Chemical Safety in the Workplace

Guidance Notes on Chemical Safety in Printing Industry

Occupational Safety and Health Branch
Labour Department

safety at work

Occupational Safety and Health Council

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This Guidance Notes is prepared by the

Occupational Safety and Health Branch

Labour Department

First edition December 2004

This Guidance Notes is issued free of charge and can be obtained from offices of the Occupational Safety and Health Branch or downloaded from the Labour Department's website at http://www.labour.gov.hk. Addresses and telephone numbers of the offices can be found on the Department's website.

CONTENTS

1 Preface

Printing is the largest manufacturing industry in Hong Kong in terms of the number of establishments according to 2002 data[1]: it employs about 42,000 workers in about 4,700 establishments that range from sizeable publishers of newspapers, magazines and books to smaller companies printing brochures, cards, calendars, various advertisements. Printing on textile, plastic and metal surfaces are also common.

Printing is a chemical-intensive industry with its workers being generally exposed to many hazardous chemicals, in particular the printing solvents. Some ten years ago, there was an outbreak of peripheral polyneuropathy among offset printers caused by contact with n-hexane, a major constituent of the solvent used for cleansing printing rollers. Other than the health hazards, organic printing solvents that contain flammable substances may pose a fire and explosion risk.

To protect workers from the chemical hazards arising from their work in the printing industry, this new Guidance Notes on Chemical Safety in the Printing Industry is compiled. Responsible personnel are encouraged to make use of the information to establish a chemical safety programme suitable to their working processes and environment. It is hoped that through the management approach, safety consciousness and initiative could be instilled in the industry.

[1] Ref.: The Hong Kong Trade Development Council website at http://www.tdctrade.com/main/industries/t2_2_30.htm (last updated: 21 October 2003)

2 Typical Printing Processes

2.1 Introduction

2.1.1 All printing processes produce graphic images on a substrate, which can be paper, textile, plastic, metal, etc. The following printing techniques are commonly practised locally:

- lithographic printing
- flexographic printing
- gravure printing
- screen printing

2.1.2 The very traditional letterpress technique is now a relic of the past, which is fast being phased out. Technological advancement, especially in information technology, has given rise to other printing processes such as digital printing, inkjet printing, etc. that operate on principles quite unlike the traditional ones.

2.1.3 A printing process is generally divided into four steps: pre-press, make-ready, press and post-press. The pre-press operation is the process that transfers the artwork or design (often in the form of negative or positive films) into an image carrier, most often a plate, but can be a cylinder or screen. This operation involves such physical or chemical processes as exposure to ultraviolet (UV) light or laser, photoengraving, developing and further processing. Make-ready prepares the press: the plate is assembled to the machine and mechanical adjustments made. Press step is the actual printing operation. Lastly, post-press is the finishing work such as binding, gluing, etc. of printed materials to the final printed product.

2.1.4 The newly developed automatic computer-to-plate (CTP) technology is a digital plate-making technique that can do away with those tedious conventional pre-press operations and so eliminate the use of many hazardous chemicals. Essentially, the plate making machine is another type of printer with the images to be printed being composed on a computer and the final output transported directly onto the press-ready plate instead of a piece of paper or film. There are different techniques of digital plate making available for the various printing processes.

2.2 Lithographic printing

2.2.1 Lithography is by far the most widely practised paper printing technique in the local market. It is a planographic process in which the printing and non-printing areas of the plate are both at the same level. It is invariably an offset process in that the image is transferred to an intermediate blanket cylinder from which it is transferred to the paper as distinct from those direct processes, such as flexography and gravure printing, where the image is directly transferred from the image carrier to the substrate.

2.2.2 Lithographic printing is based on the chemical repellence of oil and water. The image area is oleophilic (oil-receptive) so it attracts the ink whilst repelling water, whereas the obverse applies to the hydrophilic (water-receptive) non-image area.

2.2.3 Different types of printing plates are used in lithography: photomechanical, electrostatic, bimetallic, etc. They are generally made from metals like aluminium, although other base materials such as paper and polyester are also used. The most common printing plate is of the photomechanical type, which is made from thin aluminium sheets coated with light-sensitive material (also known as photo resist) such as diazos or photopolymer resins, together with asphalt, shellac, gum Arabic or polyvinyl alcohol. In practice, most surface plates in use are pre-sensitized (PS), that is, those that are supplied already coated with light-sensitive material. Photopolymer is by far the most widely used light-sensitive material. The following discussion will revolve around such plates.

2.2.4 The plate can work with either negatives (subtractive) or positives (additive). In either case, a transparency carrying the image of the artwork is placed over the sensitized plate in the exposure frame. Vacuum is applied to ensure good contact so as to get a sharp resulting image. The plate is then exposed to UV light.

2.2.5 For negative-working plates (the plates work with negative films), negative films are used and vice versa for positive-working plate, but the type of photopolymer used is different. In the former, upon exposure to UV light, the photopolymer hardens, whereas for the latter, it becomes unstable. In both cases, the end effect is that the photopolymer coating, which is ink receptive, remains on the image areas whereas those on the non-image areas are removed.

2.2.6 For colourful printing, the colour of the original is separated into the four ink colours, namely, cyan (blue), magenta (red), yellow and black, (often denoted by the four letters CMYK), and a separate printing plate is produced for each colour. The four ink colours are generally adequate for most colour printing jobs. In some cases, up to eight ink colours may be required to match the original. The sketch below (Figure 1) illustrates a typical set of rollers for printing a particular colour. Printing more colours requires more set of rollers.

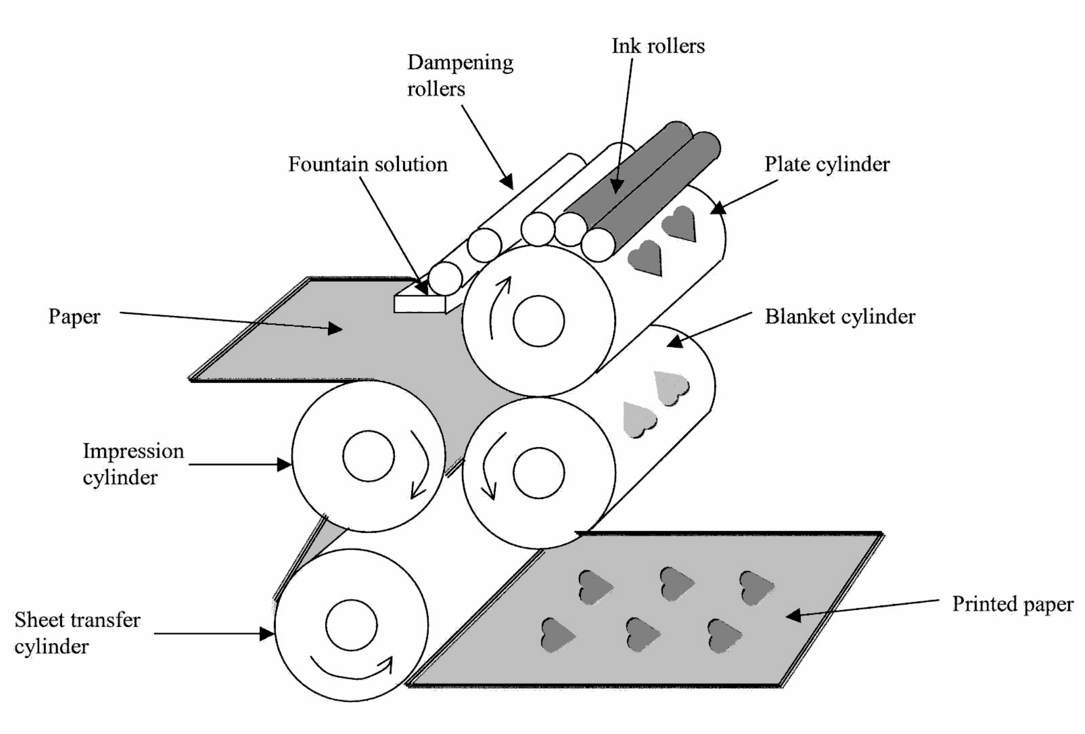

Figure 1: Lithographic printing

2.3 Flexographic printing

2.3.1 Flexographic printing is mainly used to print packaging materials. The flexographic plate, which is made of rubber, plastic or other flexible material, has the image area raised relative to the non-image area. The printing ink is applied to the raised area, which transfers the image to the substrate as illustrated in Figure 2.

2.3.2 Similar to lithographic plates, light sensitive photopolymers are used to make flexographic plates. To make the printing plate, a negative of the image is placed on the plate material and exposed to UV light that hardens the image areas on the plate. After exposure, the unexposed coating material (non-image areas) on the plate is washed out, usually with water. The plate is allowed to dry and then exposed to UV light to complete the curing process.

2.3.3 Flexographic printing uses low-viscosity, fast-drying inks that are based on alcohols, water, hydrocarbon solvents or UV monomers. The ink is first applied to the anilox roller (a steel cylinder engraved with a pattern of pits or cells). The cells (the depressions) are then filled and doctored before delivering the ink to the image area of the plate cylinder for printing onto the surface of substrate.

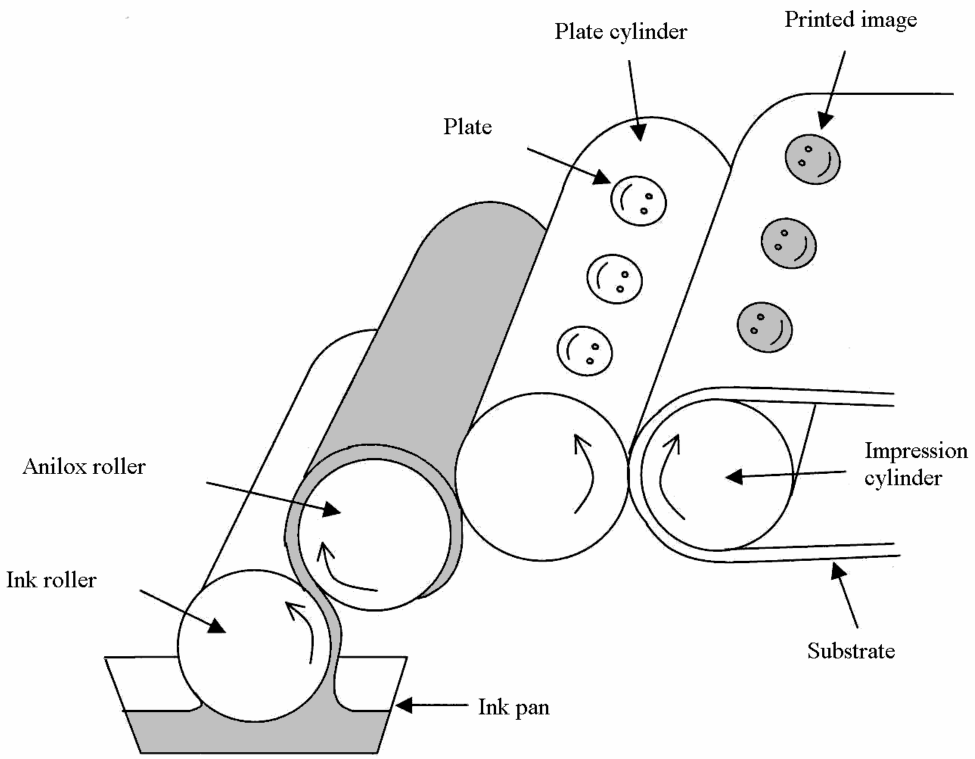

Figure 2: Flexographic printing

2.4 Gravure printing

2.4.1 Gravure printing is the reverse of flexography in that the image is recessed below the printing plate surface. In most cases, the image is directly formed on the plate cylinder. During printing, the ink is contained in the recessed image cells that are arranged in a regular grid, typically 60 lines/cm on the cylinder. As schematically shown in Figure 3, the cylinder rotates through a trough of ink and is scraped by a metal doctor blade to remove surplus ink from the non-image surface of the cylinder while the cup-like shape of each cell holds the ink in place.

2.4.2 The various shades of tonal gradations are governed by the size and depth of these cells that in turn control the volume of ink delivered. Thus larger and/or deeper cells contain more ink and give darker shades.

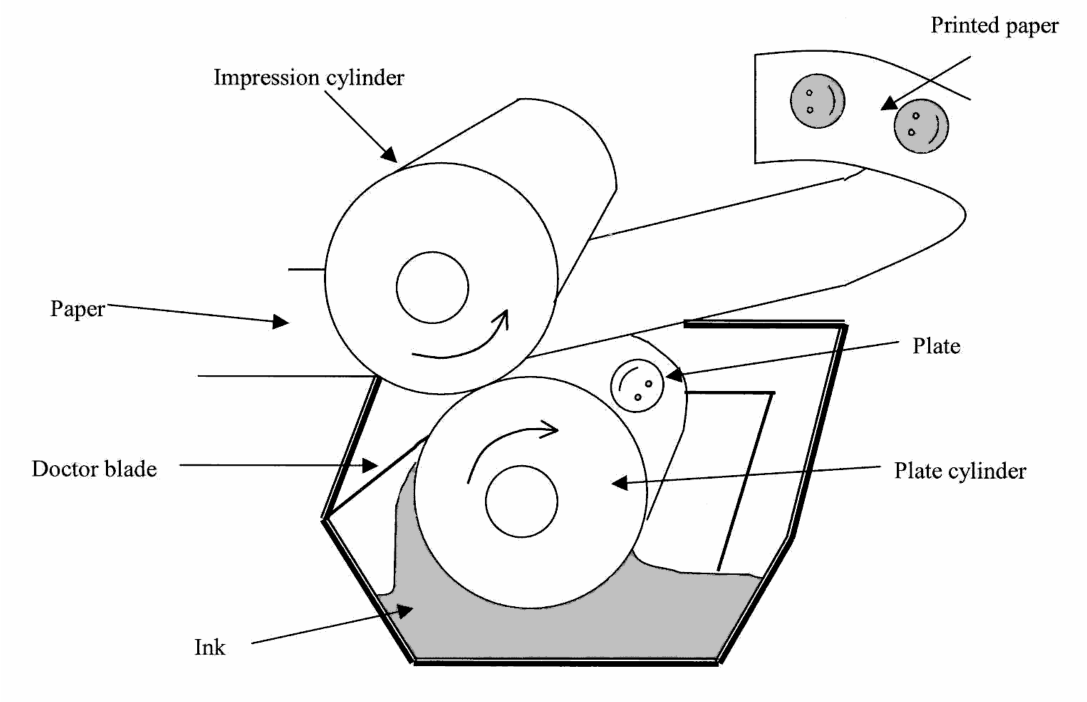

Figure 3: Gravure printing

2.4.3 In the cylinder preparation, the printing cells are formed by exposing positives to carbon tissue which is a fibrous paper coated with smooth gelatine resist. The resist is sensitized to light by submerging it to potassium bichromate solution.

2.4.4 The carbon tissue is wrapped around the cylinder, and after exposure to UV light the exposed areas are hardened with alcohol and forced air-drying in amber light. In the areas exposed through the positives, membranes of variable thickness are formed, depending upon the amount of light passed through the image positive. The membranes are thick in the highlights and thin in the solids. The tissue is then etched using ferric chloride solution. The thickness of the membranes controls the etching speed, resulting in the formation of cells.

2.4.5 Photopolymers are used to make gravure plates, as in lithography and flexography, so doing away the use of the etching chemicals. In this polymer photogravure process, after the consecutive exposures to UV light in a way similar to the above discussion, the photopolymer-coated plate is developed simply using water, which dissolves away the unexposed parts (image). The final result is a gravure plate where the image is replicated by recessed cells on the surface of the plate.

2.5 Screen printing

2.5.1 Screen printing is a versatile process that can be applied not only to ordinary substrates like plastics, fabrics, metals, paper, but also exotic ones like leather, glass, ceramics, wood or electronic circuit boards. In this printing process, a fine-mesh screen made of silk, nylon or stainless steel is tightly mounted onto a rigid frame. With the non-image area of the screen being blocked, printing ink is forced through the mesh and transferred to the substrate surface by scraping with a rubber squeegee as shown in Figure 4.

2.5.2 It is common to prepare the screen stencil using a photomechanical process, in which a photographic emulsion of bichromated gelatine or bichromated polyvinyl alcohol (PVA) is directly coated, spread and levelled on a screen fabric. The screen is then exposed to a positive of the image using UV light, which "hardens" the emulsion. The unreacted portion (image area), which is water soluble, is rinsed off.

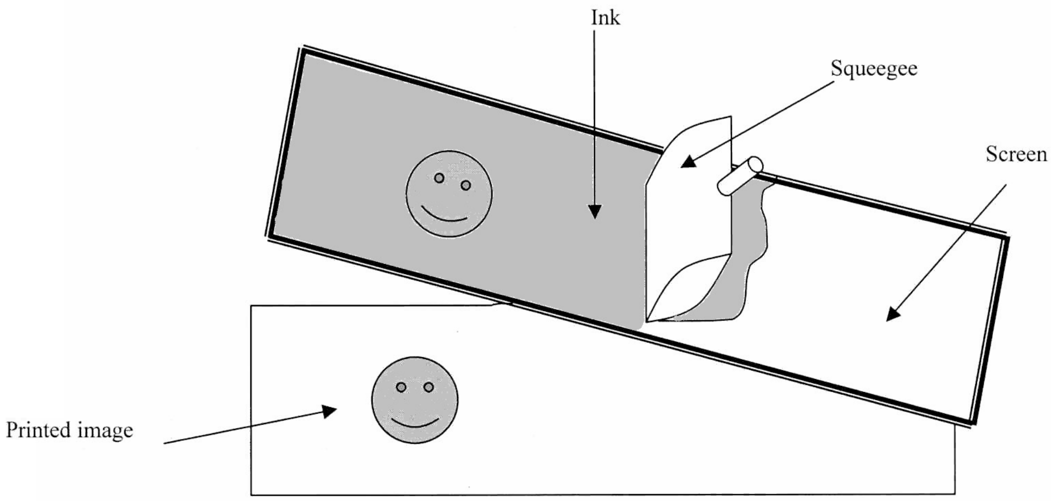

Figure 4: Screen printing

2.6 Letterpress

2.6.1 Letterpress is a traditional relief process, with the image area being raised relative to the non-image area on the printing plate. The original letterpress plate was made by manual mounting of movable pieces of cast metal type in a frame. To improve the efficiency, better plate making techniques have evolved, resulting in the stereotype[2] and electrotype[3] plates.

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[2] A stereotype plate is made with the use of a mould of the original metal type by pouring molten metal into the mould to create the plate which can be flat or conforms to the shape of the plate cylinder of a rotary press.

[3] An electrotype plate is made by spraying the mould with a silver coating and then electroplated with copper or nickel. The resulting plate is removed from the mould and reinforced by filling with lead or plastic.

2.6.2 The plate can also be made by photoengraving technique. A film negative is placed on the plate coated with a photo resist and then exposed to light. After developing, the coating on the unexposed non-image areas is dissolved away whereas that on the light-exposed image areas remains to serve as a protective mask. The plate is then immersed in ferric chloride solution to etch away the non-image areas to the appropriate depth. After removing the masking material and washing thoroughly to eliminate all chemical residues, the plate is ready for printing use.

2.7 Dyeline printing

2.7.1 Dyeline printing is used to produce a pre-press photographic proof, which is a blueprint or test copy of the printed material for checking the completeness, position and content of the individual graphic elements (texts, images, etc.).

2.7.2 It is done by exposing an original of the artwork onto paper pre-impregnated with diazos and a coupler. It is the coupling of these two that produce azo dyes giving the colours, but in the blueprint paper, there is also a stabilizing acid barrier that prevents their premature coupling. Upon action by UV light, the light-sensitive diazos are decomposed. The paper is developed by exposing it to a strong base, usually ammonia which neutralizes the acid, thus allowing coupling to occur and causing the release of azo dyes in the unexposed areas lying under the image to be reproduced. After developing, the image is shown in various shades of blue colours on the white paper.

2.8 Digital printing

2.8.1 In digital printing, the image is created directly from digital data and transmitted by light to a photosensitive material to create an electronic image, using no films, plates, nor photo-chemicals. It relies on the ability of selenium to enhance its electrical conductivity on exposure to light, the same principle which photocopying works on.

2.8.2 Instead of light, the image can be created by ion deposition or other electronic processes. In the case of laser printers, the original documents are read and re-created using a laser beam.

2.9 Inkjet printing

2.9.1 Inkjet printing is the process of creating an image on the substrate by controlling the projection of a stream of microscopic ink droplets from a minute nozzle at a small distance above the substrate surface. The process is mainly computer controlled. The design information is sent to the printer through a software programme that controls the placement of each droplet of ink onto the substrate.

2.10 Other printing techniques

2.10.1 There are some special printing methods though less commonly encountered. Hot blocking (also called foil stamping) is mainly used by small-sized printers located in domestic districts for embellishing invitation cards, book jackets, name cards, etc. It uses heat and a heat-activated foil to impart image onto the surface. The ability to produce holographic designs by this process has developed a market place in security printing on substrates such as credit cards.

2.10.2 Pad printing (heat–transfer printing), literally an offset gravure process, which due to the soft nature of the printing surface (pad), can print onto three-dimensional objects like bottles or cans.

2.10.3 Thermography is a press technique that uses heat to fuse a toner to the paper surface, which is then baked to give a professional raised letter effect. It is often used to print business cards, letterheads and invitations.

2.10.4 These miscellaneous printing processes will not be elaborated in detail but the underlying principles and practice of chemical safety discussed in subsequent paragraphs may also be applicable to them.

3 The Chemical Hazards

3.1 Sources of chemical hazards

3.1.1 The most important chemical hazards associated with the printing industry come from:

(a) pre-press chemicals;

(b) printing inks;

(c) fountain solutions;

(d) cleansing solvents; and

(e) adhesives and glues.

3.1.2 Many of these substances are proprietary prepared formulations and their chemical components are not always shown conspicuously on their original containers. For example, a product labeled as scratch remover is used to remove oil patches on the unwanted areas on lithographic plates to ensure hydrophilic property during printing. From its container, the content appears innocuous, but in fact it contains potassium hydroxide. Thus, it is advisable to be acquainted with the specific functions of the product since these will often throw some light on their chemical natures. In all cases, users should enquire from the supplier detailed hazard information and user safety precautions of their products.

3.2 Pre-press chemicals

3.2.1 As seen in the discussion on printing processes, a wide assortment of pre-press chemicals are used during the pre-press stage especially during plate making: photographic reproduction, photoengraving, etching, fixing, developing, etc.

3.2.2 Many of these chemicals are specially formulated blends which have already been mixed in the right proportions and require no further processing. They are supplied in containers, which can be fitted directly to the processing machine that reduces chance of chemical contact by workers. It is important to follow the working procedures stipulated by the supplier and observe prudent waste disposal practices.

3.2.3 By far, the most common method of plate preparation is to use light-sensitive coatings. There are three main light-sensitive coating materials: photopolymers, diazos and bichromated colloids, which are cured by UV light.

3.2.4 UV light has to be handled with care since ozone may be produced by its action on oxygen in the atmosphere of the enclosure housing the UV light source. UV light can also damage the skin and eyes whether it is viewed directly or from reflected surfaces.

3.3 Printing inks

3.3.1 Printing inks are complicated mixtures of chemical compounds, with composition varying by their solvent bases (oil or water), drying mechanisms (absorption, evaporation oxidative polymerization, etc) and adopted printing processes. Of particular concern is the UV light-curable inks since they pose UV light hazards and may contain polyfunctional acrylates and methacrylates that can cause skin irritation and sensitization.

3.3.2 The main component of a printing ink is the pigment. For examples, black inks usually contain carbon black, whereas white inks contain titanium dioxide, calcium carbonate, zinc oxide, clay, etc. Coloured pigments can be organic or inorganic. Organic pigments are mostly synthetic colourants of aromatic hydrocarbon origins such as benzene, naphthalene or anthracene, containing chromophoric groups =C=NH, -CH=N- and -N=N-. Inorganic coloured pigments usually contain metals such as lead, chromium, copper, mercury, iron, etc.

3.3.3 The fluid component that acts as a carrier for the pigment is known as the vehicle, consisting of varnishes plus performance additives like driers, waxes, fillers, modifiers, etc and solvent/diluent. A varnish is a homogeneous solution of resin in oil or a volatile solvent. The solvent or diluent may be aliphatic esters, aromatic hydrocarbons, alcohols or ketones.

3.4 Fountain solution

3.4.1 To impart an oleophobic surface to the non-image areas, lithographic printing plates are dampened with fountain solution. Its main ingredients are isopropyl alcohol (IPA) and phosphoric acid. IPA reduces water surface tension and also helps avoid emulsification of the ink into the fountain solution.

3.5 Cleaning solvents

3.5.1 Emissions of volatile organic compound (VOC) from most cleaning solvents are of a great concern to the health and safety in workplace as well as the environment. Major sources of VOC emissions are exhausts primarily from printing presses and vaporization of cleaning solvents during cleanup process.

3.5.2 The printing parts have to be frequently cleansed to prevent accumulation of dried ink and paper dusts. Common cleaning solvents used include kerosene, glycol ether, alcohols, toluene, hexane and specially formulated proprietary solvent blends. These solvents may present health and fire risks if protective measures are not adequate.

3.5.3 The blankets installed on rollers are cleaned following a run or after a colour change. This is usually done manually by workers using solvent-wetted rags. For convenience, pots of organic cleaning solvents, usually uncapped, are kept along side with printing machine, causing evaporation of VOC to the workplace. As the container is mostly not the original one and if not be properly labeled, workers may be unaware of its potential safety and health hazards.

3.6 Adhesives and glues

3.6.1 Adhesives and glues are mainly used in holding units of printed material together in the post press finishing operations. Depending on their compositions, these substances may cause irritation or sensitization of the skin or respiratory tract or even occupational asthma.

3.6.2 The chemicals that cause the health hazards include:

- isocyanates contained in screen adhesives to attach screen printing mesh onto printing frames, and adhesives used for foil lamination for food package and book binding
- epoxy in some specialized adhesives
- rosin that may be found in certain binding adhesives.

3.7 Hazards of chemicals used in printing

3.7.1 Adverse health effects related to exposure to organic solvents through inhalation and skin contact in the workplace include degreasing of the skin leading to dermatitis, irritation or sensitization of the skin and respiratory tract. Long-term health effects may be damage to internal organs such as liver, kidneys and lungs, etc. after absorption into the body. Organic solvents may also cause central nervous system depression with such effects as drowsiness, incoordination, inattention and impaired balance.

3.7.2 As the printing industry uses large quantities of flammable solvents and combustible materials like paper, fabric, plastics, the risk of fire is high.

3.7.3 At Appendix I is a table listing in detail some common chemicals encountered in the printing processes along with their associated hazards. It must be noted that these chemicals are for illustrative purpose and by no means exhaustive.

4 Chemical Safety Programme

4.1 Overview

4.1.1 To ensure the safety and health of employees engaged in printing industry, a carefully planned chemical safety programme is essential. In the programme, the chemical hazards of the materials and processes used in the whole printing process should be first identified. The risks arising from these hazards are assessed taking account of the work situations and personnel involved. Appropriate preventive and/or control measures are then set up to eliminate or mitigate the risks, with their effectiveness being regularly monitored and reviewed. The associated hazard information and protective measures should be communicated to all affected employees. The chemical safety programme should also include other elements like planning of emergency responses and training of employees.

4.1.2 The chemical safety programme should be organized and integrated into the overall safety management system of the workplace to facilitate its effective implementation. Employers should deploy adequate manpower and resources for the development, implementation and maintenance of the programme.

4.1.3 The advantages of establishing a chemical safety programme at work are as follows:

(a) to avoid possible problems or failure due to oversight of hazards that may be caused when any of the interrelated printing processing steps is changed;

(b) to provide management with a systematic overview about the entire processing work, allowing easy detection of warning signs of potential incidents; and

(c) to render a safer operation consistent with increased efficiency and productivity.

4.2 Major elements

4.2.1 A chemical safety programme should include the following major elements:

(a) risk assessment -- to identify the potential hazards arising from the materials and processes used in printing and to assess their associated risks taking into account the adequacy and effectiveness of existing control measures;

(b) safety measures -- to adopt and maintain preventive and/or control measures to eliminate the risks or minimize them to acceptable levels;

(c) emergency preparedness -- to establish plans and procedures for emergency response;

(d) hazard communication -- to establish appropriate and effective means to disseminate the safety and health information on the materials and processes to employees via adequate instruction and training; and

(e) monitoring and review -- to monitor the effectiveness of the adopted safety measures with regular review and revision which may also be required for any new requirements or significant changes in the materials or processes.

4.2.2 Depending on individual situation of the workplace, employers may find it beneficial to include other elements such as inspection, accident investigation and health surveillance in the chemical safety programme.

5 Risk Assessment

5.1 Overview

5.1.1 Risk assessment is a process to estimate the level of risks and decide whether the risk is tolerable or acceptable. Before the risks can be assessed, the hazards related to the printing and associated chemicals have to be identified. The risk is then estimated in terms of the people who might be involved and their exposure, the likelihood and potential consequences of the identified hazards. Suitable safety measures will then be developed and implemented with periodic monitoring and reviews.

5.1.2 Reference should be made to relevant legislation, codes of practice, guidelines and best trade practices in order to decide on the need and adequacy of safety measures. Employers should keep an inventory of all substances in the workplace, identify whether they are hazardous and ensure that they are handled and stored safely. It is also essential to obtain the Material Safety Data Sheet (MSDS) of the chemicals from the supplier, as it contains a wealth of information indispensable for risk assessment, stipulation of safety measures and emergency planning.

5.1.3 The risks associated with the printing processes and chemicals should be re-assessed when:

(a) there are changes to any of the processes or their scales;

(b) there are changes in the materials used; or

(c) safer procedures or improved preventive measures become available or reasonably practicable.

5.1.4 When health risk is assessed, the occupational exposure limits (OELs) of concerned chemicals should be consulted. OELs refer to the airborne concentrations of individual chemicals below which no adverse health effects would be imposed on nearly all workers upon exposures by the route of inhalation. More information on OELs can be found in the *Code of Practice on Control of Air Impurities (Chemical Substances) in the Workplace* issued by the Labour Department.

5.1.5 As OELs do not represent 'no effect' levels at which every employee can be guaranteed protection, employers should:

(a) ensure the workplace exposure standards are not exceeded under normal operational conditions; and

(b) keep the level of exposure as low as reasonably practicable.

5.1.6 Risk assessment should be performed by competent persons who are well knowledgeable about the hazards associated with the chemicals and related processes including the physical and chemical changes at each stage of the processing work. Specialist or expert advice should be consulted if needed.

5.1.7 The *Chemical Safety in the Workplace: Guidance Notes on Risk Assessment and Fundamentals of Establishing Safety Measures* published by the Labour Department provides detailed information about the systematic approaches for conducting risk assessment related to chemical hazards.

5.2 Factors to consider in the risk assessment

5.2.1 In assessing the chemical risks of printing processes and materials, the associated physico-chemical and health hazards have to be identified, and the following factors should be considered.

5.2.2 Volatility of chemicals

As the major hazard in printing comes from the organic solvents, it is important to assess their volatility. Since a more volatile substance will form greater amount of vapour at a given temperature, greater amount of harmful substance will be present in the air. The boiling point of a substance is a good indication of this property since a substance with a high boiling point is less volatile than one with a low boiling point. Thus, other factors being equal, a solvent with higher boiling point should be used.

5.2.3 Flammability of chemicals

An indication of the flammability of a liquid is its flash point, which is defined as the lowest temperature at which the liquid gives off flammable vapour in air that can catch fire or explode if exposed to an ignition source. The greater the volatility, the more readily flammable vapour is produced and the lower is the flash point. Generally speaking, a liquid having a low boiling point will have a low flash point and vice versa, as shown at Appendix II.

5.2.4 Explosive (or flammable) range of chemicals

Ignition of a flammable liquid can occur only when the concentration of its vapour in air is within a certain range, called the explosive range (defined by the lower and upper explosive limits), at temperature above its flash point. This consideration is important in the design of ventilation to ensure that the concentration of the contaminant is kept well below its lower explosive limit and no ignition sources are nearby. The explosive ranges of some commonly used solvents are given at Appendix II.

5.2.5 Physical form of chemicals

The physical form of a chemical has a pronounced effect on the extent of the hazards of the chemical. Gases, vapours, fumes, aerosols, dusts, airborne particles and powders increase their risk of entering the human body as well as fire and explosion.

5.2.6 Chemical changes

If chemical changes are involved, the chemical reactions and products should be studied, and the associated hazards identified. Attention should also be paid to any possible side reactions and by-products.

5.2.7 Temperature changes

Exothermic reactions will generate heat spontaneously and may, therefore, have the following effects:

- formation of hazardous gases, vapours or fumes
- increase of pressure in container causing explosion
- rapid bubbling causing splashes of hot hazardous fluids
- increase in reaction rate generating more heat.

These effects will be intensified if there is no effective means to dissipate the heat evolved thus resulting in localised heating and superheating in part of the reaction mixture. Moreover, some exothermic reactions may auto-accelerate rendering the reaction rate too fast to be controlled.

5.2.8 Scale of the process

Scale of the process determines the amount of hazardous chemicals involved. The larger the amount of hazardous substance is used, the greater is the likelihood of exposure to it.

5.2.9 Extent of exposure

The time of exposure of employees to hazardous chemicals associated with printing is affected by:

(a) frequency and duration of exposure;

(b) rate of generation and concentration of the hazardous chemicals in the atmosphere; and

(c) effectiveness of safety measures in minimizing the exposure.

5.2.10 Working environment and facilities

Most printing workplaces in Hong Kong are air-conditioned and humidity controlled to ensure the quality of printed products. However, the working environment may cause accumulation of hazardous chemicals in the atmosphere if ventilation is inadequate, particularly at such locations as pressroom and printing ink mixing area. Employers should therefore consider at least the following when conducting the risk assessment:

(a) any nearby ignition sources when flammable solvents are handled, transferred or mixed, such as sparks due to static discharge, poorly maintained or substandard electrical installation;

(b) adequate ventilation of the workplace;

(c) any accumulation of flammable vapours from VOCs at low spots; and

(d) whether the chemical, when used, transferred or stored is sensitive to air, moisture or light, and whether it is compatible with others when stored.

6 Safety Measures

6.1 Overall strategy in establishing safety measures

6.1.1 The primary consideration is to adopt appropriate preventive measures in order to directly remove the hazards at source, such as by elimination or substitution. If such measures are not possible, segregation of the chemicals or the processes or other control measures should be taken. The use of personal protective equipment should only be considered a supplementary means or as the last resort to minimize workers' exposure to the hazards.

6.1.2 On many occasions, the substance, equipment or process can be replaced by a safer one that eliminates or minimizes the risks to an acceptable level. For example, for processing work, the replacement may be achieved by improved material application methods such as mixing and dispensing procedures.

6.1.3 Safety measures can be realised by engineering and administrative controls. Engineering control measures such as installation of suitable types of ventilation can eliminate or lower the level of hazardous air-borne contaminants or flammable vapours at source. Administrative control measures such as by implementation of safe work practices and scheduling of breaks or rotating shifts can limit worker's time spent near the hazard thus reducing their exposure.

6.1.4 It is desirable to consider safety and health aspects of the materials, processes and equipment at the design or purchase stage. This will save additional expenses and often reduce practical difficulty in subsequent adjustments to accommodate the safety features. Management should also keep abreast of the up-coming safety alternatives or devices that are available on the market.

6.1.5 All safety measures should be documented, for example, in the standard operating procedures (SOP) of printing, and should be made known to the workers concerned. The effectiveness of such measures should be constantly monitored and reviewed to ensure adequacy of the adopted safety measures. If any changes are made to the SOP in respect of the printing processes and materials used, a fresh risk assessment should be conducted and any amended protective measures should be documented in the SOP accordingly.

6.2 Elimination/Substitution

6.2.1 Due to health and safety concerns, as well as environmental consideration, petroleum-based printing inks are now replaced by safer UV-light or electron-beam curable inks, vegetable-based inks (including soy oil-based inks) or aqueous-based inks. However, as UV-curable materials contain polyfunctional acrylates or methacrylates that can cause skin irritation or sensitisation, special care should be exercised in using these chemicals.

6.2.2 In lithographic printing, the less volatile glycol ethers can substitute isopropyl alcohol (IPA) in fountain solution. In flexography, a range of detergent-based solvent cleaners suitable for most flexographic inks has been developed and available in market.

6.2.3 Compartmentation of hazardous processes, such as polythene printing that uses flammable solvents, is an effective means to eliminate VOC emission into the general working environment.

6.2.4 With the advance in printing technology, computer-to-plate (CTP) technology has been available as an alternative to the traditional photo-processing processes that use many hazardous chemicals.

6.3 Process and equipment modification

6.3.1 On many occasions printing processes and equipment can be modified to minimize the VOC emissions and related risks arising from hazardous substances. Modifications or changes can be made to process systems, equipment or material application methods.

6.3.2 In some printing presses, automatic blanket washers are installed to do away with the need of manual cleaning, thus minimizing the risk of exposure of workers to organic solvents.

6.3.3 In roller cleansing, workers usually dip a sponge or cleaning cloth to a container of cleansing solvent that is left open all the time. In fact, a spring-loaded plunger can be used to facilitate such work without the harmful effect of solvent vapour. Upon pressing the plunger, the required amount of solvent is drawn up, and the surplus liquid drains back to the reservoir. Besides preventing inadvertent spills, the design ensures that the solvent is confined except when the plunger is pressed.

6.3.4 Traditional lithographic printing relies on water being applied to the non-image areas to impart hydrophilic or oleophobic property, which uses fountain solution containing hazardous additives like IPA. In waterless printing, the printing plate is coated with a photosensitive oleophobic layer consisting of silicone rubber compounds. The coating on the image area is removed after exposure and development processes, exposing an ink-receptive surface.

6.4 Engineering control measures

6.4.1 The primary object of adopting engineering control is to eliminate or lower the risks at source. With printing processes, the main engineering control method against chemical hazards is exhaust ventilation, which provides an effective means of preventing accumulation of hazardous chemicals in the atmosphere. There are four major types of ventilation, namely, general dilution ventilation, booth ventilation, local exhaust ventilation and push-pull ventilation.

6.4.2 Practically the ventilation methods to control inhalation and fire/explosion hazards are combined. Factors related to the materials used, such as the quantity, frequency of use, volatility, flash point, explosive limit and exposure limit should be considered.

Ventilation – General dilution ventilation

6.4.3 In general dilution ventilation, the contaminated air is diluted by fresh air which is supplied to the work area by electrical fans or natural air currents through doors, windows or other openings therein. The contaminated air is discharged through relief openings or drawn out by exhaust fan.

6.4.4 This method only replenishes fresh air supply for the whole work area. It should therefore be used in conjunction with other means of ventilation in order to remove airborne contaminants from source.

Ventilation – Booth ventilation

6.4.5 Booth ventilation is most effective in the control of air-borne contaminants. A carefully planned and designed ventilation system in a booth restricts the hazardous activity to a designated area and prevents the rest of the workplace from being contaminated.

Ventilation – Local exhaust ventilation

6.4.6 Local exhaust ventilation (LEV) allows vapours and particulates be captured and removed by forced air current through a duct near the emission point before the contaminants can be dispersed into the work area. It is generally applied to equipment that cannot be readily enclosed. Although LEV can be as effective as booth ventilation system, it may not be suitable for working with large pieces of equipment.

6.4.7 When LEV is adopted it is important to ensure that the exhaust current does not pass through the worker's breathing zone. The extraction hoods should be positioned as close as practicable to the point of generation of fume, vapour or dust, and should enclose the source to the greatest practicable extent.

6.4.8 The ducting should be of adequate diameter, and as short and as straight as practicable. Bends should be of gentle radius while 'T' section junctions avoided.

6.4.9 The system should be designed and constructed to take account of the flammable hazard of the chemicals extracted.

6.4.10 The system should vent to a safe place in the open air in such a manner that neighbours are not subjected to nuisance. If vents are poorly sited, discharged vapour may enter buildings through doors, windows, roof spaces or intakes to air conditioning system. In some cases the air may need to be cleaned before it is discharged to the outside atmosphere.

Ventilation – Push-pull ventilation

6.4.11 Push-pull ventilation system is suitable for large work pieces, in which fans are used to blow vapours away from the worker's breathing zone towards an extraction system. Again, the design of the system should ensure that the flow of contaminated air is not within the worker's breathing zone.

6.5 Administrative control measures

6.5.1 Administrative control measures include arrangement of work schedules and stipulation of safe work practices so that the risk of exposure of individual employees to hazardous chemicals can be reduced. Employers should ensure that these are incorporated into the management system as far as practicable. Typical safe work procedures that reduce the worker's exposure to VOC emissions should include the following:

(a) ensuring the time spent near the hazard is kept to minimum. Workers should not stay between the work piece and the extraction system during printing operation;

(b) keeping pots or bottles of printing inks and solvents closed when not in use; and

(c) avoiding skin contact with printing inks and solvents.

6.6 Personal protective equipment (PPE)

6.6.1 The primary objective of using PPE is to supplement control measures by minimizing worker's risks of exposure to hazardous chemicals through inhalation or skin contact. Being only passive protective measures PPE should not replace preventive measures.

6.6.2 Appropriate PPE should be chosen with regard to the hazards and physical nature of the chemicals and their routes of entry into the human body. The MSDS information and risk assessment will help determine the PPE requirements. Before and after use, PPE should be inspected for any signs of damage. It should be regularly cleaned and stored in good condition. Contaminated PPE should be properly treated or disposed of as appropriate, and replacement sets kept readily available. Moreover, as no PPE will give long-term protection, a programme should be in place for its regular replacement.

6.6.3 Wrongly selected, improperly used or maintained PPE may do more harm than good as the user may have a false sense of security. Readers should refer to *Chemical Safety in the Workplace: Guidance Notes on Personal Protective Equipment for Use and Handling of Chemicals* for details.

Protective clothing

6.6.4 Protective clothing protects the skin or personal clothing from contact with hazardous chemicals and prevents spread of contamination. When handling printing inks or solvents, such as dispensing and storage, and conducting maintenance work, employees should always wear suitable protective clothing. Employers should also provide their employees with special clothing for use in emergencies.

6.6.5 Protective clothing includes gloves, aprons, gowns and overalls. It is important to choose protective clothing made of materials that resist penetration or damage by the chemicals used.

6.6.6 As printing workers frequently have to handle many hazardous chemicals by hands, chemical resistant gloves have to be used. It should be noted that natural rubber gloves are not effective against hydrocarbon-type solvents as they can penetrate the rubber and physically degrade it. Nitrile or neoprene gloves, though more expensive, should be used against hydrocarbon-type solvents. It is prudent to always check with the supplier and consult the MSDS of the chemicals involved.

Face and eye protection

6.6.7 Where there is a reasonably foreseeable risk of eye injury, suitable eye protectors or face shields should be worn. Safety spectacles can be fitted with prescription lenses if required, while clear plastic safety goggles that completely enclose the eyes provide superior eye protection. If protection to the whole face including mouth, nose and eyes is required or there is a risk of splashing, face shield should be used.

Respiratory protective equipment

6.6.8 Respiratory protective equipment (RPE) protects workers against exposure to dusts, gases, fumes and vapours, but exposure duration should be kept short.

6.6.9 RPE should be used to protect the workers where engineering control may not be reasonably practicable such as during maintenance, cleaning, or emergencies where hazardous fumes are generated from significant chemical spillages or inadvertent mixing of incompatible chemicals.

6.6.10 The choice of RPE depends on the concentration, duration of exposure and physical and chemical nature of the hazardous substances. For fire and other major emergencies where asphyxiation or inhalation of toxic gases at levels immediately dangerous to health or life is possible, RPE should comprise self-contained breathing apparatus (SCBA).

6.6.11 With appropriate filters, the following RPE can protect against airborne contaminants:

(a) air purifying respirators – most half-face respirators equipped with appropriate filters provide protection against contaminants of concentration up to 10 times, and most full-face respirators up to 50 times its exposure standard (OEL) when fitted correctly; many powered air purifying respirators that use battery-operated motor blower to draws air through filters have similar efficiency.

(b) airline respirators – airline respirators supply clean air to the mask, helmet or hood using an airline, and the level of protection ranges from below 25 to more than 1000 times the exposure standard depending on whether a helmet, hood or mask is worn.

6.7 Monitoring

6.7.1 Monitoring provides a means to ensure the effectiveness of safety measures taken. Air monitoring generally involves measuring the concentration of airborne contaminants at strategic locations in the work area or at the worker's breathing zone. The monitoring can be continuous or periodic sampling and analysis using sensors (with alarm device), direct-reading meters, static samplers and personal samplers.

6.7.2 Based on the work activities and the result of risk assessment, the management should establish and implement appropriate monitoring programme to ensure that the levels of airborne contaminants do not exceed the acceptable hazard limits, such as the lower explosive limit (LEL) or the occupational exposure limit (OEL) of the chemicals. The monitoring programme should include:

(a) monitoring parameters such as concentrations;

(b) frequency of monitoring;

(c) location and method of monitoring;

(d) alarm levels based on the acceptable limits; and

(e) follow-up actions.

6.7.3 Investigation of serious accident or dangerous occurrence involving chemicals is a reactive means of monitoring after the event. All such events should be investigated and be taken as a 'learn-from-mistake' exercise. The investigation should be led by a line manager or professional having adequate knowledge about the operation.

6.7.4 Biological monitoring can be used to provide additional information for the assessment of chemical exposure by measuring the level of the chemical or its metabolites (what it breaks down into in the body) in the worker's urine and/or blood. Biological monitoring should be used only to complement, rather than replace, air monitoring. It can be incorporated into the health surveillance programme where appropriate.

6.7.5 Health surveillance is a means of monitoring for early adverse health effects resulted from chemical exposure. It provides clues on the need of workplace and practical interventions, thereby preventing further harm to the health, especially for employees who have regular exposure to hazardous chemicals. It usually takes the form of pre-employment and periodic medical examinations. Where appropriate, medical examination should also be conducted upon and after termination of work and upon resumption of work after prolonged sickness absence. Health surveillance should be conducted by registered medical practitioner, preferably one who has received formal training in occupational medicine.

6.7.6 If monitoring reveals over-exposure to hazardous chemicals, the process should be suspended and the causes investigated. The management should also put in place suitable control measures and ensure that such measures are operating effectively before allowing resumption of the process. The lesson learnt is also useful in reviewing the chemical safety programme.

7 Emergency Preparedness

7.1 Overview

7.1.1 Emergency preparedness is vital to provide quick and effective response to industrial incidents that may result in injuries, loss of life and damages of property. In the printing industry, emergency situations mainly arise from chemical spillages, and on some occasions from fire and explosion.

7.1.2 In regard to chemical safety and health in the printing industry, the employer or management should:

(a) identify and list out all possible emergency situations in the workplace;

(b) assess the effects and impacts of the emergency situations;

(c) develop and implement an emergency response plan, which may include procedures to handle minor leaks and spills and an evacuation plan ;

(d) provide and maintain emergency equipment and other necessary resources; and

(e) ensure that staff are familiarised with the arrangements in case of emergencies by providing procedural instructions and employee training and organising drills.

7.1.3 Appropriate first aid facilities and adequate numbers of trained first-aiders as required by the *Occupational Safety and Health Regulation* should be provided.

7.1.4 The MSDS in respect of handling accidental release of chemicals and disposal of waste should be consulted.

7.2 Emergency response plan

7.2.1 An emergency response plan should be established for handling various foreseeable emergency situations in the workplace. It should provide the following:

(a) assignment of responsibilities;

(b) alarm systems;

(c) emergency response procedures; and

(d) schedule for emergency drills.

7.2.2 Assignment of responsibilities -- It is extremely important that all employees understand their own roles during any emergency situations. A senior staff such as a line manager or safety officer should be assigned to lead the emergency response team and charged with the following duties:

(a) assessing the emergency situation and taking necessary actions;

(b) overseeing the implementation of the emergency response plan;

(c) organising regular drills; and

(d) ensuring all emergency equipment is well maintained.

7.2.3 Emergency response procedures -- Emergency response procedures are operating instructions for employees to follow in case of emergency situations. Appropriate procedures should be established for each type of emergency situations and cover the following:

(a) reporting, declaring and clearing off emergencies;

(b) handling of emergency situations;

(c) evacuation; and

(d) deployment of employees to perform critical operations before they evacuate.

7.2.4 The emergency response plan and related information should be documented and communicated to all employees: evacuation routes, names and locations of first aid team members, locations of safety equipment, telephone numbers of key personnel and emergency services. The documents should be kept or posted in prominent places in the workplace for easy access by all staff.

7.2.5 Handling of spillages of hazardous chemicals and other emergencies should be included in the chemical safe programme.

7.3 Emergency equipment

7.3.1 Appropriate emergency equipment should include but not limited to:

(a) fire alarm;

(b) fire-fighting equipment, such as fire hoses, fire extinguishers and fire blankets;

(c) emergency lights and backup for fume extraction in case of power failure;

(d) emergency showers and eyewashes;

(e) first aid facilities, such as first aid kit; and

(f) absorbent material for cleanup of minor chemical spills.

7.3.2 All emergency equipment should be properly maintained and regularly inspected for proper performance. Expired items should be replaced. Locations of emergency equipment in the workplace should be made known to all staff.

8 Hazard Communication

8.1 Overview

8.1.1 Under *the Occupational Safety and Health Ordinance*, employers are obliged to provide such information as is necessary to ensure the safety and health of their employees at work.

8.1.2 The information is indispensable in the identification of potential hazards related to the use and handling of workplace chemicals during risk assessment and preparation of emergency response plans.

8.2 Sources of hazard information

8.2.1 Limited but yet essential hazard information can be found on the label of the container of the substances, whereas detailed information can be obtained from the suppliers (chemical manufacturers, importers or distributors) of the chemicals. Other information sources include chemicals catalogues, chemistry journals, chemical handbooks and online databases.

8.3 Means of hazard communication

8.3.1 Typical means of hazard communication include labels, MSDS, standard operating procedures and employee training. Employers may also find placards, notices and signboards useful for their workplaces.

Labels

8.3.2 Labelling each container containing hazardous substance is the most direct means of hazard communication. The label should include the following information:

(a) identity of the substance -- chemical name(s) or common name(s);

(b) hazard classification and symbol(s);

(c) indication of the particular risks inherent in the substance; and

(d) indication of the required safety precautions.

8.3.3 If it is not reasonably practicable to put full information on a container, the container should at least be labelled with the identity of the chemical and the hazard group(s) and symbol(s). Other required information can be given in an information sheet placed in the close vicinity. Statutory requirements for labelling of dangerous substances are prescribed in *the Factories and Industrial Undertakings (Dangerous Substances) Regulations*.

Material Safety Data Sheet (MSDS)

8.3.4 An MSDS provides important source of information about a specific chemical used in the processing work, especially when the chemical is used for the first time. The information includes safe handling and storage of the chemical, first-aid procedures, potential effects of contact and measures to take in the event of a spill or leak. ISO 11014-1 recommends a standard format for the MSDS, which contains the following sixteen sections or headings of information:

(i) product and company identification;

(ii) composition/information on ingredients;

(iii) hazards identification;

(iv) first-aid measures;

(v) fire-fighting measures;

(vi) accidental release measures;

(vii) handling and storage;

(viii) exposure controls/personal protection;

(ix) physical and chemical properties;

(x) stability and reactivity;

(xi) toxicological information;

(xii) ecological information;

(xiii) disposal considerations;

(xiv) transport information;

(xv) regulatory information; and

(xvi) other information.

Standard operating procedures (SOP)

8.3.5 Hazard information can also be communicated via SOP, which refer to a set of systematic step-by-step written procedures to be followed for completing a process or operation. The SOP should describe the tasks to be performed, data to be recorded, operating conditions to be applied with associated safety and health precautions.

8.3.6 The inclusion of appropriate hazard information in SOP relies very much on how thorough and thoughtful the risk assessment is undertaken, so as to effectively eliminate or control the risks in the entire process.

9 Information, Instruction and Training

9.1 Overview

9.1.1 After assessing the risks in the workplace and adopting appropriate preventive measures, employers should make sure that their employees fully understand the risks at work, and that the work practices can help them perform their jobs safely. To achieve this, employees should be provided with adequate safety information, instruction and training.

9.2 Information and instruction

9.2.1 Employees should be informed of the following:

(a) safety information about the hazardous substances that they could be exposed to, including the nature of hazards, exposure standards, possible routes of entry into the body and risks to health;

(b) correct labelling of substances and the significance of label details;

(c) content and significance of MSDS;

(d) measures to reduce the risks of exposure to hazardous substances, including practice of personal hygiene;

(e) safe work procedures on the use, handling, storage, transportation, cleaning up and disposal of hazardous substances;

(f) information on the safe handling of plant and equipment;

(g) emergency response procedures, including locating and using emergency equipment and facilities for first aid, decontamination and fire-fighting;

(h) procedures for reporting faults and incidents, including spills; and

(i) proper selection, use and maintenance of PPE.

9.2.2 Information and instruction should be provided to employees by:

(a) SOP, safety manual, and emergency procedures being located in prominent locations in the workplace easily accessible by employees;

(b) others such as notice, poster and video show arousing the safety awareness of everyone on handling hazardous substances and processes.

9.3 Employee training

9.3.1 Training helps employees to acquire the necessary skills and knowledge that enable them to follow safe working procedures, take appropriate control measures, use appropriate personal protective equipment and follow emergency procedures. Training should also enable employees to participate in decision-making relevant to workplace safety and health.

9.3.2 Employers should ensure that all persons involving in printing, including workers, supervisors, store persons, emergency personnel and safety and health representatives are adequately trained.

9.3.3 Content of the training programme should include those information and instruction aspects as detailed in paragraph 9.2.1.

9.3.4 Training should be an ongoing process so that employees can learn about the new developments of workplace safety and continue to improve their relevant knowledge and skills. Refresher training is useful and should be provided, especially to employees returning from an extended leave of absence or when there are changes of workplace that may render previous training obsolete.

9.3.5 The training programme should be reviewed periodically to make sure that employees are gaining the skills and knowledge they need. Employers should also ensure that their employees, after undergoing appropriate training, understand what they have been taught.

9.3.6 Employers should keep the training record, which should include at least the following:

(a) names of employees receiving training, and dates of attendance;

(b) outline of the course content; and

(c) names and credentials of trainers.

Appendix I

Summary of some commonly used printing processes and materials with their associated hazards

Processes/materials	Chemicals	Potential hazards
Etching, engraving, plate-making, certain photographic reproduction systems, correction of litho-plates (using hydrofluoric acid)	Corrosive acids (e.g. concentrated nitric and sulphuric acids, hydrofluoric acid)	• Skin burns and blisters • Burns with concentrated hydrofluoric acid are very severe • Eye damage
Concentrated photographic developer solutions	Hydroquinone	• Irritating to eyes • Irritating or sensitizing to skin, may cause dermatitis
Photographic fixer solutions	Acetic acid, acidic salt solutions (e.g. sodium thiosulphate)	• Irritant
Hardener added to photographic fixer solutions	Dilute formaldehyde solution	• Irritant • Frequent contact may lead to skin sensitisation
Making flexographic and letterpress plates	Perchloroethylene	• Dizziness, drowsiness and other effects on the central nervous system
Adhesive laminating; Use of polyurethane lacquers	Isocyanate pre-polymers	• Irritation of respiratory and gastrointestinal tracts • Occupational asthma • Dermatitis • Lacrimation
Handling, cutting, grinding lead type, hot metal work	Lead dust/fume	• Acute intoxication leading to an encephalopathic syndrome (i.e. gross ataxia, repeated vomiting, lethargy, stupor, convulsions, headache, hallucinations, tremors and coma)

Processes/materials	Chemicals	Potential hazards
		• Chronic intoxication leads to weight loss, central and peripheral nervous system effects and anaemia
Laser engraving (gravure cylinders); Maintenance involving welding	Metal fume	• Irritation of respiratory tract, 'flu-like' illness (metal fume fever depending on the metal) • Poisoning from substances in the fume
Use of UV lamps for photo processing, UV curing, corona discharge	Ozone UV radiation	• Irritation of eyes, upper respiratory tract • Headaches and nausea • Skin burns, occular irritation to varying degrees which may cause difficulty with vision
Dyeline printing	Ammonium hydroxide	• Irritation of respiratory tract (as ammonia vapour)
Digital (ink-jet) printing	Methyl ethyl ketone (MEK), propanol	• Fire hazard • Dermatitis • Dizziness, drowsiness and other effects on the central nervous system
Lithographic printing: fountain solution, blanket restorers	Isopropy alcohol (IPA), methyl ethyl ketone (MEK)	• Fire hazard • Dermatitis • Dizziness, drowsiness and other effects on the central nervous system
Spray of anti-set-off powder (to prevent wet ink from transferring from the top of one sheet to the bottom of the next sheet)	Sugar/starch dusts	• Irritating to respiratory tract and blocking the nose
In thermography, powder is sprinkled over wet ink and baked.	Plasticizers	• Irritating to respiratory tract and blocking the nose

Processes/materials	Chemicals	Potential hazards
UV and electron beam curable inks, varnishes and lacquers	Reactive acrylates or methacrylates	• Corrosive to skin, eyes and mucous membranes • Upper and lower respiratory tract irritation • Potential for sensitisation
Gravure and flexographic printing inks	Ketones (e.g. MEK, cyclohexanone); alcohols (e.g. IPA, industrial methylated spirits); esters (e.g. ethyl acetate, isopropyl acetate); aromatic hydrocarbons, (e.g. toluene, xylenes)	• Fire hazard • Dermatitis • Dizziness, drowsiness and other effects on the central nervous system
Screen printing: UV-cured inks	N-vinyl pyrrolidone (NVP) and Michler's Ketone	• Cancer, harm to the unborn child
Screen printing: other inks	Ketones (e.g. cyclohexanone); aromatic hydrocarbons (e.g. toluene, xylenes)	• Fire hazard • Dermatitis
High-speed printing using UV ink - leading to ink misting	Reactive acrylates contained in UV inks	• Irritating to respiratory tract • Potential for occupational asthma
Cleaning of screens in screen printing	Strong alkalis (e.g. concentrated sodium or potassium hydroxide)	• Corrosive to skin, eyes and mucous membrane
Cleaning rollers, cylinders and blanket restoring	Kerosene, white spirit (contain n-hexane); chlorinated hydrocarbons (e.g. dichloromethane); ketones (e.g. methyl ethyl ketone (MEK))	• Fire hazard • Dizziness, drowsiness and other effects on the central nervous system • Peripheral poly-neuropathy (n-hexane, methyl-n-butyl ketone)

Appendix II

Some important fire/explosion data on organic solvents commonly encountered in printing processes

Chemical	Flash point (℃)	Boiling point (℃)	Explosive range (%)
n-hexane	-25.5	68.7	1.2 – 6.9
acetone	-20	56.5	2.5 – 13
benzene	-11	80.1	1.2 – 8
methyl ethyl ketone (MEK)	-9	79.6	1.7 – 11.4
n-heptane	-4	98.5	1.1 – 6.7
ethyl acetate	-4	77.2	2 – 11.5
toluene	4	110.6	1.2 – 7
isopropyl alcohol (IPA)	12	80.3	2 – 12.7
ethyl alcohol	12	78.3	3.3 – 19
ethyl benzene	15	136.2	1 – 6.7
methyl isobutyl ketone (MIBK)	15.6	115.8	1.35 – 7.5
butyl acetate	22	126.1	1.2 – 7.5
xylenes	25 – 30	138.4 – 144.4	1 – 7
styrene	34.4	146	1.1 – 6.1
turpentine (mainly $C_{10}H_{16}$) [1]	35	154 – 170	0.8 (LEL)
white spirits[2]	38[a]	156 – 202[a]	0.8 – 6[a]
blanket wash[3]	40[b]	163 – 190[b]	0.6 – 7[b]
thinner[4]	42[c]	156[c]	1 (LEL) [c]
cyclohexanone	43	115.6	1.1 – 9.4
butyl cellosolve	66[d]	171[d]	1.1 – 10.6[d]
kerosene[5]	37.7 – 65.5[e]	180 – 300[e]	0.7 – 5[e]

Remarks:

[1] turpentine:	a volatile essential oil whose major constituents are pinene and diterpene
[2] white spirits:	petroleum distillate containing >65% C10 or higher hydrocarbons
[3] blanket wash:	petroleum-derived complex substance containing aliphatic, cycloparaffinic hydrocarbons
[4] thinner:	solvent containing aliphatic hydrocarbon
[5] kerosene:	a mixture of petroleum hydrocarbons, mainly of the methane series having 10~16 carbons per molecule

Data obtained from 《危險化學品安全技術全書》（化學工業出版社，1997） except those indicated with superscript as follows:

a. MSDS from Mallinckrodt Baker, Inc. (02/11/2001)

b. MSDS from ExxonMobil Chemical (31/10/2002)

c. MSDS from Bennette Paint Mfg. Co. Inc. (25/09/1995)

d. MSDS from Union Carbide Corp. (24/10/1988)

e. Hawley's Condensed Chemical Dictionary, 11th edition, 1987

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8. Safety data sheet for chemical products, ISO 11014-1:1994, International Organization for Standardization, Geneva, Switzerland.

Enquiries

If you wish to obtain further information about this guide or require advice on occupational safety and health, please contact the Occupational Safety and Health Branch of the Labour Department through:

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Information on the services offered by the Labour Department and on major labour legislation can also be found by visiting our Home Page at http://www.labour.gov.hk.

You can also obtain information on the various services provided by the Occupational Safety and Health Council through its telephone hotline at 2739 9000.