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The development and regulation of occupational exposure limits in Singapore

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Abstract

Singapore is an island republic in South East Asia with a workforce of about 2.1 million including 0.7 million employed in the manufacturing industry. Singapore's industry is diversified and the main growth sectors include microelectronics, chemical, petrochemical, pharmaceutical, and biomedical sectors. Exposure to chemical hazards is one of the main occupational health problems in the manufacturing sectors. The main roles of government in the protection of workers against safety and health hazards are to set standards and provide a proper infrastructure for industry to self-regulate. The occupation safety and health laws must provide adequate protection of workforce but must not disadvantage local industry in this globally competitive economy. To ensure a level playing field, Singapore's occupational exposure standards are benchmarked against those established in the developed countries. These standards are reviewed regularly to ensure they are realistic and relevant in tandem with worldwide trends. Industry and stakeholders are consulted before any new standards are introduced. In enforcing the laws relating to exposure standards, legal and administrative procedures are followed to ensure fairness and to prevent abuse.

Keywords: Occupational exposure limits; Singapore; Health and safety law

1. Introduction

Singapore is an equatorial island republic situated in South East Asia. It has a land area of 685 km^2 and a population of 4.17 million persons. Singapore has a multi-ethnic population, comprising Chinese (76.7%), Malays (13.9%), Indians (7.9%), and others (1.5%). Persons under the age of 15 years formed 21.4% of the population, those aged between 15 and 64 years accounted for 71.2% of the population, and those aged 65 years and older represented 7.4% of the total population.

The general literacy rate for those aged 15 years and above is 93.7%. In 2003, the labour force comprised 2,034,000 employed persons (males: 1,123,000; females: 911,000). The unemployment rate was 4.7% (Singapore Yearbook of Manpower Statistics, 2004).

The distribution of the labour force by industry in 2003 is as follows: community, social and personal services—27%, manufacturing—18%, wholesale and retail trade—15%, business and real estate services—12%, transport, storage and communications—11%, hotel and restaurants—6%, construction—6%, and others—9% (Singapore Yearbook of Manpower Statistics, 2004). Electronics is a major industry in Singapore's manufacturing sector, accounting for 39% of total industrial output. This is followed by chemicals manufacturing—27%, precision engineering—10%, biomedical manufacturing—9%, general manufacturing—8%, and transport engineering—7% (http://www.singstat,gov/keystats/mqstats/ess.html, XXXX).

Virtually all process and manufacturing industries can involve the use of chemicals substances and the evolution of airborne contaminants. Persons are at risk to airborne

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contaminants if there is inadequate control of the substances used or given off in the process or operation. The setting of occupational exposure standards is essential in the assessment and control of chemical hazards.

2. Health and safety legislation in Singapore

In Singapore, the main law relating to the health, safety and welfare of persons employed in factories and other workplaces is the Factories Act (Republic of Singapore Government Gazette, 1998). The Act was enacted in 1973 and has been amended frequently over the years in tandem with industrial development. It is administered by the Occupational Safety and Health Division of the Ministry of Manpower. The safety provisions of the Act and its subsidiary legislation are enforced by the Occupational Safety Department while the health provisions are enforced by the Occupational Health Department.

The Act has a number of provisions for protecting workers and employed persons against toxic or harmful substances. These include labelling and material safety data requirements, prevention and control of airborne contaminants, regular workplace monitoring, the requirement of a competent person to be in charge of toxic substances, and provisions for protective equipment and appliances in the workplace.

The Act also empowers the Minister for Manpower to specify the permissible exposure levels (PEL) of toxic substances by notification published in the Gazette.

At the time of writing this paper, the Act is being reviewed and it will be expanded with the intention to cover all workplaces in phases.

Prior to 1997, the list of threshold limit values (TLVs) for chemical substances published by the American Conference of Governmental Industrial Hygienists (ACGIH) were used as a guide for good industrial hygiene practice.

3. Permissible exposure levels in Singapore

In 1997, the Factories (permissible exposure levels of toxic substances) Notification (Republic of Singapore Government Gazette, 1985) was gazetted under the Factories Act. It specifies the PEL of some 700 substances, and makes the entire manufacturing industry subject to exposure standards regulation for the first time. Under the main Act, every occupier or every employer who undertakes any process or work in any factory shall take all necessary measures to ensure that no person is exposed to toxic substances in excess of the PEL specified in the notification.

4. Definition of PEL

The Notification defines "permissible exposure level" as the maximum time weighted average concentration of a toxic substance to which persons may be exposed. A "toxic substance" refers to any substance in the form of a gas, vapour, dust, fume, fibre or mist which may cause irritation, injury, illness, disease or any harmful effect to a person through ingestion, inhalation or contact with any body surface. Two types of PELs are specified in the notification, viz. PEL (long term) and PEL (short term).

- "PEL (long term)" means the permissible exposure level over an 8 h working day and a 40 h workweek.
- "PEL (short term)" means the permissible exposure level over a 15 min period during any working day.

The PELs of toxic substances apply to every factory where, in connection with any process or work carried on therein, there is produced or given off any toxic substance.

4.1. Determination of permissible exposure level under certain circumstances unspecified PEL (short term)

Where the PEL (short term) of a toxic substance is not prescribed in the notification, the PEL (short term) of the substance shall be deemed to be exceeded if the time weighted average concentration of the substance measured over a 15 min period during any working day exceeds five times the PEL (long term) of that substance.

4.2. Mixed exposures to substances with similar and dissimilar harmful effects

Where there is exposure to more than one toxic substance at the same time and where the substances have similar harmful effects, the permissible exposure level is considered to have been exceeded if the sum of the ratios between the time weighted average concentration and the permissible exposure level of each substance exceeds 1.0.

On the other hand, where there is exposure to more than one toxic substance at the same time and where the substances do not have similar harmful effects, the permissible exposure level is considered to have been exceeded if the time weighted average concentration of any one of the substances exceeds the permissible exposure level of that substance.

5. How PELs are established in Singapore

PELs are established to limit exposure and to prevent occupational diseases, ill effects or health impairments. In Singapore, they are established on the recommendation of the Chemical Hazard Management Committee following assessment by the Occupational Health Department's industrial hygiene engineers and specialist medical advisers. The Committee consists of representatives from the Ministry, National Environment Agency, Singapore Confederation of Industries, National University of Singapore, Nanyang Technological University, Singapore Polytechnic, Ngee Ann Polytechnic, Environmental Engineering Society of Singapore, Institution of Engineers Singapore, Singapore Institution of Safety Officers, Singapore Institution of Manufacturing Technology and companies from the chemical industry.

The first set of the PELs as specified in the Notification were mostly adopted from the ACGIH list of TLVs for chemical substances published in 1996. Periodic reviews have been conducted by the Department. The starting point is the list of chemicals with new TLVs recommended by ACGIH. Priority is given to chemicals which are used locally, and that have significant health effects (e.g., carcinogenicity or extreme toxicity).

The review of the PEL of a substance includes a review of its biological exposure index, if it exists, and the relevant medical examination requirements which are specified in the Factories (Medical Examinations) Regulations (Republic of Singapore Government Gazette, 2004). The review takes into consideration the scientific basis for establishing the PEL including the reasons for the revision, a comparison of the various exposure standards developed in industrialized countries (e.g., USA, EU, Australia, Canada, and Japan), the usage and local exposure levels, the potential impact to local industry, and whether local industry can comply with the new standards. During the period 2003–2004, the department reviewed the PELs of eight substances and adopted new standards for four of them viz. asbestos, benzene, cadmium, and manganese. No changes were proposed for acetone, ethylene glycol, pentane, and silica. Annex 1 shows the flow process of reviewing a PEL.

5.1. Typical example: PEL of benzene

Benzene was selected for review because ACGIH had lowered the TLV from 10 to 0.5 ppm in 1997 (American Conference of Governmental Industrial Hygienists, 2001a). Benzene is a confirmed human carcinogen which can cause leukaemia. Singapore is a major oil refining centre. In 2003, there were about 1400 workers from 22 companies undergoing medical surveillance for benzene. Most (90%) of them came from oil refineries, chemical plants, and laboratories.

Following a dialogue with the stakeholders, the PEL (long term) of 5 ppm was adopted in the early 1990s. A review was carried out in 1995 and the PEL (long term) of 5 ppm was maintained.

A study conducted in 1992–1994 involving 313 workers from four oil refineries and one benzene manufacturing plant showed that all the personal air samples were below 1 ppm except for truck drivers (Ong et al., 1995). There were levels exceeding 0.5 ppm among refinery technicians and oil movement operators. Their urine tt-muconic acid levels were all below the corresponding biological threshold limit value of 1.6 mg/g creatinine except for truck drivers. A review of more recent monitoring data submitted to the department showed that it was not a problem for the industry to comply with a PEL (long term) of 1 ppm.

ACGIH recommended a TLV of 0.5 ppm on the basis of studies that suggested no long term increased risk of leukaemia compared to the general population (American Conference of Governmental Industrial Hygienists, 2001b), However, most major developed countries adopted 1 ppm as the occupational exposure limit for benzene including USA, EU, UK, and Canada (Alberta). The choice was between adopting 1 and 0.5 ppm. The PEL (long term) of 1 ppm was decided, being what most developed countries had already adopted, and was also feasible for industry to comply.

From a review of the ACGIH recommendation on biological exposure indices (American Conference of Governmental Industrial Hygienists, 2001b), the available scientific literature, local data on urinary phenol, and study involving urinary tt-muconic acid (Ong et al., 1995), it was clear that urinary phenol was no longer sensitive, given the current low exposures to benzene. Discussions were held with several laboratories to confirm the availability and reliability of analytical services for urine tt-muconic acid and s-phenyl mercapturic acid, and the possible cost impact to industry with the use of these new indicators.

The major oil refineries and chemical industries and the union were consulted, and the proposal was also discussed at various seminars and briefing sessions involving industry and environment, safety and health professionals. In November 2004, the regulations were amended to reduce the PEL (long term) for benzene to 1 ppm, and to replace the use of urine phenol with the use of urine tt-muconic acid or s-phenyl mercapturic acid for biological monitoring of benzene.

5.2. Another example: PEL of silica, crystalline-quartz

The PEL of silica (quartz) was recently reviewed since ACGIH had lowered the TLV from 0.1 to 0.05 mg/m^3. Silicosis was a prevalent occupational disease among granite quarry workers in Singapore in the 1960s and 1970s. It was through a determined effort by the government, applying a multi-pronged approach including—engaging the cooperation of the granite quarry operators, enactment of legislation, enforcement of dust control measures, dust monitoring, and medical surveillance as well as organising promotional and educational campaigns, that silicosis has eventually been eliminated in Singapore (Lee, 1997). Although, there are no more granite quarries operating in Singapore, exposure to silica occurs in the manufacture of paints, jewellery, electronic components, iron and steel foundries, and dental laboratories. Generally, the silica-in-air levels have been below 0.05 mg/m^3 since 1998. So far, there have been no new cases of silicosis detected in the medical surveillance of workers from these industries.

The PEL (long term) of silica (quartz) was maintained at 0.1 mg/m^3 after the review. The new TLV proposed by ACGIH was on the basis that fibrosis undetected by chest X-ray probably does occur among workers exposed at levels near the 0.1 mg/m^3 level (American Conference of Governmental Industrial Hygienist, 2001c). However, epidemiological studies of workers protected at 0.1 mg/m^3 level did not demonstrate a change in longevity or functional capacity even though a small percentage had radiological changes. As such, the PEL (long term) of 0.1 mg/m^3 is probably sufficient for the prevention of clinically significant silicosis. Other developed countries such as Finland, Germany and the UK and USA adopt levels which are above 0.1 mg/m^3.

6. Criteria for establishing PELs

Setting of PELs is largely based on the relationship between the level of exposure (dose) and the degree of response of the subjects exposed. For a dose–response relationship with a demonstrable threshold, the PEL is set at a level at which there is no adverse short or long-term effects on health as a result of long term exposure to that level. For a dose–response relationship having no established threshold, it would still be possible to set a PEL with an acceptable risk appropriate with the severity of the health effects.

In setting a PEL for a particular substance, several steps are involved:

- identification of critical health effects or responses,
- determination of a no-observed adverse health effect level based on human or animal exposure studies, and
- establishment of PEL by extrapolation which usually involves the application of uncertainty factors and scientific judgement.

The PEL for a particular substance is set at a level which is realistic so that practicable control measures can be applied to achieve an exposure level below the PEL. It does not make sense in setting a PEL which cannot be achieved in practice. The principle is similar to that in stipulating other occupational safety and health requirements, which must be reasonably feasible for industry to comply.

7. Exposure monitoring at the workplace

The Factories Act requires the atmosphere of any workplace in which dangerous or obnoxious substances are manufactured, handled, used or given off be tested. The test has to be conducted by a competent person at sufficient intervals to ensure that toxic or irritating dusts, fumes, gases, fibres, mists, or vapours are not present in quantities liable to injure the health of persons employed. Notwithstanding this, the Chief Inspector of Factories may, by order in writing, require air samples to be taken in the breathing zone of the persons who are exposed to dust, fumes or other contaminants by using appropriate personal sampling equipment.

A “competent person” for the purpose of workplace monitoring refers to someone who has attended and passed such courses as may be required by the Chief Inspector of Factories. Furthermore, a record of the result of every environmental test carried out must be kept available for inspection by an inspector for at least five years from the date of the test.

Guidelines on air sampling and analysis are issued by the Occupational Health Department to assist factories to comply with the air monitoring requirement. The frequency of monitoring is once a year if the exposure levels are between 10 and 50% of the PEL, twice a year if the exposure levels are between 50 and 100% of the PEL, and at least four times a year if the exposure levels are above the PEL.

8. Training for monitoring

Training for monitoring can be done overseas or locally. For example, a four-day course on Air Sampling and Monitoring has been conducted by the Occupational Health Department and the National Environment Agency since 1997 to train persons to be competent in carrying out workplace monitoring. So far, more than 300 persons have been trained.

9. Exposure database

The department established a chemical exposure database in the early 1990s. Inputs are the results of monitoring obtained from hygiene monitoring carried out by its industrial hygiene professionals as well as data submitted from factories that carry out their own in-plant hygiene monitoring. The database enables computerised storage and selective retrieval of information and data on chemical exposure. Currently, there are more than 13,000 exposure records in the database which serves as a national focal points for information on chemical exposure. Between 2001 and 2005, the percentage of workplaces monitored with exposure exceeding the PELs is about 13%.

10. Penalties for violations

The Factories Act empowers the enforcement authority to compound or prosecute companies or persons who contravene or violate the law. The Act also specifies the quantum of composition fines and the penalties for prosecution in court. Legal action can be taken against companies or individuals for causing excessive exposure of persons to airborne contaminants. In addition, legal action can also be taken against companies or individuals for not taking practical measures to control the emission of contaminants and to protect the exposed persons.

10.1. Composition fines and prosecution in court

The Factories Act stipulates that the Chief Inspector of Factories may compound any offence under the Act or any subsidiary legislation made there-under by accepting from the person reasonably suspected of committing such offence a sum of money not exceeding S$2000 (US$1 is approximately S$1.7).

A composition fine may be imposed if a person is exposed to a toxic contaminant above the PEL. For first time offenders, the fines are usually less than the maximum quantum of S$2000. However, whenever bodily injury occurs as a result of excessive exposure to airborne contaminants, the maximum fine may be imposed for a first offence. Annex 2 shows the flow process of PEL enforcement.

Prosecution may be instituted against a company or an individual if the offender ignores or contests the offer of composition fines. Prosecution may also be initiated if the contravention causes or is likely to cause adverse health effects, serious bodily injury or death as a result of exposure in excess of the PEL. When a case is prosecuted in court and a person is found guilty of an offence for which no express penalty is provided by the Act, the person is liable on conviction to a fine not exceeding S$2000 (if he is an employed person), or to a fine not exceeding S$5,000 (if he is a factory occupier or employer).

In relation to a contravention which was likely to cause the death of, or bodily injury to any person, e.g., loss of consciousness with subsequent recovery, the person guilty of an offence is liable on conviction to a fine of up to S$20,000 or to imprisonment for up to six months or to both. If the contravention results in serious bodily injury to any person, e.g., disease, illness or poisoning with irreversible damage, the person guilty of an offence can be fined up to S$35,000 or imprisoned up to 12 months, or to both.

When a worker dies because of the contravention, the penalties are more severe. The person guilty of the offence can be fined up to S$50,000 or imprisoned up to 12 months or to both. In the event that two or more deaths occur, the fine can be up to S$200,000, and the imprisonment for up to 12 months, or both.

11. Prohibition of work

The Factories Act empowers the Chief Inspector of Factories to issue a stop work order if he is satisfied that any process or work carried on in the factory cannot be carried on with due regard to the safety and health of persons employed; or any process or work is carried on or anything is or has been done in any factory in such a manner as to cause risk of bodily injury. In such situations, the Chief Inspector of Factories can order the occupier of the factory to cease the process or work indefinitely or until such steps have been taken as may be specified in the order to enable the process or work to be carried on safely.

A stop work order can therefore be issued if any work or process carried on in a factory gives off airborne contaminants resulting in persons exposed to high concentrations of contaminants exceeding their PELs, and causing chemical poisoning or adverse health effects to the exposed persons. A case of issuance of the stop work order is reported below.

The occupier of a factory who fails to comply with the stop work order is liable on conviction to a fine not exceeding S$200,000 or to imprisonment for up to 12 months or to both. In the case of a continuing offence, further fines can be imposed, not exceeding S$20,000 for every day or part thereof during which the offence continues after conviction.

11.1. Typical stop work order case

A worker was admitted to hospital for acute breathlessness and found to be partially blind. He was confirmed to have methanol poisoning as a result of exposure to methanol during mixing of fuel for manufacturing of canned fuel products. Pure methanol was used in the process and the level of methanol in air was found to be above 4000 ppm during pouring. The PEL (long term) for methanol is 200 ppm. No local exhaust ventilation system was provided. The employer and workers were not aware of the toxicity of methanol, and were even using it to wash their hands. A stop work order was issued together with requirements to substitute the methanol with a less harmful substance and provide effective local exhaust ventilation and suitable respirators. The factory subsequently closed down the manufacturing process.

12. Some issues and challenges in the application of PELs

There are issues that need to be considered with the application of exposure standards. Some of the main ones are described below.

13. Adjustment for extended working hours

Long term PELs are established as time weighted average concentrations for 8 h shift exposure, followed by an exposure-free period of 16 h. Such limits are not applicable to overtime work, such as five 10 h workdays per week or 12 h workshifts which are becoming more common in the manufacturing industry. Since dose is proportional to exposure time, the effective dose increases with exposure duration for a given concentration of exposure. Therefore, the numerical value of a PEL should be appropriately reduced for work involving longer hours of exposure.

Reduction factors can be used to adjust PELs for extended workday, typically 0.7 for 10 h workdays and 0.5 for 12 h workshifts. However, these may not be applicable to all PELs. Hence, they should be used with caution.

14. Hypersensitivity and allergic reactions

PELs do not protect persons with hypersensitivity. Some allergic disorders occur in such individuals when they are exposed to certain chemicals even if the PELs are not exceeded. In the assessment of exposure conditions, it is important to pay special attention to persons with hypersensitivity and allergic reactions.

A typical example is trichloroethylene (TCE) which has a PEL (long term) of 50 ppm. TCE can cause adverse health effects to the central nervous system, the skin and mucus membranes, and the liver and the kidneys. However, TCE can cause severe allergic reactions in hypersensitive individuals even at levels of exposure that are below the PEL (long term). A number of such cases have been documented (Phoon et al., 1984). The affected persons first developed skin rash within weeks of exposure to TCE. The rash became severe and spread to the whole body, including the face, which became swollen. They then developed jaundice due to liver damage. Several of the victims subsequently died of liver failure.

15. Monitoring strategies and interpretation of results

The results of a full-shift sampling may not be used to make inferences about short-term exposure. Similarly, the results of short-term sampling may not be used to evaluate long-term exposure. A combination of long-term and short-term sampling strategies is often required. The cost of sampling and analysis can be exorbitant to small and medium enterprises.

Ideally, monitoring devices with data-logging features should be used to measure personal exposure, record and display the data, and subsequently print-out the data as a time history profile, excursions, TWA, maximum or peak, and other parameters. However, such devices are limited to the measurement of a small number of chemicals.

16. Conclusion

Occupational exposure standards are based on scientific evidence. However, the setting of the standards is influenced by practical considerations and other factors. The main purpose of establishing occupational exposure standards is to provide a basis for interpretation of the results of workplace or worker monitoring as an indication of the severity of exposure.

Comparison of monitoring results with standards indicates either acceptable conditions or otherwise, which requires control measures to be implemented. Exposure standards therefore facilitate enforcement of legal provisions for protection against airborne contaminants at work. Exposure standards exist for several hundred chemicals. However, there are still thousands of chemicals which have no established exposure standards.

Exposure standards are not static; the numerical values change from time to time as new evidence of health effects is discovered. Exposure standards are not fool-proof for health protection of all workers, merely the majority. The standards do not address atypical work situations such as extended workshift. Despite their limitations, exposure standards will continue to be a valuable tool for exposure hazard evaluation and control.

Currently, PELs are established on the recommendation of the Chemical Hazard Management Committee. With the recent formation of the Workplace Safety and Health Advisory Committee which comprises industry leaders and different stakeholders of workplace safety and health to advise the Ministry of Manpower on setting of OSH standards, promotion of OSH awareness, and training of key stakeholders to raise competency and capabilities in OSH, it is envisaged that any review of PELs or setting of new PELs would need to be endorsed or approved by the Advisory Committee. This would provide an additional check and balance before PELs are made into legally enforceable standards.

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