the machine. Less toxic toner, emitting lower quantities or less toxic chemicals, can be chosen as a substitute if the toner currently being used in the photocopier is more toxic, similarly selection of appropriate, lower emitting, copying equipment will reduce emissions.

In summary these strategies are;

1) Substitution of toxic printing process chemicals with less toxic alternatives.

2) Substitution of vegetable based printing inks for the conventional petroleum based inks.

3) Substitution of toxic photocopier toners with less toxic ones.

4) Choice of lower toxic chemical emitting photocopying equipment.

CASE STUDY 2: CARPET EMISSIONS.

Due to the synthetic nature of the majority of new products many building materials, including carpets and their adhesives, emit VOCs into the indoor air. This process, known as 'off-gassing', has been implicated as the cause of many consumer complaints throughout Australia and the world. Health complaint data compiled by the US Consumer Product Safety Commission (CPSC) indicates that 335 residents lodged complaints about their newly installed carpets from 1988 to early 1991. Two thirds of these complaints reported that symptoms started immediately or within a few days of installation (Schachter, 1990). Complaints about adverse effects of carpet range from distress at the strong odour emitted, to actual physical illness such as eye and respiratory tract problems, headaches, nausea and dizziness.

Since 1992 approximately 13,800m^2 of new carpet tiling has been laid down at Murdoch University in new buildings and for the maintenance of previously carpeted areas (Morey, 1994). Due to the large extent and frequency of these new carpet installations it is important that toxic chemical reduction practices be utilized at the university to limit the adverse impact of carpet emissions on occupants of the buildings. Complaints have been received about strong chemical smells and poor indoor air quality in new lecture theatres and other new buildings from staff and students at the university.

Chemicals given off by newly installed carpets have various sources; (Hodgson et al, 1993)

1) The carpet fibre; ie nylon carpet may emit cyclohexanol which is an intermediate in the production of nylon-6.

2) Backing bonds; ie SBR latex backing emits 4-ethenylcyclohexene, styrene, 4-PCH and alkyl benzenes.

3) Textile finishing; carpets may be treated with various chemical combinations to protect against soiling staining, microbe infestation etc.

4) Carpet adhesives; a variety of solvent containing adhesives are generally used to affix the carpet.

The carpet installed at Murdoch University is Du Pont's Antron Lumena Solution Dyed Nylon, by Interface Heuga Australia. It is backed by fibreglass reinforced Graphlar compound and has been chemically treated for soiling and staining (scotchgard) and microorganisms.

Installation of carpet with low emissions would aid in reducing the use of toxic chemicals, however, there is little or no information of the chemical constituents and emissions of many carpets. This lack of information makes it difficult to compare emissions of Murdoch's current carpet type with others.

Whilst emission of VOCs from carpet is a problem, tests indicate that emissions from the sealants and adhesives used in the carpet laying process are significantly higher in the short term. Conventional adhesives and sealants contain high levels of organic solvents and various other volatile chemicals which under go a similar off-gassing process as the carpet itself. Emission from adhesive is some 30 times greater than the emissions from the carpet alone.

An example of a conventional solvent-based adhesive is 'Anchor-weld 50', which contains mineral oils and toluene. Toluene is a reported animal teratogen and mutagen (Australian Health, 1989, Sittig, 1991). VOC emissions from these adhesives are much higher than those of the carpet and appear to be the main cause behind reported occupant discomfort and illness, and thus should be the major target of toxic use reduction strategies applied indoors.

Carpet installation at Murdoch University utilises 'Feltex Modular Adhesive' and 'Heuga Tac-S*' adhesives. These products both contain Acrylic Copolymer (11-60%) and Heuga Tac-S* also contains water soluble organics and a defoamer (no information was available on the constituents of these two components). These adhesives contain a total of 50-55% volatile substances (Davco Services, 1994, Architectural and Structural Adhesives, 1994). Girman et al, 1986 showed that 5 solvent-based and 3 water-based samples continued to emit significant amounts of VOCs 7 days after application. Solvent-based adhesives emitted toluene, styrene and a variety of cyclic, branched and normal alkanes. The water-based adhesives emitted similar compounds with the exception of lower levels of toluene and no styrene.

Due to the decreasing quality of indoor air, and the increasing number of consumer complaints about these emissions, the Building Management Authority of Western Australia has adopted a policy of using low VOC emitting products. Since the adopting of this approach adhesive manufacturers have developed low solvent adhesives, containing less than 4% liquid hydrocarbons. Examples of such adhesives are 'Actionbond 2000' and 'Westbond 59', which contain 10-29% hydrocarbon resin and less than 10% hydrocarbon solvent (Chem Alert, 1993). Further developments have led to the manufacture of 'solvent free' adhesives ie 'Anchorweld 80' (Building Management Authority, 1993). This adhesive, however, contains low concentrations (<10%) of styrene and butadiene and may therefore still create adverse effects and respiratory tract irritation (Chem Alert, 1994).

In summary the following strategies may be implemented at Murdoch University to reduce the impact of carpet, adhesive and sealant emissions on indoor air quality;

1) A low emitting carpet can be chosen from the many carpet formulations available.

2) Solvent free adhesives can be used as a replacement for conventional solvent-based adhesives.

3) After installation extensive ventilation should occur.

CASE STUDY 3: PAINTS

Many varieties of liquid paint composition exist, however, all contain resins or pigments combined with solvents which facilitate the application of the paint product onto the surface (Tellus Institute, 1993b). The most commonly utilized paints are;- conventional solvent-based paints; found to have the highest levels of VOC emissions (Plehn, 1990),- varnishes; clear coatings that form by the evaporation of the solvent followed by the oxidation and polymerisation of the resin.

Solvents are utilized in paint products to maintain an even product consistency and 'spreadability'. They also help to clean residual grease and dirt from the surface to allow proper adhesion and penetration of the film. Common solvents used in solvent-based paint products include toluene, xylene, methyl ethyl ketone (MEK), methyl isobutyl ketone (MIBK), acetone, methylene chloride and naphtha (Plehn, 1990, Tellus Institute, 1993b).

The majority of aqueous paints still use small quantities of organic solvents to help the dispersion of the resin in the water and to maintain relatively short drying times (Plehn, 1990) (Tellus Institute, 1993b). Chemicals found in water-based paints include 1,2-propanediol, 2-butoxythanol, 2,2,4-trimethyl-1,3-pentanediol monoisobutyrate (also known as texanol) etc (Nielsen et al, 1990, Clausen et al, 1991).

Low solvent content paints, such as water-based and high solid paints, were still found to emit chemicals such as nonane, 1,3,5-, 1,2,3- and 1,2,4-trimethylbenzene (Gehrig et al, 1993), all of which are eye irritants and may also cause headaches and dizziness (Sittig, 1991).

Paint products may also contain 'hidden' toxic chemicals in the form of surfactants, flattening agents, preservatives, biocides, antifoam agents and various others (Plehn, 1990, Tellus Institute, 1993b). Plehn (1990) suggests that many paint manufacturers do not know the exact chemical composition of their products, only the primary products. Paints and varnishes, on average, may contain up to 50 ingredients that remain unknown until later detailed analysis (Plehn, 1990).

The toxicity of these products are now being recognised. The Massachusetts 1987 federal limits on the VOC content of paints require all 'architectural' paint to contain no more than 250g of VOCs per litre of paint. Architectural paints are defined as all paints formulated for normal environmental conditions and general application on new and existing structures (Tellus Institute, 1993b).

The German Federal Environmental Agency (1980) decided to award the 'environmental label' to the product group of low pollutant paints and varnishes. The majority of these products are water-based (Plehn, 1991). The essential requirements behind the environmental labelling was that the product must contain components that have no evidence of chronic effects eg carcinogenicity and mutagenicity, VOC content must be <10% by weight for water soluble paints and <15% for high solid paints, the product must not contain heavy metals eg cadmium, lead or mercury. Few regulations or incentive policies such as those listed above have been implemented in Australia. Alternatives to high VOC emitting paints exist. These alternatives are either reduced VOC level products or non volatile containing products. Reduced VOC products include water-based or latex coating systems, high solid coating or UNICARB systems. Although small quantities of petroleum based solvents are still required to keep drying times moderate, the general result is decreased levels of VOC emissions.

Information on the chemical constituents of the paint products used on the Murdoch University campus were not available when this report was compiled. As for toxic use reduction at the university in this area, it is suggested that if high VOC content paints are currently being utilized, then these products can be substituted with lower emitting water-based or non volatile alternatives.

CONCLUSION

In this study we have found that there are many areas on the Murdoch University campus where toxic chemical use is degrading the quality of indoor air. In the case studies we have identified at these toxic chemicals have less toxic alternatives or other factors that can be used to reduce the impact on indoor air quality and the health of occupants.

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