STUDENT MANUAL

学生手册

Measurement of Hazardous Substances

危险物质测定

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ABBREVIATIONS 缩略语

µg	Microgram 微克
µg/m^3	Microgram per Cubic Metre 微克/立方米
µm	Micrometre 微米
AAS	Atomic Absorption Spectroscopy 原子吸收光谱法
ACGIH	American Conference of Governmental Industrial Hygienists 美国政府工业卫生学会
AIDS	Acquired Immune Deficiency Syndrome 获得性免疫缺陷综合症
AIHA	American Industrial Hygiene Association 美国工业卫生协会
AIOH	Australian Institute of Occupational Hygienists 澳大利亚职业健康专家研究所
AM	Arithmetic Mean 算术平均数
AS	Australian Standard 澳大利亚标准
AS/NZS	Australian Standard/New Zealand Standard 澳大利亚标准/新西兰标准
BEI®	Biological Exposure Indices 生物风险指数
BCIRA	British Cast Iron Research Association 美国铸铁研究协会
BIOELV	Binding Occupational Exposure Limit Values 绑定职业风险限值
BMGV	Biological Monitoring Guidance Values 生物监测指导值
BOHS	British Occupational Hygiene Society 英国职业卫生学会
CIS	Conical Inhalable Sampler 锥形吸入性采样器
cm	Centimetre 厘米
CNS	Central Nervous System 中枢神经系统
COSHH	Control of Substances Hazardous to Health 健康危险物质控制
CS2	Carbon Disulphide 二硫化碳
CV	Coefficient of Variation 变异系数
ES	Exposure Standard 暴露标准
FID	Flame Ionisation Detector 火焰电离检测器
g/cm^2	Grams per Square Centimetre 克/平方厘米

ABBREVIATIONS (Cont'd) 缩略语（续）

g/L	Grams per Litre 克/升
GC	Gas Chromatography 气相色谱法
GHS	Globally Harmonised System of Classification and Labelling of Chemicals 全球统一分类和标签制度
GM	Geometric Mean 几何平均数
GSD	Geometric Standard Deviation 几何标准差
HEG	Homogeneous Exposure Group 均匀接触组
HF	Hydrofluoric Acid 氢氟酸
HPLC	High-Performance Liquid Chromatography 高效液相色谱法
HSE	Health & Safety Executive (UK) 健康与安全执行官（英国）
IARC	International Agency for Research on Cancer 国际癌症研究所
ICP	Inductively Coupled Plasma Spectrometry 电感耦合等离子体光谱法
ILO	International Labor Organisation 国际劳工组织
IOELV	Indicative Occupational Exposure Limit Values 指示性职业暴露限值
IOM	Institute of Occupational Medicine (UK) 职业医学研究所（英国）
IR	Infra-red 红外线
ISO	International Standards Organisation 国际标准组织
L	Litre 升
LD_{50}	Lethal Dose 50% 致命剂量 50%
LEL	Lower Explosive Limit 爆炸下限
L/M	Litre per Minute 升/分钟
LOD	Limit of Detection 检测限值
LOQ	Limit of Quantitation 定量限值
m^3	Cubic Metre 立方米
MCE	Mixed Cellulose Ester 混合纤维素脂

ABBREVIATIONS (Cont'd) 缩略语（续）

MDA	Methylene dianiline 亚甲基双苯胺
MDHS	Methods for the Determination of Hazardous Substances 危险物质测定法
MEL	Maximum Exposure Limits 最大暴露限值
mg/m^3	Milligrams per Cubic Metre 毫克/立方米
MHSWR	Management of Health and Safety at Work Regulations 工作健康和安全管理条例
ml	milliliter 毫升
MMMF	Man Made Mineral Fibre 人造矿物纤维
Mins	Minutes 分钟
MOCA	Methylene bis-orthochloroanaline 二苯基甲烷二胺
MS	Mass Spectrometer 质谱仪
MSDS	Material Safety Data Sheet 矿物安全性数据表
MSHA	Mine Safety & Health Administration (USA) 矿山安全与健康管理局（美国）
MVUE	Minimum Variance Unbiased Estimate 最小方差无偏估计
NATA	National Association of Testing Authorities (Australia) 全国测试机构协会（澳大利亚）
NIOSH	National Institute of Occupational Safety & Health (USA) 全国职业安全与健康研究所（美国）
N/A	Not Applicable 不适用
nm	Nanometre 纳米
NMAM	NIOSH Manual of Analytical Methods 分析方法手册
NOAEL	No Observed Adverse Effect Level 无可视不利影响水平
NOHSC	National Occupational Health & Safety Commission (Australia) 全国职业健康与安全委员会（澳大利亚）
OD	Outside Diameter 外径
OEL	Occupational Exposure Limits 职业暴露限值
OES	Occupational Exposure Standards 职业暴露标准
OSHA	Occupational Health & Safety Administration (USA) 安全与健康管理局（美国）

ABBREVIATIONS (Cont'd) 缩略语（续）

PAT	Proficiency Analytical Testing Programme 能力分析测试方案
PCB	Polychlorinated Biphenyls 多氯联苯
PCM	Phase Contrast Microscopy 相衬显微镜
PDM	Personal Dust Monitor 个人粉尘监测器
PEL	Permissible Exposure Limits 容许暴露限值
PM10	Particulate Matter less than 10 micrometres 小于 10 微米颗粒物
PNA	Polynuclear Aromatics 多核芳烃
PNS	Peripheral Nervous System 外围神经系统
PPE	Personal Protective Equipment 个人防护设备
ppb	Parts Per Billion 十亿分率
ppm	Parts Per Million 百万分率
ppt	Parts Per Trillion 兆分率
PTFE	Polytetrafluoroethylene (Teflon) 聚四氟乙烯（特仑氟）
PVC	Poly-Vinyl Chloride 聚氯乙烯
REL	Recommended Exposure Limit 推荐暴露限值
RPE	Respiratory Protective Equipment 呼吸道防护设备
S (or SD)	Standard Deviation 标准偏差
SCBA	Self Contained Breathing Apparatus 自给式呼吸器
SEG	Similar Exposure Groups 类似暴露组
SEN	Sensitisation 敏化作用
SIMPEDS	Safety In Mines Personal Environmental Dust Sampler 矿山个人环境安全粉尘采样器
SiO_2	Silicon Dioxide 二氧化硅
SMF	Synthetic Mineral Fibre 合成矿物纤维
STEL	Short Term Exposure Limit 短期暴露限值
T ½	Half Life 半衰期

ABBREVIATIONS (Cont'd) 缩略语（续）

TD	Thermal Desorption 热解吸附
TDI	Toluene Diisocyanate 甲苯二异氰酸酯
TEOM	Tapered Element Oscillating Microbalance 锥形元素振荡微量天平
TEL	Tetra Ethyl Lead 四乙基铅
TEM	Transmission Electron Microscopy 透射电子显微镜
TLV®	Threshold Limit Value 危险物质容许最高浓度
TNT	Tri-nitrotoluene 三硝基甲苯
TWA	Time Weighted Average 时间加权平均数
UK	United Kingdom 英国
UKAEA	United Kingdom Atomic Energy Authority 英国原子能管理局
UKAS	United Kingdom Accreditation Service 英国皇家认可委员会
USA	United States of America 美利坚合众国
UV	Ultra Violet 紫外线
WA	Western Australia 西澳大利亚
WASP	Workplace Analysis Scheme for Proficiency 工作场所能力分析方案
WEEL	Workplace Environmental Exposure Levels 工作场所环境暴露水平
WEL	Workplace Exposure Limits 工作场所暴露限值
WHO	World Health Organisation 世界卫生组织
XRD	X-ray Diffraction Spectrometry x 射线衍射谱光谱仪
XRF	X-ray Fluorescence Spectrometry x 射线荧光光谱法
Zn	Zinc 锌

1. COURSE OVERVIEW

1.1 INTRODUCTION

A Course developed by the Occupational Hygiene Training Association (OHTA) as part of the International Training and Qualifications framework for occupational hygiene. The BOHS administers a number of such modules; further information on which can be obtained by visiting the BOHS website at www.bohs.org.

At the time of publication every care has been taken to ensure all topics covered in the BOHS syllabus for the subject (W501) has been included in this Student Manual. Providers of training courses should check the BOHS website for any changes in the course content.

The developers of this Student Manual take no responsibility for any material which appears in the current BOHS syllabus for Module W501 which is not covered in this manual.

1.2 AIM OF COURSE

To provide students with a sound understanding of the techniques for assessing exposure to hazardous substances in the workplace and with an understanding of how exposure information can be used to assess risk.

1. 课程概述

1.1 简介

“职业卫生培训协会（OHTA）开发的一套课程，是职业卫生国际培训和资质框架的一部分。”BOHS 管理着大量此类模块。欲了解进一步信息，请登陆 BOHS 网站：www.bohs.org。

我们尽可能确保出版后的手册涵盖 BOHS 大纲中关于培训主题（W501）的所有问题。培训课程组织者应查看 BOHS 网站，了解课程内容是否有任何变化。

如本手册未能收录现行 BOHS 大纲中关于模块 W501 的任何资料，开发者不承担任何责任。

1.2 课程目标

使学生深入理解工作场所危险物质暴露评估技术，了解怎样利用暴露信息进行风险评估。

1.3 LEARNING OUTCOMES

On successful completion of this module the student will be able to:

- describe the general approach to occupational chemical health risk assessment, including the role of atmospheric monitoring;
- select appropriate equipment to measure specific airborne contaminants and devise a suitable sampling strategy;
- present the results in a form useful for health risk assessment purposes to enable management to comply with relevant legislation.

1.3 学习目的

顺利完成本模块学习后，学生应能够：

- 描述职业化学健康风险评估的一般方法，包括大气监测的作用；
- 选择适当设备来测量特定空气污染物，设计适当采样策略；
- 以适当形式列举健康风险评估结果，确保依法管理。

1.4 FORMAT OF MANUAL

This manual has been specifically designed to follow the syllabus for this course as published by the BOHS. Similarly, the material provided in this manual has been aligned with the presentations for each topic so students can follow the discussion on each topic.

It should be recognised that the format presented in this manual represents the views of the authors and does not imply any mandatory process or format that must be rigidly observed. Presenters using this manual may well choose to alter the teaching sequence or course material to suit their requirements. In this regard the case studies are provided as illustrative examples and alternate case studies relevant to a particular industry

1.4 手册格式

本手册根据 BOHS 出版的课程大纲设计，内容符合大纲的每个主题，使学生能理解关于每个主题的讨论。

注意，手册内容仅代表作者个人观点，并非强制性程序或要求。使用本手册的培训人员可视情况调整课程顺序或课程资料。作者在手册中提供的案例研究仅作为例证，用户可根据行业情况选用其它案例。

may be used if desired.

In the final outcome, the aim of this manual is to transmit the principles of hazardous substances measurement to attendees and provide guidance as to how those principles should be applied.

总之，本手册的目的是向学员讲解危险物质测定原则，并指导学员怎样应用这些原则。

2. INTRODUCTION TO PHYSIOLOGY & TOXICOLOGY

2. 生理学和毒物学介绍

2.1 THE HUMAN BODY

2.1 人体

The human body has many different interacting sub-systems. It is important to have some understanding of the function and features of these systems to appreciate the effects that exposure to occupational hygiene hazards and in particular exposure to hazardous substances may have.

人体由许多相互作用的系统构成。理解这些系统的功能和特点才能了解职业卫生风险，尤其是危险物质暴露对人体的影响。

2.1.1 Cardiovascular System

2.1.1 心血管系统

The main components of the cardiovascular or circulatory system are the heart, the blood and the blood vessels. The blood vessels consist of arteries, capillaries and veins.

心血管系统或循环系统主要由心脏、血液和血管组成。血管由动脉、毛细血管和静脉组成。

Arteries bring the oxygenated blood, pumped from the heart, to the tissues and the veins bring the deoxygenated blood back to the heart. Blood passes from arteries to veins through capillaries, which are the thinnest and most numerous of the blood vessels.

动脉携带来自心脏的含氧血液供给组织，静脉携带不含氧血液返回心脏。血液通过全身无数毛细血管从动脉进入静脉。

2.1.2 Digestive System

The digestive system takes in food, digests it to extract energy and nutrients for the body and expels the remaining waste. It consists of:

Upper gastrointestinal tract – mouth, oesophagus and stomach Lower gastrointestinal tract – small and large intestine

Related organs including liver, gall bladder and pancreas

2.1.2 消化系统

消化系统摄入和消化食物，从而产生人体所需能量和营养物质，并将废物排出。消化系统包括：

上部消化道-口腔、食道和胃

下部胃肠道-大小肠

相关器官，包括肝脏、胆囊和胰腺

2.1.3 Endocrine System

The endocrine system is a control system of ductless glands that secrete “instant messengers” or hormones that circulate within the body via the bloodstream to affect distant cells within specific organs. Endocrine glands secrete their products immediately into the blood or interstitial fluid, without storage of the chemical.

Hormones act as messengers and are carried by the bloodstream to different cells in the body which then interpret the message and act on them. Examples include the pituitary gland, the thyroid gland, adrenal gland and the pancreas and gonads.

2.1.3 内分泌系统

内分泌系统是一个无管腺控制系统，分泌“即时信使”，即激素，激素在体内随血液循环，作用于特定器官内的远端细胞。内分泌腺分泌产物迅速进入血液或组织液，不存储化学物质。

激素发挥“信使”作用。血流携带激素进入人体内不同细胞，然后解释信息，作用于细胞。分泌激素的部位包括脑下垂体、甲状腺、肾上腺、胰腺和生殖腺。

2.1.4 Immune System

The immune system protects the body from infection by creating and maintaining barriers that protect bacteria and viruses from entering the body. If a pathogen breaches the barriers and gets into the body the innate immune system is equipped with specialised cells that detect, and often eliminate, the invader before it is able to reproduce, potentially causing serious injury to the host. A pathogen that successfully invades the innate immune cells faces a second, adaptive immune system. It is through the adaptive response that the immune system gains the ability to recognise a pathogen and to mount stronger attacks each time that pathogen is encountered. Examples of disease that arise from damage or impairment of the immune system are Hepatitis, Ebola, AIDS, Influenza, Cholera, Typhoid and Malaria.

2.1.4 免疫系统

免疫系统保护身体免受感染，创建和维护屏障，阻止细菌和病菌入侵身体。如果病原体突破屏障进入人体，那么先天免疫系统的功能性细胞在病原体入侵、繁殖和对寄主产生严重伤害前就能探知和消灭入侵者。成功入侵先天免疫细胞的病原体面临第二道适应性免疫系统。根据适应性反应，免疫系统能识别病原体，击退更强的病原体进攻。免疫系统损伤或损害导致的疾病包括肝炎、埃博拉病毒、艾滋病、流感、霍乱、伤寒、疟疾等。

2.1.5 Integumentary System

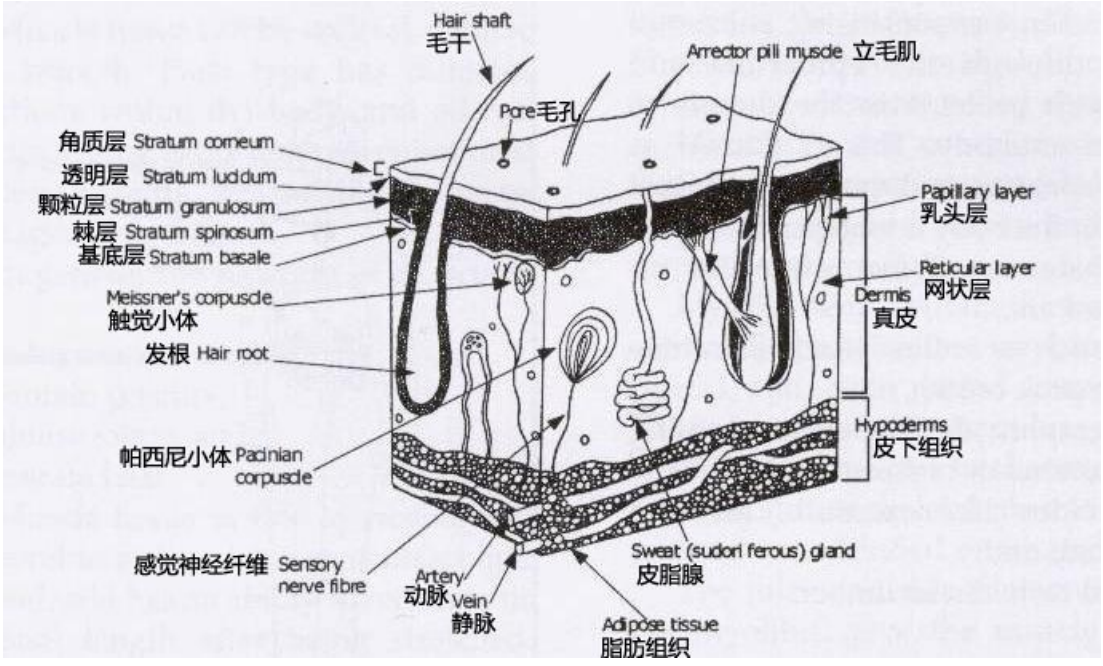
The integumentary system comprises of the skin (cutaneous membrane) and its accessory structures of hair, nails and exocrine glands. There are three layers of skin – epidermis, dermis and subcutaneous tissue. The cutaneous glands include the sweat glands, oil glands, glands of the ear and the mammary glands.

The skin is often known as the largest organ of the body and as the interface with the surroundings it provides protection against the physical hazards such as heat, radiation and abrasion, chemicals and bacteria. Its other important functions are insulation and temperature regulation, sensation and Vitamin D and B synthesis.

2.1.5 皮肤系统

皮肤系统包括皮肤（皮肤膜）及其附属结构：头发，指甲和外分泌腺。皮肤结构分为三层：表皮，真皮和皮下组织。皮肤腺包括汗腺、油腺体、耳腺和乳腺。

人们通常认为皮肤是人体最大的器官，是人体与周围环境的接触面，保护人体免受热、辐射和磨损、化学物质和细菌等物理危害。其它重要功能包括保温和温度调节、感知和合成维生素 D 和 B。



(Source: Tranter 1999 – *Reproduced with permission*)
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Figure 2.1 – Diagram of the Layers of the Human Skin
图 2.1– 人体皮肤层次结构

2.1.6 Lymphatic System

The lymphatic system is a complex network of lymphoid organs, lymph nodes, lymph ducts and lymph vessels that produce and transport lymph fluid from tissues to the circulatory system. It is a major component of the immune system.

The lymphatic systems has three interrelated functions

- removal of excess fluids from body tissues
- absorption of fatty acids and subsequent transport of fat to the circulatory system
- production of immune cells (such as lymphocytes, monocytes and antibody producing cells called plasma cells.

2.1.6 淋巴系统

淋巴系统是一个复杂的网络，包括淋巴器官、淋巴结、淋巴导管和淋巴管，在组织中产生淋巴液，向循环系统输送。它是免疫系统的一个重要组成部分。

淋巴系统具有三个相互关联的功能：

•去除身体组织多余液体

•吸收脂肪酸，随后将脂肪输送到循环系统

•产生免疫细胞（例如淋巴细胞、单核细胞和产生血浆细胞的抗体）

2.1.7 Muscular System

The muscular system is the biological system that allows us to move. It is controlled by the nervous system, although some muscles (such as the cardiac muscle within the heart) can be completely autonomous.

In general the function of muscle is to produce movement, maintain posture, stabilise joints and to generate heat.

Muscles are attached to bone by tendons and other tissues. They exert force by converting chemical energy into force. Nerves link the muscles to the central nervous system.

2.1.7 肌肉系统

肌肉系统是允许人体移动的生物系统。它由神经系统控制，但有些肌肉（例如心肌）可完全自主控制。

一般来说，肌肉的功能是产生运动，维持姿势，稳定关节和产生热量。

肌肉附着在骨胳肌腱和其它组织上，通过将化学能转换为动能，肌肉产生力量。神经肌肉与中枢神经系统相连。

2.1.8 Nervous System

The nervous system is often divided into the central nervous system (CNS) and the peripheral nervous system (PNS). The CNS consists of the brain and the spinal cord and functions as the body"s control centre. The PNS consists of all of the other nerves and neurons in the body that do not lie within the CNS and carry electrical impulses to and from the spinal cord and cranial nerves that carry electrical impulses to and from the brain.

The peripheral nervous system is divided into the somatic nervous system and the autonomic nervous system.

The somatic nervous system is responsible for co-ordinating the body's movements, and also for receiving external stimuli. It is the system that regulates activities that are under conscious control.

The autonomic nervous system is then split into the sympathetic division, parasympathetic division, and enteric division. The sympathetic nervous system responds to impending danger or stress, and is responsible for the increase of one's heartbeat and blood pressure, among other physiological changes, along with the sense of excitement one feels due to the increase of adrenaline in the system. The parasympathetic nervous system, on the other hand, is evident when a person is resting and feels relaxed, and is

2.1.8 神经系统

神经系统通常分为中枢神经系统（CNS）和外围神经系统（PNS）。中枢神经系统包括脑和脊髓，是人体控制中心。PNS 包括人体内没有位于 CNS 的所有其它神经和神经细胞，它们携带往返脊髓的电脉冲，另外 PNS 还包括携带往返大脑的电脉冲的颅神经。

外围神经系统分为躯体神经系统和自主神经系统。

躯体神经系统负责协调身体运动和接收外部刺激。系统的作用是对有意识的控制下的活动进行调节。

自主神经系统又分为交感神经系统、副交感神经系统和肠神经系统。交感神经系统对即将到来的危险或压力产生反应，导致心跳和血压等生理变化，使肾上腺素增加，使人产生兴奋感。另一方面，副交感神经系统在人体感觉休息和放松时发挥作用，导致瞳孔收缩、心跳减慢、血管扩张和消化系统与泌尿生殖系统刺激等。

responsible for such things as the constriction of the pupil, the slowing of the heart, the dilation of the blood vessels, and the stimulation of the digestive and genitourinary systems.

The role of the enteric nervous system is to manage every aspect of digestion, from the oesophagus to the stomach, small intestine and colon.

肠神经系统的作用是管理所有消化功能，从食道到胃、小肠和结肠。

2.1.9 Reproductive System

The role of male and female reproductive systems is to produce offspring. The male reproductive organs include the sperm producing region – the testes located inside the scrotum and the duct system comprising the epididymis, the vas deferens and the urethra.

2.1.9 生殖系统

男性和女性生殖系统的作用是繁殖后代。男性生殖器官包括产生精子的区域-位于阴囊内的睾丸，以及由附睾、输精管和尿道组成的管道系统。

The female reproductive system consists of the internal organs including the ovaries, fallopian tubes, uterus, cervix and vagina.

女性生殖系统由卵巢、输卵管、子宫、子宫颈和阴道这些内部器官组成。

2.1.10 Respiratory System

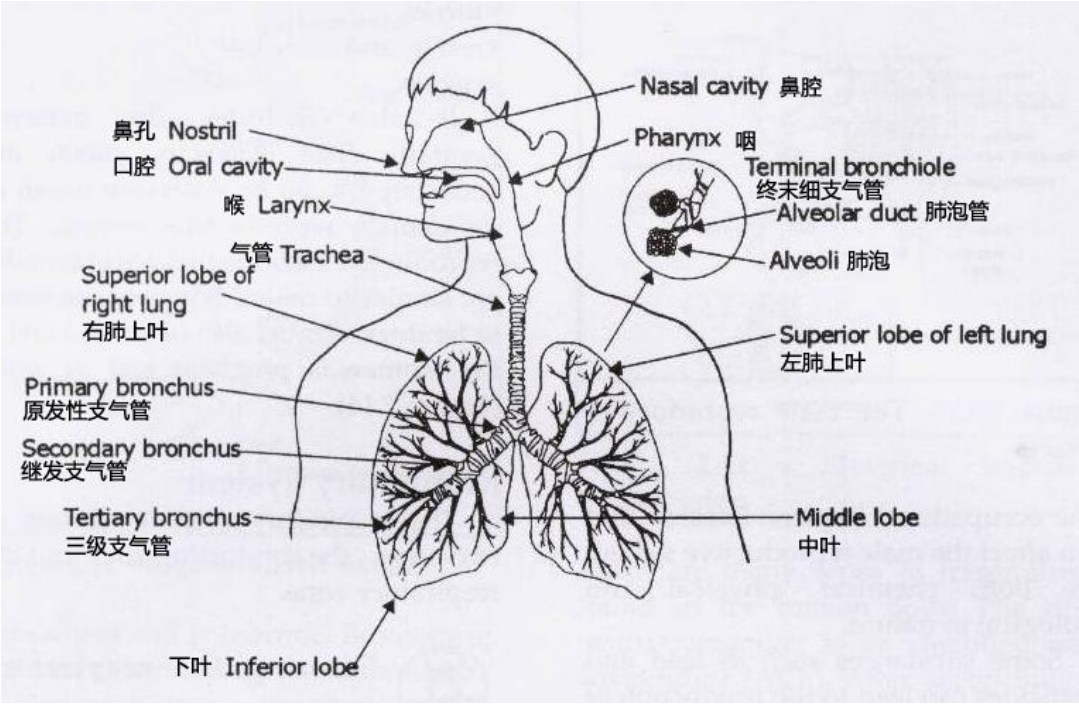
The respiratory system consists of the airways, the lungs and the respiratory muscles that mediate the movement of air into and out of the body. Inhaled air passes from the nose and mouth through the trachea and into the branched structures of the lungs called bronchi.

Air then travels along the bronchioles to its ending (the terminal bronchiole) which is covered in tiny multi lobed sacs called alveoli where most of the gas exchange occurs.

2.1.10 呼吸系统

呼吸系统包括气道、肺部和负责协调空气进出人体的呼吸道肌肉。空气从鼻孔和嘴部吸入，通过肺部气管，进入分支结构-支气管。

然后空气沿着细支气管旅行到端部（细支气管末稍），端部被细小的叶状的囊“肺泡”覆盖，大部分气体交换在肺泡里发生。



(Source: Tranter 1999 – *Reproduced with permission*)
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Figure 2.2 – Respiratory System
图 2.2– 呼吸系统

2.1.11 Skeletal System

The human skeleton is made of 206 individual or joined bones, such as the skull, supported and supplemented by a structure of ligaments, tendons, muscles, cartilage and other organs.

The most obvious function of bone is to support the body. It is also the site of haematopoiesis, the manufacture of blood cells that takes place in bone marrow and why bone marrow cancer is very often a terminal disease. The skeleton is also necessary for the protection of vital organs. Human movement is dependent on the skeletal muscles which are attached to the skeleton by tendons. Without the skeleton to give leverage movement would be greatly restricted. Bone also serves as a storage deposit in which fat and minerals such as calcium and phosphorous can be stored and retrieved.

2.1.11 骨骼系统

人类骨骼由 206 块独立或联合的骨组成，例如头骨，这些骨骼由韧带、肌腱、软骨和其它器官支持和补充。

骨骼最重要的作用是支持身体，同时也具有造血作用，骨髓的作用是制造血细胞，所以说骨髓癌是不治之症。骨骼对于保护人体重要器官极为重要。人体运动依赖于骨骼肌，即附着在骨骼上的肌腱。没有骨骼的话，人体杠杆运动将极为受限。骨还充当脂肪和矿物质的“仓库”，例如钙和磷可在骨中存储和存在。

2.1.12 Urinary System

The urinary system is the organ system that produces, stores and eliminates urine. In humans it includes two kidneys, two ureters, the urinary bladder, two sphincter muscles and the urethra.

The kidneys' are one of the various organs (together with the lungs, intestine and skin) that participates in the elimination of the wastes of the organism. The kidneys are bean-shaped organs about the size of a bar of soap. They are near the middle of the spine, just below the ribcage. They are situated behind the organs of digestion within the abdominal cavity. Situated on the superior surface of each kidney is an adrenal gland.

A kidney consists of about 1 million filtering units termed nephrons, each consisting of a glomerulus, ball-shaped network of capillaries, and a network of tubules. Blood plasma is filtered by the glomerulus, and the resultant "prourine" passes through the tubular system where water, and nutrients are reabsorbed under the supervision of hormone activity and the autonomic nervous system.

Humans produce about 1.5 litres of urine over 24 hours, although this amount may vary according to circumstances. Increased fluid intake generally increases urine production, while increased

2.1.12 泌尿系统

泌尿系统是产生、存储和排泄尿液的系统。人类有两个肾脏、两个输尿管、一个膀胱、两块括约肌和一个尿道。

肾脏是参与机体废物排泄的器官（连同肺、小肠和皮肤）之一。肾脏是豆形器官，大小和一块肥皂差不多。肾脏接近脊柱中部，位于胸腔下面，在腹腔内消化器官后部。每个肾脏上表面都有一个肾上腺。

肾脏包含约 100 万个过滤单元，即肾元。每个肾元包括肾小球、球形毛细血管网络和小管网络。肾小球过滤血浆，合成的“原尿”穿过管式系统，其中水和养分在激素活动监督和自主神经系统监控下被重新吸收。

人类每 24 小时产生 1.5 升左右尿液，虽然这个数字可能视情况有所变化。一般情况下，增加液体摄入就会增加尿量，而增加汗液和呼吸会减少通过肾脏排液。一般情况下，减少水份摄入就会

perspiration and respiration may decrease the amount of fluid excreted through the kidneys. A reduced intake of water will normally result in less urine production as well. Some medications interfere directly or indirectly with urine production, such as diuretics.

减少尿量。有一些药物能直接或间接促进排尿，如利尿剂。

The kidney plays a crucial role in regulating electrolytes in the human blood (e.g. sodium, potassium, calcium). pH balance is regulated by the removal of excess hydrogen ions (H^+) from blood. In addition, they remove urea, a nitrogenous waste product from the metabolism of proteins from amino acids. The metabolism process forms ammonia which is transported by blood to the liver and detoxified to a less harmful byproduct called urea.

肾脏在调节人体血液电解质（如钠、钾、钙）方面起至关重要的作用。肾脏将血液中过量氢离子（H+）除去来实现酸碱平衡。肾脏的功能还包括排出尿素-氨基酸中蛋白质代谢产生的含氮废物。在新陈代谢过程中形成氨，然后氨从血液被输送到肝脏解毒，从而减少“尿素”这种有害副产品。

2.2 ROUTES OF ENTRY

There are four primary routes of entry for contaminants into the human body;

1. Inhalation

The requirements of a man in a normal day are approximately 3.4 kg food and water (water is obtained in the food we eat and as direct ingestion).

For light physical work an average person breathes in between 1-1.2 m^3 of air per hour. This rate would be much higher for heavy physical exertion.

Therefore it is easy to understand why inhalation is by far the most common route of entry due to both the volume of air coming into contact with the large surface area of the lungs and the thin cell layer in the lungs separating the air from the blood, with skin absorption next (especially pesticides) and ingestion last. Inhalation is the major route of entry of dusts, fumes, mists, gases and vapours into the body.

2. Skin Absorption (includes injection)

Skin absorption via direct contact with chemicals especially organic solvents and organophosphate pesticides is the second most important route of entry to the body.

2.2 进入人体路径

污染物进入人体主要通过四个路径：

1. 吸入

正常人每天摄入约 3.4 公斤的食物和水（从我们所食用的食物中获取，属于直接摄取）。

轻体力工作者平均每小时吸入 1-1.2 立方米空气，重体力工作者吸入的量要高得多。

这样我们就能理解为什么迄今为止呼吸是最常见的进入人体路径，这是由于大量吸入空气接触肺部内较大表面，而肺部薄薄的细胞层将空气从血液中分离。其它主要路径依次为皮肤吸收（特别是杀虫剂）和摄取。吸入是粉尘、气体、烟雾、气体和蒸气进入人体的主要路径。

2. 皮肤吸收（包括注射）

通过直接皮肤接触吸收化学物质（尤其是有机溶剂和有机磷酸酯杀虫剂），是污染物进入人体的第二大途径。

3. Eye

The eye is a relative minor route of entry into the body. It should also be noted that the eye is also at risk from direct contact with chemicals.

4. Ingestion

Ingestion is a relatively minor route of absorption of chemicals in the workplace. It is usually as a result of an accidental ingestion or as from poor personal hygiene eg eating with dirty/contaminated hands.

It should be noted that insoluble aerosols can end up in the digestive tract from where they can be absorbed into the body. Additionally, involuntary ingestion as a result of clearance mechanisms in the upper respiratory tract can also be another route of entry, especially in the case of large particles of toxic substances.

3. 眼部

眼部是污染物进入人体的一个相对次要的路径。这里还要指出，如果化学物质不慎沾在眼部，也会产生风险。

4. 摄取

摄取是一个相对次要的工作场所化学物质吸收路径。通常是由于意外摄入或不良个人卫生习惯导致，例如在未洗手时/受到污染后习惯性地啃手指。

请注意，不溶性气溶胶可以在消化道中被吸收入体内。此外意外摄入会导致上呼吸道的间隙机制成为另一个进入路径，尤其对于大颗粒的有毒物质。

2.3 TARGET ORGANS AND SYSTEMS

There are numerous target organs for contaminants in the human body such as;

- Heart
- Lungs
- Kidneys
- Liver
- Brain
- Central Nervous System
- Bones
- Thyroid
- Blood

Target organs are defined as organs in which critical effects are observed as the result of exposure to a harmful input. There are many identifiable instances of inputs which affect a number of critical organs. Which they affect depends upon the circumstances of exposure, the interplay of defence processes and the susceptibility of the individual, as well as the tissues of the target organ. Thus, in discussing effects it is required that all possible target organs are considered.

The definition of 'target organs' must, necessarily, be wide, and must include, where appropriate, systems and tissues as well as organs.

2.3 靶器官和系统

人体内有许多污染物靶器官，例如：

•心

•肺

•肾脏

•肝

•大脑

•中枢神经系统

•骨骼

•甲状腺

•血液

通过观察靶器官，我们能发现进入人体的危险物质产生的重大影响。进入人体的污染物对多个关键器官产生影响，这些影响取决于暴露情况、防御机制的相互影响和个体的易感性，以及靶器官的组织情况。因此，在讨论物质影响时应考虑到所有可能的靶器官。

“靶器官”的定义是广义的，在适当情况下必须包括系统和组织以及器官。

For example, the target organ of hydrogen sulphide, which attacks the nerve tissue and causes respiratory paralysis, might be categorised as the central nervous system.

例如，硫化氢的靶器官会攻击神经组织，导致呼吸麻痹，可能被归类为中枢神经系统。

Crocidolite induces serious disease of the pleura and peritoneum (the tissue lining in the inner surface of the chest wall, and the lungs or the inner surface of the abdominal cavity and the abdominal organs). In this instance the pleura and peritoneum are the target organs.

青石棉会引起胸膜和腹膜（胸壁和肺部内表面或腹腔和腹部器官内表面的组织内层）的严重疾病。在这种情况下，胸膜和腹膜就是靶器官。

A series of target organs and an outline of their principal functions are given in Table 2.1.

表 2.1 列举了一些靶器官及其主要功能简介。

Table 2.1 – Target Organs, With an Outline of Their Principal Functions

表 2.1 -靶器官及其主要功能简介

TARGET ORGAN 靶器官	PRINCIPAL FUNCTIONS 主要功能
Skin	Protects against friction, water/fluid loss, entry of harmful inputs; thermal insulation; self-greasing by means of sebaceous glands; thermoregulatory by means of sweat glands; receives afferent information.
皮肤	防止摩擦、水份/液体损失、危险物质进入；隔热；通过皮脂腺自我润滑，通过汗腺调节体温；接收信息传导。
Respiratory tract	Oxygen and carbon dioxide exchange; defence against aerosols; warming and moistening of incoming air; excretion of gases, vapours.
呼吸道	氧气和二氧化碳交换，防御气溶胶侵入；温暖和湿润空气，排泄气体、蒸气。
Blood, plasma, blood-forming organs: heat circulatory system	Metabolism: transformation and conjugation. Chief transport system for oxygen, carbon dioxide nutrients, and fluids.
血液、血浆、血液代谢：转换和结合。 形成器官：氧气、二氧化碳和营养物质最重要输送系统，热和液体循环系	
Kidney, urinary tract	Excretion: Water, salts and nitrogenous wastes (includes homeostasis as well as bio- dumping). Secretion: Hormones for controlling blood pressure and production of red blood cells Metabolism: Transportation and conjugation
Liver	Secretory: a) Bile - contains waste non-nutrients, aids digestion b) Heparin - anti-coagulant for blood Storage: a) Vitamins b) Iron (for haemoglobin) c) Glycogen-energy store substance Metabolism: Transformation and conjugation

肾和尿道	排泄：水、盐和含氮废物（包括体内平衡以及生物排泄）。 分泌：控制血压和产生血红细胞的激素 新陈代谢：运输和结合
肝脏	分泌：a) 胆汁-容纳废物，帮助消化 b）肝素-抗凝血因子 储存：a）维生素 b）铁（血红蛋白） c）肝糖能量存储物质 新陈代谢：转换和结合
Brain and nervous system	Information processing and control of bodily activities.
大脑和神经系统	处理信息和控制身体活动。
Bone 骨骼	Support framework for movement and protection (certain bones house blood-forming organs; but those are functionally separate from bone). 运动和保护支持框架（有些骨骼有造血功能，但这些功能独立于骨骼）
Gut	Input of nutrients; digestion; excretion of non nutrients; defensive processes of gastric-acid barrier.
内脏	营养输入，消化；废物排泄；完成防御过程，例如阻止
Lymphoid system lymphatics	Tissue drainage; filtration; site of defensive processes such as immune response and phagocytosis.
淋巴系统和组织	排水；过滤；完成防御过程，例如淋巴的免疫反应和噬
Ductless glands	Such as thyroid, parathyroids, adrenals (suprarenals); produce hormones - substances exercising key control over function and morphology.
无管腺	如甲状腺、副甲状腺和肾上腺；产生荷尔蒙——对功能和形态进行关键控制的物质。

2.4 CONCEPT OF DOSE RESPONSE

"No substance is a poison by itself, it is the dose that makes a substance a poison."

--Paracelsus 1540

Ideally dose should be defined as the concentration of a substance at the site of effect, regard being made for the time for which the substance concentration is maintained. For practical purposes dose refers to the amount of a substance to which a person is exposed and is a combination of the amount or concentration of exposure and the duration of exposure. Exposure can arise from inhalation (most common route) or skin absorption (common with some substances) or via eye absorption (rare).

In simplistic terms dose can be expressed as:
Dose = Concentration of exposure x duration of exposure

This simplistic equation does not account for the following factors:

- Dose may be less than the amount inhaled if most is exhaled without any absorption (eg many gases)
- Heavy physical workload results in higher breathing rates than light workloads and thus have higher doses.

2.4 剂量反应的概念

“物质本身都是无毒，但是达到一定剂量就会成为毒药。”

--帕拉塞尔苏斯，1540 年

从理论上说，剂量应定义为特定地点特定物质的浓度，并考虑物质浓度保持时间。从实践上说，剂量指人体接触的物质量，涉及接触量、物质浓度和和接触时间、接触可包括吸入（最常见的方式）和皮肤吸收（对于一些物质来说这很常见）或通过眼部吸收（罕见）。

剂量可简要解释为：

剂量 = 暴露浓度 x 暴露时间

以上简要公式未考虑以下因素：

- 如果大多数是呼出，没有任何吸入，剂量可能小于数量（例如许多气体）
- 重体力工作者呼吸率高于轻体力工作者，因此剂量更高。

Dose may depend on an individual being a mouth or nose breather.

剂量还取决于一个人用嘴还是用鼻子呼吸。

- Additional exposure may come from non occupational sources (carbon monoxide from smoking).

- 非职业来源（来自于吸烟产生的一氧化碳）产生的其它风险。

Effect can be any observable, biological change associated with the input concerned, and ideally it should be quantifiable. It is implicit in dose-effect relations that effect is related to and caused by the dose.

影响可能表现为任何与输入有关的可观察的生物变化，理想情况下影响是可量化的。这意味着剂量与影响的关系是影响与剂量有关，由剂量导致。

Effect does not necessarily denote an adverse biological change, but embraces any biological change. Certain effects can be beneficial and only become adverse if the dose is excessive or remains for a critical period of time.

出现影响并不一定表示生物变化是不利的，但说明出现了生物变化。有些影响是有利的，只有当剂量过多或存在于特定关键时期，影响才能向不利方向发展。

Types of toxic effects include acute, chronic, local and systemic.

毒性作用类型包括急性、慢性、局部和系统性。

Acute or immediate effects occur during or immediately after exposure and last for a short period of time. Examples of acute effects include the immediate eye and respiratory tract response to exposure to, and inhalation of, chlorine or burns to the skin caused by direct contact with strong acids or alkalis.

急性影响在接触期间或之后立即发生，持续很短一段时间。例如，当眼部和呼吸道接触或吸入氯气时会产生直接反应，当皮肤直接接触强酸或强碱时会被烧伤。

Chronic effects are long lasting and may be, but not necessarily, permanent. Some examples of chronic exposures are pneumoconiosis from long term exposure to coal dust, silicosis after

慢性影响持续时间很长，可能（但也不一定）是永久性的。例如长期接触煤尘导致尘肺病，吸入石英粉尘会患上矽肺。

exposures to quartz dusts.

Local effects occur at the point of entry to the body of the toxin and systemic effects are associated with distant target organs (eg with lead the main route of entry is by inhalation but the toxic effect is upon the blood forming process, nervous system, kidneys and reproductive functions).

局部影响产生在毒性物质进入人体的部位，系统性影响与远端靶器官有关（如铅进入人体的主要途径是吸入，但毒性发作于血液形成过程、神经系统、肾脏和生殖功能）。

Critical organ concentration seems, given the present state of knowledge, to be the parameter of greatest utility in estimating dose. Whole body concentration provides a less useful criterion, because the organs in which greatest accumulation occurs may not be critical organs.

鉴于现有知识，临界器官浓度是预计剂量的最重要参数。第二个依据是全身浓度，因为积累最严重的器官可能不是关键器官。

Bone, for example, accumulates lead, but the critical organ is bone marrow, which is functionally separate from the bone which surrounds it.

例如，铅在骨中积累，但关键器官是功能独立于外部的骨髓。

At some time in the future it will, no doubt, be possible to estimate dose in terms of critical cell concentrations - or subcellular concentration - but at present this is impracticable.

毫无疑问，未来某一天我们可以根据临界细胞浓度，或亚细胞浓度来预计剂量，但目前不行。

There are complexities in the specification of effect, since certain effects, such as death, are of an all-or-none character, while others are of a graded nature, such as occupational deafness.

影响类型非常复杂，一些影响，例如死亡具有“全或无”特征，而另一些适合进行分级，例如职业性耳聋。

Specification is further complicated by the

fact that certain all-or-none effects (cancer, for example) require only a trigger. Once triggered they continue by self-propagation or by the other processes independent of the dose of the triggering input. On the other hand, many observable and gradable effects are both trivial and reversible.

更复杂的是，某些具有“全或无”特征的影响（例如癌症）只需一个“触发器”。一旦被“触发”，它们就会通过自我繁殖或其它与进入人体的触发性物质的剂量无关的进程继续。从一方面来说，许多可见的和可分级的影响都是微不足道的，可逆的。

However, the complexities do not end here. The specification of dose needs to take account of all possible modes of input, and the non-occupational as well as the occupational possibilities. For example, in the case of metals like lead, in most if not in all countries, input by ingestion from the normal diet is inevitable. Any occupational exposure, probably by inhalation, will be supplemented by the non-occupational dose. Combination of the two may cause a critical organ concentration to be reached in the bone marrow or in other organs.

但是还有更复杂的问题需要考虑。剂量类型涉及所有潜在的输入模式和非职业与职业因素。例如，除少数国家，大多数国家人民在正常饮食中不可避免会摄入铅等一些金属。非职业剂量会加剧任何可能由吸入引起的职业暴露的后果。两种情形一起出现会导致骨髓或其它器官中的浓度达到临界器官浓度。

2.4.1 Dose Response

Dose response is that proportion of a human population which experiences a specific effect following exposure of the total population to specified harmful contaminant. The correlation of the response with estimates of the dose provides a dose-response relation, which is normally expressed as a graph, with percentage of population affected on the y axis and estimated dose on the x axis (Figure 2.3).

2.4.1 剂量反应

剂量反应指在接触全部特定有害污染物后受到具体影响的人口比例。涉及剂量估计的反应相关性指剂量和反应的关系，通常用图表表示，受影响的人口百分比用 y 轴表示，估计剂量用 x 轴表示（图 2.3）。

2.4.2 No Observed Adverse Effect Level

The “no observed adverse effect level” (NOAEL) is the term used to define that point below which adverse effects cannot be observed. Effects, particularly adverse effects, are generally manifestations of the change in an organ and particularly the cells of the organ.

In toxicology, the NOAEL is specifically the highest tested dose or concentration of a substance at which no adverse effect is found in the exposed test species (usually animals or cells)

This level is commonly used in the process of establishing a dose response relationship, a fundamental component in most risk assessment strategies.

2.4.2 无可视不利影响水平

“无可视不利影响水平”（NOAEL）这个术语用来解释下表中无法观察到不利影响的某一点。影响（尤其是不利影响）一般是为了说明器官的变化，尤其是器官内细胞的变化。

对于毒物专家，NOAEL 指最高测试剂量或物质浓度，在这一点处于暴露中的实验物体（一般是动物或细胞）不会受到明显不利影响。

这个水平一般用于建立剂量反应关系的过程中，在大多数风险评估策略中，这种关系是一个基本原理。

Another important toxicological concept is “lowest observed adverse effect level” (LOAEL) or the lowest dose or concentration that causes any observed adverse effect. Thus by definition the NOAEL is less than the LOAEL.

另一个重要的毒理学概念就是“最低可视不利影响水平”（LOAEL）或导致任何可视不利影响的最低剂量或浓度。因此通过定义可知，NOAEL 小于 LOAEL。

As these determinations of exposure and effect have generally been established in species other than humans, various safety factors or uncertainties are applied before this data is used in the establishment of workplace exposure standards.

由于对暴露和影响的测定一般在人类以外物种上进行，因此在使用本数据来建立工作场所暴露标准前必须考虑各种安全因素和不确定性。

2.4.3 Threshold

2.4.3 阈值

The term "threshold" is used in toxicology to describe the dividing line between no-effect and effect levels of exposure. It may be considered as the maximum quantity of a chemical that produces no effect or the minimum quantity that does produce an effect. Every change produced by a chemical, whether it is beneficial, indifferent, or harmful, has a threshold. (Perhaps the word "change" should be qualified with an adjective such as "biological" or "clinical" to anticipate the reader with a literal bent who will say that the mere exposure of an organism to a chemical represents a change and that such a change obviously does not have a threshold).

“阈值”这一毒理学术语用于描述没有与有暴露影响水平之间的分界线。它可被视为不会产生影响或仅产生最小影响的化学物质的最大数量。每种化学物质产生的变化，无论是有利的，无关紧要的，或有害的，都有一个阈值。（由于一些读者对“变化”存在误解，认为只有器官暴露于某种化学物质中才会产生变化，因此变化没有阈值，因此可能需要用“生物”或“临床”等形容性来限制术语“变化”）。

The precise threshold for a given effect can, and usually does, vary within certain limits with species, with individuals within

对不同物种的具体影响的精确阈值是不一样的，而且相同物种的不同个体，甚至同一物种在不同时间段，阈值也是不

a species, and perhaps even with time in the same individual.

一样的。

For a given population, as illustrated by the dose response relationship (Figure 2.3), it is clear that thresholds exist because it can be determined experimentally that certain low levels of exposure will produce no detectable effect, and that as the dosage is increased the effect appears.

对于特定人群来说，正如剂量反应关系图（图 2.3）所描述，由于实验能测定在一般探测中不会发现的较低暴露水平，而且当剂量增加时影响就会出现，这显然证明存在阈值。

Since the dose-response relationship is a continuum, somewhere between the experimental no-effect and effect levels is the turning point known as the threshold.

由于剂量反应关系是一个连续体，实验上无影响和有影响之间的转折点就是阈值。

Dose-response curves typical of those plotted from data obtained in chronic toxicity experiments exist for a number of contaminants. It is very important to recognise that such a curve is drawn from only several points, one for each exposure group in the experiment. The greater the number of exposure groups, the greater the number of points, and hence, the greater the accuracy of the curve that is drawn. But without an infinite number of points, the precise shape of the dose-response curve cannot be known.

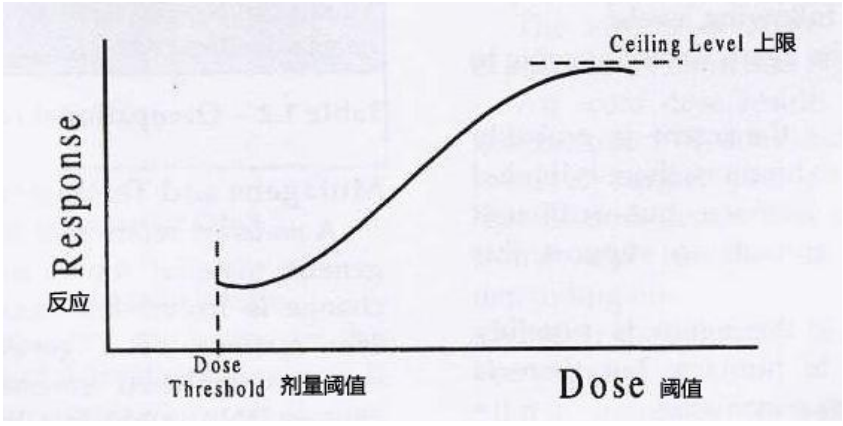
剂量反应曲线一般来说，对于许多污染物，都可能利用慢性毒性实验数据绘制剂量反应曲线。必须认识到此类曲线仅从几个点开始绘制，每一个点都代表实验中一个暴露组。数据组越多，点越多，因此曲线的准确性就超高。但是由于不存在无限量的点，因此我们无法绘制精确的剂量反应曲线。

The curve is interpreted as follows: with chronic exposure of increasing doses up to the threshold, no effect is detectable because some biochemical or physiologic mechanism, handles the chemical in a manner that prevents an effect from

曲线解释如下：曲线解释如下：随着逐渐增加的剂量导致的慢性暴露达到阈值，由于一些生物和物理机制以避免影响的方式处理化学物理，因此探测不到

occurring. At the threshold, the defence mechanism is saturated, or in some manner overwhelmed, for the more susceptible individuals and the effect begins to appear. With increasing doses, increasing numbers of individuals show the effect until finally a dose is reached where all of the members of the population show the effect (ceiling level).

影响。在阈值上，对于更易受到影响的个体来说防御机制是饱和的，或在一些方面是占优势的，影响开始出现。随着剂量增加，越来越多的个体展示影响，直到到最终剂量，因此影响在人口中所有成员身上出现（上限水平）。



(Source: Tranter 1999 – *Reproduced with permission*)
（来源：Tranter 1999–许可转载）

Figure 2.3 – Dose Response Curve
图 2.3– 剂量反应曲线

The threshold concept is of great importance to toxicologists because it permits them to make judgements about the potential hazard, or lack thereof, to humans from exposure to chemicals.

阈值概念在毒理学中极为重要，因为它使毒理学家能判断人类在暴露于某种化学物质时有无潜在风险。

Another toxicologic question relates to the shape of dose-response curves for carcinogens as they approach zero dose. The inability of toxicology to answer this question by experiment has given rise to a scientific controversy concerning whether or not there is a threshold (no-effect level) for carcinogenic effects. If there is no threshold, extension of the experimentally derived dose-response

另一个毒理学问题涉及在接近零剂量时致癌物剂量反应曲线的形状。毒理学不能通过实验来回答这个问题，这引发了关于是否存在一个致癌效应阈值（无影响级别）的科学争议。如果没有阈值，实验产生的剂量反应曲线对零效应的延展将导致一条经过原点（零剂量）的线。如果存在一个阈值，延展线将位于高于零剂量的横坐标的某个点上。

curve to zero effect would yield a line that would go through the origin (zero dose). If there is a threshold, the extended line would meet the abscissa at some point greater than zero dose.

关于致癌物质，必须注意，除了高剂量外很难得到数据，所以一般来说，低于最低实际数据点的剂量响应曲线的形状必须涵盖许多数量级。当无法确定阈值时，通常来说限值是基于和依赖于特定物质动态的风险。

In regard to carcinogens, it is important to note that it is rare to have any data except for high doses, so the estimate of the shape of the dose response curve below the lowest actual data point must typically cover many orders of magnitude. Where a threshold cannot be identified, limits are generally risk based and dependent upon the dynamics of the particular substance.

在考虑所有阈值考虑因素时，要认识到可检测的生物影响并非都是不利的。

It is extremely important, as background to all considerations of the threshold, to recognise that detectable biological effects are not universally adverse.

要认识到，任何一组测试对象中都有一些易受较低浓度的实验污染物的影响的易感（敏感）个体和一些即使浓度较高也不易受到影响的具有较强抵抗能力（不敏感）的个人，但在大多数普通个体都处于中间位置（图 2.4）。

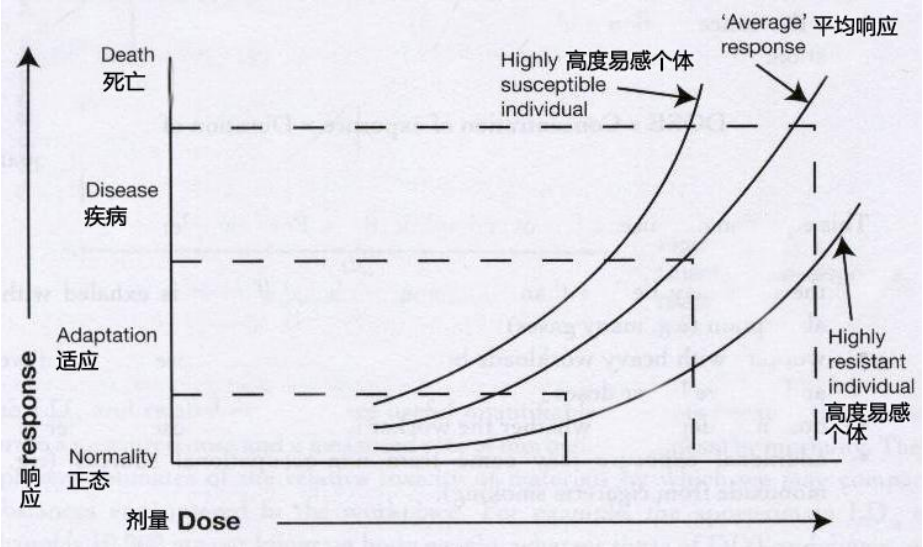
What should be recognised is that in any group of test subjects there are some susceptible individuals (hypersensitive) who are affected at low concentrations of the test contaminant and there are also some highly resistant individuals (hyposensitive) who are not affected at high concentrations but there are the vast majority of “average” individuals in the middle (Figure 2.4).

所以暴露标准一般适用于“普通”个体的剂量反应关系，因此还要认识到同一

Consequently exposure standards tend to be based on dose response relationships

applicable to “average” individuals and thus it is important to recognise that some hypersensitive individuals may be in a work group and that they may suffer adverse health effects at exposures below the recognised exposure standard.

个工作组中有一些个体具有高敏感性，他们在低于暴露标准限值的暴露中也会受到不利健康影响。



(Source: AIOH 2007 – *Reproduced with permission*)
（来源：AIOH 2007–许可转载）

Figure 2.4 – Variability of Human Exposure to Dose
图 2.4– 人体对剂量暴露的可变性

2.4.4 Threshold of Intoxication

The threshold of intoxication can be defined as:

For each substance, no matter how toxic, there exists a dose level called the threshold of intoxication, which the human body is capable of accepting and detoxifying without injury to itself.
It is this principle that the major exposure standards used within the western world are based upon.

2.4.4 中毒阈值

中毒阈值可定义为：

对于每种物质来说，无论毒性怎样，都有一个称为中毒阈值的剂量水平，在这个水平上，人体能接入和排出毒素，而不会伤害自己。

这是西方世界制定暴露标准的基本原则。

3. RISK ASSESSMENT

3.1 DEFINITIONS

3.1.1 Introduction

Many formal definitions of “risk” and “hazard” have been put forward covering all situations (eg health, safety, finance, and engineering), however they all strive to communicate similar messages.

In this publication the terms “risk” and “hazard” will be treated solely in relation to chemical risk and not in any broader concept. In the context of this course, “hazard” and “risk” is not the same thing.

3.1.2 Hazard

The “hazard” of a chemical substance is the potential for that substance to cause harm, injury, etc. Concentrated acids, for example, pose a clear hazard because incorrect handling of these chemicals could result in serious burns.

3.1.3 Exposure

In terms of chemical substances “exposure” can be defined as the ability (or potential) for someone to come into contact with a substance by breathing it in (inhalation), getting it onto the skin or into the eyes (absorption), or swallowing it (ingestion).

Thus, if a chemical is completely enclosed within a process (eg pipework) the potential for worker exposure to the chemical is low (except during maintenance or failures when the process

3. 风险评估

3.1 定义

3.1.1 简介

目前已推出多个“风险”和“危险”的定义，涵盖所有情形（例如健康、安全、财务和工程），但是所有这些都在试图传达类似信息。

在本出版物中，“风险”和“危险”只用于与化学有关的风险，不涉及其它领域。在本课程范围内，“风险”和“危险”不是同一件事。

3.1.2 危险

化学物质的“危险”性指物质伤害伤害、损伤等的潜在可能性、例如浓酸就有明确危险，这是由于如果处理不当的话会导致严重烧伤。

3.1.3 暴露

化学物质“暴露”可定义为某人通过吸入、皮肤或眼部接触（吸收）或吞咽（摄取）接触某种物质。

因此，如果某种化学物质被完全密封在一个流程中（例如管道），工人暴露在化学物质中的可能性就比较低（除非维修期间或由于流程整体性被破坏导致的

integrity is breached), however if the chemical can readily escape from the process the potential for exposure is high.

故障），但是如果化学物质可轻易从流程中逃逸的话，暴露的潜在可能性就会变高。

In many cases it will be necessary to undertake workplace monitoring to have an understanding of the true exposure of a worker to a chemical.

在许多情况下要熟悉工作场所监测情况，理解工人对化学物质的真正暴露情况。

In the vast majority of cases the focus will be on airborne exposure as this is the major route of entry to the body but with some chemicals other pathways (eg skin) must be considered.

在大多数情况下，人们主要关注机载暴露，这是由于它是主要进入人体路径，但是对于一些化学物质来说，其它一些路径（例如皮肤）必须考虑在内。

3.1.4 Risk

The “risk” presented by a chemical substance is the likelihood that the substance will cause injury or illness in the conditions of its use. Thus, if we consider life savers (life guards) on beaches who are surrounded by tonnes of silica sand yet the incidence of silicosis in such persons is incredibly low. This is because the particle size of the sand is such that it is not inhaled and also that each particle has an “aged” surface rendering it less biologically active. In this case the risk is low.

3.1.4 风险

化学物质的“风险”就是物质在使用条件中导致伤害或疾病的可能性。因此，如果我们考虑到海滩上的救生员，我们就会发现，他身边全是成吨的硅砂，但他患上硅肺病的可能性却不可思议地小。这是由于硅砂颗粒尺寸无法吸入，而且每一个颗粒表面都已老化，生物活性很小。在这种情况下，风险很低。

If however the same sand is crushed or abraded and used in the construction industry for example, where workers breathe in the material during their work duties, then the risk is much higher as the material is inhaled and more biologically active due to “fresh” surfaces being exposed.

但是，如果同样的砂子被碾碎或磨碎，用于建筑业的话，如果工人在工作期间吸入此类物质的话，那么风险就会升高，这是由于物质被吸入，而且暴露的表面比较“新鲜”，使生物活性提高。

In general, the risk to health usually increases with the severity of the hazard, the amount used and the duration and frequency of exposure.

一般来说，健康风险通常随着危险的加剧、使用量增加、暴露持续时间增长，暴露频率提高而增加。

3.2 THE RISK ASSESSMENT PROCESS

3.2 风险评估流程

3.2.1 Introduction

3.2.1 简介

The risk management process can be applied across all sectors of the political, business and community environment. In many instances we do this as part of our everyday activities (eg driving to work), however the concept of risk assessment lies central to the occupational health and safety legislative framework of many countries. The process extends in many countries to occupational hygiene hazards with some statutory authorities requiring the mandatory conduct of risk assessments for specific hazards (eg hazardous substances).

风险管理流程适用于所有政府、商业和社区环境领域。在许多情况下，我们在日常活动（例如开车上班路上）中进行风险管理，但在许多国家，风险评估的概念是对职业健康和安全立法框架的核心。在许多国家这个流程拓展到职业卫生危险，许多执法机构强制要求对某些危险（例如危险物质）进行风险评估。

In general all risk assessments for hazardous substances follow a similar pattern, however regulatory authorities or businesses may require a specific process to be followed to ensure consistency.

一般来说，危险物质所有风险评估的模式都差不多，但是监督当局或企业可要求采用特殊程序来确保统一性。

Notwithstanding these requirements the key steps to a successful risk assessment are indicated in Figure 3.1.

尽管有这些要求，风险评估关键的步骤详见图 3.1。

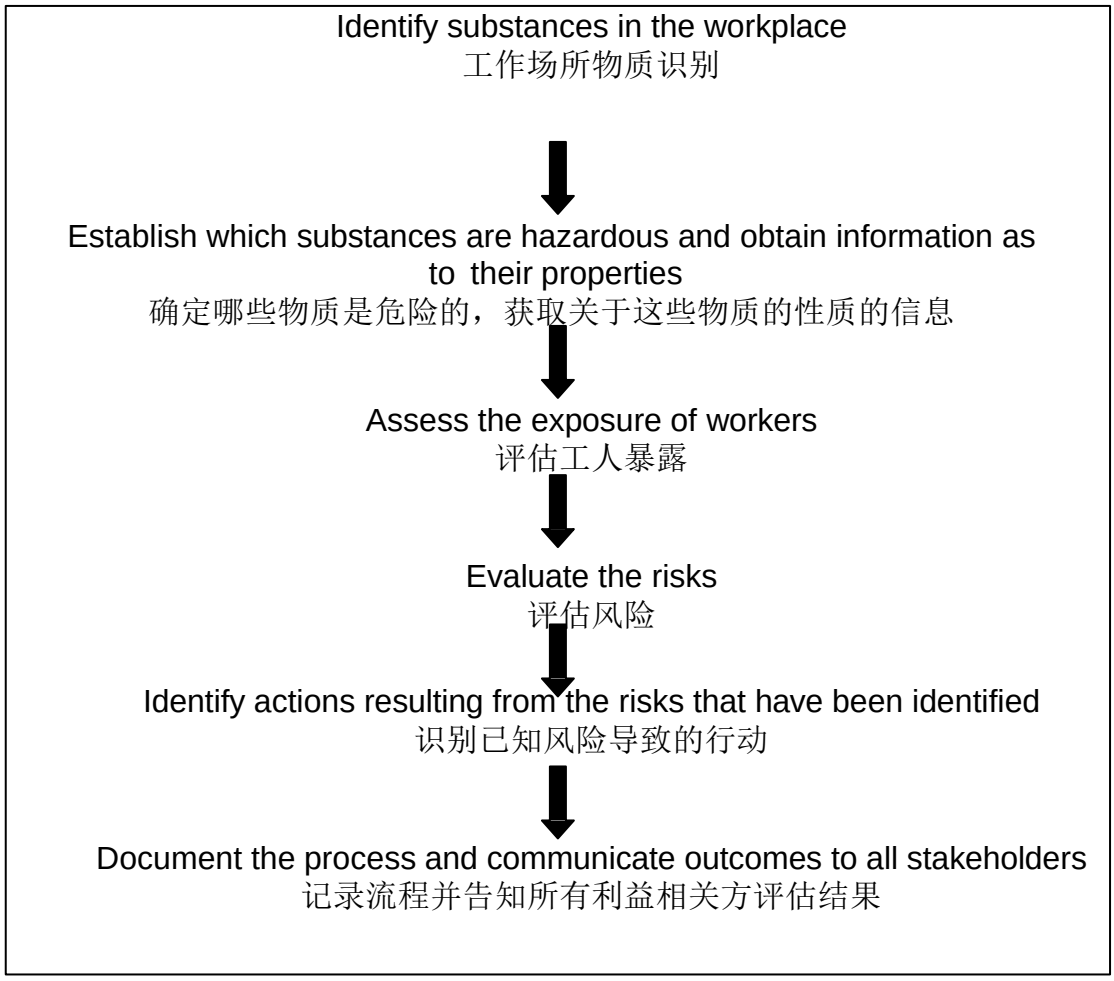


Figure 3.1 – Generic Risk Assessment Process for Hazardous Substances
图 3.1– 危险物质一般风险评估流程

3.2.2 Information

The outcome of any risk assessment will largely depend on the quality and amount of information available as an input to the risk assessment process (eg good quality detailed information will ensure a realistic assessment of the risks involved is obtained).

Where can information be obtained on hazardous substances? In general the primary source of information about any substance will be the supplier"s Material Safety Data Sheet (MSDS) and the label fixed to the product. Care must however be exercised when using suppliers MSDS as an information source as the hazard information in the data sheet is sometimes incomplete or inaccurate.

Most countries require suppliers to provide users with a MSDS and under a United Nations sponsored scheme such documentation is moving towards a uniform format.

As previously indicated, a significant number of countries are participating in the development of a Globally Harmonised System of Classification and Labelling of Chemicals (GHS) through the United Nations. The GHS provides a uniform way of classifying chemicals, as well as informing chemical users about chemical hazards they may be exposed to.

3.2.2 信息

任何风险评估结果在很大程度上取决于风险评估程序中输入的可用信息的质量和数量（例如有效优质详细的信息会确保对涉及的风险进行实际评估）。

从哪里能获得关于危险物质的信息？一般来说，这方面信息的主要来源是供应商《矿物安全性数据表（MSDS）》中和产品标签。但在任何情况下请注意：当使用供应商的 MSDS 作为信息来源时，数据表中危险物信息有时并不完整或准确。

大部分国家要求供应商提供一个MSDS。根据根据联合国发起的计划，此类文档应逐步采用统一格式。

正如前面指出的，相当数量的国家通过联合国参与《全球统一化学物质分类和标签系统（GHS）》。GHS 提供了一个统一化学物质分类法，向化学用户描述他们可能接触到的化学危害。

The GHS builds on the attributes of existing national regulatory systems to form a single international system that has application across a wide range of chemicals and hazard types. The GHS when implemented will:

- enhance the protection of human health and the environment by providing an internationally comprehensible system for hazard communication
- provide a recognised framework for those countries without an existing system
- reduce the need for testing and evaluation of chemicals, and
- facilitate international trade in chemicals whose hazards have been properly assessed and identified on an international basis.

GHS 的成功取决于国内现行监管系统在形成一个能在化学和危险品领域广泛应用的独立国际体系方面的性质。GHS 有助于：

- 通过提供一个国际公认的危险物沟通系统来提高对人体健康和环境的保护；
- 向那些没有这方面体系的国家提供一个公认的框架；
- 减少对化学物质测试和评估的需求，和
- 促进那些在国际范围危险得到适当评估和识别的化学品的国际贸易。

Pictograms are a key hazard communication tool within the GHS. They are designed to appear on chemical labels. The pictograms give an immediate indication of the type of hazard that the chemical may pose.

象形图是一个 GHS 内一个关键风险沟通工具，专门用于化学品标签。象形图直接表现化学可能带来的危险类型。

They are intended to be used in combination with other harmonised GHS elements which together convey information about the type, severity and management of chemical hazards. An example of the pictograms to use is provided in Figure 3.2.

它们用于与其它传递危险化学品的信息类型、严重程度和管理的统一 GHS 元素结合使用。图 3.2 是象形图使用的一个例证。

Under the GHS these pictograms will be

supported by hazard statements which will replace the risk and safety phrases (eg R26 – very toxic by inhalation or S3 – keep in a cool place), which are currently used in many countries.

根据 GHS，这些象形图下应有一个代替原来的风险和安全短语（例如 R26-吸入毒性极其危险或 S3-阴凉处存放）的危险成份表，目前许多国家都要求使用这种表格。

A significant number of countries have indicated they will implement the GHS as a key part of their national chemical regulation systems.

他们将落实 GHS，视其为国家化学监管系统的关键部分。

(Source: ASCC Information Sheet)
（来源：ASCC 信息表）

Figure 3.2 – GHS Pictograms
图 3.2– GHS 图表

In some cases the hazardous substance present in a process may be generated as a result of the process. Moreover it may be the process itself which results in a change in the form of a material (eg generation of fine dusts from solid materials, fumes from heating of a chemical) which may be a cause for concern. In such cases it is generally possible to obtain useful information by conducting interviews of workers, managers, engineers, medical and safety personnel. An indication of the types of information that it is possible to obtain from this process is provided in Table 3.1. Additional information may also be obtained from records, government and industry standards, as well as the scientific literature.

在一些情况下，流程中出现的危险物质可能是流程本身产生、而且流程会导致物质形态变化（例如将固体原料变成细尘，将化学物质加热变成烟雾），引起忧虑。在一些情况下，一般能从与工人、管理者、工程师、医务和安全人员面谈获得有用信息、表 3.1 提供了以上流程可能获得的信息类型的迹象。读者还可从记录、政府和行业标准及科学文献中获得其它一些有关信息。

Table 3.1 – Sources of Additional Information
表 3.1–其它信息来源

Collection Method	收集方法	**Type of Information**	信息类型
Interviews of workers, managers and engineers	与工人、管理者和工程师面谈	Tasks Work practices Health issues Processes Exposure controls Maintenance Environmental agents	任务 工作实践 健康问题 流程 暴露控制 维护 环境因素
Interviews of medical and safety staff	与医务和安全员工面谈	Health problems Patterns of problems Work practices Exposure history Environmental agents	健康问题 问题模式 工作实践 暴露历史 环境因素
Records: Process standards Standard operating procedures Production Personnel Medical Engineering Environmental reports Process flow diagrams	记录： 流程标准 标准操作程序 生产 人员 医疗 工程 环境报告 工艺流程图	Historic conditions Chemical inventories Usage amounts Tasks Work histories Performance of engineering controls Past environmental monitoring results Past biological monitoring results	历史条件 化学物质库存 使用量 任务 工作史 性能工程控制 以往环境监测结果 以往生物监测结果
Governmental and non- governmental standards	官方和非官方标准	Current exposure limits Proposed exposure limits	当前暴露限值 推荐暴露限值
Literature	文献	Epidemiological studies Toxicological studies Emerging issues	流行病学研究 毒理学研究 紧急问题

Experience has long demonstrated that the simple process of conducting a “walkthrough survey” can provide information that may otherwise not be evident. The walkthrough survey involves commencing at the starting point of a process and physically following the various components of a process until the end product is reached. To obtain value from the exercise it must be conducted in the company of someone familiar with each step of the process.

长期以来的经验表明，“预先排除调查”这个简单的过程可以提供利用其它方式可能无法发现的信息。预先排除调查从流程起点开始，通过流程的不同部分，直到出现最终产物。为了获得调查结果，必须由熟悉公司流程每一步的人进行调查。

The basic observations arising from a walkthrough survey include:

a) An understanding of the process

b) The number of workers involved

c) The materials (including quantities) used or handled

d) Evidence of reactions and any material transformations

e) Engineering controls in place and their effectiveness

f) Housekeeping standards

g) Visible conditions at the site (any dusts, mists, etc)

h) Possible routes of entry to the body

i) Personal protective equipment and its use

j) An understanding of ancillary activities, eg waste management, maintenance procedures, laboratory facilities, etc

Using information from the above sources, it is then possible to assess the risks presented by using the hazardous substance(s) in question.

预先排除调查得出的基本观察资料涉及：

a）对流程的理解

b）涉及的工作的数量

c）使用或处理的资料（包括数量）

d）反应证据和任何物质转换

e）落实的工程控制及其有效性

f）内务管理

g）现场可视条件（任何尘雾等）

h）可能的人体进入路径

i）个人防护设备及其使用

j）理解辅助活动，例如废物管理、维护程序、实验设施等

利用以上来源信息就能对使用有关危险物质导致的风险进行评估。

3.2.3 Assessing the Risk

When assessing the risk of a hazardous substance it is important to understand that a number of factors influence the level of risk. These include

a) How much a worker is exposed to a hazardous substance (exposure)

b) How the worker is exposed to the substance (inhalation, skin contact, ie route of entry to the body)

c) How severe are the adverse health effects under the conditions of exposure (hazard)

d) Duration and frequency of exposure (a single short exposure or continuous long term exposure)

Thus the level of risk posed by using a hazardous substance (without controls) depends on the combination of the hazard of that substance and the duration and frequency of exposure.

ie Risk (uncontrolled) α hazard x exposure

Thus, if the exposure is zero (exposure controlled) then the risk will be zero (controlled). Conversely, reducing the hazard (by, for example, substitution of a hazardous product with a non hazardous one) will also reduce the risk.

3.2.3 风险评估

在评估危险物质的风险时，必须理解影响风险水平的各种因素，这些因素具体包括：

a）工人对危险物质的暴露（暴露值）有多少？

b）工人怎样暴露在物质中（也就是物质进入人体路径，例如吸入、皮肤接触）？

c）在暴露（危险）条件下不利健康影响的严重程度

d）暴露持续时间和频率（单独短期暴露或持续长期暴露）

因此使用危险物质（无控制）构成的风险水平取决于物质的危害性和暴露的持续时间和频率。

即（失控的）α 风险 x 暴露

因此，如果暴露是零（受控风险），那么风险将为零（受控）。相反，降低危险（例如通过将有害产品用非危险品代替），风险也将减少。

In order to estimate the level of risk of a hazardous substance it is necessary to draw together all available information about the substance (health effects), its use (the quantity involved and control technologies), and the degree of exposure.

为了评估危险物质的风险水平，必须收集所有可用的物质（健康影响）、其使用（涉及的数量和控制技术）和暴露程度的信息。

Before undertaking such a step it is of value to understand the types of risk analysis possible. In general, analysis may be qualitative or quantitative or a combination of these depending upon circumstances. In practice, qualitative analysis is often used first in order to obtain a general indication of the level of risk and to highlight the major risk issues. Subsequent to this process it may be necessary (and often is) to undertake a more detailed quantitative analysis of the major risk issues. These two types of analysis can be described as follows:

在采取这一步之前，必须理解可能的风险分析类型。一般来说，分析可以是定性，也可以是定量的，或两者结合，视情况而定。定性分析最常用，它能获得风险水平的一般特征和突出重要风险问题。随后可能需要（经常需要）理解对主要风险问题进行更详细的定量分析。这两种分析类型具体如下：

a) *Qualitative Analysis*

Qualitative analysis uses words to describe the magnitude of potential consequences and the likelihood that those consequences will occur. These scales can be adapted or adjusted to suit the circumstances, and different descriptions may be used for different risks.

a）定性分析

定性分析用一些词汇来描述潜在后果的严重性和这些后果发生的可能性。分析范围可根据环境进行改变或调整，对不同风险可进行不同描述。

Qualitative analysis may be used:

- as an initial screening activity to identify risks which require more detailed analysis;
- where this kind of analysis is appropriate for decisions; or
- where the numerical data or resources are inadequate for a quantitative analysis.

Qualitative analysis should be informed by factual information and data where available.

定性分析的作用：

•为识别风险而作为初步筛查活动，这需要更详细的分析；

•当这种分析有利于决策时使用；

或

•数值数据或资源对于定量分析来说不充分。

在适当时，定性分析应以事实信息和数据形式提供。

b) *Quantitative Analysis*

Quantitative analysis uses numerical values (rather than the descriptive scales used in qualitative and semi-quantitative analysis) for both consequences and likelihood using data from a variety of sources.

The quality of the analysis depends on the accuracy and completeness of the numerical values and the validity of the models used.

b）定量分析

定量分析使用数值（而不是定性和半定量分析采用的描述性尺度），利用不同来源数据来得出后果和可能性。

分析质量取决于数值准确性和完整性，以及模型有效性。

Consequences may be determined by modelling the outcomes of an event or set of events, or by extrapolation from experimental studies or past data. In some cases, more than one numerical value is required to specify consequences for different times, places, groups or situations.

后果可由建立事件或事件组结果模型，或通过实验研究，或根据以往数据推断确定。在一些情况下，需要一个以上数值来说明不同时间、地点、组或情形的后果。

The Health & Safety Executive (HSE) in the United Kingdom has regulated the

英国的健康和安全执行部门（HSE）对《健康危险物质控制》（2002 年 COSHH 条例）进行调控，其指导材料强调了考虑危险物质导致的人体健康风

Control of Substances Hazardous to Health (COSHH Regulations 2002) and in its guidance material highlights the importance of considering the risks hazardous substances present to people"s health.

险的重要性。

When assessing the risk that any hazardous substance may present to people"s health, there are some basic steps that can be followed. For example, ask yourself the following questions and seek to find the appropriate answers before making any judgement.

当评估任何危险物质可能导致的人体健康风险时，你可遵循一些基本步骤。例如，在判断之前回答以下问题，并发现合适的答案。

- How much of the substance is being used and how could people be potentially exposed?

- 使用多少物质？怎样使人承受潜在风险？

- Who could be exposed to the substance and importantly, how often?

- 谁会暴露在物质中？暴露频率如何？

- What is the route of entry to the body (eg absorbed through the skin, ingestion or inhalation)?

- 进入人体的路径是什么（例如通过皮肤吸收、摄取或吸入）？

For a number of substances the HSE has developed a generic risk assessment tool called “COSHH Essentials: Easy steps to control chemicals”. The guide uses information on the hazardous nature of the substance, amount used, estimates of exposure (based on simple definitions of dustiness for solids or volatility for liquids) to establish a level of risk. The process also provides suggested actions that can be used to control the risks and therefore control exposure.

对于众多物质，HSE 已经开发出一套基本风险评估工具 《COSHH 概要：只要几步就能轻松控制化学品》。指南采用物质危险性质、使用量和暴露预测（基于固体污染度或液体挥发性的简单定义）的信息来确定风险水平。流程还提供一些风险和风险暴露控制的行动建议。

A free version of COSHH Essentials can be found on the internet at www.coshh-essentials.org.uk.

您可从 www.coshh-essentials.org.uk 下载《COSHH 概要》免费版本。

The International Labor Organisation (ILO) Tool Kit (see section 5.2.1), offers a similar approach to that of the UK COSHH Essentials system. It should be noted that neither of these approaches are validated methodologies but were developed as an approach to assist small to medium enterprises who do not usually have access to risk assessment expertise.

国际劳工组织（ILO）工具包（参看章节 5.2.1）提供的方法与英国《COSHH 概要》系统差不多。必须注意任何一个方法都没有法律效力，只是用来帮助一般没有风险评估专业知识的中小企业制定它们自己的评估方法。

From the preceding information, it is evident that the process of assessing the risk of using a hazardous substance depends on obtaining adequate information on the hazards of a substance and the degree of exposure. Subsequent chapters of this manual will discuss how the degree of exposure to a hazardous substance can be evaluated and assessed against recognised exposure standards.

根据前述信息，显然评估过程中使用危险物质产生的风险取决于是否拥有关于物质危险性和暴露程度的充分信息。在以下章节，我们将讨论怎样依据公认的暴露标准来评估和评价对危险物质的暴露程度。

Once information on exposure has been obtained (for a quantitative risk assessment this will need to be evaluated to cover all situations), some estimate of risk can be obtained by considering this and the hazards involved.

一旦得知暴露风险（对于定量风险评估来说，风险评估需要考虑所有情形），可通过考虑所涉及的风险和危险对风险进行预估。

The risk may generally be described as „significant" or „not significant". The risk can be regarded as „not significant" if it is unlikely that the work will adversely

风险通常被描述为“重大的”或“不重大的”。如果工作不太可能对工作场所的工人的健康造成不利影响，这就是“不重大的”风险，如果工作很可能影响人体健康，这就是“重大的”风险。

affect the health of people in the workplace. A „significant risk" means that the work is *likely* to adversely affect the health of people in the workplace. For example, there would be a „significant risk" if:

例如以下情形就属于重大风险：

• exposure is high or the substance used is highly toxic;

•暴露值较高或使用的物质是高毒性的；

• a dangerous reaction with other substances might occur; or

•与其它物质可能发生危险反应；或

• it is reasonably foreseeable that leaks or spills of a hazardous substance might occur.

•能合理预见会发生危险物质泄漏或喷溅。

In the event of a significant risk being established it is important that actions are taken to ensure that the risks are adequately controlled. In these circumstances, further work may be required to ensure that control measures are maintained and implemented. This could include the need for regular workplace monitoring or health surveillance, or a repeat of the assessment.

如确定存在重大风险，必须采取能确保充分控制风险的行动。在这些情形下要采取进一步行动来确保维持和落实控制措施。这可能需要进行常规工作场所监测或健康监督或反复评估。

3.2.4 Actions

3.2.4 行动

The process of risk evaluation provides a list of risks requiring control, often with priorities. The next step in the process involves identifying a range of control options for minimising these risks, evaluating those options, developing appropriate control technologies and implementing them in the workplace.

在风险评估过程中列一个需要控制的风险列表，通常标出优先级。过程的下一步涉及一系列控制方案来减少这些风险，评估这些方案，开发适当的控制技术和在工作场所应用这些技术。

Development of options to control individual risks will seldom occur in isolation and should be part of an overall

一般情况下企业不会单独制定个体风险控制方案，这种方案应是总体策略的一

strategy. Having a clear understanding of a complete strategy is important to ensure that critical links are maintained.

部分。为了维持关键环节，必须明确理解整体策略。

It is wise in the development of any control strategy to be flexible and be prepared to consult with stakeholders as well as specialists. It is important that workers have some participation in this process if the controls are to be effective and sustainable.

明智的方式是制定一个灵活的控制策略，随时准备与利益相关者和专家磋商、如果想进行有效和可持续的控制，应让员工也参与这个过程。

Thus, if the risk assessment indicates a significant risk then further actions are necessary to control the risk. Such actions may include:

因此如果风险评估表明存在重大风险，那么必须采取进一步行动来控制风险。此类行动可包括：

- **Selection of appropriate measures to achieve control**

- 采取适当措施来实现控制

These measures may include, *in priority order:*

这些措施可包括（按优先顺序）：

- elimination of the hazardous substance from the workplace;

——清除工作场所的危险物质；

- substitution with a less hazardous substance;

——用危害小一些的物质代替；

- isolation (separating the employees from where the substance is used);

——隔离（将采用危险物质的场所与员工隔离）；

- engineering methods (for example, local exhaust ventilation systems);

——工程法（例如局部排气通风系统）；

- administrative control (for example, work procedures designed to prevent or minimise exposure to chemicals);

——管理控制（例如旨在防止或减少化学物质暴露的工序）；

- personal protective clothing and equipment (gloves, safety glasses, respirators, etc).

——个人防护服和装备（手套、安全眼镜、口罩等）。

The above approach is referred to as the

"hierarchy of control".

以上方法被称为“控制层次”。

It might be necessary to use a combination of these control measures to eliminate or minimise exposure.

控制措施可能需要结合使用来消除或减少风险。

To ensure that adequate control is maintained, all control measures should be reviewed at regular intervals. Routine checks, regular maintenance and appropriate supervising procedures are also necessary.

为了确保充分控制，定期审查所有控制措施的落实情况。常规检查、定期维护和适当监督程序也是必要的。

- **Arrange induction and training**

- 安排入职培训和在职培训

The extent of training will depend on the level of risk, with more extensive training being required for workers who are exposed to significant risks. The information collected during the assessment about the nature of the hazards and the control measures required should be used in preparing induction and training.

培训的范围取决于风险水平，对于暴露于重大风险中的工人来说，应提供额外的扩展培训。在评估期间收集的关于危险性质和控制措施的必要信息用于编制入职培训和在职培训课程。

- **Determine if workplace monitoring is required**

- 确定是否有必要进行工作场所监测

Ongoing monitoring may be required where the assessment indicates that it is necessary to check the effectiveness of control measures or where serious health effects might result if control measures fail because the substance is highly toxic, or the potential exposure is high.

当出现以下情况，应进行持续监测：评估表明有必要检查控制措施的有效性；物质具有高毒性，控制措施失灵的话会导致严重的健康影响；或潜在暴露水平较高。

- **Determine if health surveillance is required**

- 确定是否需要进行健康监督

Health surveillance is required for those substances nominated under the relevant

当出现以下情况，应进行健康监督：对

regulations, and where the information gathered during the assessment shows that:

- there is an identifiable work-related disease or adverse health effect for a hazardous substance used in the work;
- the risk assessment indicates that it is likely the disease or condition might occur during the conditions of the work; and
- valid techniques are available to detect early signs of the disease or condition.

于有关法规明确规定的物质；或评估期间收集到的信息显示以下问题：

- 工作中使用的危险物质导致与工作有关的明显疾病或不利影响；
- 风险评估表明，工作条件可能导致疾病或患病条件；和
- 当前有能检测疾病早期迹象或条件的有效技术。

- **Establish emergency procedures and first aid when necessary**

Appropriate procedures should be established if an assessment suggests a risk of leaks, spills or other uncontrolled releases of hazardous substances. These include procedures for prevention, provision of first aid, safety showers and eye wash facilities, evacuation procedures, emergency procedures, etc.

- 建立应急程序，在必要时进行急救

如果评估结果显示有危险物质泄漏、喷溅或其它失控释放的风险，就要建立适当的程序，包括预防程序、急救程序、安全灭火程序和洗眼设施、疏散程序、应急程序等。

The UK HSE COSHH regulations require employers to prevent exposure to hazardous substances if it is reasonably practicable to do so. This may be done by:

- change the process or activity so that the hazardous substance is not needed or generated;
- replace it with a safety alternative;
- use it in a safer form, eg pellets instead of powder.

美国 HSE COSHH 法规要求雇主采取合理可行的危险物质暴露预防措施，包括，但不仅限于：

- 对过程或活动进行修订，使其不需要或产生危险物质；
- 用安全物质代替；
- 以安全形式使用，例如改粉末状为

球状。

If prevention is not reasonably practicable, employers must adequately control exposure. Employers are required to consider and put in place measures appropriate to the activity and consistent with the risk assessment, including, in order of priority, one or more of the following:

如果预防不合理或不可行，雇主就必须对暴露进行充分控制。雇主必须按风险评估情况考虑和采取以下一项或多项适当活动措施的（按优先级排列）：

• use appropriate work processes, systems and engineering controls, and provide suitable work equipment and materials, eg use processes which minimise the amount of material used or produced, or equipment which totally encloses the process;

• 采用适当的工作流程、系统和工程控制，提供适当的工作设备和原料，例如采用使需要或产生的材料量或涉及的设备量最少的流程；

• control exposure at source (eg local exhaust ventilation), and reduce the number of employees exposed to a minimum, the level and duration of their exposure, and the quantity of hazardous substances used or produced in the workplace;

• 控制对污染源（例如局部排风通气）的暴露，在最大程度上降低员工暴露量、暴露程度和持续时间，以及工作场所需要或产生的危险物质的数量。

• provide personal protective equipment (PPE) (eg face masks, respirators, protective clothing), but only as a last resort and never as a replacement for other control measures which are required.

• 提供个人防护装备（PPE）（如口罩、呼吸器和防护服），但这只是最后的手段，不能代替其它必要的控制措施。

The above is provided as an example of what one regulatory authority requires in terms of actions to control the risks identified in using hazardous substances. Many other countries have similar

上述内容仅为举例说明对危险物质使用过程中发现的风险所采取的控制行动。其它许多国家也有类似方法，但是规定

approaches, however the degree of prescription depends totally on the local regulatory authority.

的严厉性取决于当地监管当局。

What should be clearly understood is that emergency response planning is a critical function. This must be done well in advance of an incident; personnel must be trained and be adequately equipped to handle any potential significant incident the risk assessment process identifies.

必须明确了解应急计划是一项关键功能。计划必须在事故发生前落实；人员必须训练有素，有充分的装备来处理风险评估中识别的任何潜在重大事故。

3.2.5 Records

Documentation of risk assessments is a fundamental step in the process and should be given adequate attention. Some reasons for documenting each step of the risk assessment process are:

3.2.5 记录

风险评估建档是一项基本步骤，应给予足够关注。要记录风险评估过程的每一个步骤，其目的是：

a) to demonstrate to stakeholders that the process has been conducted properly;

a）向股东证明过程正常进行；

b) to provide evidence of a systematic approach to risk identification and analysis;

b）提供采用系统方法来进行风险识别和分析的证据；

c) to enable decisions or processes to be reviewed;

c）使决策或流程审核成为可能；

d) to provide a record of risks and to develop the organisation"s knowledge database;

d）提供风险记录，开发组织的信息数据库；

e) to provide decision makers with a risk management plan for approval and subsequent implementation;

e）为决策者提供风险管理计划，用于审批和后续实施；

f) to provide an accountability mechanism and tool;

f）提供问责机制和工具；

g) to facilitate continuing monitoring and review;

g）促进持续监测和审查；

h) to provide an audit trail; and

i) to share and communicate information.

h）提供审计跟踪；

i）分享和交流信息。

Most organisations choose to document their risk assessments in a form that is familiar to site personnel no matter what risk is involved (ie finance, health, production). This brings benefits in familiarity with the process and ensures that the level of detail provided in the documentation is sufficient so that the whole process can be reviewed at regular intervals in an effective manner.

大多数组织采用现场人员熟悉的记录风险评估形式，无论涉及任何风险（财政、卫生或生产风险）。这样做的好处是熟悉过程，确保文档中信息详细水平是适当的，今后可以用来以有效的方式定期审核整个过程。

In some jurisdictions, specific requirements are set down in law as to the risk assessment process including the level of documentation required.

在某些地区，风险评估过程的具体要求，包括关于记录范围的规定，是依法制定的。

3.2.6 Management

In many countries throughout the world the degree of prescription in occupational health and safety legislation has diminished. Over the past 15-20 years most statutory authorities have moved to a risk based approach whereby employers must establish the level of risk for all operations within their organisation. This can range from tasks such as electrical connections to our area of interest, hazardous substances.

Most statutory authorities produce guidance material which essentially defines minimum standards, however the onus is solely on the employer to establish the level of risk associated with any activity.

In large mature organisations this has become standard practice, however small to medium enterprises still struggle with the concept. Occupational hygienists fill an important role in establishing the level of risk in workplace through the evaluation of hazards, etc.

3.2.6 管理

危险物质。在全球许多国家，职业健康和安全立法时效性已经减小。在过去15-20年，大多数法律当局已经开始采用一个基于风险的方法，要求雇主为组织内所有运营活动确定风险水平，这涉及许多任务，从电力连接到我们关注的领域。

大多数法律当局制定了一些关于最低标准的指导文件，但是雇主应负责确定与任何活动有关的风险水平。

在成熟的大企业，以上要求已成为标准实践，但中小企业仍无法完全贯彻这个概念，因此，通过危害评估，职业卫生在确定工作场所风险水平方面发挥重要作用。

4. HYGIENE STANDARDS

4.1 PRINCIPLES OF CALCULATION/SETTING OF STANDARDS

A standard is any rule, principle or measure established by an authority. Occupational hygiene is about minimising risks of ill health caused by the working environment.

By “hygiene standard” we are referring to the level of exposure, via inhalation, that should not cause ill health to a healthy adult when exposed to a contaminant. The results from air sampling can thus be compared against these standards and can be used as a guide to assist in the control of health hazards. Other names for hygiene standards commonly used throughout the world are Threshold Limit Values (TLVs®), Exposure Standards (ES), Occupational Exposure Limits (OEL), Workplace Exposure Limits (WEL). In general all such terminology is interchangeable.

Hygiene standards in many cases are based on the concept of the “no observed adverse effect level”, while in other cases many are based on the lowest observed adverse effect level and some are by analogy to similar substances with better data sets. This is possible because for many chemicals there seems to be a “threshold dose”

4. 卫生标准

4.1 计算原则/标准设定

标准指任何由权威部门确立的规则、原则或测量标准。职业卫生是关于工作环境导致的疾病风险最小化的一门学科。

通过“卫生标准”，我们了解吸入导致的暴露水平不会使暴露在污染物中的健康成年人生病。因此我们可用这些标准来比较空气采样结果，并将结果作为健康危害控制指南。全球范围内使用的其它卫生标准包括危险物质容许最高浓度（TLV®），暴露标准（ES），职业暴露限值（OEL）和 工作场所暴露限值（WEL）。一般来说所有这些术语都是可互换的。

在许多情况下，卫生标准基于“无可视不利影响水平”的概念制定，在其它一些情况下，许多标准基于最低可视不利影响水平制定，还有一些采用更好的数据集通过与类似物质进行类比制定。这样做是由于许多化学物质剂量低于对于大多数人没有重大不利影响的“阈剂量”。流行病学和毒理学研究结合职业

below which no significant adverse effect will occur in most people. Epidemiological and toxicological studies coupled with occupational hygiene measurements help to identify this threshold.

卫生测定有助于识别这个阈值。

Occupational hygiene standards include allowances variously referred to as uncertainty or safety factors. The magnitude of the cumulative factor is based on many considerations (data quality, length of exposure in studies, routes of exposure in the studies, severity of effect, species with available data, etc). The cumulative uncertainty factor could range from 1, such as irritants where there is human data, to several thousand for extremely serious effects with great uncertainty.

职业卫生标准包括有时被称为“不确定性”，有时被称为“安全因素”的公差。累积因素的数量基于多种考虑（研究数据质量、暴露时间、暴露路径、影响严重性、可用数据种类等）确定。累积不确定性可从 1 开始，例如人体数据中的刺激物，对于极为严重的影响，不确定性相当大，甚至达到数千。

A “hygiene standard” represents an airborne concentration of a particular substance in the workers breathing zone, exposure to which, according to current knowledge, should not cause adverse health effects nor cause undue discomfort to nearly all workers. The “hygiene standard” can be of three forms; Time-Weighted Average (TWA), Short Term Exposure Limit (STEL) or Ceiling or Peak.

“卫生标准”指工人呼吸区内特定物质的机载浓度，根据当前认知，基本所有工人暴露在其中都不会致病或感到不适。“卫生标准”有三类：时间加权平均（TWA）、短期暴露限值（STEL）或上限或峰值。

It is important to realise that “hygiene standards” are based on the concept of the threshold of intoxication - for each substance, no matter how toxic, there exists a dose level, called the threshold

必须认识到“卫生标准”是基于中毒阈值概述制定，对于每种物质来说，无论毒性大小，都有一个作为人体能在不受伤害的情况下接受或排出的中毒阈值的

of intoxication, which the human body is capable of accepting and detoxifying without injury to itself.

剂量水平。

It should also be appreciated that the "hygiene standards" which have been established for chemical and physical agents are based on a number of factors including toxicity, physiological response (biologic action) and unbearable odours. Examples of such factors include:

而且还应认识到目前化学和物质试剂的"卫生标准"都是基于很多因素制定，例如毒性、生理反应（生物反应）和难以忍受的气味。例如：

Irritants - Ability to cause inflammation of mucous membrane with which they come in contact eg. hydrochloric acid fumes, ammonia, ozone, acrolein.

刺激物 - 能使所接触的粘膜产生炎症，例如盐酸气体、氨、臭氧和丙烯醛。

Asphyxiants - Ability to deprive the tissue of oxygen. Simple asphyxiants eg. nitrogen, carbon dioxide, helium. Chemical asphyxiants eg. carbon monoxide, cyanides.

导致窒息物 - 能导致缺氧的物质，简单的窒息物包括氮、二氧化碳和氦等。化学窒息物包括一氧化碳和氰化物等。

Anaesthetics - Depressant action upon the central nervous system, particularly the brain eg. ether, chloroform.

麻醉剂 - 对中枢神经系统，尤其大脑起抑制作用，例如醚和氯仿。

Carcinogens - Cancer causing substances eg. asbestos, vinyl chloride monomer.

致癌物 - 石棉、氯乙烯单体等致癌物质。

Unbearable Odour - eg Mercaptans

无法忍受的气味 - 例如硫醇

Toxic Effect - eg silica, lead

毒性作用 - 例如硅和铅

4.2 THRESHOLD LIMIT VALUES

The best known list of "hygiene standards" is the Threshold Limit Values (TLVs®) produced by the American Conference of Governmental Industrial Hygienists (ACGIH 2007), and this list will be used as an example (see section 4.9 for exposure standards used in some other countries) in the following discussion as the principles discussed are used by many standard setting bodies throughout the world.

"Threshold Limit Values (TLVs®) refer to airborne concentrations of chemical substances and represent conditions under which it is believed that *nearly all* workers may be repeatedly exposed, day after day, over a working lifetime, without adverse health effects. TLVs® are developed to protect workers who are normal, healthy adults."

People who use TLVs® must refer to the latest "Documentation of Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices" by the ACGIH to ensure they understand the basis for the setting of the TLV®.

Included in the TLV® List is a column outlining the Basis and or Critical Effect(s) and are intended to provide a field of reference for symptoms of overexposure and as a guide for

4.2 危险物质容许最高浓度

最有名的"卫生标准表"就是美国政府工业卫生大会（ACGIH 2007）制定的危险物质容许最高浓度（TLV®），下面的讨论中我们将以该表为例，因为它是全世界许多标准设定机构遵守的原则。

"危险物质容许最高浓度（TLV®）指空气中的化学物质浓度，代表被认为基本所有工人在工作期间可每天重复暴露，而不会受到不利健康影响的条件。TLV®用于保护正常健康的成年工人。"

采用 TLV® 的人必须参考 GCGIH 最新发布的"有害化学物质和物理试剂容许最高浓度和生物暴露指数"确保理解TLV®设定依据。

TLV®表中有一栏专门提供基础和/或关键影响，它有两个作用：过度暴露症状现场参考标准；决定将暴露涉及的各部分视为发挥独立或补充作用的指南。但

determining whether components of a mixed exposure should be considered as acting independently or additively. However the use of the TLV® Basis/Critical Effects column is not a substitute for the reading of the Documentation.

是，TLV®基本/关键影响栏目的使用不能代替对文件的阅读。

The ACGIH TLV booklet is updated annually and contained in it is an overview of the TLV® and BEI® development process and should be referred to for further information.

ACGIH TLV 手册每年更新一次，更新在 TLV®审查和 BEI®开发过程中进行。欲了解更多信息，详见手册。

4.3 TLV® Definitions, Terminology, Units

4.3 TLV® 定义、理论和单位

There are three types of TLVs®

共有三类 TLV®

1. TLV-Time Weighted Average (TLV-TWA)
2. TLV-Short Term Exposure Limit (TLV-STEL)
3. TLV-Ceiling (TLV-C)

1. TLV-时间加权平均数（TLV-TWA）
2. TLV-短期暴露限值（TLV-STEL）
3. TLV-上限（TLV-C）

4.3.1 TLV-TWA

4.3.1 TLV-TWA

“The TWA concentration for a conventional 8-hour workday and a 40-hour work week, to which it is believed that nearly all workers may be repeatedly exposed, day after day, for a working lifetime without adverse effect.”

“即传统 8 小时工作日和 40 小时工作周的 TWA 浓度。人们认为在这个浓度水平下，基本所有工人可在工作期内每天重复暴露，不会受到不利影响。”

However, during this eight hour averaging period, excursions above the TLV- TWA are permitted providing these excursions are compensated for by equivalent excursions below the standard during the working day. Because some substances can give rise to acute health effects even

然而在这个平均 8 小时的期间，对 TLV-TWA 的偏移是允许的，只要获得工作期内低于标准的等量偏移的补偿。一些高浓度物质即使短期暴露也会引起急性健康影响，因此对 TWA 浓度的偏移应受到严格限制，而且偏移量也表示对流程中污染物释放的有效控制的真正

after brief exposures to high concentrations, it is prudent that excursions above the TWA concentration should be restricted, moreover, the magnitude of excursions is an indication of the true degree of effective control over the release of contaminants from a process.

程度。

The 8-hour reference period may be represented mathematically by:

$$\frac{C_1T_1 + C_2T_2 + ... + C_nT_n}{8}$$

8 小时参考期可用以下数字公式表示：

$$\frac{C_1T_1 + C_2T_2 + ... + C_nT_n}{8}$$

Where C_1 is the Concentration for Time period 1, C_2 is the Concentration for Time period T2 and so on.

C1 指第一期浓度，C2 指第二期浓度，以此类推。

Example: Calculate the 8-hour TWA for the following sampling periods
例如：在以下采样期内计算 8 小时 TWA

Working 工作时期	**Exposure** 暴露（毫克/立方）	**Duration of sampling** 采样持续时间（小时）
0800 - 1030	0.32	2.5
1045 – 1245	0.07	2
1330 – 1530	0.2	2
1545 – 1715	0.1	1.5

Answer: Assumed exposure is zero during the periods 1030 to 1045, 1245 to 1330 & 1530 to 1545 as the worker was away from the work area having a rest break and was considered to be non exposed.

答：假定暴露为 0，在 1030 -1045、1245 -1330 和 1530 -1545 期间工人离开工作区域休息，这些期间应视为无暴露。

The 8 hour (8 小时)TWA $= \frac{C_1T_1 + C_2T_2 + \ldots\ldots + C_nT_n}{8}$

$= \frac{(0.32 \times 2.5) + (0.07 \times 2) + (0.2 \times 2) + (0.1 \times 1.5) + (0 \times 1.25)}{8}$

$= \frac{0.8 + 0.14 + 0.4 + 0.15 + 0}{8}$

$= 0.19\ mg/m^3$

4.3.2 TLV-STEL

"A 15 minute TWA exposure that should not be exceeded at any time during a workday, even if the TWA is within TLV-TWA. The TLV-STEL is the concentration to which it is believed that workers can be exposed continuously for a short period without suffering from:

1. irritation
2. chronic or irreversible tissue damage
3. dose-rate dependent toxic effects, or
4. narcosis of sufficient degree to increase the likelihood of accidental injury, impaired self rescue, or materially reduced work efficiency."

The TLV-STEL is not a separate, independent exposure guideline, but it supplements the TLV-TWA where the recognised acute effects from a substance whose toxic effects are primarily of a chronic nature.

Exposures above the TLV-TWA up to the TWA-STEL should be less than 15 minutes, should occur less than four times a day, and there should be at least 60 minutes between successive exposures.

4.3.3 TLV-C

"The concentration that should not be exceeded during any part of the working exposure.

If instantaneous measurements are not available, sampling should be conducted

4.3.2 TLV-STEL

"任何情况下每个工作日对 TWA 的暴露不得超过 15 分钟，即使 TWA 在 TLV-TWA 范围内。TLV-STEL 是人们认为工人可以短时间内，不受伤害接触的浓度：

1. 刺激

2. 慢性或不可逆转的组织损伤

3. 由剂量-速度决定的毒性；或

4. 足以增加意外伤害、自我拯救能力损伤或工作效率实质性降低的可能性的麻醉。"

TLV-STEL 不是一个单独的或独立的暴露指南，但它是对 TLV-TWA 的补充，使毒性主要呈慢性的物质显示急性作用。

高于 TLV-TWA，达到 TWA-STEL 的暴露应不少于 15 分钟，一天小于 4 次，连续两次暴露之间至少 60 分钟。

4.3.3 TLV-C

"工作暴露任何部分浓度不应超标。

如果无法获得瞬时测量结果，采样应在足以检测不低于上限的暴露的最短时间

for the minimum period of time sufficient to detect exposures at or above the ceiling value."

内进行。"

The ACGIH believes that the TLVs® based on physical irritation should be considered no less binding than those based on physical impairment. There is increasing evidence that physical irritation may initiate, promote, or accelerate adverse health effects through interaction with other chemical or biological agents or through other mechanisms.

ACGIH 认为，基于物理刺激的 TLV® 具有的约束力不应比那些基于物理损伤 TLV 的小。越来越多证据表明物理刺激可能通过与其它化学或生物制剂发生反应或通过其它机制发起、推动或加速不利健康影响。

4.3.4 Excursion Limits

4.3.4 偏移限值

In practice the actual concentration of airborne substances can and does vary significantly. For many substances with a TLV-TWA there is no TLV- STEL. However the excursions above the TLV-TWA should be controlled even if the recommended 8-hour TLV-TWA is not exceeded. Excursion limits are applied to TLV-TWAs that DO NOT have TLV-STELs.

在实践中，实际机载物质浓度会发生显著变化。对于许多具有 TLV-TWA 的物质来说，不存在没有 TLV- STEL。不过超过 TLV-TWA 的偏移应处于控制下，即使未超过建议的 8 个小时 TLV-TWA。偏移限值应用于没有 TLV-STEL 的 TLV- TWA。

Excursions in worker exposure levels may exceed 3 times the TLV-TWA for no more than a total of 30 minutes during the workday, and under no circumstances should they exceed 5 times the TLV-TWA (3 times the workplace exposure limit (WEL) in the UK), provided the TLV-TWA is not exceeded. A process is not considered to be under reasonable control if these levels occur.

工作日累计 30 分钟内工人暴露水平的偏移可超过 TLV-TWA 的 3 倍，在任何情况下不得超过 5 倍（3 倍是英国工作场所暴露极限（WEL）），倘若未超过 TLV-TWA 的话。如果达到这种程度，我们认为流程没有得到合理控制。

Where the toxicological data exists to establish a TLV-STEL or TLV-C these values take precedence over the excursion limits.

如存在用于建立 TLV-STEL 或者 TLV-C 的毒理学数据，与偏移限值相比，以这些值为准。

4.3.5 Mixtures

When two or more hazardous substances have a similar toxicological effect on the same target organ or system, their combined effect rather than that of either individually, should be given primary consideration.

4.3.5 混合物

如果两种及以上危险物质对相同靶器官或系统具有类似毒性，应主要考虑其合并影响，而不是个体影响。

In the absence of information to the contrary, different substances should be considered as additive where the health effect and target organ or systems is the same ie:

在没有相反信息的情况下，如果健康影响或靶器官或系统相同，即使物质不同，也应累计考虑，即：

$C_1/TLV_1 + C_2/TLV_2 + \ldots\ldots + C_n/TLV_n \leq 1$

$C_1/TLV_1 + C_2/TLV_2 + \ldots\ldots + C_n/TLV_n \leq 1$

the threshold limit of the mixture should be considered as being exceeded (where C_1 is the airborne concentration and TLV_1 is the corresponding threshold limit value etc).

混合物阈值应视为超标（这里 C1 指机载浓度，TLV1 指相应危险物质容许最高浓度，以此类推）。

The additive formula applies to simultaneous exposures for hazardous agents with TWA, STEL and Ceiling values.

以上加法公式适用于同时暴露于具有 TWA/STEL 和上限值的危险物质的多种试剂。

Example: A worker"s exposure to solvents was measured for a full shift and for one short term exposure with the following results:

例如：工人在整个班次中对试剂的暴露和短期暴露结果如下：

Agent 试剂	Full Shift Results ppm 整班暴露结果（ppm）	TLV-TWA ppm TLV-TWA（ppm）	Short Term Results 短期暴露结果（ppm）	TLV-STEL ppm TLV-STEL（ppm）
acetone 丙醇酮	160	500	490	750
Sec-butyl acetate 乙酸二级丁酯	20	200	150	N/A
methyl ethyl ketone 甲基乙基酮	90	200	220	300

From the TLV® basics column, the Documentation of the TLVs® and BEIs®, all three substances indicate irritation effects on the respiratory system and would considered as additive.

根据 TLV®基础表格“TLV®和 BEI®文件”，以上这三种物质都显示对呼吸系统的刺激，应累加在一起考虑。

Full shift calculation:
整班计算：

$C_1/TLV_1 + C_2/TLV_2 + C_3/TLV_3 \leq 1$

therefore 因此 160/500 + 20/200 + 90/200

= 0.32 + 0.10 + 0.45

= 0.87

This is less than 1 – hence full shift additive limit is not exceeded

结果小于 1–因此整班累加限值未超标。

Short term calculation:
短期计算：

$C_1/TLV\text{-}STEL_1 + C_2/TLV\text{-}STEL_2 + C_3/TLV\text{-}STEL_3 \leq 1$

therefore 因此 490/750 + 150/(200 x 5)* + 220/300

= 0.65 + +0.15 + 0.73 = 1.53

* Where no STEL exposure standard exists the general approach is to multiply the TWA exposure standard by 5 in many countries or 3 in the UK.

* 当不存在 STEL 暴露标准，在许多国家一般是用 TWA 暴露标准乘以五，在英国是乘以三。

This is greater than 1 – hence short term additive limit is exceeded.
结果大于 1–因此短期累加限值超标。

4.3.6 Units of Measure - Conversion of ppm to mg/m³.

The unit of measure of TLVs depends on the nature and physical composition of the contaminant.

For aerosols, (dusts, mists and metallic welding type fumes) the contaminant is typically measured and expressed as a weight in a given volume of air *Example:* mg/m^3.

For gases and vapours the concentrations may also be expressed volumetrically as a number of volumes of the substance in a number of volumes of air.

Example: % or ppm

1 litre of contaminant per 100 litres of air = 1%.

1 litre of contaminant per 1,000,000 litres of air = 1 part per million (1 ppm). NB 1 ppm = 0.0001%

Gases and vapours while typically expressed in ppm can also be expressed gravimetrically by using the following equation:

Concentration in mg/m^3 = Concentration in ppm x Molecular Weight/24.45

where 24.45 = molar volume of air in litres at NTP conditions (25°C and 1 atm)

4.3.6 测量单位– 将百万分率转换成毫克/立方米

TLV 测量单位取决于污染物性质和物理结构。

对于浮质（尘、雾和金属焊烟），污染物一般用一定体积空气中物质的重量表达，例如：毫克/立方米。

对于气体和蒸汽，浓度也可用一定体积空气中物质体积来表达，

例如：% 或 ppm

每 100 升空气体中有 1 升污染物= 1%

每 1，000，000 升 空气中有有 1 升污染物 = 百万分之一（1 ppm）。注：1 ppm = 0.0001%

通常以 ppm 为单位的气体和蒸汽也可通过以下公式用重量表达：

浓度（毫克/立方米 0 =浓度（ppm）x 分子重量/24.45

这里 24.45 = NTP 条件（25°C 和 1 atm）下空气摩尔体积（升）

Note: International Union of Pure & Applied Chemistry (IUPAC) use $0^0$and 100 kPa but the ACGIH and other bodies use 25 C and 1 atmosphere

注：国际理论和应用化学联合会（IUPAC）采用 0^0 和 100 kPa，但是 ACGIH 和其它一些机构采用 25 C 和 1 个大气。

where STP conditions are used ie 20° C not 25°C then the equation is

Concentration in mg/m^3 = Concentration in ppm x Molecular Weight/24.06

当采用 STP 条件时，也就是当采用 20° C，而不是 25°C 时，等式为：

浓度（毫克/立方米）= 浓度（ ppm）x 分子重量/24.06

Example: What would be the concentration of 5,000 ppm carbon dioxide in mg/m^3 (at 25°C and 1 atm)? Molecular weight of carbon dioxide = 44

例如：5，000 ppm 二氧化碳（毫克/立方米）（25°C 和 1 atm）的浓度是多少？ 二氧化碳分子重量 = 44

$$\text{Conc } (mg/m^3) = \frac{5{,}000 \times 44}{24.45}$$

$$\text{浓度（毫克/立方米）} = \frac{5{,}000 \times 44}{24.45}$$

= 9,000 (rounded to nearest 10 mg/m^3)

= 9，000（四舍五入至 10 毫克/立方米）

4.4 NOTATIONS

4.4 符号

A notation is a designation that appears as a component of the adopted TLV® value to provide additional information with respect to the particular chemical:

符号即采用的 TLV®值中某个成份的名称，以提供关于特定化学物质的补充信息：

4.4.1 Biological Exposure Indices (BEIs®)

4.4.1 生物暴露指标（BEI®）

The notation BEI® is listed when a BEI® (or BEIs®) is (are) recommended for the substance. Biological monitoring is recommended for such substances to determine the exposure from all sources, including dermal (skin) ingestion or non-occupational.

如推荐对某种物质采用 BEI®时，请说明 BEI®数值。推荐对此类物质进行生物监测。确保掌握对污染源的所有暴露，包括皮肤摄取或非职业暴露。

Most BEIs® are based on a direct correlation with the TLV® (ie the concentration of the determinant that can be expected when the airborne

基于无皮肤吸入或摄取的假设。大多数 BEI®根据与 TLV®（指当机载浓度以 TLV 衡量时存在的确定性物质的浓度）的直接相关性确定。欲了解更多信

concentration is at the TLV) with an assumption that there is no exposure by skin absorption or ingestion. Further information can be found in section 6.8 of this manual or in the TLV book or in the documentation for the TLVs® and BEI® for these substances.

息，详见本手册 6.8 部分或 TLV 手册或关于这些物质的 TLV®和 BEI®文件。

Correct application of BEIs® requires significant knowledge of the accompanying documentation and may be valuable in evaluating what exposure has actually occurred in an incident. Employee resistance may be encountered with this type of monitoring as many BEIs® require the use of invasive collection techniques.

BEI®的正确应用要求对附件内容有深刻理解，因为这对于评估事故中出现的暴露来说很重要。由于许多 BEI®要求使用侵入式收集技术，员工可能会对这种监测方式有所抵触。

4.4.2 Carcinogenicity

“A carcinogen is an agent capable of inducing benign or malignant neoplasms. Evidence of carcinogenicity comes from epidemiology, toxicology, and mechanistic studies.

4.4.2 致癌物

致癌物是一种能引起良性或恶性肿瘤的试剂。致癌证据通过流行病学、毒理学和机械学研究得出。

There are a number of different schemes for the classification of carcinogenicity and it is important to note that the classification is complicated and is not universally agreed upon. Two schemes in common use are the International Agency for Research on Cancer (IARC) and the ACGIH.

有许多机构对致癌物进行分类。必须注意有多种分类法，但没有任何一个获得普遍认可。一般采用两个分类机构的分类标准：国际癌症研究所（IARC）和美国政府工业卫生学家会议。

The IARC Monographs on the Evaluation of Carcinogenic Risks to Humans have been evaluated for more than 900 environmental agents and exposures.

《IARC 致癌物对人体风险专论》对 900 多种环境试剂和暴露进行评估。根据公开证据表现的致癌物强度，暴露共

Each exposure is classified into one of five groups according to the strength of the published evidence for carcinogenicity.

Group 1 Carcinogenic to humans
Group 2A Probably carcinogenic to humans

Group 2B Possibly carcinogenic to humans
Group 3 Not classifiable as to carcinogenicity to humans
Group 4 Probably not carcinogenic to humans

The complete list of the evaluations can be found at http://monographs.iarc.fr (accessed March 2007)

The ACGIH system uses the following notations:

A1 Confirmed Human Carcinogen: The agent is carcinogenic to humans based on the weight of evidence from epidemiologic studies.

A2 Suspected Human Carcinogen: Human data are accepted as adequate in quality but are conflicting or insufficient to classify the agent as a confirmed human carcinogen; OR, the agent is carcinogenic in experimental animals at dose(s), by route(s) of exposure, at site(s), of histologic type(s) or by mechanism(s) considered relevant to worker exposure.

The A2 is used primarily when there is limited evidence of carcinogenicity in

分为五组：

第 1 组 人体致癌

第 2 组 A 很可能人体致癌

第 2 组 B 可能人体致癌

第 3 组 非人体致癌

第 4 组 可能不会使人体致癌

评估表全文详见 http：//monographs.iarc.fr（2007 年 3 月访问）

ACGIH 系统使用以下命名：

A1 人体致癌物：基于流行病学研究中的证据重量，试剂具有人体致癌性。

A2 可疑人体致癌物：人体数据质量得到认可，但是作为人体致癌物，这些数据是矛盾的或不充分的。或者说，基于研究人员认为与工人暴露有关的管理路径、场地、组织类型或机制，试剂对实验动物具有致癌性。

A2 主要用于人体致癌证据有限，或与

humans and sufficient evidence of carcinogenicity in experimental animals with relevance to humans.

人体有关的实验动物致癌证据充分的情形。

A3 Confirmed Animal Carcinogen with Unknown Relevance to Humans: The agent is carcinogenic in experimental animals at relatively high dose, by route(s) of administration, at site(s), of histologic type(s) or by mechanism(s) that may not be relevant to worker exposure. Available epidemiologic studies do not confirm an increased risk of cancer in exposed humans. Available evidence does not suggest that the agent is likely to cause cancer in humans except under uncommon or unlikely routes or levels of exposure.

A3 对人体影响未知的动物致癌物：基于与工人暴露无关的管理路径、场地、组织类型或机制，相对较高剂量的试剂对实验动物具有致癌性。当前流行病研究无法确认人体暴露是否能增加患癌风险。可用证据不能证明试剂可能导致人体癌症，除非通过非正常或不太可能的路径或暴露水平。

A4 Not Classifiable as a Human Carcinogen: Agents which cause concern that they could be carcinogenic for humans but which cannot be assessed conclusively because of a lack of data. In vitro or animal studies do not produce indications of carcinogenicity which are sufficient to classify the agent into one of the other categories.

A4 未确认人体致癌物：人们担心具有人体致癌性，但是由于数据无法得出评估结论的试剂。体外或动物研究都没有得出足以证明试剂属于致癌物的推论。

A5 Not Suspected as a Human Carcinogen: The agent is not suspected to be a human carcinogen on the basis of properly conducted epidemiologic studies in humans. These studies have sufficiently long follow-up, reliable exposure histories, sufficiently high dose, and adequate statistical power to conclude that

A5 非人体致癌物：基于适当进行的人体流行病研究，试剂不会导致人体癌症。这些研究对足够高的剂量的暴露进行很长时间的可靠的跟踪研究，通过适当的统计，得出结论，试剂不会导

exposure to the agent does not convey a significant risk of cancer to humans, OR, the evidence suggesting a lack of carcinogenicity in experimental animals is supported by mechanistic data.

致人体重大患癌风险，或者说机械数据支持关于实验动物体内缺少致癌物的证据。

Other systems are used throughout the world and reference should be made to the system used by local regulatory or standard setting bodies.

全世界范围内还有其它一些系统也在使用，当地监管当局或标准设定机构应明确适用系统。

4.4.3 Sensitisation

The notation SEN refers to the potential for the chemical to produce sensitisation. Sensitisation may relate to respiratory, dermal or conjunctival exposures. Once a person has become sensitised, subsequent exposure to the agent, even at very low levels, usually results in an adverse allergic reaction.

Example: Toluene diisocyanate (TDI) often found in 2-pack paints is a respiratory sensitiser and subsequent exposure can result in severe asthmatic reactions to those sensitised.

When considering substances with a SEN notation it is important to understand:

1. Occupational exposure limits are not meant to be protective of those who are sensitised.

2. When there is a SEN notation, reference must be made to the documentation to understand the nature

4.4.3 敏感性

SEN 指化学物质导致敏感性的可能、敏感性可能与呼吸、皮肤或结膜暴露有关。一旦某个人变得敏感，此后对试剂的暴露，即使量很小，也会导致不利的过敏反应。

例如：人们经常在双组分涂料中发现的二异氰酸甲苯酯（TDI）就是呼吸致敏源，而且这样的暴露会使过敏者严重哮喘。

在考虑带有 SEN 符号的物质时，必须理解：

1. 职业暴露限值的目的不是保护那些过敏者。

2. 如有 SEN 符号，必须在文件中注明，以表现过敏性质和致敏源的作

of the sensitisation and the potency of the sensitiser.

用。

3. Some bodies (eg AIHA) use different notation to indicate specific sensitisation, eg DSEN for dermal sensitisers, RSEN for respiratory sensitisers.

3. 一些机构（例如 AIHA）采用不同符号来说明特定过敏，例如皮肤致敏源 DSEN 和呼吸道致敏源 RSEN。

4.4.4 Skin

4.4.4 皮肤

The Skin notation „refers to the potential significant contributions to the overall exposure by cutaneous route, including mucous membranes and the eyes, either by contact with vapours or, of probable greater significance, by direct skin contact with the substance. Typically skin exposure is from splashes or wearing of contaminated clothing.

皮肤符号指通过皮肤路径，包括黏膜和眼部，或接触蒸汽或直接接触物质（危害更严重）对整体暴露潜在重大作用。一般情况下皮肤暴露是由于喷溅或穿着受过污染的衣服导致。

Example: Organophosphate pesticides such as Malathion.

例如：马拉松等有机磷酸盐杀虫剂。

It is important to note that skin notations are not assigned on the basis of any harmful effects on the skin such as irritation or allergic contact dermatitis. Substances with a skin notation are not necessarily harmful to the skin.

必须注意到皮肤符号不是基于对皮肤的任何有害作用，例如刺激或过敏性皮炎而确定的，具有皮肤符号的物质不一定对皮肤有伤害。

The use of a skin notation is to alert the reader that air sampling alone is not sufficient to quantify worker exposure, biological monitoring may also be required in addition to changes to work practices including the use personal protective equipment to prevent cutaneous absorption from occurring.

皮肤符号被用来警告读者空气采样本身不能量化工人的暴露水平，在具体工作实践中还要进行生物监测，包括使用个人防护设备来防止皮肤吸入。

4.5 APPLICATION OF STANDARDS

When measuring the airborne concentration of a particular contaminant it is imperative that the measurement is representative of the workers exposure to that contaminant. Therefore the contaminant is measured in the breathing zone of the worker. The breathing zone is defined as a hemisphere of 300mm radius extending in front of the face and measured from the midpoint of a line joining the ears.

If the sample is collected in this fashion it is referred to as occupational or personal sampling and the occupational hygiene standards for the contaminant can then be applied.

If para-occupational or static or area sampling is carried out the results should not be compared directly with exposure standards as they are not indicative of the worker"s actual exposure and hence risk.

4.5 标准应用

在测量具体污染物机载浓度时，测量结果必须能代表性地表现工人对污染物的暴露水平。因此要在工人呼吸区进行污染物测量。呼吸区被定义为工人面前一个半径 3 米的半球，测量从两耳之间连线中点进行。

如果以这种方式收集的样本被称为职业或个人样本，那么可以采用污染物职业卫生标准

如果进行非职业或静态或局部采样，不要将结果与暴露标准直接比较，因为它不能表现工人的实际暴露和导致的风险。

4.6 EXTENDED WORK SHIFTS

Almost all occupational exposure limits are derived on the assumption that exposures would follow a traditional work week of a conventional 8-hour workday followed by a 16-hour break from the exposure over a 40-hour work week. Many models have been used to adjust TWA for unusual and extended work schedules. It is not necessary to adjust TWA-STEL and TWA-Ceiling values as

4.6 班次时间延长

几乎所有职业暴露限值都基于这样一个假设：每次工作 8 小时，然后休息 16 小时，每周工作 40 小时。对于非正常和超时工作情况下，人们采用许多模型来调整 TWA。必须调整 TWA-STEL 和 TWA-上限值，因为它们与急性，而不是慢性暴露有关。

these are associated with acute rather than chronic exposures.

It should be noted that before any adjustment of an exposure standard is attempted, the basis of that occupational exposure limit must be understood so as to determine whether it is appropriate to adjust for non-traditional work shifts, and if so, which model to apply.

注意：在调整任何暴露标准前，必须理解职业暴露限值基础，以确定是否应调整非正常班次，如果应调整，请使用模型。

4.6.1 Brief and Scala Model

This model, originally derived within the petroleum industry, reduces the 8-hour OEL proportionally for both increased exposure and reduced recovery time. The suggested approach is set out below.

Daily Adjustments of Occupational Exposure Limits:

Daily Reduction

Factor = $\left\{\frac{8}{h} \times \left[\frac{24-h}{16}\right]\right\}$

Where h = hours worked per day

Adjusted Exposure Limit = 8 hr OEL x

Daily Reduction Factor Weekly

Adjustments of Occupational Exposure

Limits:

Weekly Reduction

Factor = $\left\{\frac{40}{h} \times \left[\frac{168-h}{128}\right]\right\}$

4.6.1 Brief 和 Scala 模型

本模型源自于石油工业，为了增加暴露和减少恢复时间，按比例减少 8 小时 OEL。建议的方法具体如下：

每日职业暴露限值调整：

每日换算系数 = $\left\{\frac{8}{h} \times \left[\frac{24-h}{16}\right]\right\}$

当 h = 每日工时数

调整后暴露限值 = 8 小时 OEL x 每日换算系数

每周职业暴露限值调整：每周换算系数 = $\left\{\frac{40}{h} \times \left[\frac{168-h}{128}\right]\right\}$

Where h = hours worked per week

当 h = 每周工时数

Adjusted Exposure Limit = 8 hr OEL x Weekly Reduction Factor

调整后暴露限值 = 8 小时 OEL x 每周换算系数

Note: The adjusted exposure limit should be calculated using each equation and the most restrictive value adopted.

注：调整后暴露限值应用规定的方程式和最严格的值计算。

Example: A worker is exposed to toluene for a 12-hour shift. The 8-hr OEL for Toluene is 50 ppm. Using the Brief and Scala model the adjusted OEL is calculated

例如：一个工人在一个 12 小时的班次中连续暴露在甲苯中。甲苯 8 小时 OEL 为 50ppm，使用 Brief 和 Scala 模型计算调整后 OEL，具体如下：

Adjusted Exposure Limit = $\frac{8 \times (24 - h) \times OEL}{16 \times h}$

调整后暴露限值 = $\frac{8 \times (24 - h) \times OEL}{16 \times h}$

= $\frac{8 \times (24 - 12) \times 50 \text{ ppm}}{16 \times 12}$

= $\frac{8 \times (24 - 12) \times 50 \text{ ppm}}{16 \times 12}$

= 25 ppm

= 25 ppm

4.6.2 OSHA (Direct Proportion) Model

4.6.2 OSHA（正比）模型

Another approach, which was formerly used by the OSHA in the US, was to adjust the occupational exposure limit in direct proportion to the hours worked.

OSHA 在美国正式使用的另一个方法就是与工时成正比调整职业暴露限值。

This type of adjustment may be particularly appropriate for substances where the exposure limit is based upon estimated life-time excess risk (parts per million – years) rather than a specific toxic threshold.

当暴露限值基于预计使用期超限风险（百万分率-年数），而不是具体毒性阈值时，调整类型主要根据具体物质确定。

For example if a 10-hour shift is being worked: Adjusted OEL = OEL (8/hours worked)

例如，如果每班工作 10 小时：调整后 OEL = OEL（工作 8 小时）

$$= OEL \times \frac{8}{10}$$

$$= OEL \times \frac{8}{10}$$

If we use the example in Section 4.6.1 and apply the OSHA model we would have the following:

$$\text{Adjusted OEL} = 50 \times \frac{8}{12}$$

$$= 33 \text{ ppm}$$

As can be observed, the Brief & Scala model is significantly more conservative than the OSHA model.

如果我们采用章节 4.61 中的案例，并适用 OHA 模型，我们就得出以下结果：

$$\text{调整后 OEL} = 50 \times \frac{8}{12}$$

$$= 33 \text{ ppm}$$

如我们所见，Brief 和 Scala 模型比 OSHA 模型保守得多。

4.6.3 Pharmacokinetic Model

4.6.3 药物动力学模型

Other more complex models, such as the Pharmacokinetic Model of Hickey and Reist (1977) have been based on pharmacokinetic actions that consider metabolism, biotransformation and excretion. This model is described by the formula

其它综合模型，例如 Hickey 和 Reist 药物动力学模型（1977 年）就是基于考虑到新陈代谢、生物转化和排泄的药物动力学行动。模型公式如下：

$$\text{Modified TLV} = \text{TLV} \times \frac{[1-e^{-8k}]\ \ [1-e^{-120k}]}{[1-e^{-t_1 k}]\ \ [1-e^{-t_2 k}]}$$

修改后的

Where t_1 = hours worked per day on usual schedule

这里 t_1 = 正常班每日工时数

t_2 = 24 times days worked/week on unusual schedule

t_2 = 24 倍工作日/周（正常班）

$$k = \frac{\ln 2}{t_{½}}$$

(Note: If half life ($t_{½}$) not known, use 16 hours)

（注：如果半衰期（$t_{½}$）不知道，采用 16 小时）

A detailed understanding of this model is beyond the scope of this course.

对模型的具体理解不包括在本课程范围内。

4.6.4 Western Australian Department of Minerals & Energy

4.6.4 西澳大利亚矿产和能源部

A much more practical approach (albeit based on the Brief and Scala Model) has been adopted by the Western Australian (WA) Department of Minerals & Energy (1997) as demonstrated in Table 4.1.

西澳大利亚州（WA）矿产和能源部（1997）通过了更可行的方法（虽然是基于 Brief 和 Scala 模型）（1997 年），如表 4.1 所示。

Table 4.1 – WA Department of Minerals & Energy Altered Workshift Model
表 4.1–西澳大利亚矿场和能源部轮班模型

EXPOSURE STANDARD	TIMEFRAME FOR ACTION	HEALTH EFFECT	TYPICAL SUBSTANCES	SHIFT ROSTER	EXPOSURE REDUCTION FACTOR
Peak	Fast - immediate	Acute poisoning	Cyanide, Caustic, Acid mists	n/a	1
STEL	Fast - immediate	Acute irritation	Nitrogen dioxide Sulphur dioxide Hydrogen sulphide Ammonia	n/a	1
TWA	Medium – within shift or over a few shifts	Respiratory irritation, narcosis	Solvents, Nitrogen dioxide, Sulphur dioxide, Hydrogen sulphide, Carbon monoxide	10 h/day	0.7
				12 h/day	0.5
TWA	Long – over many shifts or years	Cumulative poisoning, respiratory disease (silicosis, asbestosis) , cancer	Silica, Asbestos, Nickel, Lead, Welding fumes, Talc, Inspirable dust, Respirable dust, Diesel fume	<170 h/mth	1
				> 170 h/mth	170/*x**
TWA	Unknown or unsure			10 h/day	0.7
				12h/day	0.5

LEGEND

* x	Average number of hours worked in the month; 170 is the typical hours worked in a month for a normal 8 h/day, 5 day/week work cycle
STEL	Short Term Exposure Limit
TWA	Time Weighted Average Exposure Standard
n/a	Not Applicable
h	hours
mth	Calendar month

暴露标准	行动时间表	健康影响	典型物质	班次	暴露减少因素
峰值	快–中	剧毒	氰化物、腐蚀剂、酸雾	不适用	1
STEL	快 - 中	急性刺激	二氧化氮 二氧化硫 硫化氢 氨	不适用	1
TWA	中–班次内部或几个班次	呼吸性刺激 麻醉	溶剂 二氧化氮 硫化氢 一氧化碳	10小时/天	0.7
				12小时/天	0.5
TWA	长–多个班次或多年	累积性中毒 呼吸性疾病（矽肺、石棉肺、癌症）	硅、石棉、镍、铅、焊接烟雾、滑石粉、可吸入性粉尘、呼吸性粉尘、柴油烟雾	<170小时/月	1
				>170小时/月	170/x*
TWA	不知道或不确定			10小时/天	0.7
				12小时/天	0.5

说明

*x 一个月内平均工作小时数；170是一个月内典型工作小时，每天8小时，每周5天。

STEL 短期暴露限值

TWA 时间加权平均暴露标准

n/a 不适用

h 小时

mth日历月

(Source: *Reproduced with permission from* - "Table 1 Recommended Exposure Reduction Factors for the Western Australian Mining Industry" that is located in the Appendix of the Guideline for Adjustment of Exposure Standards for Extended Workshifts available from: http://www.docep.wa.gov.au/resourcessafety/Sections/Mining_Safety/Guidance_material_and_publications/Guidelines.html)

（来源：允许转载——《延长工作班次调整指南》附件"表1- 西澳大利亚采矿行业建议减少暴露因素"，见网址：http//www.docep.wa.gov.au/resourcessafety/Sections/Mining_Safety/Guidance_material_and_publications/Guidelines.html）

4.7 PROBLEMS

Many people in the Occupational Environment fail to understand that Exposure Standards are not fine lines between safe and unsafe but are merely guides for the use of occupational hygienists in the control of potential health problems.

In countries or jurisdictions where occupational exposure standards are used as regulatory limits they are of course legally binding and not guidelines. Their application to situations outside the norm (eg. 12 hour shifts) for which they were designed can be disastrous. Effects such as synergism and potentiation, addition etc need to be understood and allowances made.

With many new products coming onto the market, it is impossible for any group to develop appropriate Exposure Standards for each before they are in Commercial use. With this in mind, analogy to other compounds of similar type, common-sense and good Occupational Hygiene practice may reduce any unnecessary exposure.

It should be noted that regulatory standards usually include consideration of many policy concerns, such as engineering feasibility, economic impact, analytical limits etc. Non government guides such as the ACGIH TLVs® and the Workplace Environment Exposure

4.7 问题

职业环境中的许多人都不了解，暴露标准不是安全和不安全之间的明确划分，而仅仅是职业保健专家用来控制潜在健康问题的指南。

在一些国家或地区职业暴露标准作为监管限制使用，这些标准当然具有法律约束力而不是指导方针。在设计规范（如12小时轮班）之外的情况下使用可能导致灾难性后果。需要理解一些效应如协同、势差和添加等，并做出让步。

随着许多新产品进入市场，任何一个群体都可能在用于商业用途之前为其制定合适的解除标准。记住了这一点，与其它同类化合物一样，常识和良好的职业卫生实践可以减少不必要的暴露。

应当指出的是，监管标准通常包括许多政策问题的考虑，如工程可行性、经济影响、分析限制等。非政府指导如ACGIH TLV®和AIHA的《工作场所的环境暴露限值》通常是以健康为基础，不考虑任何其它因素。

Limits from the AIHA are usually health based and do not take any other factors into consideration.

A simple guide to follow is if you are not familiar with the application of exposure standards in workplace situations seek out the services of someone with good professional experience in this area, **before** making any decisions.

如果你不熟悉工作场所环境的暴露标准的话，简单的办法是在做任何决定时，咨询当地专业人员。

4.8 LIMITATIONS

4.8 限制

Occupational exposure limits, such as the Threshold Limit Values, apply only to the workforce. In deriving Occupational Exposure Limits, it is presumed that workers are in reasonably good health. Industrial environments usually exclude the very young, the very old and those unable to work due to illness and physical impairment or disability.

职业暴露限值如阈限值仅适用于劳动力。在推导职业暴露限值时，假定工人健康状况良好。行业环境通常排除和年轻和很老的以及由于疾病和身体损伤或残疾而无法工作的人。

Occupational exposure limits are not meant to apply to the general public. They are set to protect worker health and while zero exposure is a goal to strive towards, exposures are likely to be higher and sometimes significantly higher than those encountered by the general public. They must not be divided by an arbitrary number such as 100 and turned into environmental or boundary emission standards.

职业暴露限值不适用于公众。它们保护的是工人的健康，而“零暴露”则是努力目标，暴露可能会较高，有时明显高于公众所遇到的。不能由任意数字如100而推导出并变成环境或边界排放标准。

Occupational exposure limits are generally described in supporting information as not being fine lines between safe and

职业暴露限值通常在支持性信息中描述，而不是作为安全和危险情况之间的明确划分，不应由未接受过行业/职业卫生培训

dangerous conditions and should not be used by anyone who is not trained in the discipline of industrial/occupational hygiene. They were never intended to be regulatory standards, however this has occurred in some countries and is thus legally binding.

的人来使用。这些数字本来并不是用作监管标准，尽管在有些国家是这样，而且有法律约束力。

Regulatory standards usually include consideration of various policy concerns such as engineering feasibility, economic impact etc, while non governmental guides are usually based entirely on health effects. Consequently, indiscriminate mixing of the two approaches can lead to difficulties.

监管标准通常包括对各种政策问题的考虑，如工程可行性研究、经济影响等方面，而非政府指导通常是完全基于对健康的影响。因此，这两种方法不作辨别而混用可能导致问题。

4.9 HYGIENE STANDARDS USED IN OTHER COUNTRIES

4.9 其它国家采用的卫生标准

Many other countries have established their own lists of exposure standards, a brief overview of which is provided below. It is important that reference always be made to local exposure standards if they are published but if none are available reference to one of the more established lists is appropriate.

许多国家都建立了自己的暴露标准列表，概述见下文。重要的是，如果有发布当地暴露标准的话，应参考这些标准，如没有的话，参考其中众多已确立清单中的一个即可。

4.9.1 Australia

4.9.1 澳大利亚

The first edition of an Australian list of exposure standards was published in 1990 by WorkSafe Australia under the title of:

第一版澳大利亚的暴露标准列表由澳大利亚劳动安全局出版于1990年，标题如下：

Exposure Standards for Atmospheric Contaminants in the Occupational Environment - Guidance Note and National Exposure Standard.

《职业环境中空气污染物的暴露标准——指导说明和国家暴露标准》。

These were based on ACGIH TLV® list but also cross referenced exposure standards from Germany, Sweden and the UK. Specific differences included reference to Workplace Exposure Standards and the use of Peaks rather than Ceilings.

这些都以ACGIH TLV®列表为基础，也交叉引用了德国、瑞典和英国的暴露标准。具体差异参见《工作场所暴露标准》，使用峰值而不是上限值。

The second edition was published in October 1991, and a third edition (the latest) in May 1995 by the National Occupational Health and Safety Commission.

国家职业安全与健康委员会1991年10月发布第二版，1995年5月发布第三版。

Updates are now published on the Australian Safety & Compensation Council ASCC website: www.ascc.gov.au (accessed January 2008) where a database exists of the 696 current national exposure standards (Hazardous Substances Information System or HSIS).

澳大利亚安全和赔偿委员会ASCC出版了更新，网站：www.ascc.gov.au（2008年1月访问）其中一个数据库中存在696个国家现行的暴露标准（危险物质信息系统或HSIS）。

While these standards do not automatically have the force of law behind them the various States and the Commonwealth are actively moving towards these standards becoming uniform in law across Australia.

虽然这些标准不会自动具有法律效力，各州和联邦正积极努力使这些标准成为澳大利亚的统一法律。

4.9.2 United Kingdom

4.9.2 英国

The UK Health & Safety Commission has established Workplace Exposure Limits (WELs) for a number of substances hazardous to health as part of The Control of Substances Hazardous to Health Regulations. WELs replaced the previously adopted Occupational

英国健康与安全委员会对危害健康的许多物质确立了工作场所暴露限值（WELs），作为《危害健康的物质的控制条例》的一部分。WELs更换了之前通过的《职业暴露标准》（OESs）和《最大暴露限值》（MELs）。

Exposure Standards (OESs) and the Maximum Exposure Limits (MELs).

HSE"s publication EH40 (Workplace Exposure Limits) includes the list of substances assigned WELs and provides more detailed guidance on their use. They are maximum acceptable levels of exposure and should not be exceeded. Moreover, exposure should be reduced below the limit as far as is reasonably practicable by applying the principles of good occupational hygiene practice. The listing includes: 8-hour TWA, STEL, the Comments Column containing Safety & Risk Phrases plus the Carcinogen, Skin, Respiratory Sensitiser and Biological Monitoring Guidance Value notations.

HSE的出版物EH40（《工作场所暴露限值》）包括物质列表并对其用途提供了更详细的指导，即最高可接受等级，不得超过。此外，暴露应减少到低于限值并尽可能地通过应用良好职业卫生行为原则而合理执行。该列表包括：8小时TWA、STEL、包含安全与风险短语加致癌物质、皮肤和呼吸敏化剂和生物监测指导价值符号的评论专栏。

4.9.3 European Limits

There are two kinds of Occupational Exposure Limit Values in European Legislation: Indicative (directive 98/24/EC on chemicals) and Binding (directive 2004/37/EC on carcinogens and mutagens) and there are also biological limit values.

4.9.3 欧洲限值

欧洲立法中有两种职业暴露限值：指示（化学品指令98 / 24 / EC）和法令（对致癌物和致突变物的指令2004 / 37 / EC），还有生物限值。

Indicative Occupational Exposure Limit Values (IOELVs) can be established when an assessment of the available scientific data leads to the conclusion that a threshold can clearly be identified below which exposure to the substance should not have an adverse impact on human health.

如对现有科学数据的访问可得出结论，即阈值可清楚地确定暴露哪种物质不会对人体健康造成不利影响，则可确立指示性职业暴露限值（IOELVs）。

When establishing IOELVs feasibility factors (including socio-economic and technical) are not taken into account.

确立IOELVs时不考虑可行性因素时（包括社会经济和技术）。

Binding Occupational Exposure Limit Values (BIOELVs) reflect socio- economic and technical feasibility factors, plus criteria taken into account when establishing IOELVs.

法令职业暴露限值（BIOELVs）反映社会经济和技术可行性的因素，再加上确立IOELVs时考虑的标准。

The Occupational Exposure Limits Values can be 8-hour TWA, short term, and/or biological limit values and can be supplemented by further information such as notations and routes of absorption.

职业暴露限值可为8小时TWA、短期的和/或生物限值，可进一步补充信息如符号和吸收途径。

The original list has been expanded and up-to-date information can be found at http://ec.europa.eu/employment social/health safety/occupational en.htm http://osha.europa.eu/good practice/risks/ds/oel/notes.stm (accessed December 2006)

最初的清单已扩展，更新的信息可以在以下网址查阅：

http://ec.europa.eu/employmentsocial/healthsafety/occupational en.htmhttp：//osha.europa.eu/good practice/risks/ds/oel/notes.stm（2006年12月访问）

If substances not assigned then the individual states are responsible for setting their own.

如未指定物质，各个国家自己负责确定。

4.9.4 USA – OSHA

In the USA, the Occupational Safety and Health Administration has established Permissible Exposure Limits (PEL), most of which are based upon the 1968 Threshold Limit Values. They have subsequently promulgated a limited number of detailed regulatory requirements applicable to specific substances such as benzene,

4.9.4 美国–OSHA

在美国，职业安全与健康管理局已确立了允许暴露限值（PEL），其中大部分是基于1968阈限值。他们随后颁布了有限数量的详细监管要求，适用于特定的物质如苯、石棉和氯乙烯。这些都包含在美国联邦法规法典第29篇中。大多数适用的规定可登陆：http://www.access.gpo.gov/nara/cfr/waisid

asbestos and vinyl chloride. These are contained in Title 29 of the US Code of Federal Regulations. Most of the applicable regulations can be found at: http://www.access.gpo.gov/nara/cfr/waisidx_06/29cfrv6_06.html(accessed March 2007)

x_06/29cfrv6_06.html（2007年3月访问）

4.9.5 USA - NIOSH

National Institute of Occupational Safety and Health (NIOSH) in the USA has established Recommended Exposure Limits (RELs).

NIOSH recommends standards to OSHA/MSHA (Mine Safety & Health Administration) and some of the recommended exposure limits are lower than PELs, TLVs etc.

It should also be noted that NIOSH has language in its enabling legislation that directs it to recommend limits that will ensure protection of “all” workers rather than “nearly all” workers. This has driven many of their recommendations to be lower than those established by others.

The NIOSH list of Recommended Exposure Limits is available on CD-ROM or http://www.cdc.gov/niosh (accessed December 2006).

4.9.5 美国- NIOSH

美国国家职业安全卫生研究所（NIOSH）确立了建议的暴露限值（RELs）。

NIOSH对OSHA / MSHA（矿区安全与健康管理局）提出建议标准，一些建议的暴露限值低于PELs、TLVs等。

还应指出的是，HIOSH在指导其提出建议的授权立法中指出，将确保保护“所有”工人而不是“几乎所有”工人。这使得他们的许多推荐值低于那些由别人确立的标准。

NIOSH的建议暴露限值可在CD-ROM

或http：//www.cdc.gov/niosh（2006年12月访问）上查看。

4.9.6 USA - AIHA

Since 1980 the American Industrial Hygiene Association has produced Workplace Environmental Exposure Levels (WEELs) which, together with their documentation, are updated annually. The current list of over 100 substances is available at:

http://www.aiha.org/Content/InsideAIHA?Volunteer+Groups/WEELcomm.htm
(accessed March 2007).

WEELs are intended to provide guidance on exposure levels where no legal or authoritative limits exist eg benzyl alcohol, butylenes oxide. They include recommendations for 8-hour TWA, Ceiling limit and a Short Term TWA limit plus Skin, Dermal sensitiser and Respiratory sensitiser notations.

The AIHA also publishes Emergency Response Planning Guidelines. These should be used for risk assessments when considering exposures of either the workforce or for the public for accidental releases. Information on these guides is available at:
http://www.aiha.org/Content/InsideAIHA/Volunteer+Groups/WEELcomm.htm
(accessed March 2007).

4.9.7 Germany – MAK Commission

The Commission for the Investigation of Health Hazards of Chemical Compounds in the Work Area (MAK Commission) is responsible for determining the current

4.9.6 美国-AIHA

自1980年以来，美国行业卫生协会制定了《工作环境暴露等级》（WEEL）以及相关文件，每年更新一次。目前的列表上有超过100种物质，参见以下网址：

http://www.aiha.org/Content/InsideAIHA?Volunteer+Groups/WEELcomm.htm

（2007年3月访问）。

WEEL的目的是没有法律或权威限值的暴露等级如苄醇和环氧丁烷提供指南，包括对8小时TWA、上限值和短期TWA限值的提议以及皮肤致敏源和呼吸致敏源符号。

AIHA还出版了《应急计划指南》，用于劳动力或公众意外暴露时的风险访问。有关这些指南的信息请登陆：
http://www.aiha.org/Content/InsideAIHA/Volunteer+Groups/WEELcomm.htm
（2007年3月访问）。

4.9.7 德国–MAK 委员会

工作区化学化合物健康危害调查委员会（MAK委员会）负责确定工作场所使用的物质和材料所带来的健康风险

state of research relating to the health risks posed by substances and materials used at the workplace and for advising public authorities accordingly. To this end, the MAK Commission draws up proposals for MAK values (maximum concentration at the workplace) for volatile chemicals and dusts, BAT values (biological tolerance values), and also develops procedures to analyse chemical substances in the air and in biological materials. Substances that are carcinogenic, germ cell mutagenic, sensitising or percutaneously absorbed, as well as those that pose a risk to the embryo or foetus, are classified accordingly.

的研究现状。为此，MAK委员会提出了挥发性化学物质和灰尘的MAK值（工作场所的最大浓度），BAT值（生物公差值），并开发出程序来分析空气和生物材料中的化学物质，对致癌的、生殖细胞突变的、敏感或经皮吸收的以及对胚胎或胎儿构成风险的物质进行分类。

Each year the proposals for the MAK and BAT values and the classifications are published in the annual List of MAK and BAT values which is presented to the German Federal Minister of Labour and Social Affairs. The Ministry"s Committee of Hazardous Substances subsequently reviews the proposals and makes a recommendation for their inclusion in the Hazardous Substances Ordinance.

每年对MAK与BAT值和分类所作的提议都发表在MAK与BAT值年度清单上，然后呈交给德国联邦劳工和社会事务部。然后危险物质委员会审查这些提议并建议使其纳入危险物质条令中。

5. AIR SAMPLING THEORY & PRACTICE

5. 空气采样理论和实践

5.1 WORKPLACE SAMPLING STRATEGIES

5.1 工作场所采样策略

5.1.1 Strategies

A possible objective of a monitoring strategy is to provide analytical information about the workplace, which workers and management can use to ensure that, as far as is reasonably practicable, no-one in that workplace suffers injury or illness as a result of exposure to hazardous contaminants. Other objectives could include: determining exposures in response to complaints, determining compliance with respect to various recommended occupational health exposure limits, or to evaluate the effectiveness of engineering controls installed to minimise workers" exposure.

A sampling strategy, like any other experimental design, cannot be formulated until the objectives of the exercise are clearly understood and documented. The concept of just collecting a few samples to see how “good” or ”bad” a workplace may be, is potentially biased and may not give an accurate picture of workplace exposures.

Thus, when developing any monitoring strategy it is important to ask the fundamental question:

5.1.1 策略

监测策略的目的之一是提供有关工作场所的分析信息，工人和管理可使用这些信息在合理的范围内确保工作场所内没有人由于暴露有害污染物而受伤或生病。其它目的包括：确定回应投诉风险，确定是否符合各种建议的暴露职业健康解除限值，或评价安装的工程控件的有效性，减少工作暴露。

同任何其它实验设计一样，只有清楚理解并记录下之后才能形成实践目标。仅收集一些样本，就判断工作场所条件是“好”或“坏”，可能会存在偏见，无法对工作场所的暴露进行准确的描述。

因此，制定任何监控策略时，重要的

"How will the data generated from this exercise be used?"

是询问基本的问题："从该行为生成的数据如何使用？"

Without a reasonable answer to this question the survey merely becomes the collection of data "for the sake of it", which is a wasteful and meaningless exercise.

对这个问题没有合理的回答，调查仅仅成为"由于它"的数据的集合，这是一种浪费的和毫无意义的行为。

The British Occupational Hygiene Society (BOHS 1993) also suggests other factors should be considered before developing any monitoring programme. These include:

英国职业卫生学会（BOHS 1993）也建议，在制定任何监测计划还要考虑其它一些因素，包括：

• The requirement for a qualitative risk assessment and appraisal of the workplace prior to doing any measurements.

- 在作任何测量之前考虑定性风险评估和工作场所评估要求。

• The need to obtain measurements other than those of airborne contaminant concentrations, eg wipe tests to determine surface cleanliness as a way of assessing the potential for skin contact or measurements of ventilation plant performance.

- 需要获得降了大气污染物浓度之外的其它测量数据，例如用擦抹测试来确定表面清洁度，从而评估皮肤接触风险或测量通风设备性能。

• Any requirements for biological monitoring and the integration of these into the overall survey strategy.

- 生物监测和将这些整合成一个整体测量策略的任何要求。

• Any requirements for monitoring overall performance or auditing the process.

- 监管整体性能或审查流程的任何要求。

• Any other health hazards which may exist within the workplace, eg noise or

biological hazards, etc which may also need to be considered.

• Any environmental or personal characteristics of the workers which may affect the measurement.

Once all these factors have been assessed it is appropriate to develop a workplace exposure sampling strategy. In doing so it is appropriate to consider the following:

• What type of sample(s)? (area vs personal)

• Where should the sampling device be located?

• How many samples should be taken?

• How long should the sampling interval be?

• What periods during the work day should the employee"s exposure be determined?

• How should the samples be taken?

• What contaminants are likely to be present?

• What is (are) the expected concentration(s)?

• What (if any) compounds are present which may interfere with the sampling (or analytical) procedure?

• What analytical methods are to be used and what (if any) constraints will these place on sampling techniques?

When developing a sampling strategy it is important to understand that the

- 任何其它可能在工作场所存在的健康风险，例如噪音或生物危险等也需要考虑的风险。
- 任何可能会影响测量的环境或操作人员个人特征。

一旦评估所有因素，应制定一个工作场所采样策略。这需要考虑以下因素？

- 哪种样本？（面积 Vs 个人）
- 采样设备应放在什么地方？
- 采样量多少？
- 采样间隔多久？
- 工人暴露值应在工作日哪个时期测定？
- 如何采样？
- 可能存在哪些污染物
- 预期浓度是多少？
- 会有哪些会干预采样（或分析）程序的化合物？
- 采用什么分析方法，采样技术会受到哪些限制（如有）？

在制定采样策略时必须理解工作场所

variability of the workplace environment is such that no universal approach is possible to cover all possible situations.

环境不同，不存在适用于所有情形的方法。

The inconsistency of the workplace, in terms of density and intensity of activity, variability of activity, variability of exposure cloud and the influence of uncontrolled factors such as wind direction, employee practices, etc results in the fact that data can only be related to the situation being studied at the time it was studied.

工作场所活动密度和强度、活动可变性和暴露可变性以及风向和员工行为等不可控制的因素的影响导致数据只与研究时的情形有关。

Any exposure assessment based on a single worker for a single day will have errors of space (location) and time and we will have little to link this outcome to the real situation.

任何基于某个工人在某一天进行的暴露评估都有空间（地点）和时间错误，将评估结果与真实情形联系起来是不现实的。

Individual measurements will not necessarily represent the group, but by accounting for as many influencing factors as is practicable, we can ensure that some assessments are substantially better than others.

个人测量不一定能代表他所在的群体，但是考虑到许多影响因素都可能存在，我们可以确保一些评估方法要比其它的强得多。

Other factors affecting the measurement results include:

其它影响测量结果的因素包括：

- The choice of monitoring equipment
- The choice of the sampling method
- The choice of the analytical method
- The skill level of persons conducting the sampling and analysis

- 监测设备的选择
- 采样方法的选择
- 分析方法的选择
- 采样和分析人员的技术水平

All the above factors need to be considered when considering a sampling strategy. It is important to appreciate that

在考虑采样策略时必须考虑到以上所

monitoring the workplace does not in itself protect anyone, it merely provides information; however in some circumstances the mere act of monitoring does raise awareness of the workforce and management which often results in initiatives to reduce exposure, regardless of the actual results of the measurements.

有因素。必须认识到监测工作场所本身不能保护任何人，它只是为了提供信息；但是在一些情形下仅仅依靠监测无法了解工作场所和管理情况，而且这些认识有助于减少暴露，无论测量实际结果如何。

The sampling system should be appropriate to the situation being studied and part of an overall occupational hygiene monitoring strategy.

该采样系统对于所研究的情形来说是适当的，属于整体职业卫生监测策略的一部分。

Guidance on the assessment of exposure can also be obtained from other sources such as BSEN 689 (1996) “Workplace Atmospheres – Guidance for the Assessment of Exposure by Inhalation to Chemical Agents for Comparison to Limit Values and Measurement Strategy”.

暴露评估也可从其它来源获得，例如BSEN 689（1996）“工作场所环境–用于限值和测量策略比较的化学试剂吸入暴露评估指南”。

5.1.2 Surveys

5.1.2 调查

Regulatory authorities throughout the world have different approaches to the design of monitoring surveys. Some bodies are very prescriptive whereby individual workers in a workplace are listed in regulation to be monitored at set frequencies using prescribed methods. In recent years this approach has changed, with a move by some authorities to a risk based approach.

世界各地监管机构采用不同方法来设计监测调查。一些机构非常规范，他们对采用规定方法监测单个场所个体工人的频率列表说明。但是近年来这种方法已经发生改变，一些机构开始采用基于风险的方法。

In such situations it is not unusual for a common approach to be adopted with following components:

在这种情况下采用包括以下步骤的方法并不奇怪：

• Initial appraisal

• Basic survey
• Detailed survey
• Routine survey

While the names given to these components may be different in various countries and some components may be combined (eg initial appraisal and basic survey), the concept remains the same.

• Initial Appraisal

In many situations this is commonly referred to as a "walkthrough survey" (see section 3.2.2) and has the objective of being able to provide sufficient information to answer these questions:

- What are the potential exposures?
- Where and when do they occur?
- Can the exposures be prioritised in terms of risk?
- Is further evaluation necessary?
- If further evaluation is necessary what is the preferred approach?

As previously indicated, collection of sufficient information to answer these questions is paramount. While the walkthrough survey provides valuable information on the process, (eg materials being used and current controls), it may be necessary to seek further details. Such information regarding the substances being used could include:

- *Physical properties.* For example boiling point, vapour pressure, relative evaporation rate, dustiness, particle size

• 初步评估
• 基本调查
• 具体调查
• 常规调查

这些步骤的名称在不同国家可能不同，有一些步骤可能经过合并（例如初步评估和基本调查），但概念相同。

• 初步评估

这个步骤经常被称为“预先排除调查”（参看 3.2.2），其目标是为解答以下问题提供充分信息：

- 什么是潜在暴露？
- 何地和何时发生？
- 是否能对暴露进行风险分级？
- 是否需要进一步评估？
- 如果需要进一步评估，首选方法是什么？

根据此前迹象，利用充分信息来回答这些问题是至关重要的。当研究人员在预先排查调查中发现有用的流程信息后，（例如正在使用的原料和当前采用的控制方法），他们可能需要发掘更多细节。此类与正使用的原料有关的信息可包括：

- 物理性质。例如沸点、蒸汽压力、相对蒸发率、污染度、颗粒尺寸分

distribution, ability to sublime, etc.

布、升华能力等。

- *What form is the substance?* Is it a gas, vapour, mist, fume, or if it is an aerosol, is it fibrous?

- 质量是什么形式？是气体、蒸汽、烟雾，还是浮质或纤维？

- *Hazardous nature of the substance*. This could include any known toxic effects in man (both acute and chronic); other indications of toxicity (eg animal studies, *in vitro* tests, structural factors, etc); any special toxic potential (carcinogenicity, respiratory sensitisation, reprotoxicity, etc); and any indication of increased hazard from exposure to mixtures of substances.

- 物质的危险性。这包括对于人体的已知毒性（急性或慢性）；其它毒素指标（例如动物研究，体外测试、结构因素等）；任何特殊毒性可能（致癌性、呼吸敏感性、毒繁殖性等待）；和暴露于多种物质导致的高度危险指标。

- *Potential routes of entry to the body*.

- 进入人体的潜在路径。

- *Any effects on skin* (eg corrosion, dermatitis) or mucous membranes (eg drying, irritation).

- 任何对皮肤（例如腐蚀和皮炎）或黏膜（例如干燥或刺激）的潜在影响。

- *Any available exposure limits* and the documentation for these.

- 任何可用暴露限值和有关文件。

During this initial information collection stage the use of direct reading instruments or detector tubes may be helpful in identifying emission sources or employees with potentially significant exposures.

在信息初步收集阶段应使用直读仪器或检测管来识别污染源或可能面临重大风险的员工。

This information will be very limited and should only be used to support observations. At the conclusion of the information collection exercise it may be possible to make a reasonable assessment of potential risk. It should at least provide sufficient information to

手册信息有限，仅作为观察资料的补充。在对收集到的信息进行汇总时，应对潜在风险进行合理评估，至少提供充分信息来确定是否需要进一步研究或采

decide if a more detailed study is required or if a non sampling approach would be effective.

样方法是否有效。

• **Basic Survey**

• **基本调查**

A basic survey is generally required when one or more of the following situations arise:

如出现以下一个或多个情形，一般要进行基本调查：

- The initial appraisal suggests that unacceptable exposures may be present in the workplace.

- 初步评估结果显示工作场所可能存在无法接受的暴露。

- A new process is being started up.

- 正开始一个新流程。

- Substantial changes have been made to the process, operations or control measures.

- 对于流程、运行和控制措施来说物质产生变化。

- Unusual, infrequent or intermittent processes or operations are to be conducted, eg maintenance.

- 异常的、罕见的或间歇性的流程或程序将开始，例如维护。

- An occupational exposure limit has been set where one did not previously exist.

- 此前无暴露的地方被设定职业暴露限值。

A basic survey will have limited objectives but these should include obtaining sufficient information to answer the following questions:

基本调查目标有限，但是这些应包括获得充分的信息来解答以下问题：

- Does an exposure problem exist as suggested by the initial appraisal?

- 是否确实如初步评估所述存在暴露问题？

- Are available engineering, or other, controls adequate and likely to remain so?

- 是否可以采取适当的工程或其它控制措施，而且将来也能持续采取？

- Is a more detailed survey necessary and what strategy should it follow?

- 是否应采取更详尽的调查，随后应采取什么策略？

In some cases an initial appraisal may be followed by a detailed survey without the intermediate step of a basic survey.

Such a step would depend on what was found during the initial assessment and the skill and experience of the hygienist performing the evaluation.

在一些情况下在完成初步评估后要进行一次具体调查，无需基本调查这一中间步骤。

该步骤取于第一次评估时发现什么，负责评估的卫生人员的技术和经验。

At this stage four questions need to be addressed before proceeding. These are:

在这个阶段要解决以下四个问题，然后才能继续：

- *Who should be monitored?*

- 谁来监测？

The question of whose exposure should be monitored can be answered only by reference to the objectives of the proposed survey and the details of the observed work practices. If the process only involves several workers doing exactly the same thing then the task is relatively easy, however if the process involves large numbers of persons doing different tasks then the choice of who to monitor becomes more difficult.

“监测谁的暴露值”这个问题只要参考调查方案目标就能解答。如果流程只涉及几个从事同样工作的工人，那么任务相对简单，但是，如果流程涉及大量从事不同任务的人员，那么解答“谁来监测”这个问题就难多了。

In many basic surveys the practice is to target “worse case” situations, however there is merit in including some workers who are expected to have lower exposures. This provides a level of quality control in respect to the initial appraisal and the choice of “worse case” individuals sampled.

在许多基本调查中惯例是针对“最坏”情形。但是将一些预计暴露值会低一些的工作包括在内是有帮助的。这样在初步评估和选择“最坏”情形个人样本时就能控制质量水平。

- *When should they be monitored?*

- 何时监测？

The choice of when to monitor is directly related to what process or tasks give rise to significant exposures. The other major factor that must be considered is the toxicology of the substance under consideration.

选择监测时机直接关系到那个流程或任

For example if it is an acute acting toxin it is important to undertake short term sampling, whereas with a chronic toxin, longer sampling would be more appropriate.

The other point to consider when considering when to monitor is the type of exposure standard appropriate to the substance of concern (eg TWA, STEL, Ceiling or Peak). These are generally related to the toxicological properties of the substance.

As a general rule it is reasonable to state that if the objective of the survey is to evaluate the exposure of a worker during a specific task then the monitoring duration should equal the whole, or a representative part, of the task.

- *Where should the monitoring take place?*

Recognition that a contaminant in a workplace is associated with a particular source may be very valuable when designing a monitoring programme. Identification of the source provides a spatial element to the monitoring strategy which may assist in deciding what type of monitoring approach is required (eg direct reading instrumentation).

- *How should sampling be performed?*

The selection of sampling equipment and analytical methods will in general result from the properties of the contaminant

务会产生重大暴露。另一个必须考虑的重要因素是有关物质的毒性。

例如，如果这是一种急性作用毒素，必须进行短期采样，如果是慢性毒素，更适合长期采样。

在考虑监测时机时应考虑的另一点是适用于有关物质的暴露标准类型（例如TWA、STEL、上限或峰值）。这些一般与物质的毒物学性质有关。

一般来说应说明是否调查目标是评估正在执行具体任务的调查目标，那么监测持续时间应等于任务的全部或有代表性的部分。

- 在何地监测？

在设计监测方案时，最好认识到工作场所污染物与哪种来源有关。对来源的识别为监测策略提供了空间要素，这有助于确定应采用什么类型的监测方法（例如使用直读仪器）。

under investigation. Other factors that will come into the equation include:

* Legislative requirements
* The accuracy and precision required
* Intrinsic safety requirements
* The need for subsequent laboratory analysis
* Transport of samples to the laboratory
* Portability of equipment

In all cases it is prudent to use sampling methods from recognised authorities (eg National Standards, NIOSH, OSHA, HSE).

Both the sampling method and the analytical method are subject to error and thus what may be the most desirable choice from one standpoint may not be from the other.

Ultimately the choice will be a compromise, often dependent on the experience of the occupational hygienist and the working relationship between the hygienist and the laboratory that will perform the analysis.

The BOHS (1993) suggests that the following considerations need to be taken into account when selecting the sampling method.

* Is the sampling device (and collection medium) suitable for collecting the contaminant of interest and is the medium compatible with the subsequent analytical method?

- 应怎样进行采样？

采样设备和分析方法的选择一般来说由所调查的污染物的性质决定。而且还要考虑其它一些因素，包括：

* 法律要求
* 准确和精确性要求
* 固有安全要求
* 随后需要进行实验室分析
* 样本向实验室运输
* 设备的便携性

在任何情况下，必须谨慎使用公认的机构提供的采样方法（例如国家标准、NIOSH、OSHA 和 HSE）。

采样和分析方法都有可能出现误差，因此在某种情形下最好的选择可能不适用其它情形。

总之，无论选择哪种方法都要做出一些妥协，这通常取决于职业卫生师的经验和卫生师和分析实验室之间的工作关系。

BOHS（1993）认为，在选择采样方法时必须考虑以下因素：

* 是否采样设备（和采样媒介）适合采集有关污染物，是否媒介与随后

* Is sufficient known about the dynamics of the collection process so that any variables can be accounted for in the design of the sampling programme?

A number of factors can influence the selection of the sampling device and collection medium, but in practice they are generally limited to:

* For aerosols, what is the most appropriate device to collect the size range of particles of interest? Are wall losses (material which sticks to the sampling head and does not lodge on the filter), either within the sampling head or train, of an order such that account needs to be taken of them?

* For mists, especially, does possible vapour loss need to be taken into account?

* For gases and vapours sampled from a mixed atmosphere does preferential sorption of one or more contaminants take place in the collection medium? Does the presence of high water-vapour levels affect sorption characteristics of the sampling medium or the presence of particulate material adversely affect the collection characteristics?

* With all contaminants, is the total capacity of the collecting medium sufficient to cope with the likely loading of the contaminant given the intended sampling rate over the proposed sampling

采用的分析方法配套？

* 是否充分了解采样流程情况，这样就能在设计采样方案时考虑到可能出现的各种 情况？

在选择采样设备和采集媒介时要考虑许多因素，但在实践中要考虑以下限制：

* 对于浮质来说，对于有关颗粒的尺寸范围来说，什么才是最适当的采样设备？是否还要考虑采样头或采样器的壁部损失（粘在采样头未进入过滤器的材料）？

* 对于烟雾来说，是否需要考虑可能出现蒸发损失？

* 对于混合气体中采集到的气体和蒸汽来说，是否一种或多种污染物会首先吸附在收集媒介中？是否较高水蒸汽水平会影响样本媒介的吸附特性，或特定物质的存在会对收集特征产生不利影响？

period?

Other issues (such as the number of samples) need to be addressed but these will be discussed in section 5.2.2.

• Detailed Survey

A detailed survey has a clear objective, usually to obtain reliable measurements of personal exposures for comparison to exposure standards, reach conclusions regarding exposure levels and decide (if necessary) what measures need to be taken to control unacceptable exposures.

Thus for a detailed survey, results need to be representative of personal exposures so personal sampling techniques are normally used. Moreover, the appropriate measurement period must be used if the results are to be compared to an exposure standard which has a specific reference period.

In addition, all aspects of the survey need to be reviewed to ensure errors which may affect results are minimised. In many cases statistical based sampling techniques are adopted and detailed statistical analysis of the data undertaken.

No matter what the circumstances, the essential questions of: “Who?, When?, Where and How?” remain central to the development of an effective monitoring strategy.

* 对于所有污染物，当计划的采样期内的采样率已确定时，是否采样媒介总体能力足以收集可能存在的污染物？

还有其它一些问题（例如样本数量）也需要解决，详见 5.2.2 部分。

• 具体调查

具体调查必须在明确目标指导下进行，通常要对人体暴露进行可靠测量，然后和暴露标准进行比较，这样才能得出暴露水平结论，并决定（在必要时）需要采取哪些措施使暴露水平控制在可接受范围内。

因此在具体调查时，结果必须是代表性的个人暴露值，这样才能正常使用人体样本技术。而且，如果结果要与特定参考期的暴露标准进行比较，必须采用适当的测量期。

而且要对调查进行各方面审查来确保会对结果产生影响的错误最小化。在许多情况下采用基于采样技术的统计学理论，并进行具体的数据统计分析。

无论哪种情形，关键问题-谁？何

- **outine Survey**

Routine surveys involve periodic sampling of exposed persons (or control measures) to achieve predefined goals.

Such goals may include:

- Checking the performance of control measures

- Ensuring compliance with exposure standards and/or legislation

- Meeting the requirements of large corporations

- Providing data for epidemiological or other studies

No matter what the reason, any routine survey must take account of and be designed on the basis of information gathered in earlier surveys. The various approaches to routine monitoring will be discussed in section 5.1.3.

Irrespective of what type of survey that is used, it is important to recognise that some problems still exist. For example, processes which operate intermittently at irregular intervals or on a campaign basis make it difficult to obtain representative data for even a single substance let alone multiple substances.

Another limitation would be in the circumstance where excursions above the exposure standard could cause serious, possibly irreversible, acute effects. In such cases a routine survey using a method whereby the substance is collected for

时？何时？怎样？-仍是制定有效监测策略的核心。

- **常规调查**

常规调查涉及对暴露人员（或控制措施）进行定期采样来完成预定目标。

此类目标可能包括：

- 检查控制措施的性能

- 确保符合暴露标准和/或法律

- 满足大公司的要求

- 提供流行病或其它研究的数据

无论哪种理由，常规调查必须考虑并基于此前调查中收集的信息。对各种常规监测方法的讨论详见5.1.3。

无论采用哪种类型的调查，必须认识到一些问题仍然存在。例如，对于无规则或规模性间歇性流程，很难获得某种物质的代表性数据，更何况对于多种物质。

另一个限制就是一旦暴露超出标

subsequent laboratory analysis is obviously not appropriate. Continuous monitoring using alarmed direct reading instrumentation would be more appropriate.

准，就会产生非常严重，甚至无法逆转的急性影响。在这种情况下显然不适合学用先常规调查，然后送交实验室进行分析的方法。用具有预警功能的直读仪器进行持续监测更适合一些。

Thus, issues such as the toxicology of the substance concerned and the process itself play an important role in survey design and such factors must be considered when developing the monitoring strategy.

因此在设计调查方案时，有关物质毒性和流程一类的问题本身就很重要，在制定监测策略时必须考虑到这些因素。

5.1.3 Routine Monitoring

5.1.3 常规监测

When developing a routine monitoring strategy, four issues need to be considered. These are:

在制定常规监测策略时需要考虑四个因素：

- The frequency at which the monitoring survey is conducted
- The sampling methodology
- The number of samples required to meet the goals of the exercise
- The type of analysis of data that will be undertaken

- 监测调查的频率
- 采样方法
- 为了实现目标所需样本数量
- 数据分析类型

There are no set rules for the frequency of monitoring except where it is defined in local legislation. Some mathematical models have been developed, however such models are very reliant on the quantity and quality of available data.

对于监测频率来说没有一定之规，都是根据当地法律决定。虽然人们也开发出一些有关数字模型，但是此类模型非常依赖于可用数据的数量和质量。

Irrespective of the above, there are a few simple guidelines which can be used

不考虑以上因素，在确定常规调查频

to help in the decision process regarding the frequency of routine surveys.

率方面也有一些简单的指南可以作为参考。

• *How close are exposures to the relevant exposure standard* – as exposures approach the exposure standard more frequent monitoring will be required (as distinct from being either well below or excessively above the exposure standard).

- 暴露对相关暴露标准的符合情况-如暴露接近暴露标准，就要提高监测频率（对于明显低于暴露标准的值和明显高于标准的值，处理方法显然不同）。

• *The effectiveness of controls* – in a well controlled environment where the likelihood of control failure is low, monitoring frequency can be reduced.

- 控制有效性 –在控制失败可能性较小的有效控制环境下，监测频率会降低。

• *The process cycle* – monitoring frequency will need to match the process cycle. This is especially important in situations where periodic events occur (eg maintenance shutdowns) or irregular process cycles.

- 流程周期-监测频率必须与流程周期匹配，尤其在周期性事件（例如维护停工）或不规则流程周期情况下。

• *The temporal variability of exposures* - consideration needs to be given so as to take account of seasonal and shift variations (eg increased production on night shift).

- 时间性暴露变化-必须考虑到季节和班次变化（例如增加夜班生产）。

• *The variability of exposure* - in a process where a high level of variability of exposure is present, increased monitoring would be required to establish the reason for such variability.

- 暴露变化：如果一个流程中暴露变化极大，就要加强监测来弄清此类变化的原因。

Other factors that need to be considered are:

其它需要考虑的因素包括：

• Changes in sampling methods

• Changes in analytical methods

• Changes in behaviour patterns of workers

Such changes can affect the survey results from year to year and some understanding of these issues is necessary if data from varying years is to be compared.

In recent years many major corporate organisations have adopted a statistical approach to exposure assessment.

The problem of how to correctly (or more accurately) measure workplace exposures has been the subject of debate within the occupational hygiene profession for many years.

In the last 25 years there has been a gradual move to statistically based monitoring programmes where the workforce is divided into groups of similar exposures called “Homogeneous or Similar Exposure Groups” (HEGs or SEGs) and a statistically based subset of each group is monitored on a random basis for an extended period of time. In essence, employees are placed into groups (SEGs) based on past monitoring data or via using the knowledge of persons working in a plant as to possible exposures.

A number of persons in each group are then monitored and it is assumed that

- 采样方法的变化
- 分析方法的变化
- 工人行为模式的变化

这些变化会对每年调查结果产生影响，如果要比较不同年份的数据，必须对这些问题有一些认识。

近年来许多大公司在暴露评估方面采用统计法。

如何正确（或更准确）衡量工作场所暴露这个问题多年来一直是职业卫生行为的焦点。

过去 25 年有一个趋势：越来越多的人通过将具有类似风险的员工进行分成“相同或相似暴露组”（HEG 或 SEG）来开展静态统计项目，长期随机监控每组统计子集。从本质上说就是基于过去监测数据，或通过利用对工作在可能有风险的工厂的人员的了解进行分组（SEG）。

the exposures measured represent that of the whole group (SEG).

然后监测每组的一些人，假定整个小组（SEG）都有暴露。

Once sufficient data has been collected a statistical analysis of the exposures can be undertaken to establish the level of compliance to the relevant exposure standard and to provide an indication in the variability of the data.

一旦收集充足的数据，就能对暴露进行统计分析，确定符合有关暴露标准的程度，并提供数据变化迹象。

While statistically based sampling and evaluation of workplace exposures is very useful in giving a more accurate picture of employee exposures, it should not be considered as being the absolute test. There are many assumptions (and thus potential errors) in such programmes but by controlling as many influencing factors as is practicable a better estimate of exposure will be guaranteed.

虽然根据统计得出的工作场所暴露采样和评估有助于更准确地描述员工的暴露情况，但这并不能视为绝对的测试。在此类计划方面人们做出许多假设（因此也有许多潜在错误），但是由于许多影响因素是可控的，因此能保证更好地对暴露做出评估。

Where considered appropriate, evaluation of workplace exposures should be conducted using non-biased (random) sampling programmes using the concept of SEGs. The number of samples (NIOSH 1977) in each SEG will be determined using information like that provided in Table 5.1 and the exact sampling days should be determined using random number tables.

在适当时，工作场所风险评估应使用应用 SEG 概念的非偏倚（随机）采样方案。每个 SEG 的样本的数量（NIOSH 1977）应利用表 5.1 等提供的信息来确定，具体采样日应在随时数字表上确定。

Table 5.1 – NIOSH Sample Size Guide

表 5.1– NIOSH 样本尺寸指南

Sample size n for top 10% (τ= 0.1) and 95% confidence (α = 0.05)

前 10%（τ= 0.1）样本尺寸 n 和 95% 置信区间（α= 0.05）

Size of Group (N) 组尺寸（N）	12	13-14	15-16	17-18	19-21	22-24	25-27	28-31	32-35	36-41	42-50	∞
Required No. of Measured Employees (n) 被测员工人数要求（n）	11	12	13	14	15	16	17	18	19	20	21	29

If N <= 11 then n = N

如果 N <= 11，那么 n = N

(Source: NIOSH 1977)

（来源：NIOSH 1977 年）

Such an approach should ensure that at least one result should be within the top 10% of exposures with 95% confidence and would satisfy the requirements of a compliance based survey.

这种方法应确保至少有一个结果处于置信区间为 95%的前 10%的暴露风险范围，而且会满足基于调查的合规性要求。

It is important to understand that the information provided in Table 5.1 is designed to meet the requirements of compliance based monitoring programmes as suggested by NIOSH and thus may result in the collection of more samples than are necessary to obtain a reasonable estimate of the exposure profile.

必须理解表 5.1 提供的信息是为了满足基于 NIOSH 推荐的监测方案的合规性要求，因此会导致收集的样本多于获得暴露情况合理预测所必要的样本。

A more general approach is taken by the American Industrial Hygiene Association (AIHA 1998 and 2006) who suggest that 6-10 samples should be sufficient to give a picture of an exposure profile.

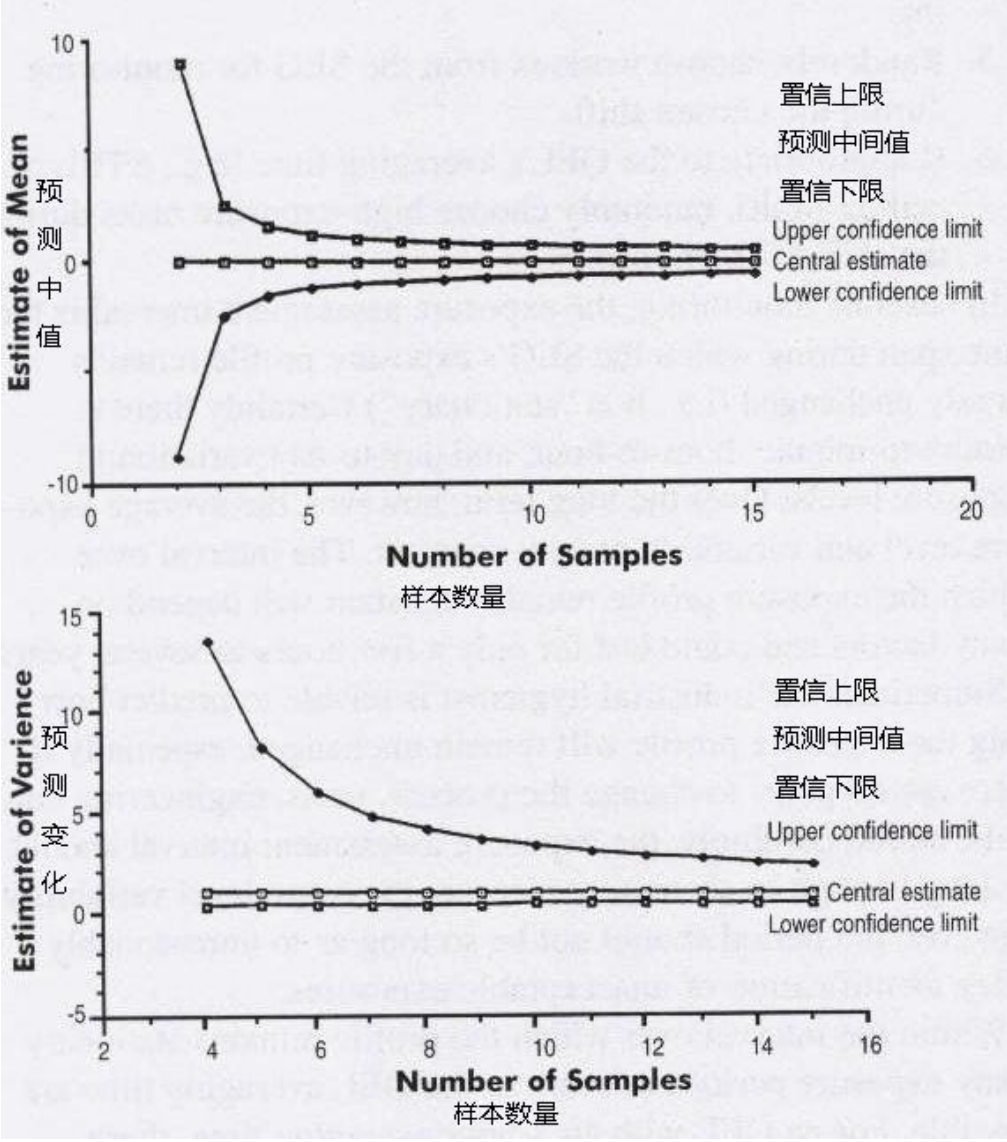
美国工业卫生协会（AIHA1998 年和 2006 年）采取一个更普遍的方法，根据这个方法，6-10 个样本足以说明暴露情况。

In respect to the minimum number of samples to be collected, fewer than six (6) samples in any one SEG leaves a great deal of uncertainty about the exposure profile (AIHA 2006).

关于最低采样数量，在任何一个 SEG 中，如果样本少于 6 个，就会使暴露情况产生很大不确定性（AIHA 2006 年）。

Figure 5.1 demonstrates this point. Many statisticians will suggest only three samples are required, however a minimum of six gives greater confidence and meets the minimum sample requirements for many computer based statistical packages.

图 5.1 演示了这一点。许多统计学家可能建议只需 6 个样本，但达到 6 个会更可靠，能满足众多计算机统计软件包的最少样本要求。



(Source: AIHA 1998 – *Used with permission of the American Industrial Hygiene Association 2007*)

（来源：AIHA 1998 年–在美国工业卫生协会许可下使用，2007 年）

Figure 5.1 – AIHA Sample Guide

图 5.1– AIHA 样本指南

Statistical analysis of data using software packages make evaluation of data relatively simple however decisions need to be made by the Occupational Hygienist as to which metric (Mean, Geometric Mean, MVUE, 95%ile, Upper Tolerance Limit etc) should be used to judge compliance (see section 5.1.5). This will depend on statutory or corporate requirements.

使用软件包进行数据静态分析可用来评估相对简单的数据，但是必须由职业卫生师就应用什么标准（平均数、几何平均数、MVUE、95%倾向、上公差极限等）来判断合规性（参看 5.1.5 部分）进行讨论。这取决于法律或公司要求。

Normally monitoring programmes should be conducted so as to ensure weather patterns are considered.

正常来说监测程序应确保考虑到天气模式。

Once a SEG has been evaluated it should be managed as per the flow chart in Figure 5.2.

一旦对 SEG 做出评估，应根据图 5.2 的流程图进行管理。

When considering monitoring strategies for any contaminant, reference should be made to appropriate documentation to ensure that participants have a full understanding of the principles supporting a statistical monitoring programme.

在考虑任何污染物的监测策略时，应参考适当的文件来确保学员能充分理解作为统计监测方案依据的原理。

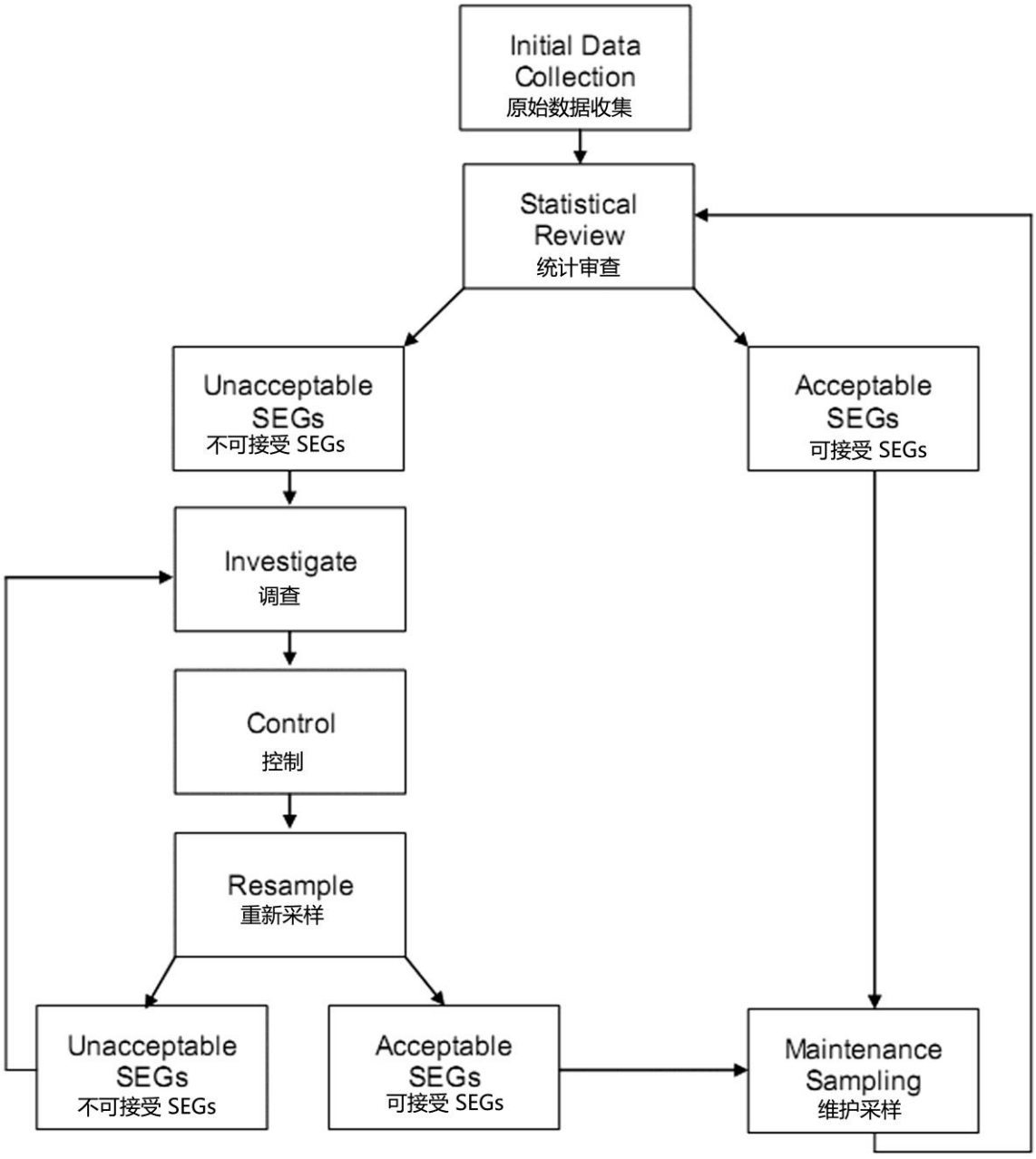


Figure 5.2 – Process for Evaluating Unacceptable SEGs (HEGs)

图 5.2– 不可接受 SEG（HEG）评估流程

5.1.4 Interpretation of Results

In its most simplistic form, the interpretation of a set of workplace exposure measurements depends on the original purpose of the sampling exercise.

If the original exercise was for compliance purposes then that legislation will direct how the data is to be evaluated (eg compliance with a prescribed exposure standard). If however, the original purpose of the exercise was to meet either corporate or epidemiological requirements, a different approach will be necessary. An overview of the different approaches is provided below.

• Compliance Analysis

One of the significant issues that must be understood with all workplace monitoring is the high degree of variability in workplace exposures within a group of workers carrying out similar tasks from day to day. Invariably this variation is much greater than that attributable to sampling and analytical errors.

In many countries the means of dealing with this variability has been the use of appropriate sampling strategies linked with the professional judgement of the occupational hygienist performing the analysis of the data.

For example if all the exposures are well below the exposure standard (half of the

5.1.4 结果解释

简而言之，要根据采样的最初目的来解释一组工作场所暴露测量结果。

如果本来的目的是为了检验是否符合规定（例如，是否符合规定的暴露标准），那么应根据法律要求进行数据评估。但是，如果本来的目的是检验是否符合公司和流行病预防要求，那么就要采用不同的方法。以下简要介绍了一些分析方法。

- **合规性分析**

其中一个重要问题是必须理解，无论任何工作场所监测，从事类似工作的一组工人的每天暴露值都有重大差异，但这些变化总是远远高于那些导致采样和分析误差的变化。

在许多国家处理这些变化的方法就是采取适当的采样策略，同时结合从事数据分析工作的职业卫生专家的专业判断。

例如，如果所有暴露都远远低于暴露标准（许多卫生专家采用标准的中间

exposure standard is used by many hygienists), the process is under reasonable control and judged to be acceptable. This does not mean that problems may not still exist, however if they do they will usually be as a result of unusual circumstances (eg maintenance). If the exposure data is below the exposure standard but approaching it, then the situation requires further evaluation and potentially the introduction of better controls. If however, the exposures are above or very close to the exposure standard then the process is probably out of control and a mitigation programme to control exposures should be developed.

值），那么就意味着流程得到合理控制，暴露情况是可接受的。但这并不意味着没有问题，如果有人做出这种判断，通常是处于特殊情况（例如维护）。如果暴露数据低于标准，但是很接近，那么就需要进一步评估，可能还要使用更好的控制方法。但是如果暴露值刚好高于标准，那么流程可能失控，就要制定一个暴露缓解方案。

• Non-Compliance Analysis

When considering monitoring programmes which are non-compliance dependent, the interpretation of the data is solely end use dependent. For example many large organisations require their business units to conduct routine monitoring programmes, the results of which may be used for different purposes. Increasingly, organisations are moving to statistical based programmes and are using statistical tools (see section 5.1.5) to assist in the evaluation of that data.

- **违规性分析**

在考虑不符合规定的监测方案时，必须根据终端使用来解释数据。例如，许多大组织要求其业务部门执行常规监测方案，执行结果可能会用于不同目的。越来越多的组织开始基于方案进行统计，使用有助于数据评估的统计工作（参看详见 5.1.5）。

Interestingly, there is no uniform approach within industry as to which statistical metric should be used, with

重要的是，关于统计标准，行业内没有一定之规，有人用可信度为 95%，另一

some using the 95%ile, others the geometric mean and some the 95% upper confidence limit of the Minimum Variance Unbiased Estimate (MVUE). While these metrics will be discussed in section 5.1.5, it is useful to show the diversity of interpretation within the industrial environment.

些人采用几何平均数，还有一个人用最小方差无偏估计（MVUE）的置信上限95%。关于这些标准的讨论详见 5.1.5 部分，根据行业环境进行多元化解释是有必要的。

For epidemiological purposes, interpretation of the data usually involves placing exposures into broad groupings (eg high, medium and low) so that these can be linked to health effects. This usually involves complex statistical analysis on a group basis which can be distinctly different from interpreting individual exposures.

从流行病预防方面来说，数据解释一般涉及考虑多个群组的暴露情况（例如高、中和低暴露），这样才能显示暴露对健康的影响。这通常涉及复杂的分组统计分析，这与人体暴露解释方法截然不同。

No matter what the situation, interpretation of exposure data is an important task and should only be undertaken by those qualified and experienced to do so. This does not mean that you should not do this task but merely suggests that if you don’t have experience in this area then you should seek the input of someone who does.

无论情况怎样，解释暴露数据是一项重要任务，只能由经验丰富的专业人员进行。这并不意味着你不能做这项工作，只是提醒你，如果你没有这方面经验，你要找一个有经验的帮手。

5.1.5 Basic Statistical Analysis

5.1.5 基本统计分析

In the interpretation of data statistical tools provide a powerful option, however it is important that their theoretical basis and limitations are understood.

在解释数据时，统计工作是一个有力的选择，但必须理解理论基础和局限性。

In many cases the rules for applying statistical analysis techniques to data are

在许多情况下，统计分析技术的规则非常严格，在现实生活中许多情况下可能

very rigid and in many real life cases may be difficult to meet. For example, the requirement for random sampling may present challenges, especially as few work processes are constant from day-to-day. Nevertheless, such requirements should be observed as much as is possible and in the end a degree of "professional judgement" will be required.

很难符合这些规则。例如，随机采样要求可能很难满足，因为工作内容很难天天都一样。此类要求应尽可能地遵守，总之，需要一定的职业判断能力。

• Distribution of Data

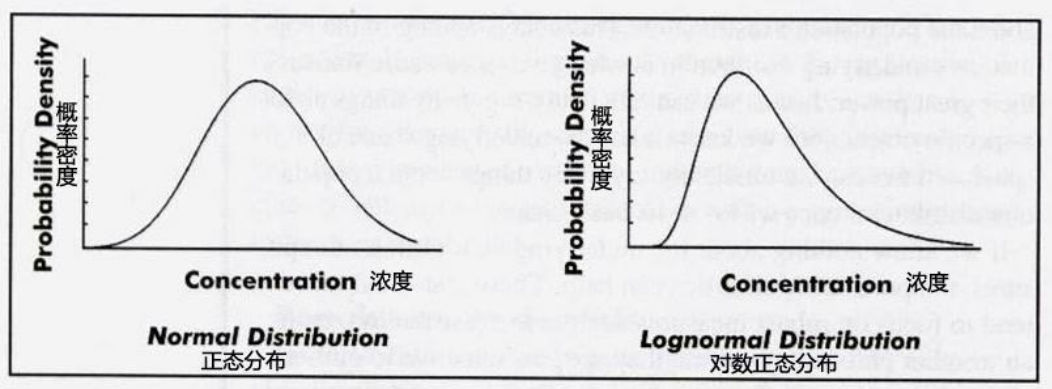
• 数据分布

A distribution is a description of the relative frequencies of the members of that population. In essence, a distribution of a dataset describes how the data is distributed about a central point.

分布是人口成员相对频率的一种描述。从本质上说，数据集分布描述了数据怎样围绕中点分布。

Two distributions are commonly encountered in reviewing occupational hygiene data. If the data is distributed equally around a simple central mean (ie about as many values are above the mean as below), this kind of distribution is referred to as a "normal" or Gaussian distribution. However, if the data is not symmetrical about a simple central mean but skewed to one side then this type of distribution is referred to as lognormal. Both these distributions are indicated in Figure 5.3.

在审查职业卫生数据时一般将两种分布放在一起考虑。如果数据在简单中值附近均匀分布（即中值上下的值一样多），这种分布就是常态分布，或高斯分布，但是，如果数据不是在简单上值附近对称对布，而且是偏斜到一侧，那么这种分布就叫对数正态分布。两种分布详见表 5.3。



(Source: AIHA 1998 – *Used with the permission of the American Industrial Hygiene Association 2007*)
（来源：AIHA 1998 年–在美国工业卫生协会许可下使用，2007 年）

Figure 5.3 – Normal and Lognormal Distributions
图 5.3–正常和对数正态分布

Each of these distributions can be described in statistical terms by the use of simple descriptors, eg arithmetic mean (AM) and standard deviation (SD or s) for a normal distribution and the geometric mean (GM) and geometric standard deviation (GSD) for a lognormal distribution. While the AM and GM tells us information about the central tendency of data, the SD and GSD tell us about the variability of the data.

这些分布中每一个都能使用简单的描述符，用统计学方法进行描述，例如，对于常态分布来说，采用算术平均数（AM）和标准偏差（SD 或 s），对于对数正态分布来说采用几何平均数（GM）和几何标准偏差（GSD）。AM 和 GM 告诉我们，关于数据中间趋势的信息，SD 和 GSD 告诉我们关于数据可变性的信息

Observations of many occupational hygiene datasets have shown that it is usually highly skewed to the right (but not always). One reason for this is that exposures cannot be less than zero so the left tail of the distribution is compressed whereas there is potentially no upper limit to exposure levels in a workplace.

许多职业卫生数据集观察资料已经说明偏斜度通常很高（但不总是这样）。其中一个理由就是，暴露不可能小于 0，因此，分布的左侧尾部是被压缩的，但是工作场所暴露水平很可能没有上限。

Thus, it is reasonable to assume that the underlying distribution for workplace exposure data is the lognormal

因此，假定工作场所暴露数据基本分布是对数正态分布是合理的，除非另有明确理由。但是应检验对数据集对数正态

distribution unless there is a compelling reason to believe otherwise, however the assumption of lognormality of a dataset should be checked.

假定。

• **Basic Statistical Formulae**

•基本统计公式

The following simple formulae are used to calculate the AM and SD for normal distributions and GM and GSD for lognormal distributions.

以下简化公式用于计算常态分布 AM 和 SD 和对数正态分布 GM 和 GSD。

$$AM = \frac{\Sigma X_i}{n}$$

$$SD(s) = \sqrt{\frac{\Sigma (X_i - \bar{X})^2}{n - 1}}$$

Where ∑ = sum of data items of X and n is the number of observations
这里 ∑ = X 数据项总数，n 是观察数据数量

$$GM = e^{\frac{\Sigma (\ell n X)}{n}}$$

$$GSD = e^{\sqrt{\frac{\Sigma (y_i - \bar{y})^2}{n - 1}}}$$

Where y = ℓnX and n = number of observations
这里 y = ℓnX，n = 预测报告数量

When interpreting data the following guidance is of value:
在解决数据时，最好参考以下指南：

GSD	Inference
1.0	No variability. All readings have the same value
<1.44	Data approximates a normal distribution
1.5 - 2.0	Very little variability in data
2.0 – 3.5	Moderate variability in data
> 3.5	High variability in data

• **Other Statistical Measures**

Other statistical measures in common use include:

• Upper and lower confidence limits
• 95th percentile
• Minimum variance unbiased estimate

Confidence limits allow one to gauge the uncertainty in the parameter that we are estimating (AM or GM). For example the wider the confidence limits the less certain we are of the point estimate of the parameter (AM or GM). Confidence limits are usually calculated for the AM or GM in order to determine, with a specified degree of confidence (usually 95%), the range in which the true population parameter (AM or GM) is likely to lie.

Forming a “picture” of an exposure profile"s upper tail is especially important when evaluating the health hazards of agents with acute health effects. It is also useful when estimating the risk of non compliance to an exposure standard: usually the 95th percentile (95%ile) is used and can be calculated using statistical

GSD	推论
1.0	无变化。所有读值都相同
<1.44	数据接近一个常态分布
1.5 - 2.0	数据很少变化
2.0– 3.5	数据正常变化
> 3.5	数据经常变化

• **其它统计措施**

一般还采用其它一些统计措施：

• 置信上下限值
• 95%
• 最小方差无偏估计

置信区间使我们能测量所估计的参数（AM 或 GM）的不确定性。例如，置信区间范围越大，我们对参数（AM 或 GM）的估计就更不确定。置信区间通常用于计算 AM 或 GM，用特定置信水平（通常为 95%）确定真正总量（AM 或 GM）可能无法准确表达的范围。

在对具有急性健康影响的试剂的健康危害进行评估时，尤其注意要使暴露廓线上尾部形成一幅图像。这同样有助于估计不合规对暴露标准产生的风险：通常采用 95%，并使用静态技术或图形进行计算（请参考对数正态概率图）。

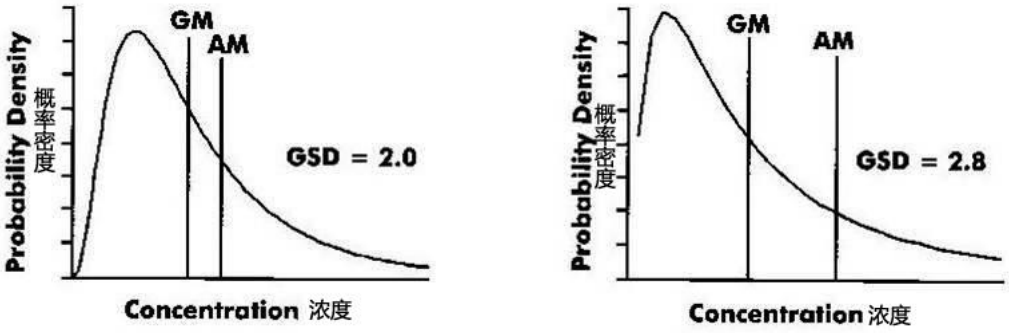
techniques or graphically (refer ***Log Probability Plots***).

The minimum variance unbiased estimate (MVUE) is especially useful in those cases when the data is heavily influenced by high results.

最小方差无偏估计（MVUE）尤其适用于数字受较高结果严重影响的情况下。

MVUE is simply (but difficult to calculate) an unbiased estimate of the true arithmetic mean of a lognormal dataset. When the data has little variability (GSD <2.0) the GM and MVUE (AM) will be close together, however as variability increases (GSD 2.0 – 3.5) the MVUE (AM) will give a better estimate of the central point of the exposure profile (Figure 5.4).

MVUE 只是（但是却很难用来计算）一个真正的算术平均对数正态数据集的无偏估计。当数据变量很小时（GSD <2.0），GM 和 MVUE（AM）就会很接近，但是当变量增加时（GSD 2.0–3.5），MVUE（AM）就能更准确地估计暴露情况的中点（图 5.4）。



(Source: AIHA 1998 – *Used with the permission of the American Industrial Hygiene Association 2007*)
（来源：AIHA 1998 年–在美国工业卫生协会许可下使用，2007 年）

Figure 5.4 – AM and GM of Lognormal Distributions
图 5.4–对数正态分布 AM 和 GM

• ***Log Probability Plots***

• **对数正态概率图**

If data is expected to follow a lognormal distribution this can easily be proved via the use of a probability plot.

如果预计数据符合对数正态分布，那么就能通过使用概率图轻易证明。

The process involves ranking the exposure data from the lowest to highest and assigning each a rank from 1 (lowest

流程涉及对暴露数据从低到高排列，每列从 1（最低值）至最高值（n）。每个

value) to the highest (n). The plotting position of each is calculated from the formula:

图形位置的计算公式为：

plotting position (%)
图形位置（%）

$$= \frac{\text{Rank}}{n+1} \times \frac{100}{1}$$

Each exposure is plotted against its plotting position (%) on special log probability paper and a line of best fit drawn. If it is indeed a lognormal distribution the data should fall on or near the straight line.

每种暴露都与在特殊对数正态概率图上一条最适当的线上的一个位置（%）相对应。如果它的确是一个对数正态分布，数据应在直线上或附近。

Log probability graphs are useful in that they provide a simple means of obtaining the GM and GSD. The GM is found by reading off the concentration at the 50%ile while the GSD is obtained by dividing the concentration at the 84%ile by the 50%ile. The 95%ile (used by some organisations as a measure of compliance) can also be read off the graph if required.

正态对数概率图的用处是提供一个能获得 GM 和 GSD 的简单中值。通过将浓度读取为 50%得出 GM，而 GSD 通过将浓度分为 84%和 50%获得。在必要时还可以在图上读取 95%（一些组织用其测定合规性）。

The above process is also useful when checking that persons have been assigned to the correct similar exposure group (SEG) as described in section 5.1.4. In such cases mixed SEGs will be indicated by groups of outlying data which also follows a straight line.

以上过程同样有助于检查是否将所有人分布到 5.1.4 部分所述正确的类似暴露组（SEG）。在这种情况下，各组同样落在直线上的一些无关数据会形成混合 SEG。

While undertaking a log probability plot is a valuable exercise to enshrine the concept in your memory, most computer packages available for use with

在制定正态对数概率时，图形是一个有价值的手段，使你记忆深刻，大多数职业卫生暴露方面的计算机软件包都有这

occupational hygiene exposure data have this facility.

样的功能。

5.1.6 Quality Assurance

5.1.6 质量保证

The degree of confidence one can have in workplace exposure data is dependent on two key criteria. These are:

工作场所暴露数据置信水平取决于两个关键标准：

a) An appropriately validated analytical method

a）适当的经过验证的分析方法

b) The use of appropriate sampling methodology and practice

b）使用适当的采样方法和实践

Having one of these factors in isolation does not guarantee that the results from a monitoring exercise will be appropriate.

缺少其中任何一个因素都不能保证监测行为是适当的。

While numerous quality assurance schemes operate throughout the world in respect to analytical methods and the performance of laboratories that use them, no such schemes have been developed to cover sampling methodology and practice in workplace monitoring.

世界各地执行各种各样分析方法和实验室使用方面的质量保证方案，但是没有任何一种能涵盖工作场所采样方法和实践。

Good occupational hygiene practice dictates that self-applied quality control processes should form part of any workplace monitoring exercise. For example, the measurement protocol should be evaluated and documented in advance and then adhered to during the exercise. Analytical variation can be assessed using blank or spiked samples.

良好的职业卫生实践规定，组织内部的质量控制流程应是任何工作场所监测工作的一部分。例如，对测量协议进行提前评估和记录，然后在执行中遵守。使用未做记号的或做记号的样本对各种分析方法进行评估。

Field quality control is generally limited to field and media blanks together with well-defined calibration practices.

现场质量控制一般限于现场和 media banks，连同合理定义的校准工作。

Failure to follow such basic quality assurance practices could give rise to a lack of confidence in the results of a workplace evaluation and thus a waste of time and resources.

未能遵循这些基本的质量保证的行为会导致工作场所结果评估缺少可靠性，浪费时间和资源。

5.2 SURVEY DESIGN

5.2 调查设计

5.2.1 Non-Sampling Approaches

5.2.1 非采样方法

In recent years the concept of “control banding” has achieved significant prominence, especially in Europe.

近几年“控制段”的概念非常流行，尤其在欧洲。

The concept of control banding was developed in the late 1980"s by occupational health experts in the pharmaceutical industry. This industry uses large numbers of new chemical compounds with limited toxicity data. The experts reasoned that such compounds could be classified into bands by their toxicity and by their need for restriction of exposure. Each band was aligned with a control scheme.

“控制段”的概念于二十世纪八十年代后期由制药业职业卫生专家提出。制药业使用大量新化合物，但是其毒性数据有限。专家认为，这些化合物可以根据毒性和暴露限制要求分为若干段。每段都有一个样应的控制方案。

Control banding is a process in which a single control technology (such as *general ventilation* or *containment*) is applied to one range or band of exposures to a chemical (such as 1 – 10 mg/m^3) that falls within a given hazard group (such as *skin and eye irritants* or *severely irritating and corrosive*). Four main control bands have been developed for exposure to chemicals by inhalation:

控制段是一个过程，在这个过程中，一个单一的控制技术（例如普通通风或围堵）用于某个危险组（例如皮肤和眼部刺激或严重刺激和腐蚀）中某一范围或某一段的化学暴露（例如 1-10 毫克/立方米）。目前人们对化学吸入暴露已经制定了四个主要控制段：

• Band 1 – Use good industrial hygiene

practice and general ventilation
• Band 2 – Use local exhaust ventilation
• Band 3 – Enclose the process
• Band 4 – Seek expert advice

• 第一段–采用良好的工业卫生实践和一般通风
• 第二段–采用局部排气通风
• 第三段–对流程进行封闭
• 第四段–寻求专家建议

For some activities, processes, tasks or jobs, experts can specify that respiratory protective equipment (in combination with other control approaches) is always necessary. The most developed model for control banding has been established by the HSE of the United Kingdom.

在一些活动、流程、任务或工作中，专家应指定使用某些呼吸保护设备（连同其它控制方法）。绝大多数控制段模型已由英国 HSE 开发出来。

The control banding approach focuses resources on exposure controls and describes how strictly a risk needs to be managed. This qualitative risk assessment and management tool is intended to help small businesses by providing an easy-to-understand, practical approach to controlling hazardous exposures at work.

控制段方法的重心是暴露控制资源，并具体说明为什么要进行严格的风险控制。这种风险评估和管理工具的目的是向小企业提供一个简单易懂，实用的方法来控制工作中的有害暴露。

The principle of control banding was first applied to dangerous chemicals, chemical mixtures, and fumes. The control banding process emphasises the controls needed to prevent hazardous substances from causing harm to people at work. The greater the potential for harm, the greater the degree of control needed to manage the situation and make the risk “acceptable”.

控制段原理首先被应用于危险化学品、化学混合物和烟雾。控制分段过程强调采用控制手段来防止危险物质从对人体造成伤害。如伤害可能性很大。就要采取更高的控制程度来管理形势，将风险控制在“可接受”程度。

The basis of these bands for exposures to chemicals by inhalation is detailed in Table 5.2.

吸入化学暴露分段的依据详见表 5.2。

Table 5.2 – Control Bands for Exposures to Chemicals by Inhalation
表 5.2– 吸入化学暴露控制段

Band No.	Target Range of Exposure	Hazard Group	Control
编号	暴露浓度目标范围	危害分组	控制措施
1	>1 to 10 mg/m^3 dust >50 to 500 ppm vapour	Skin and eye irritants	Use good industrial hygiene practice and general ventilation
1	>1 - 10 毫克/立方米粉尘 >50 - 500 ppm 蒸汽	皮肤和眼部刺激物	采用良好的工业卫生实践和采取一通风措施
2	>0.11 to 1 mg/m^3 dust >5 to 50 ppm vapour	Harmful on single exposure	Use local exhaust ventilation
2	>0.11 t-1 毫克/立方米粉尘 >5 to 50 ppm 蒸汽	单一暴露有害	采用局部排气通风
3	>0.01 to 0.1 mg/m^3 dust >0.5 to 5 ppm vapour	Severely irritating and corrosive	Enclose the process
3	>0.01-0.1 毫克/立方米粉尘 >0.5 to 5 ppm 蒸汽	严重刺激和腐蚀性	流程封闭
4	<0.01 mg/m^3 dust <0.5 ppm vapour	Very toxic on single exposure, reproductive hazard, sensitiser*	Seek expert help
4	<0.01 毫克/立方米粉尘	单一暴露就会导致很大毒性，可复制	寻求专家帮助

* Exposure to any concentration of a sensitiser requires expert advice
*对于任何浓度的致敏剂暴露，必须征询专家意见。

This approach has been developed into web based applications specifically to assist small and medium-sized enterprises to do risk assessments for chemicals and mixtures of chemicals.

这种方法已经发展为网站应用，帮助中小企业进行单一和混合化学品的风险评估。

The most developed of these is COSHH Essentials. COSHH Essentials (http://www.coshh-essentials.org.uk/) (accessed December 2006) is a control banding tool that helps small and medium-

以上大多数研究成果已成为COSHH的要素。COSHH 要素（http：//www.coshh-essentials.org.uk/）（2006 年 12 月访问）是一个控制分段工具，帮助中小企业进

sized enterprises to do risk assessments for chemicals and mixtures of chemicals. This tool requires four pieces of information:

· The type of task (eg mixing liquids, sack filling, manually cleaning and disinfecting surfaces)

· The hazard classification from the material safety data sheet (MSDS) obtained from the chemical manufacturer or supplier

· The volatility or dustiness of the chemical or product

· The amount used in the task (small quantities = grams or millilitres; medium quantities = kilograms or litres; large quantities = tons or cubic metres)

The system then:

· Identifies the control band (control approach),

·produces advice on controlling risk from the chemical used in the specified task, and

· provides written guidance and documentation as a result of the assessment.

In British law, the duty to control risk remains with the employer. Both the web and paper versions of the COSHH Essentials tools are designed to assist the small or medium-sized employer meet regulatory requirements. COSHH Essentials is a free service and was developed by the HSE in collaboration with

行单一和混合化学品的风险评估。

工具要求具备四方面信息：

• 任务类型（例如混合液体、装袋、表面人工清洁和消毒）

• 化学制造商或供应商提供的矿物安全性数据表（MSDS）危险分类

• 化学或产品粉尘挥发性

• 任务使用量（少量 = 克或毫升；中量 = 千克或升；在量 =吨或立方米）

然后系统：

•识别控制段（控制方法），

• 提供如何控制具体任务中使用的化学品带来的风险的建议；和

• 在评估后提供书面指导和文件。

根据英国法律，雇主有责任控制风险。COSHH 要素工具的网站和书面版本的目的是为了帮助中小企业满足监管要求。COSHH 要素是一项由 HSE 在英国工业和贸易协会协助下开发出的免费服务。

British industry and trade unions.

A similar approach to COSHH Essentials has been developed jointly by the ILO, WHO and United Nations Environment Programme and published as the ILO Chemical Control Toolkit http://www.ilo.org/public/english/protection/safework/ctrl_banding/toolkit/icct/index.htm (accessed 2006)

ILO、WHO 和联合国环境署已经联合开发出与 COSHH 要素类似的一个方法，即 ILO 化学控制工具箱，详见 http://www.ilo.org/public/english/protection/safework/ctrl_banding/toolkit/icct/index.htm（2006 年访问）。

The ILO Toolkit has five (5) stages which need to be followed. These are:

ILO 工具箱涉及五个必要阶段：

Stage 1: Find the hazard classification and match it to a hazard group. For common solvents this has already been done and the information provided on the ILO website. For other substances there is a need to establish the risk phrases for the substance and then find the hazard group from the ILO website.

第一阶段：进行风险分类，将其与风险组进行匹配。对于常用溶剂，这一阶段已经完成，信息详见国际劳工组织网站。对于其他物质，需要建立物质的风险阶段，然后从国际劳工组织网站上找到对应的风险组。

Stage 2: Establish the amount of substance to be used and use this to determine the scale of use from the table supplied by the ILO.

第二阶段：建立物质使用量，并从国际劳动组织提供的表格中确定使用规模。

Stage 3: Establish how much of the substance will escape to the atmosphere. This is done via looking at the physical state of solids (eg pellets – low, crystalline – medium, fine powders – high) or via comparison of the boiling point of liquids to a table provided by the ILO.

第三阶段：确定多少物质会逃到大气中。这通过观察固体的物理状态（如颗粒-低，结晶介质，细粉-高）或通过国际劳工组织提供的液体沸点比较表实现。

Stage 4:Find the control approach by using a selection guide that has been prepared by the ILO.

第四阶段：通过国际劳工组织提供的选择指南确定控制方法。

Stage 5:Find the task-specific control guidance sheet(s) from a table which links the task description and the control approach.

第五阶段：从任务描述和控制方法表中查找任务控制指南表。

Once the appropriate control approach has been determined it needs to be implemented and maintained.

一旦确定适当的控制方法，就要执行和维护。

Control banding approaches are also being developed in Belgium (REGETOX project), The Netherlands (Stoffenmanager), and Norway (KjemiRisk). The World Health Organisation is working with its Collaborating Centres to pilot control banding programmes in more than a dozen countries.

比利时（REGETOX 项目）、荷兰（Stoffenmanager）和挪威（KjemiRisk）当前也在研究控制分段法。世界卫生组织与其合作中心正在全球 10 多个国家发起控制段试点项目。

It is important to realise that non sampling approaches such as COSHH Essentials and the ILO Chemical Control Toolkit are not appropriate for many situations. Such situations are “hot” processes, open spray applications, gases, etc. However, the COSHH Essentials scheme is being progressively extended by the addition of industry and task-specific guidance on many situations; see http://www.hse.gov.uk/pubns/guidance/index.htm (accessed March 2007). Sheets are

必须认识到，COSHH 要素和 ILO 化学控制工具箱等非采样法在许多情形下是不适合的。例如加热流程、开放喷雾、气体等。不管怎样，人们通过制定适用更多情形的工业和任务指南来不断发展 COSHH 要素方案，参看 http：//www.hse.gov.uk/pubns/guidance/index.ht

now available for welding, metalworking fluids, silica exposures and low-level asbestos work. Particular industries such as printing have developed customised sheets for their own specialised processes.

It should also be recognised that all such systems provide general guidance based on the most likely scenario and do not take account of individual process variations. While such systems are a useful tool for small businesses, assessment of a workplace by an experienced occupational hygienist may be (and in many cases is) required.

m（2007 年 3 月访问）。关于焊接、金属加工液、硅暴露和低级石棉作业的要素表目前已经制定。而且印刷等一些特殊行业还能获得关于其特殊流程的定制表。

还要注意到，所有这些系统提供的一般指导都是针对最可能出现的情形，而不考虑个体变化过程。对于小企业来说该系统是一个有用的工具，他们可以（许多情况下必须）指定一位由经验丰富的职业保健师进行评估工作。

5.2.2 Sample Numbers

When developing any sampling strategy, one question which always arises is "how many samples do I need to collect to provide representative and useful information?" The answer depends on what information is required from the exercise. Some examples would be:

• ***Compliance*** – The number of samples is sometimes prescribed in legislation so the decision process may be straight forward. In other cases it is necessary to collect enough samples to be able to demonstrate compliance. For very low exposures this may be just a few samples but as exposures approach the exposure standard this will require many more samples.

5.2.2 样本数量

在开发任何一个采样策略时，必须时刻考虑一个问题：多少样本才能提供代表性的有用信息？答案取决于具体情况。考虑因素包括：

- 合规性–有时法律会规定样本的数量，因此很容易决定。有时必须收集到足够的样本来符合法律规定。对于极低的暴露来说，只需要几个样本就足够了，但是有点暴露标准却要求收集许多样本。

• ***Epidemiology*** – Such exercises invariably involve collecting as much data as possible and is usually limited by time, budgets and resources.

• ***Corporate Requirements*** – Again, such programmes usually have specific requirements but in many organisations are based on one or more of the statistical monitoring approaches.

• ***Degree of Confidence*** – In such cases an increased level of confidence (99% as against 95%) will result in a significant increase in sample numbers.

Some general “rules of thumb” have been proposed (eg 1 in 10 workers should be sampled or a minimum of 3 samples with a spread of less than 25%), however such approaches should be used with care as they could significantly affect the quality of the data.

Grantham (2001) describes a number of other approaches. These include:

- 流行病学–此类实践不可避免地涉及尽可能采集更多数据，但一般受时间、预算和资源限制。
- 公司要求–此外，而且这种方案一般都有具体要求，但许多机构都基于统计监测法来制定方案。
- 置信水平– 在许多情况下如置信水平提高（例如从 95%提高到 99%），就要大大增加样本数量。

人们提出一些一般性的“拇指定律”（例如每 10 名员工就应该有 1 名被采样，或至少 3 个样本，采样比率小于 25%），但是这些方法要谨慎使用，因为它们以数据质量有重大影响。

Grantham（2001 年）还详细介绍其它一些方法，具体包括：

• ***Using rough estimates of the mean and the standard deviation***

• 粗略估计平均数和标准偏差

This approach requires some preliminary data and is represented by the formula

这种方法需要一些初步的数据，用公式表示：

$$\text{Number of samples} = \left[t_{value} \cdot \frac{CV}{E} \right]^2$$

Where t_{value} = t-statistic for degrees of freedom (number of samples -1)

CV = Coefficient of variation $\left[\frac{\text{Rough standard deviation}}{\text{Rough mean}} \right]$

E = Error that is acceptable

$$\text{CV 样本数量} = \left[t_{value} \cdot \frac{CV}{E} \right]^2$$

这里 t 值 = 自由度 t-统计（样本数量 -1）

$$CV = \left[\frac{\text{变异系数} \quad \text{粗略标准偏差}}{\text{粗略中值}} \right]$$

E = 可接受错误

For example:

If five measurements have a rough mean of 60 ppm and standard deviation of 15 ppm then

例如：

如果五次测量结果的粗略中值是 60ppm，标准偏差是 15ppm，那么：

$$CV = \frac{15}{60} = 0.25$$

No. degrees of freedom = 5-1 = 4, so value of t - statistic (from reference tables) = 2.776 (95% confidence)

自由度数量为 = 5-1 = 4，所以 t –统计值（源自参考表）= 2.776（95% 置信）

If we assume the acceptable error is 15% (0.15)

如果我们假定可接受误差率为 15%（0.15）

Number of Samples
样本数量

$$= \left[2.776 \times \frac{0.25}{0.15}\right]^2$$

$$= 4.62^2$$

$$= 21.4$$

=22 samples (approximately)

= 22 个样本（近似）

• Method of Rappaport and Selvin (1987)

This process determines the number of samples needed to test the mean exposure of a lognormal distribution of exposures against an exposure standard. This approach also requires some preliminary data and is demonstrated in Table 5.3.

• Rappaport 和 Selvin 法（1987）

该流程能确定根据暴露标准测定暴露对数正态分布的暴露中值所需的样本数量。该方法还需要使用一些初步数据，详见表 5.3。

Table 5.3 – Rappaport and Selvin Sample Number Model (α= 0.05,β= 0.10)

表 5.3– Rappaport 和 Selvin 样本编号法（ α = 0.05， β = 0.10）

	GSD				
F	**1.5**	**2.0**	**2.5**	**3.0**	**3.5**
0.10	2	6	13	21	30
0.25	3	10	19	30	43
0.50	7	21	41	67	96
0.75	25	82	164	266	384
1.25	25	82	164	266	384
1.50	7	21	41	67	96
2.00	2	6	11	17	24
3.00	1	2	3	5	6

$$\text{Where} \quad F = \frac{\text{True sample mean of exposures}}{\text{Exposure Standard}}$$

$$= \frac{\text{Approximated arithmetic mean}}{\text{Exposure Standard}}$$

GSD = Geometric standard deviation

$$\text{这里 } F = \frac{\text{真正的样本暴露平均数}}{\text{暴露标准}}$$

$$= \frac{\text{近似算术平均数}}{\text{暴露标准}}$$

GSD =几何标准偏离

α= 5% chance that it is claimed that the workplace complies with the exposure standard when in fact it does not

α = 5%机率，表示工作场所符合暴露标准，而事实上不符合。

β = 10% chance that it is not claimed that the workplace complies with the Exposure Standard when in fact it did

β = 10% 机率，不代表工作场所符合暴露标准，而事实上符合。

Table 5 has been prepared from the equations developed by Rappaport and Selvin (1987) and clearly demonstrates the fact that as the mean of the exposures approaches the exposure standard, more samples are necessary to make an accurate judgement as to whether the exposure standard is exceeded. Clearly, if the mean of the exposures is well below or greatly above the exposure standard, few samples are required. Similarly, as the variability in the data increases (increasing GSD) then more samples are needed to make an accurate judgement. While the above may seem logical, it was not until Rappaport and Selvin proposed this approach that such simple logic evolved in respect to this matter.

表 5 中的数值用于 Rappaport 和 Selvin（1987）开发的公式，清楚地显示了有必要准确判断大多数样本是否超出暴露标准。显然，如果暴露的中值低于或严重高于暴露标准，那么采样就没有必要了。同样，由于数据增加可能会发生变化（随着 GSD 的增加），那么需要更多样本来进行准确判断。虽然以上观点看起来合理，但是直到 Rappaport 和 Selvin 发现这一方法之前，人们都不认同这个简单的道理。

Other approaches are:

其它方法包括：

• NIOSH Compliance Method

• NIOSH 合规性方法

See section 5.1.3 for details.

细节参看 5.1.3 部分。

• AIHA Approach

• AIHA 法

The AIHA (1998 and 2006) indicates that there is a point of diminishing returns in respect to the number of samples required to adequately define an exposure profile. Fewer than six (6) measurements leaves a great deal of uncertainty about the exposure profile, while more than ten (10) provides additional refinement in exposure estimates but the marginal improvement is rarely cost effective.

AIHA（1998 年和 2006 年）指出，关于足以说明暴露情况的样本数量，存在一个收益递减点。如果测量数据少于 6 个，那么暴露情况就具有很大不确定性。如果超过 10 个，就会使暴露估计可靠性提高，但是边际改进的成本效率却极低。

While it is possible to obtain a reasonable approximation of an exposure distribution with 6-10 samples, as the exposures approach the exposure standard 30 or more measurements may be necessary to ensure the distribution of exposures is well defined.

虽然用 6-10 个样本可能会获得合理的暴露分布近似值，作为一个暴露标准方法，为了确定合理说明暴露分布，至少需要 30 个测量值。

5.2.3 Sampling Patterns

When designing a sampling strategy there are a number of different sampling approaches that can be adopted. These are usually based on the contaminant, type of survey, work patterns and process variability. These include:

- Grab samples
- Partial period consecutive samples
- Full period consecutive samples
- Full period single samples

In some countries this is referred to as:

- Grab sampling
- Task duration sampling
- Short period sampling (less than the task duration and sometimes taken consecutively)
- Full shift sampling

Irrespective of the nomenclature used the fundamental concept is similar.

5.2.3 采样模式

在确定采样策略时，有许多采样方法可供选择。通过根据污染物、调查类型、工作模式和流程可变性进行选择。这些方法包括：

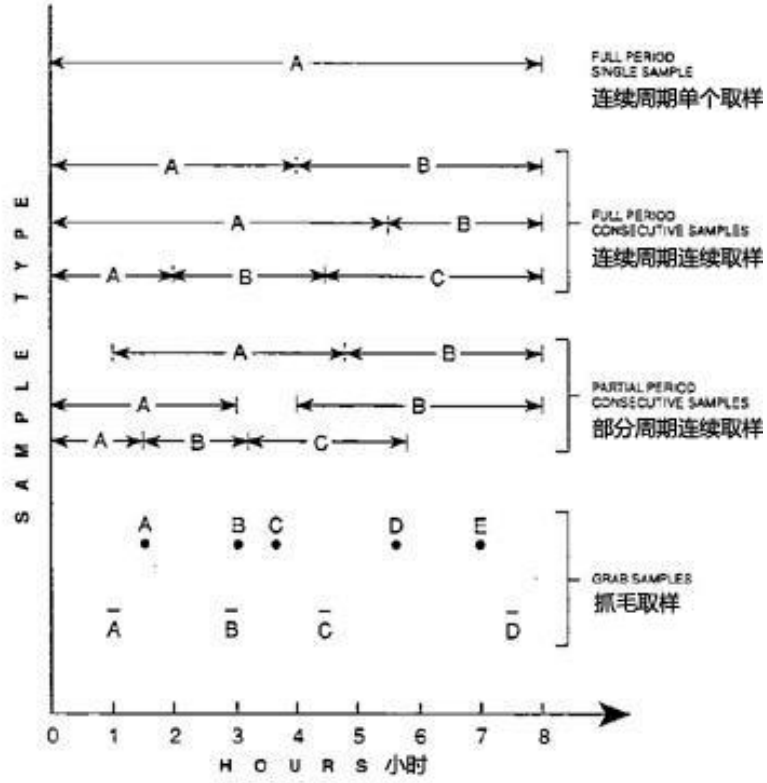
- 随机采样
- 期间某一时段连续采样
- 整个期间连续采样
- 整个期间一次采样

在一些国家称为：

- 随机采样
- 任务期采样
- 短期采样（短于任务期，有时连续进行）
- 整班采样

不考虑术语名称，基本概念都是差不多的。

These different approaches are shown graphically in Figure 5.5.
这些不同的方法详见图 5.5。



(Source: NIOSH 1977)
（来源：NIOSH 1977 年）

Figure 5.5 – Sampling Patterns
图 5.5– 采样模式

What is important to appreciate is that the sampling approach adopted must take into account the exposure pattern of the person being sampled if representative data is to be obtained. In the following discussion “period of interest” can refer to either the period upon which the exposure standard is based (8 hours in many cases) but also in modern working patterns to the period of exposure while conducting a task. It is for the hygienist to make a judgement as to what is their “period of interest” for the exercise being conducted.

如果得到代表性数据，重要的是理解使用的采样方法必须考虑到被采样人员的暴露模式。在以下讨论中，“有关期间”指暴露标准基于现代工作模式（许多情况下为 8 小时）或执行任务期间暴露时间。实际“有关期间”由卫生专家判断。

• ***Grab Samples*** – are samples lasting only a few minutes or seconds.

They are usually taken using direct reading instrumentation during an initial survey (walkthrough survey) to highlight potential exposures or sources of exposure.

• 瞬时采样– 只持续几分钟或几秒。通常他们在第一次调查（总体调查）期间使用直读仪器来了解潜在暴露或暴露来源。

• ***Partial Period Consecutive Samples*** – consists of one or more samples of equal or unequal duration covering only a part of the period of interest. The major problem with this approach is how to estimate the exposure that occurred during the period not sampled. NIOSH (1977) recommend that at least 70-80% of the full period is sampled.

• 期间某一时段连续采样– 包括有关期间一次或多次持续时间相等或不等的采样。这个方法的主要问题是怎样估计非采样期发生的暴露。 NIOSH（1977）认为整个期间 70-80%的时间是采样期。

Some international standards indicate that in situations where exposures are likely to be constant as little as 50% of the full period need be sampled. In all cases professional judgement plays a significant role in choosing the best approach.

一些国际标准认为在暴露可能是持续的情况下，将整个期间的 50%作为采样期就足够了。在任何情况下选择最佳方法都需要专业判断。

• ***Full Period Consecutive Periods*** – these cover the full period of the relevant standard (eg 8 hours for an 8 hour TWA exposure standard or 15 minutes for a STEL). This approach is very useful in those situations where the process is intermittent, thus giving data not only on the TWA exposure but also the variation in exposures in relation to the process.

• 整个期间连续采样– 包括有关标准的整个期间（例如对于 8 小时 TWA 暴露标准来说是 8 小时，对于 STEL 是 15 分钟），如果流程是间歇的，那么这个方法非常有效，这样的话不仅能提供 TWA 暴露数据，而且还能显示流程中暴露的变化。

• ***Full Period Single Samples*** – are normally carried out to establish the

• 整个期间一次采样– 通常是为了确定

average exposure of workers during their normal work day.

正常工作日工人平均暴露值。

5.2.4 Sampling to Assess Acute or Chronic Effects

5.2.4 急性或慢性影响采样

The toxicology of individual substances can have a significant influence on the design of sampling strategies. For example chronic acting substances such as crystalline silica (quartz) are sampled over an extended period (eg full shift duration) while acute acting substances should be sampled over a time period in accordance with the appropriate STEL or if the onset of an effect is rapid the appropriate use of alarmed direct reading instrumentation may be appropriate.

单个物质的毒性对采样策略会产生重大影响。例如慢性作用物质，例如结晶二氧化碳（石英）等慢性作用物质采样时间很长（例如整班时间），而且急性作用物质根据适当的 STEL 确定采样时间，如果属于急性发作，应适当使用警报直读仪器。

In some instances it may be appropriate to sample for both the full shift and over short periods as a substance may have both TWA and STEL exposure standards (eg trichloroethylene).

有时物质同时适用 TWA 和 STEL 暴露标准（例如三氯乙烯）最好同时进行整班和短期采样。

5.2.5 Practicalities of Sampling Programmes

5.2.5 采样方案实用性

While the previous sections (see also section 5.1.3) describe the various approaches to sampling and the number of samples to be collected, there are a number of practical issues that also need to be addressed.

以上部分（同时参看部分 5.1.3）描述了各种采样方法和关采集的数量，但是仍有许多实践问题需要解决。

The first of these is cost effectiveness. Large statistically-based monitoring programmes are very difficult to undertake in terms of the equipment required, the resources necessary to

第一个问题就是成本效率问题。考虑到所需设备和资源以及流程干扰问题，那些基于统计数据监测的大规模方案是不现实的。因此，除了跨国公司外，很少

undertake the exercise and the ongoing disruption to the process. Consequently it is rare for such programmes to be implemented outside of multi-national corporations and thus the question arises “what can reasonably be done?”

有公司开展此类方案，由此引出一个问题：“能做到什么程度？”

For example, a single person operating without any assistance will find it difficult to calibrate, distribute, monitor and recalibrate more than five sample collection devices at one time. Given this, it is important that the quality of the monitoring be excellent, the persons and situations determined for monitoring be appropriate and the collection of data be such that any abnormalities in results can be explained.

例如，如果无人协助，一个人可能会发现他很难同时协调、分配、监测和校准五台以上采样设备。因此，监测质量必须是保证，监测人员和条件必须适当，收集到的任何异常数据都应得到解释。

Obviously, professional judgement and experience are major factors in this situation but provided the basics are clearly understood and correctly applied, a good assessment of worker exposure can be made.

显然，专业判断和经验是这方面的主要因素，但是必须明确理解和正确应用基本信息，这样才能对工人暴露进行有效评估。

The relationship between observations (work practices, control measures, dustiness of process, etc) and measurements cannot be over-stated; it is better to have fewer samples that can be clearly interpreted than a large number of samples with limited data which can"t. The balance between what is reasonably possible to achieve and what is necessary to obtain a picture of exposure needs to be assessed for

观察数据（工人做法、控制措施、流程污染度等）和测量数据之间的关系不得夸大；明确解释几个样本比用有限数据解释一大堆样本要好得多，因为后者无法平衡能得得到的信息的和了解暴露情况所需必要评估信息之间的关系。如果一个人无法获得了解暴露情形所需必要信息，那么还需要获得其它一些资源。

each and every exercise. If one person cannot achieve what is necessary to obtain an exposure profile, then extra resources will be required.

不幸的是，经过良好培训的人员在工作场所中的采样质量可能会限制工作的程度。

Unfortunately, there is a shortage of good quality well trained people to perform sampling exercises in the workplace, which may well limit what can be done.

在许多情况下，采样方案的最终限制则流程本身。在一些情况下流程（例如很少出现的批量生产）不太适当基于统计的随机采样监测工作。在考虑能做到任何程度前必须对每个流程进行评估。

The final limitation on sampling programmes, in many cases, is the process itself. In some situations the processes (eg batch process which occurs infrequently), do not lend themselves well to statistically-based random sampling monitoring exercises. An evaluation of each process is required before considering what can be reasonably achieved.

5.3 PERSONAL SAMPLING

5.3 人体采样

5.3.1 Breathing Zone

5.3.1 呼吸区

As the main route of entry into the body for many substances is via inhalation, it is logical that any estimate of exposure of such substances should be conducted in a location consistent with normal inhalation patterns of workers. By convention, this has been deemed the “breathing zone” and is defined by some statutory authorities (eg AS2985) as:

许多物质通过吸入进入人体，因此应对工人正常吸入位置进行物质暴露评估。从传统上说，这就是“呼吸区”，许多法律机构（例如 AS2985）对其做出以下定义：

“A hemisphere of 300 mm radius extending in front of the face and measured from the midpoint of a line joining the ears.”

“从双耳连线中点开始，脸部前半径为 300 毫米的一个半球区。”

Samples collected in the breathing zone of a worker are termed “personal samples” and are directly linked to workplace exposure standards.

工人工作场所呼吸区收集到的样本即“人体样本”，直接与工作场所暴露标准有关。

Research in wind tunnels has demonstrated that the location of the sampling head can result in significant concentration differences over short distances. To avoid such variations it is common practice to attach sampling heads in the area of the worker"s lapel but still within the breathing zone.

风洞研究已经证明采样头所在位置的浓度与附近有显著差异，为了避免此类差异，普遍的作用是将采样头放在工人的衣领，始终保持在呼吸区内。

The other variable in the sampling head location equation is worker practices, which may have a significant influence on exposure. One such case occurs when a worker inserts his or her head into a reaction vessel to monitor the process.

采样头位置公式的另一个变量就是工人的工作，这对暴露有重大影响 。如果一个工人将其头部探到反应容器中来监测流程的话，就会产生暴露。

Such actions may give rise to incredibly high exposures of short duration. The sampling device needs to be positioned in such a manner within the breathing zone to collect the contaminant of concern.

此类行为会产生无法想象的短期暴露，采样设备需要放在呼吸区来收集有关污染物。

One approach to overcome (or at least minimise) some of the difficulties if factors are significantly influencing the exposure cloud, is the use of dual lapel sampling. This at least gives some estimate over the variation in the exposure profile over relatively short distances.

如果对暴露云有重大影响的话，一个克服（至少是最小化）一些困难的方法是采用双重衣领采样。至少这有助于在短期内估计暴露情况。

5.3.2 Operator Variability

The concentration of contaminants in the workplace is subject to both temporal and spatial variation and thus likely to be in a constant state of flux. This is not only due to changes in the process, but also ventilation rates, climatic conditions, etc.

For workers, the range of tasks undertaken during a work day can dramatically influence an exposure pattern and concentrations. In many cases individual approaches to performing the same task (eg left or right handed shovelling) may (and often does) result in significant exposure differences between workers performing the same task.

Such factors must be considered when designing a sampling strategy so as to ensure they are minimised.

5.3.2 操作人员可变性

工作场所污染物浓度取决于时间和空间的变化，因此可能处于一个恒定的流动状态。这不仅是由于流程的变化，而且还与通风率、气候条件等有关。

对于工人来说，在工作日承担的任务的范围对暴露模式和浓度有重大影响。在许多情况下，个人执行这些任务（例如使用铁铲）可能会（而且经常会）导致执行同一任务的工人的暴露情况有重大差异。

在设计采样策略时必须考虑此类因素来确保使其影响最小化。

5.4 AREA SAMPLING

5.4.1 General or Background Measurements

Samples which are not taken on the individual in the breathing zone are generally referred to as static (or area) samples. Such samples do not normally correlate well with actual personal exposures but they still do have a useful role. Static samples are useful for the following purposes:

• To check the performance of control devices.

• As a surrogate for personal exposures,

5.4 区域采样

5.4.1 一般或背景测定

非呼吸区人体样本一般指静态（或区域）样本。此类样本一般与人体实际暴露无关，但是同样有用。静态样本适用于以下情形：

• 检查控制设备性能；

when a clear correlation between the results from static samples and personal samples has been established.

• 当静态采样结果和人体采样结果有明显关联时代替人体采样；

• In identifying and quantifying contaminant sources in the workplace and in delineating areas of unacceptable contamination.

• 识别和量化工作场所和显示污染情况无法接受的区域的污染物来源；

• As part of the process for assessing trends in baseline concentrations.

• 作为检查基线浓度趋势的流程的一部分；

• Are sometimes the only realistic means of measurement when certain types of continuous monitoring are required.

• 当需要某些类型的持续监测时，经常被作为可行的唯一方法。

• As the only realistic method of sampling high volumes of air (eg asbestos clearance monitoring).

• 在采集大量空气样本（例如石棉间隙监测）时被作为可行的唯一方法

It should be understood that workplace exposure standards are linked to personal sampling and the use of static or area samples for health assessment is not generally accepted.

必须理解工作场所暴露标准与人体采样有关，在健康评估中使用静态或区域样本一般不被认可。

5.4.2 Particle Size

5.4.2 颗粒尺寸

The way in which aerosols distribute themselves in an airstream depends on the aerodynamic properties of the aerosol concerned. When applied to dust, larger particles tend to settle out of the air quite quickly due to gravitational forces and smaller particles tend to remain airborne for longer periods.

浮质在气流中分布的方式取决于有关浮质的空气动力学特性。对于粉尘来说，较大颗粒由于重大趋向于在空气中下沉，而且较小的浮质会在长期内在空气中漂浮。

Such behaviour is directly attributable to the aerodynamic diameter of the particles. If a dust particle has the same settling velocity as a spherical particle of

此类行为与颗粒的空气动力学直径有关。如果一个粉尘颗粒和一个单位密度（1 克/立方厘米）和直径为 1 微米的球

unit density (1 g/cm^3) and diameter of 1 µm, it is deemed to have an aerodynamic diameter of 1 µm. This is independent of the particle"s size, shape, density and mass.

形颗粒的下降速度相同，其空气动力学直径就视为 1 微米。这与颗粒尺寸、外形、密度和质量无关。

This concept is fundamental in our understanding of why particles deposit in the lungs and airways in the manner that they do.

我们在理解为什么颗粒会以其特有方式进入肺中和呼吸道时要以这个概念为基础。

Particle size also has an influence on contaminant concentration. If we have a mixed dust of varying particle size, upon settling it is not unusual to find one particular contaminant is highly concentrated in one size fraction. This could mean that close to a source concentrations of the contaminant are relatively low (on a mass/mass basis), however at a point where the finer particles have settled the concentration is significantly higher.

而且颗粒尺寸还会影响污染物的浓度。如果粉尘中的颗粒大小不一，在沉降时通常会发现某个粒度级区域某种污染物的浓度特别高。这意味着接近污染源的地方污染物的浓度相对较低（基于质量比），但是在较细颗粒沉降的点浓度显示增高。

5.4.3 Breathing Air Quality

Air supplied or self-contained breathing apparatus relies on the use of air generated by air compressors to provide the air source. It is important to ensure that the quality of this air is assessed at regular intervals to check for contaminants such as carbon monoxide and oil mist, which may have been inadvertently generated by the compressor. If significant pipework is used to direct the breathing air around a plant, it is not uncommon for condensation to occur in the pipes, leading to corrosion.

5.4.3 呼吸空气质量

供气或独立呼吸设备以空气压缩机产生的气体作为气源。必须定期评估空气质量来检查压缩机无意中产生的一氧化碳或油雾等污染物的存在。如果使用重要管道设备来引导工厂附近的呼吸气体，管道会很容易产生冷凝，导致腐蚀。在一些情形下此类腐蚀会使空气中出现涩味。

Under some circumstances such corrosion can give rise to an astringent taste in the air.

In most commercial systems filters are installed to control moisture, oil mist and carbon monoxide, but these have a finite life and need to be changed when expended.

There are varying approaches to monitoring these contaminants in the air but the advent of direct reading devices has made the inline analysis of carbon monoxide on site relatively easy.

In modern systems continuous monitoring instrumentation for carbon monoxide and built-in filtration are common. For older systems it may be necessary to sample the breathing air using external procedures. In such cases air is drawn into a gas sampling bag from which it is extracted and presented to the instrument (carbon monoxide monitor or indicator tube) for measurement. Oil mist is usually sampled by passing a known volume of air through a small pore size filter. The collect oil is either analysed gravimetrically or more accurately by infra-red or gas chromatographic means.

在大多数商用系统中都使用过滤器来控制湿气、油雾和一氧化碳，但是过滤器寿命有限，需要花钱更换。

有许多监测空气中污染物的方法，但是直接读值设备的出现使现场一氧化碳内联分析变得容易一些。

在现在系统中，一氧化碳持续监测仪器和内置过滤系统非常普遍。对于较老的系统来说，必须借助于外部流程进行呼吸气体采样。在这方面，就要使用一个先抽取气体，然后再抽进食仪器（一氧化碳监测器或指示器）的气体采样包来进行测量。油雾采样的过程一般是使已知体积的气体通过一个孔隙较小的过滤器。油雾一般通过重量分析，如果为了获得更精确的结果，就使用红外或气体层析法 。

5.5 SURFACE AND OTHER MEASUREMENTS

5.5.1 Surface Contamination Measurements

If a comprehensive risk assessment for exposure to contaminants in the workplace is to be developed, it is essential that any contribution from surfaces be evaluated. This will always be dependent on the toxicological properties of the substance and is common practice in the nuclear industry.

There are various methods used for evaluating surface contamination, such as micro vacuuming, disposable paper towels and manual wipe methods. The manual wipe method (also called smear and wipe) is the most commonly used and involves a filter paper being drawn over a known area of contaminated surface and then being analysed to produce an assessment of the level and nature of the deposit.

Another method which has shown good results in laboratory trials (Wheeler& Stancliffe 1998) is the use of adhesive tape, more specifically forensic tape. Such tapes are constructed of a clear plastic top coat, a sticky middle layer and a base layer. By removing the clear plastic top coat the sticky layer can be pressed into a surface thus collecting what contaminants are present. In general samples (both wipe and adhesive tape) are treated with acid to dissolve any

5.5 表面和其它测量

5.5.1 表面污染物测量

如果制定了一套工作场所污染物暴露综合风险评估方法，就必须评估表面的任何物质，这必须依赖于物质的毒性，在核工业中这是很普遍的做法。

有许多评估表面污染物的方法，例如微真空法、一次性纸巾法和手擦法。手擦法（又叫抹布法）用法最为普遍，涉及在已知面积的污染物表面上设置一张过滤纸，然后对其进行分析，得出沉降物水平和性质评估结果。

实验室实验（Wheeler 和 Stancliffe，1998 年）中另一个效果较好的方法是使用胶带，更有针对性的法医专用胶带。这种胶带由一个无粘性的上部塑料层、一个粘性的中间层和一个基层组成。将无粘性的上层揭开，然后将粘性中层压在表面，那么就会收集到上面的污染物。一般来说，样本（抹布或胶带）用酸处理，使上面的污染物溶解，然后用原子吸收分光光度测量法分析，或不使用酸性消化技术，而且是使用 X

contaminants present, followed by atomic absorption spectrophotometry, or the samples can be analysed without any acid digestion by X-ray fluorescence spectrometry (XRF).

射线荧光光谱测定法（XRF）进行分析。

Other approaches to assessing contaminated surfaces involve the use of pH sticks or colorimetric pads (acids and alkalis) or instrumentation such as mercury sniffers (the high vapour pressure of mercury makes this a particularly effective technique).

还有一个评估被污染表面的方法是使用 PH 棒或比色板（酸和碱）或汞嗅探器等仪器（高压汞尤其有效）测定。

The question as to why you would undertake surface contamination invariably arises. Such sampling (especially during evaluation of contaminated waste sites) improves the characterisation of what hazards may be present and allows for better decision-making.

现在有一个问题：为什么你会认定表面存在污染。此类采样（尤其是评估受到污染的废物现场期间）会改善危害存在的特征，有助于做出更好的决定。

Surface contamination samples can indicate sources of leakage and help to track the spread of contamination. They can give an indication of how and where skin contact might occur. However, they are not a direct measure of exposure and cannot readily be compared with any exposure limits.

表面污染样本会指示泄露来源，有助于跟踪污染物的分布。它们能说明皮肤接触的方式和位置。但是，它们无法直接用来测定暴露和与任何暴露限值进行比较。

5.5.2 In-situ XRF Metal Analysis

5.5.2 现场 XRF 金属分析

An XRF spectrometer uses primary radiation from an X-ray tube to excite secondary emission from a sample. The radiation emerging from the sample includes the characteristic X-ray peaks of

XRF 分光计使用 X 射线管中的初级辐射来刺激样本的二级发射。样本辐射包括样本中存在的主要和可追踪元素的典型的 X 射线峰。这些二级 X 射线漫射

major and trace elements present in the sample. Dispersion of these secondary X-rays into a spectrum, usually by X-ray diffraction, allows identification of the elements present. The height of each characteristic X-ray peak relates to the concentration of the corresponding element in the sample, allowing quantitative analysis of samples for most elements in the concentration range 1 ppm to 100%.

进一个光谱-一般由 X 射线衍射实现-使人们能识别各个元素的存在。每个典型 X 射线峰的高度与样本中有关元素的浓度有关，使大多数元素浓度的样本量化分析限于 1 ppm -100%的范围内。

In recent years small hand-held XRF analysers have been developed which are extremely useful for measurements of samples within the field. One such application is their use to measure elements in contaminated soils and unknown bulk materials. This is particularly useful for metal analysis.

便携式 XRF 分析仪近几年刚刚面世，它对于现场样本测定来说极为有效。其中一个用途就是测定受过污染的土壤中的元素和未知的批量物质。尤其适用于金属分析。

It should be noted that particle size and surface preparation can influence results. Improved analysis can be achieved if the sample is dried, sieved, ground or pressed.

请注意，颗粒尺寸和表面预备也会影响评估结果。如果样本经过干燥、过滤、研磨或碾压，那么分析结果会更准确。

Dost (1996) evaluated a field XRF unit in relation to the measurement of dusts from surfaces in workplaces and commented on the ease with which the elemental nature and level of contamination in the workplace could be determined. Dost also concluded that the XRF technique had a distinct advantage over the traditional wipe method where the contaminant material

Dost（1996 年）对测定工作场所表面粉尘的野外 XRF 仪器进行了评价，认为它能测定工作场所污染的自然性质和水平。Dost 还认为，XRF 技术与将污染物粘在粗糙的、多孔渗水的表面（例如混凝土）的传统抹拭法相比有重大优势。但是它不适合钢等表面，因为它在收集表面元素的同时也将污染物覆盖在

was on a rough and porous surface (eg concrete). Conversely, it was not suitable on surfaces such as steel as it picked up the elements of this surface as well as the overlaying contaminant material.

上面。

A common use for XRF instruments is in the evaluation of coatings for the likely presence of significant amounts of lead.

如果有可能存在大量的铅，那么涂层评估一般使用 XRF 仪器。

5.5.3 Bulk Sampling

5.5.3 批量采样

In many instances it will be necessary to collect some bulk samples to identify which contaminants are likely to be present in the workplace. This is commonly the case in regard to asbestos identification where bulk samples are collected and the presence and type of asbestos identified by dispersion staining or other confirmatory techniques.

在许多情况下必须收集批量样本来识别工作场所可能存在的污染物。在识别石棉时，人们一般收集批量石棉，通过分散着色或其它确认技术来判断石棉的存在和类型。

The same principles can be applied to other unknown substances found in workplaces. Before developing a monitoring programme, bulk samples of an unknown material can be sent to a laboratory for analysis to check on the specific contaminants present and to check for any contaminants which may interfere with some sampling methods.

如果工作场所还存在其它一些不知名物质，可根据相同原则确定。在制定一套监测方案前，将不知名物质的批量样本送到实验室进行分析来检查是否存在特定物质，并检验是否有会对一些采样技术造成干扰的任何污染物。

The results will guide what type of monitoring strategy is required and thus it is very useful in the overall process.

判断结果将用来指导监测策略类型，对于整个流程来说非常重要。

5.5.4 Skin Exposure

Dermal exposure can present a significant pathway for some contaminants to enter the body. This is especially the case with pesticides, but other compounds can be absorbed this way.

Dermal exposure evaluation methods have been broadly categorised into direct and indirect methods.

• Direct

Direct means assessing what is deposited onto the skin; indirect means estimating dermal dose either as attributable to some biologic indicator that is actually measured or that which could potentially result from a contaminant measured on an accessible surface.

The most common direct method is the use of dermal dosimeters in the form of patches. Other direct evaluation methods include skin washes and wipes, and the video detection of fluorescent tracers.

• Indirect

Indirect methods refer primarily to measuring a biologic response such as cholinesterase activity in blood or urinary excretion, but also include measuring surface contamination.

In comparison to air sampling and even biological monitoring, dermal dosimetry is not a simple or routine procedure.

5.5.4 皮肤暴露

皮肤暴露是一些污染物进入一体的重要路径，尤其是一些杀虫剂，还有一些化合物也通过这个路径被人体吸收。

皮肤暴露评估方法在广义上被分为直接法和间接法。

• 直接法

直接法指分析是什么物质粘在皮肤上，间接法指用某个实际测得的或源自可接触表面测得的污染物的生物指标来估计皮肤剂量。

最普遍的直接法是以皮肤贴片的形式使用放射量测定器。其它直接评估法包括皮肤清洗和擦拭，以及荧光追踪器视频探测。

• 间接法

间接法主要指测定血液或尿液中胆碱脂酶活动等生物反应，但也包括测定表面污染。

与空气采样，甚至生物监测相比，皮肤放射量测定不是一件简单或经常采用的程序。

An individual applying dermal dosimeters should be thoroughly trained regarding the placement and retrieval of the dosimeters and recording of observations and other information about the activity.

适用于人体放射量测定的人应经过放射量测定器定位和取出，以及观察数据和其它活动信息记录培训。

In addition to objective parameters, observed work practices can also have statistically significant important influences on dermal exposure.

除了客观参数外，观察工作实践对统计皮肤暴露影响也具有重大作用。

Each patch dosimeter is a sandwich holding a passive matrix (like a cotton gauze sponge) flat and to protect it from skin perspiration. Either one or two sets of patch dermal dosimeters can be used. The most important is the set placed against the skin under the clothing. It is believed that errors will result from using patch dosimeters attached to the inside of clothing that is free to move relative to the skin; such dosimeters will neither collect contaminants reaching the skin via penetration through openings (such as the neck, sleeves, or cuffs) nor be affected by the air motion carrying contaminant through the weave of the fabric. A second set of dosimeters may be placed outside of any clothing; it is also important that no inner dosimeter is placed beneath an outer dosimeter.

每个皮肤贴片放射量测定器都是一个中间夹着一层防止皮肤排汗损害仪器的被动矩阵（例如一层棉布）的“三明治”。一般使用一套或两套皮肤贴片放射量测定器。最重要的是放在外衣内，紧贴皮肤的那一套。人们认为在衣服下面使用不会相对于皮肤移位的皮肤贴片放射量测定器会产生误差。此类放射量测定器不能通过开口（例如脖子、袖子或被器）渗透收集皮肤污染物，也不能通过纤维织物，受到携带污染物的空气运动的影响。第二套放射量测定器可固定在衣服外。注意：外部放射量测定器下不要放置内部测定器。

After dosimeters have been in place throughout an activity involving exposure, they are carefully removed, prepared for extraction (the quantitative removal of the chemical from the collection matrix),

当完成涉及暴露的整个活动后，要将放射量测定器小心取下，准确提采样本（从收集到的样本中取出一定量的化学

and the extract is analysed for the mass of chemical.

品），进行化学质量分析。

Whole body dosimeters are typically a set of long cotton underwear that minimises the effect of non-uniform depositions within a body part, but suffers from the lack of a barrier between the skin and dosimeter and may add heat stress to the wearer. After use, the whole body dosimeter may still be dissected into portions covering individual body parts.

全身放射量测定器一般是一套棉质长内衣，这样就能尽量避免人体部位上不均匀沉积造成的影响，但是这样的话皮肤和放射量测定器之间没有隔离，可能会对使用者产生热应力。在使用后全身放射量测定器可能会裂开，粘在人体某个部位。

As with all other approaches to assessing dermal exposures, there are limitations to the use of dermal dosimeters. Among the most important of these limitations (not restricted to dermal dosimeters) is the difficulty in accurately collecting depositions of volatile chemicals.

与所有其它皮肤暴露测定方法一样，使用皮肤放射量测定器也有很多局限。其中最重要的是（不限于皮肤放射量测定器）它很难收集挥发性化学品沉降物。

Biological monitoring to assess dermal exposure is a common technique (eg cholinesterase activity in blood for pesticides); however it may be invasive and unless correct sample collection techniques are observed may grossly underestimate exposure. In such cases dermal dosimetry (patches) may be a good alternative.

皮肤暴露生物监测是一门很普遍的技术（例如为了检测杀虫剂，监测血液中的胆碱脂酶活动），但是它很可能是侵入性的，可能会低估暴露的严重性，除非采用正确的采样技术。在这种情况下皮肤放射量测定（皮肤贴片）可能会有用。

In other cases (Tetraethyl lead) where skin absorption is a significant exposure pathway, a combination of environmental monitoring and biological monitoring may give the most accurate picture of employee exposure.

在另外一些情况下（例如四乙铅），如果皮肤吸入是一个重要暴露途径，环境监测和生物监测结合使用是了解员工暴

Irrespective of the circumstance, dermal monitoring should only be undertaken by persons trained and experienced in the appropriate monitoring techniques.

不考虑具体情况的话，皮肤监测只能由经过培训，经验丰富的人员使用适当的监测技术来进行。

Tool kit for Dermal Risk Assessment and Management - RISKOFDERM

皮肤风险评估和管理工具箱-RISKOFDERM

The European Research Project RISKOFDERM – Risk Assessment of Occupational Dermal Exposure – has developed a conceptual model for dermal risk assessment and a simple to use tool kit for assessment and management of health risks from dermal exposures and is currently undergoing final evaluation. The tool kit can be downloaded at:

欧洲研究项目 RISKOFDERM– 职业皮肤暴露风险评估–已经开发出一个皮肤风险评估概念模型，只要使用一个工具箱就能评估和皮肤暴露管理健康风险，目前研究人员正在进行最终评估。工具箱下载网址为：

http://www.eurofins.com/research-development/occupational_hygiene/risofderm.asp

http：//www.eurofins.com/research-development/occupational_hygiene/risofderm.asp

The tool kit was constructed by analysing the major determinants of dermal hazard and control exposure. The results were combined in the form of a decision tree. The tool kit does not show all the details behind the assessment, but asks the user a series of questions that are translated by the system into hazard and exposure categories that lead to an estimate of health risk from dermal exposure together with suggested control strategies.

工具箱通过分析皮肤危害和暴露控制的主要决定性因素进行分析。结果以决策对的形式结合。工具箱未显示评估背后所有细节，但是向用户提出一连串问题，由系统转化成为危险和暴露类别，用于评估皮肤暴露的健康风险以及推荐的控制策略。

Hazard

The user is asked to enter the identification of the chemical and the risk

phrases and any additional information such as pH and the physical state of the chemical.

The information is translated into two hazard categories – one concerning local effects, the other systemic effects after uptake through the skin. The hazards are rated – negligible, low, moderate high very high or extreme.

Exposure

User asked to enter information to identify the workplace or process that is assessed and which one of the Dermal Exposure Operational units best fits with the sub category of exposure to solid or liquid:

- Handling of contaminated objects – solid or liquid
- Manual dispersion – solid or liquid
- Hand tool dispersion – solid or liquid
- Spray dispersion – solid or liquid
- Immersion – solid or liquid
- Mechanical treatment – solid or liquid

From the information the tool kit will apply a default exposure rates, take into account duration and the exposed body areas and the actual exposure score from local effects and the internal exposure score from systemic effects are then calculated separately and ranked as health risk scores with suggested controls ranging from no action required up to substitute in either case and stop working.

危害

用户需要输入化学品和风险特征和任何补充信息，例如化学品的 PH 值和物理状态。

信息被转换成两类-一类是关于局部影响，另一类在通过皮肤进入人体后产生的组织影响。风险评估中低、中、高、过高或极端可忽略。

暴露

用户需要输入信息来识别要评估的工作场所或流程的情况，以及操作部门最容易发生的固体或液体皮肤暴露门类：

- 污染物处理– 固体或液体
- 手工分发– 固体或液体
- 手工工具分发– 固体或液体
- 喷雾扩散 – 固体或液体
- 浸– 固体或液体
- 机械处理- 固体或液体

从信息中得知，工具箱采用了默认暴露率，考虑工程处持续时间和接触的人体的面积，然后单独计算具有局部影响的急性暴露分值和具有组织影响的内部暴露分值，并按推荐的控制范围将其作为

The toolkit is an attempt to adapt elements of exact science to a situation where the necessary input data are of limited quality and are only estimates. The purpose is to enable the user to estimate the order of magnitude of hazard, exposure and risk and to encourage the user to deal with issues of dermal hazard, exposure and control.

The RISKOFDERM project has been the subject of significant controversy and more detail can be found in an overview by Oppl et al (2003).

健康风险分进行排列，从不需要采取行动到使替代品或停工。

工具箱试图将精密的科学要素应用到必要的输入数据质量受限和人们只能估计的情形下。其目的是使用户估计危险、暴露和风险的数量级顺序，鼓励用户处理皮肤危险、暴露和风险问题。

目前围绕 RISKOFDERM 项目存在很大争议。具体情况详见 Oppl 等人（2003 年）做出的概述。

5.6 CONFINED SPACES

5.6.1 Identification and Nature of Hazards

Confined spaces have various legal definitions in different parts of the world and while a full list of such definitions is not appropriate for this course, all contain the same (or similar) key elements. These include:

• They are enclosed or partially enclosed spaces at atmospheric pressure during occupancy.

• May have a deficiency or an excess of oxygen.

• May have an atmosphere which has

5.6 密闭空间

5.6.1 危害识别和性质

世界不同地区对密闭空间的法律定义各种各样，但是本课程无需将这些定义一一列举。这些定义都含有相同（或相似）的关键元素。具体包括：

• 他们是大气压下全封闭或部分封闭的被占用的空间。

• 可能存在氧气不足或过量情况。

potentially harmful levels of contaminants.

• May contain a product which could cause engulfment.

• Could have restricted means of entry and exit.

• 其大气污染物可能处于潜在危害程度。

• 可能包含会导致吞入的产品。

• 出入方式有限。

Examples of confined spaces include:

• Storage tanks, boilers, silos, pressure vessels, etc

• Pits, pipes, sewers, ducts, etc

密闭空间的例子包括：

• 储油罐、锅炉、筒仓、压力容器等

• 坑、管道、下水道、导管等

A confined space is determined in part by the hazards associated with entry into such a space and not just work performed in a physically restrictive location.

密闭空间在一定程度上取决于进入空间的相关的危险物，而不仅仅在受到物理限制的位置进行的工作。

The presence of chemical agents (alone or in combination) may present a risk to personnel in a confined space that would not otherwise occur in the general atmosphere.

存在化学药剂（单独或联合）可能使密闭空间里的人面临在一般大气中不会面临的风险。

Some of the hazards that may be associated with work in confined spaces are:

密闭空间工作涉及的一些危险包括：

• **Hazardous Substances**

This includes the use of chemicals, previously stored substances or their by-products (eg H_2S from decomposing plant material), fumes from welding, painting, etc.

• **危险物质**

包括化学品、此前曾存储的物品或副产品（例如分解工厂物质产生的 H2S）、焊烟、油漆等。

• **Flammable Atmospheres**

This includes gases, vapours and dusts which are present in the explosive range.

• **Unsafe Oxygen Level**

This includes oxygen deficient atmospheres as a result of oxidation, combustion, displacement, absorption, consumption by some process and, excess oxygen as a result of a leaking oxygen supply fitting, oxy-propane cutting, oxygen injection and the use of chemicals that liberate oxygen (eg hydrogen peroxide).

• **Engulfment**

Asphyxiation caused by a stored supply of material immersing workers within the confined space.

• **Physical and Other Factors**

This includes manual handling, ignition hazards, electrical hazards, mechanical hazards, noise, radiation, biological hazards and heat stress.

5.6.2 Monitoring in Confined Spaces

The human senses should never be trusted to determine if the atmosphere within a confined space is safe. Many toxic gases and vapours (such as carbon monoxide) cannot be seen or smelt, nor can the level of oxygen be established accurately without appropriate instrumentation.

• **可燃性气体**

包括达到爆炸程度的气体、蒸汽和灰尘。

• **危险氧气水平**

包括氧化、燃烧、排放、吸收、消耗等一些过程导致的大气缺氧，以及供氧部件泄漏、氧丙烷切割、氧气注入和放氧化学物质（如过氧化氢）的使用导致的氧气过量。

• **吞食**

工人在密闭空间内由于存储的材料的浸泡导致的窒息。

• **物理和其它因素**

包括人工处理、点火危险、电气危险、机械危险、噪声、辐射、生物危险和热应力。

5.6.2 密闭空间监测

人类的感官无法确定密闭空间内大气的安全性。人类无法看到或闻到许多有毒气体和蒸汽（如一氧化碳），而且没有适当的仪器也无法准确定氧气水平。

As permit to enter procedures for confined spaces invariably involve a risk assessment, this process should ensure that appropriate arrangements are put in place to test the atmosphere within the confined space.

在允许进行密闭空间之前必须进行风险评估，这个程序应确保适当安排密闭空间大气测试。

Where appropriate the atmosphere should be tested for:

- Oxygen content; and/or
- airborne concentration of flammable contaminants; and/or
- airborne concentration of potential harmful contaminants.

在必要情况下应测试以下大气指标：

- 氧气含量；和/或
- 可燃性污染物大气浓度；和/或
- 潜在有害污染物大气浓度。

The common means of sampling the air to assess the risk of adverse health effects is to test for specific materials with a suitable portable analyser. There are many different kinds of analysers available but the results are only as good as the operator"s skill and the state of analyser maintenance. An explosimeter, used for measuring the percent Lower Explosive Limit (LEL) in a confined space, should be tested against a known standard gas, both before and after a test for vessel entry, to ensure that an accurate reading is obtained. It should be noted that a reading below the LEL could still mean that hundreds or even thousands of ppm of contaminants are present in the atmosphere.

评估不利健康影响风险的普遍方法是用适当的便携式分析仪来测试具体材料。目前有许多种分析仪可用，但是操作者的技术和分析仪的维护情况是决定分析结果质量的要素。在密闭空间里测量爆炸下载（LEL）的爆炸性气体浓度测量仪在探进容器测试前后都应进行标准气体检验，以确保获得准确读值。请注意：低于 LEL 的读值仍意味大气中包含成百上千 ppm 的污染物。

Instruments used for testing the atmosphere in a confined space should be selected for their ability to measure hazardous concentrations and should be

当在密闭空间测试大气时，应选择能测量危险物浓度的，并根据制造商指南或

calibrated in accordance with the manufacturer"s guidelines or manuals.

手册校准的仪器。

If atmospheres that are to be sampled are potentially explosive, intrinsically safe monitoring equipment will be necessary. Initial monitoring should be performed from outside the confined space by inserting a sample probe at appropriately selected openings. Telescopic extension probes or probes attached to a line can be used to reach remote regions.

如果待采样的大气有潜在爆炸危险，必须使用本身安全的监测设备。第一次监测应在密闭空间外进行，将样品探针探入经过精心选择的开口。可采用可伸缩探针，或将探针系在一条线上进行来探测较远的地方。

Some gases or vapours are heavier than air (for example, hydrogen sulphide) and in unventilated areas will settle to the bottom of a confined space. Also, some gases are lighter than air (for example, methane) and will be found around the top of the confined space. As it is possible for contaminants to settle at different levels, the top, middle and bottom of a space should be sampled. Horizontal spaces should also be sampled at representative intervals along their length. Sampling should be such as to reflect accurately the conditions within the confined space.

一些气体或蒸汽密度大于空气（例如硫化氢），如果在不通风的密闭空间会沉入底部。还有一些气体密度小于空气（例如甲烷），在密闭空间会浮在顶部。污染物可能会聚集在待采样的空间内的不同高度，顶部，中部或底部。在水平空间内应沿长度方向每隔一定间隔取一次样本。采样应准确地反映密闭空间的状况。

When considering the appropriate time to monitor the atmosphere, it should be understood that unless monitoring is undertaken immediately prior to entry, the results may not be relevant and an unsafe condition may potentially exist.

在考虑适当的大气监测时机时，必须了解除非在进入后立即进行监测，否则结果可能会失去相关性，而且不安全的条件可能仍然存在。

While pre-entry testing indicates whether

the atmosphere in the confined space is acceptable for entry, atmospheric conditions in the confined space can change, therefore the atmosphere should be re-tested during the work day.

而进入前预测结果能说明是否密闭空间内大气允许进入，空间内大气条件可能发生变化，因此应在工作时间内反复进行大气检测。

Testing the atmosphere within the confined space while work is in progress will indicate whether or not the ventilation system is adequate or if the work processes are making the atmosphere unsafe.

在密闭空间内一边工作一边测试大气会了解通风系统是否合适，工作流程是否使大气变得不安全。

Continuous monitors provide constant surveillance of atmospheric conditions in a confined space. Personal direct reading monitors can be used to initially test the space, and then can be worn by an employee during work to detect atmospheric changes during entry. These monitors should be fitted with visual and audible alarms to warn employees of the hazard and the need for further action as set out in the entry procedure and permit.

持续监测可对密闭空间大气条件提供持续监测。人体直读监测可用于对空间进行初步测试，然后由工人在工作期间穿戴监测仪器来测定在进入期间的大气变化。监测中应使用视听警报来警告处于危险中的工人，而且应采取进入程序和许可条件规定的进一步行动。

Re-testing and continuous monitoring of the atmosphere may be necessary:

- if determined under the risk assessment;
- as indicated from the initial testing of the atmosphere;
- because of the potential for later release or disturbance of hazardous material. Such material includes sludge, scale or other deposits, brickwork and liquid traps. The hazardous material may be released if disturbed or if heat is applied. Where

在以下情况下应重新测试和继续监测大气：

- 如果根据风险评估结果确定有必要这么做；
- 大气第一次测试结果显示有必要这么做；

harmful contaminants are released, control measures should be based on the assumption that any further disturbance of the sludge will release more vapour; or

- because of the work undertaken in the space. For example, heat or fumes from processes such as welding can build up rapidly in a confined space.

No matter what type of instrumentation is used to assess a confined space (or any other workplace), it is important that the operator clearly understands the limitations of that equipment. For example, an explosimeter exhibits different sensitivities towards different flammable gases or vapours and thus to give accurate results it should be calibrated with known concentrations of the gas or vapour likely to be present in the atmosphere being assessed.

Moreover, most chemical sensors used for the measurement of contaminant gases are fitted with filters to minimise cross sensitivity from other contaminants. These filters need to be replaced according to the manufacturer"s instructions and the potential problems of cross sensitivity well understood by the instrument operator.

It should also be noted that monitoring is never a substitute for the systematic and

- 由于后期可能出现危险物质释放或干扰，此类物质包括污泥、水垢或其它沉积物、砌砖和流动井等材料。如果受到干扰或发热，危险物质就会释放。在危险物质释放时，控制措施应基于淤泥的任何进一步干扰会导致更多蒸汽被释放的假设；或

- 由于在空间内从事的工作。例如，一个窄小的空间会在很短时间内充满焊接过程中产生的热或烟雾。

无论使用哪种仪器来评估密闭空间（或任何其它工作场所），操作人员必须明确理解设备的局限性。例如，爆炸计对不同可燃气体或蒸汽表现出不同敏感性，从而能给出准确的结果，仪器会根据可能在被评估的大气中存在的气体或蒸汽的已知浓度对结果进行校准。

而且，大部分污染气体测量使用的化学传感器都配有过滤器来尽量避免来自其它污染物的交叉敏感性。这些过滤器需要根据制造商指示以及仪器操作人员所正确理解的潜在交叉敏感性问题进行更换。

verified isolation of the confined space from any outside source of hazardous material.

还要注意，监测绝对不能代替将密闭空间与任何外部危险物质来源进行系统和验证隔离这个过程。

6. BIOLOGICAL MONITORING

6.1 FUNDAMENTALS OF BIOLOGICAL MONITORING

Workplace air monitoring and comparison of the results with exposure standards provides information about the probable exposure of workers to inhalation hazards. It does not provide information about the other exposure routes of skin absorption, ingestion and non work related exposures.

Biological exposure monitoring, or biological testing, is a way in which you can determine how much of a particular contaminant has actually entered and has been taken up by the body from all these routes. A number of substances can be measured in this way. The advantages of such an approach include:

- It provides additional information where there is a respiratory hazard
- It can be used where the main route of exposure is not inhalation
- It can highlight deficiencies in the wearing of personal protective equipment, ie respirators and gloves and/or clothing
- It provides evidence for medical assessment

Biological monitoring is one of the three tools used in the prevention of disease from hazardous substances in the work environment, the other two being occupational hygiene or environmental

6. 生物监测

6.1 生物监测基本原理

工作场所生物监督和与暴露标准进行结果比较会提供工人潜在吸入危害暴露信息。但它不能提供其它途径信息：皮肤吸收、摄取和非工作暴露。

生物暴露监督或生物测试是一个确定通过所有这些路径共有多少污染物真正进入体内和被人体吸收的方法。许多物质可用这个方法进行测定。这种方法的优势包括：

- 它提供关于吸入危害的补偿信息；
- 如果吸入不是主要暴露路径时，可以使用这个方法；
- 它能突出穿戴个人防护设备，例如面罩和手套和/或防护服的不足之处；
- 它能提供医学评估的证据。

生物监测是用于预防工作环境危险物质的三个重要工具之一，其它两个工具是职业卫生或环境监测和环境监

monitoring and health surveillance.

Biological monitoring means the assessment of exposure to chemicals (substances) that are present in the workplace, through the measurement of appropriate determinants in biological specimens from exposed workers. In most cases, the specimen used for biological monitoring is urine, blood or exhaled air.

The risks associated with the obtaining and handling of bodily fluids, in terms of potential exposure to possible pathogens, ie HIV, Hepatitis, viruses etc have to be considered.

In many countries only a qualified doctor or nurse can obtain such samples. Local advice must be sought before such work is to be carried out.

Biological monitoring can be divided into:

• Direct biological monitoring also referred to as biological monitoring of exposure
• Biological effect monitoring

6.2 DIRECT BIOLOGICAL MONITORING

The purpose of direct monitoring is to assess the health risk through the evaluation of internal dose of the chemical in question with the aim of ensuring the

督。

生物监测指通过从暴露工人身上提取的生物标本中某些决定性物质进行测定来进行工作场所化学（物质）暴露评估。在大多数情况下，用于生物监测的标本包括尿、血液或吸入空气。

在血液抽取和处理过程中可能出现接触病原体的风险，例如 HIV、肝炎和病毒等必须考虑在内。

在许多国家只有有资质的医护人员才能提采样本。在开展此类工作之前必须征得当地有关当局的意见。

生物监测可分为：

- 直接生物监测，即暴露生物监测
- 生物影响监测

6.2 直接生物监测

直接监测的目的是通过评估可疑化学物质的内部剂量来评估健康风险，以确保暴露不会达到导致不利影响的水

exposure does not reach levels that can cause adverse effects.

平。

The direct analysis of the contaminant is undertaken in the specimen: Blood – eg for lead and mercury

在样本-血液-中直接分析污染物-例如铅和汞。

Urine – eg for cadmium and MOCA (methylene bis-orthochloroaniline)

尿液–例如镉和 MOCA（亚甲基双邻氯苯胺）；

Hair and nails - eg for arsenic

头皮和指甲-例如砷中毒

Breast milk and body fats – eg for pesticides and Polychlorinated Biphenyls (PCBs)

母乳和体脂–例如杀虫剂和多氯联苯（PCB）

Expired air – eg for carbon monoxide and organic solvents – eg benzene

呼气–例如一氧化碳和苯等有机溶剂

OR analysis of its metabolites

或代谢物分析

Blood – carboxyhaemoglobin from carbon monoxide Urine – mandelic acid from styrene

血液-来自一氧化碳的碳氧血红蛋白

尿液-来自苯乙烯的扁桃酸

6.3 BIOLOGICAL EFFECT MONITORING

6.3 生物影响监测

Biological effect monitoring is aimed at identifying early and reversible biochemical changes resulting from exposures, ie no detrimental effect has occurred but one or more measurable biochemical changes has occurred. The degree of change is less than that which leads to injury and is not associated with a known irreversible pathological effect.

生物影响监测的目的是识别暴露导致的早期和可逆的生化变化，即没有发生不利影响，但已经发生一个或多个可测量的生化变化。变化程度尚不能导致伤害，与已知的不可逆的病理作用无关。

Some examples of biological effect monitoring are:

这里举几个生物影响监测的例子：

• Zinc protoporphyrin in blood – these levels increase with exposure to lead, because lead inhibits the biosynthesis of

heme.

• Cholinesterase activity in red blood cells and plasma – exposure to organophosphate pesticides depresses cholinesterase activities.

Biological effect monitoring is not health surveillance through which individuals with early signs of adverse health effects are identified.

• 血液中锌原卟啉-这些水平随着对铅的接触而升高，因为铅抑制血红素的生物合成。

•在红细胞和血浆中的胆碱酯酶活动-接触在有机磷农药中会抑制胆碱酯酶的活动。

生物影响监测不是用来识别不利健康影响早期征兆的健康监督。

6.4 GENERAL CONSIDERATIONS

6.4 一般考虑因素

The extent and rate of absorption of a chemical after exposure depend on the properties of the chemical, especially its solubility in lipids and water, and the route of exposure. Once absorbed a chemical is distributed and spreads into various tissues depending on the susceptibility of the tissue due to variations in pH, permeability etc. Very water soluble chemicals may be distributed throughout the total body water, while lipophilic (attract non polar organics such as fats and oils) may concentrate in the body fat or other lipid tissues such as the brain.

暴露后化学物质吸收程度和速度取决于化学物质的性质（尤其是在液体和水中的溶解性）和暴露路径。一旦吸收，化学物质就会分布或散布在不同组织内，取决于由于 PH 值变异组织的感受性、渗透性等。不同水溶性化学物质可能通过全身的水份分布，而亲脂性的（吸引非极性有机物。例如脂肪和油）可能会集中在身体脂肪或其他脂质组织，例如大脑。

The loss of chemical from the body or elimination depends on metabolism and excretion. Chemicals may be eliminated by numerous routes including faecal, urinary, exhalation, perspiration and lactation.

人体化学物质的流失或消除取决于新陈代谢和排泄。化学物质可以从许多路径被排除，包括粪便、尿、呼气、汗水和哺乳。

A chemical may be excreted from the body

without metabolism, ie the particular chemical can be measured directly. In other cases, the chemical may be metabolised through oxidation, reduction, hydrolysis or combination of these followed by often very complex biochemical reaction in the body. Hence the choice of the indicator of exposure and even the timing of when to take a sample is critical.

化学物质可以用新陈代谢之外的途径从身体排出，即特定的化学物质可以直接测量。在其它一些情况下，化学可能通过氧化、还原、水解或几种组合进行代谢，随后体内会发生非常复杂的生化反应。因此暴露指标甚至采样时机的选择都是至关重要的。

6.5 BIOLOGICAL HALF-LIFE

The biological half-life of a substance is the time required for half of that substance to be removed from the body by either a physical or a chemical process. The half lives for different substances vary significantly and hence the importance of the correct sampling time cannot be over emphasised.

6.5 生物半衰期

物质的生物半衰期就是一半物质从体内排出的一个物理或化学过程。不同物质的半衰期有很大不同，因此适当的采样时机极其重要。

6.6 SAMPLING TIME

The timing of biological samples can be very important. Substances absorbed into the body are removed at different excretion rates. The concentration of some determinants can change rapidly, so in these cases sampling time must be observed and recorded carefully. On the other hand, a determinant that accumulates slowly may not need a specific sampling time.

6.6 采样时机

生物样本采样时间非常重要。吸入体内的物质以不同排泄速度排出。一些决定性物质的浓度会迅速发生变化，这样必须观察和仔细记录采样时机。从另一方面来说，缓慢积累的决定性物质可能不存在具体采样时机。

Practical guidance on the interpretation of sampling times is given by the ACGIH (2007). While the ACGIH provides the recommendations as listed in Table 6.1, it is important to understand that this

ACGIH 曾发布一个用于解释采样时机的实用指南（2007 年）。对于 ACGIH 提供的表 6.1 所列建议，我们应理解指南中信息仅用作指导，帮助理解为了获

information is for guidance only and an understanding of the substance being monitored is critical if accurate results are to be achieved.

得准确结果，必须重视物质监测。

Table 6.1 – Recommended Sampling Times
表 6.1– 建议的采样时机

Sampling Time	采样时机	**Recommended Collection**	推荐采样时机
Prior to shift	换班前	16 hours after exposure ceases	暴露停止后 16 个小时
During the shift	班组工作中	Anytime after 2 hours of exposure	暴露两小时后任何时间
End of shift	班组工作结束时	As soon as possible after exposure ceases	暴露停止后尽快
End of the work week	工作周结束时	After 4 or 5 consecutive working days with exposure	连续 4-5 个暴露工作日后
Discretionary	任意	At any time	任何时候

The UK Health & Safety Executive (HSE) in the Guidance Note EH56 "Biological Monitoring for Chemical Exposures in the Workplace" (HSE 1992) uses the following (Table 6.2) to provide advice on the timing of sample collection.
指南附注 EH56 "工作场所化学暴露生物监测"（HSE 1992）中的英国健康和安全执行（HSE）采用推荐以下采样时机（表 6.2）。

Table 6.2 – Optimum Time for Collecting Samples
表 6.2–最佳采样时机

Half Life	半衰期	**Optimum Time for Taking Samples**	最佳采样时机
<2 hours	<2 小时	Concentration changes too fast – not suitable	浓度变化太快-不适当
2 to 10 hours	2 -10 小时	End of shift or next morning	班组工作结束时或次日早晨
10 to 100 hours	10 -100 小时	End of shift at end of week	周末班组工作结束时

>100 hours	>100 小时	Random sampling acceptable	可随机采样

(Source: HSE – *Reproduced with permission*)
（来源：HSE–许可转载）

6.7 URINE SPECIMEN ACCEPTABILITY

The concentration of urine can have a marked effect on the results of the analysis of the contaminant. Sample results can be corrected for urine concentration in one of two ways: by adjusting for the specific gravity of the sample or by correcting for the creatinine level in the urine as creatinine excretion from the body occurs naturally at a nearly constant rate. The World Health Organisation has adopted the following guidelines for acceptable limits to assist in overcoming the issues associated with highly diluted and highly concentrated urine samples:

Creatinine concentration:
>0.3 g/L and <3 g/L
or
Specific Gravity: >1.010 and <1.030

Samples outside these guidelines should be discarded and another sample collected.

Some BEIs® for determinants whose concentrations is dependent on urine output are expressed as relative to creatinine concentration. For other determinants correction for urine output is

6.7 尿样可接受性

尿液浓度对污染物分析结果有显著影响。可通过以下任意一个方式将尿液浓度采样结果进行纠正：调整样本的具体重力或纠正尿肌酐水平，这时因为体内尿肌酐排泄本身速度基本是恒定的。世界卫生组织已经通过以下关于可接受限值的指南来协助解决与高度稀释和高度浓缩的尿液样本有关的问题：

肌酐浓度：>0.3 g/L 和 <3 g/L

或

具体比重：>1.010 和<1.030

超出这些指南范围的样本应作废，重新收集样本。

相对于酐浓度表示一些认定哪种物质的浓度与尿量无关的决定性 BEI®。对于其它决定性因素来说，不需要纠正尿量。

not appropriate.

6.8 BIOLOGICAL STANDARDS

6.8.1 Biological Exposure Indices

Similarly to TLVs®, the results of biological monitoring are compared against Biological Exposure Indices or BEIs®. The main source of BEIs® is from the ACGIH in their handbook *Threshold Limit Values and for Chemical Substances and Physical Agents and Biological Exposure Indices* (ACGIH 2006).

Biological Exposure Indices (BEIs®) are guidance values for assessing biological monitoring results. BEIs® represent the levels of determinants that are most likely observed in specimens collected from healthy workers who have been exposed to chemicals to the same extent as workers with inhalation exposure at the TLV®.

In a similar fashion to TLVs®, BEIs® are to be used as guidelines in the evaluation of occupational hygiene health hazards. BEIs® do not indicate a sharp distinction between hazardous and non hazardous exposures. Due to the often varied nature of concentration in biological specimens great care and caution must be exercised in the

6.8 生物标准

6.8.1 生物暴露指数

类似于 TLV®，生物监测结果应与生物暴露指数或 BEI®进行比较。BEI®主要来源于手册《危险物质、化学物质和物理试剂的容许最高浓度和生物暴露指数》（ACGIH，2006 年）中的 ACGGIH。

生物暴露指数（BEI®）是评估生物监测结果的指导值。BEI® 代表决定性因素水平，这是最可能在与化学品吸入暴露达到 TLV®的工人的暴露程度相同的健康工人身上收集到的样本中观察到的。

与 TLV®类似，BEI®被用于职业卫生健康危险评估指南。BEI®无法显示危险和非危险暴露之间的显著差别。由于生物样本浓度不断变化，在解释单一样本的分析结果时必须极为小心和谨慎。

interpretation of the results from a single specimen.

BEIs® apply to 8-hour exposures, 5 days per week. Although modified, altered and extended shifts are often used across industry the BEI® Committee does NOT recommend the adjustment or use of a correction factor be applied to the BEIs®.

Use of BEIs® should only be done by experienced occupational health professionals in consultation with the associated documentation for them. The BEI® is a guideline for the control of potential health hazards for workers and the values are inappropriate for use for the general public and for non occupational exposures. In the application of BEIs® reference must be made to the current edition of the Documentation of the Threshold Limit Values and Biological Indices from the ACGIH®.

BEI® 适用于每周 5 天，每天 8 小时暴露。虽然修改、更改和延长后的班次经常使用，但跨行业 BEI® 委员会建议不对 BEI®采用的修正因数进行调整或使用。

BEI®只能由有经验的职业卫生专业人员在关文件指导下使用。BEI®是一个控制潜在工人健康危害的指南，对于一般公众和非职业暴露来说，使用此类数值并不合适。在使用 BEI®时，必参考 ACGIH®的危险物质容许最高浓度和生物指标文件的最新版本。

6.8.2 Notations

A notation is a designation that appears as a component of the adopted BEI® value to provide additional information with respect to the particular chemical:

“B” = Background

The determinant may be present in biological specimens collected from subjects who have not been

6.8.2 符号

符号是一种名称，是采用的 BEI® 值的一部分，用于提供特定化学物质的补充信息：

“B” =背景

决定性因素可能在没有职业暴露的实验受体中收集到的生物样本上存在，其浓度会影响结果解释。

occupationally exposed, at a concentration which could affect the interpretation of the result.

“Nq” = Nonquantitative

Biological monitoring should be considered for this compound based on the review; however a specific BEI® could not be determined due to insufficient data.

“Ns” = Nonspecific

The determinant is nonspecific, since it is also observed after exposure to other chemicals.

“Sq” = Semi-quantitative

The biological determinant is an indicator of exposure to the chemical, but the quantitative interpretation of the measurement is ambiguous.

These determinants should be used as a screening test if a quantitative test is not practical or as a confirmatory test if the quantitative test is not specific and the origin of the determinant is in question.

6.8.3 UK Limits

In the UK the HSE has established a system of non-statutory biological monitoring guidance values as an aid in the interpretation of biological monitoring data.

Biological Monitoring Guidance Values (BMGVs) are set where they are likely

“Nq” = 非定量

化合物生物监测应以审查为主；但是由于数据不充分，无法测定某些 BEI® 。

“Ns” = 非特定

由于在其它化学物质暴露后同样发现决定性因素，因此它是非特定的。

“Sq” =半定量

生物决定性因素是化学物质暴露的一个指标，但是测量值的定量解释是不明确的。

如果定量测试是不现实的，这些决定性因素应用作筛选测试，如果定量测试是非特定的，而且决定性因素的来源不确定，那么用作确认测试。

6.8.3 英国限值

在英国 HSE 已经建议一套非强制生物监测指导值，以解释生物监测数据。

如生物监测指导值（BMGV）可能成为实际值，存在适当的监测方法，而且有

to be of practical value, suitable monitoring methods exist and there are sufficient data available. The type of data that are available will vary between substances and therefore the route taken to deriving the BMGV will vary between substances. BMGVs are either based on a relationship between biological concentrations and health effects, between biological concentrations and exposure at the level of the WEL or are based on data collected from a representative sample of workplaces correctly applying the principles of good occupational hygiene practice. The technical basis for each BMGV will be clearly described in supporting documentation such as an EH64 summary or other guidance.

充分可用据。那么就可以设定BMGV。不同物质之间可用数据类型不同，因此，得出不同物质 BMGV 的路径也是不同的。BMGV 是基于生物浓度和健康作用，或生物浓度和在 WLE 水平暴露程度之间的关系建立，或基于适当适用良好职业卫生实践的工作场所的代表性样本中收集到的数据确定。每个 BMGV 的技术基础将明确描述在辅助文件中，例如 EH64 概述或其它指南。

BMGVs are non-statutory and any biological monitoring undertaken in association with a guidance value needs to be conducted on a voluntary basis (ie with the fully informed consent of all concerned). BMGVs are intended to be used as tools in meeting the employer"s primary duty to ensure adequate control under COSHH. Where a BMGV is exceeded it does not necessarily mean that any corresponding airborne standard has been exceeded nor that ill health will occur. It is intended that where they are exceeded this will give an indication that investigation into current control measures and work practices is necessary.

BMGV 是非强制性的，任何与指导值有关的生物监测都在自愿基础上进行（也就是让所有有关人员在充分了解信息后做出同意的决定）。BMGV 的目的是作为工具来使雇主行使主要职责，确保在 COSHH 下进行充分控制。即使 BMGV 超标，也并不一定意味着超过任何相关的机载标准，或影响健康。、它的目的是如果超标的话，就表示有必要调查当前控制措施和工作实践。

Of course, that is not necessarily to say that because biological monitoring results are below a particular guidance value an employer need take no further action to reduce exposure; but it should be noted that BMGVs are not an alternative or replacement for airborne occupational exposure limits.

当然，这并不表示，如果生物监测结果低于具体指导值，雇主就无须采取进一步行动来减少暴露。要知道，BMGV并不是机载职业暴露限值的代替值。

6.9 CONFIDENTIALITY

6.9 机密性

There are several ethical and confidentiality issues that must be considered and implemented before commencing a biological monitoring programme.

在开始生物监测方案前，必须考虑和落实一此伦理和机密性问题。

• The method should be appropriate for the requirements of the investigation.

• 方法应符合调查要求。

• The procedures should not threaten the health of the participant.

• 程序不得对参与者健康造成威胁。

• The risk of using invasive methods must be justified by the benefits.

• 侵入式方法风险在利害方面必须被证明是正当的。

• The informed consent from the participants is needed. This consent must only be given when the participant feels no fear of reprisals if their consent is not given.

• 必须得到参与者的知情同意书。同意书只有在参与者认为如果他们不同意的话不会被打击报复时才视为有效。

• Results of the monitoring should be kept confidential and shared only with the occupational health professional and the participant.

• 监测结果必须保密，知情者只能限于职业卫生专家和参与者。

7. SAMPLE ANALYSIS

7.1 INTRODUCTION

Analysis of occupational hygiene samples may be done on the job using some form of direct reading device or instrument. Alternatively, a sample is often collected at the workplace and sent to a laboratory for analysis. This analysis could vary from a relatively simple weighing of the contaminant on a filter to the determination of a metal using an inductively coupled plasma (ICP) spectrometer or the use of a gas chromatograph linked to a mass spectrometer for the determination of an organic solvent.

In most cases the hygienist does not perform the laboratory analysis, but an understanding of some of the basics is required to:

- Select an appropriate monitoring and analytical method
- Communicate with the analytical laboratory
- Understand the principles of the direct reading instrument
- Make an assessment of the reliability of the results

7.2 ANALYTICAL METHODS

Most methods currently employed for occupational hygiene sample analysis are instrumental rather than the classical “wet chemical methods” common prior to the 1960‟s.

7. 样本分析

7.1 简介

职业卫生样本分析可使用直接读值设备或仪器进行，不过一般在工作场所收集样本，然一送到实验室进行分析。这种分析会不同于为了测定有机溶剂而使用一台电感耦合等离子体（ICP）分光计或使用一台与一台质谱仪连接的气相色谱仪对过滤器中污染物与金属测定值进行相对简单的权重。

在大多数情况下卫生专家不进行实验室分析，但是必须理解以下方面：

- 选择适当的监测和分析方法
- 与分析实验室沟通
- 理解直读仪器的原理
- 评估结果的可靠性

7.2 分析方法

目前职业卫生样本分析采用的大多数方法都是仪器法，而不是二十世纪 60 年代前流行的典型的“湿式化学法”。

The types of analysis can typically be divided into two main types

- Spectroscopy
- Atomic
- Molecular
- Chromatography

7.2.1 Spectroscopy

The basic underlying principle of spectroscopy is that all elements or chemical compounds absorb or emit electromagnetic radiation at specific frequencies. If a sample is radiated at a specific frequency for a particular element, if that element is present the amount of radiation absorbed or emitted is proportional to the concentration of that element in the sample.

a) **Atomic Spectrometry**

Typically used for the analysis of the metallic elements. Samples usually collected using conventional sampling methods onto filters, impingement into liquids or adsorption onto a solid. Samples then prepared by appropriate method for subsequent analysis.

- *Flame Atomic Absorption Spectrometry (AAS)*

The sample in solution is atomised by flame and the absorption of a specific wavelength of light from the hollow cathode lamp in the flame is measured to quantify the element. This technique

分析类型一般分为以下几种：

- 光谱学
  - 原子
  - 分子
- 色谱分析法

7.2.1 光谱分析法

光谱法的基本原理是所有元素或化合物都以特定频率吸收或散发光谱射线。如果样本以特定频率放射出特定元素，如果该元素的确存在，那么吸收或发射的辐射量与样本中元素的浓度成比例。

a） 原子光谱法

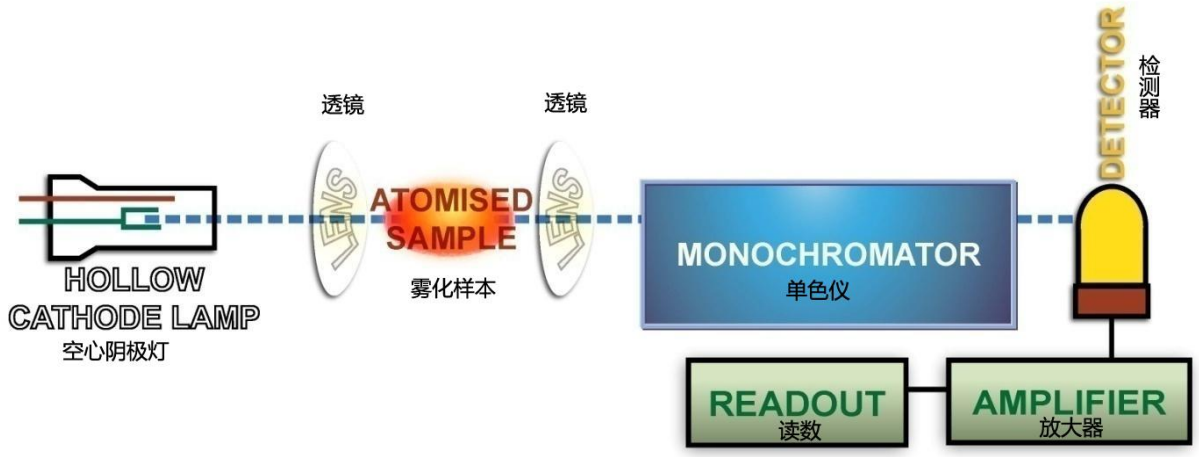
一般用于金属元素分析。一般情况下使用传统采样法将样本收集到过滤器上、浸入液体中或吸入到固体中。然后用适当方法准备样本，以备此后分析。

- 火焰原子吸收光谱法（AAS）

溶液中的样本被火焰雾化，空心阴极灯释放的光线的特定波长的吸收量被测量，以量化元素。近 60 种金属采用这

typically used for the analysis of approximately 60 metals.

种分析技术。



(Source: BP International)

（来源：英国石油国际有限公司）

Figure 7.1 – Schematic of an Atomic-Absorption Spectrometer

图 7.1– 原子吸收光谱分析仪原理图

(Source: University of Wollongong)

（来源：伍伦贡大学）

Figure 7.2 – Atomic Absorption Spectrometer

图 7.2–原子吸收光谱法

• *Hydride Generation*

Arsenic and selenium have poor sensitivity using conventional Flame AAS because their spectral lines are in the far UV. Hydride generation overcomes this issue. As and Se are converted to their respective hydrides AsH_3 and H_2Se. When these hydrides are swept through the flame or a through a heated quartz cell a larger proportion of the element reaches the light path resulting in increased sensitivity.

b) **Flameless Atomic Absorption**

AAS is not sensitive enough for analysis of low concentration of metals in biological samples such as blood. During AAS there is a high flow rate of sample through the flame and a more sensitive method where less material is used is required.

• *Graphite Furnace*

Atomisation of elements without the use of a flame can be achieved with the use of electricity (electrothermal atomisation). The sample is placed inside a hollow graphite tube and rapid heating of the tube using a high electric current causes the sample to atomise.

• 氢化物产生

如果采用传统的火焰 AAS，砷和硒显示很低的敏感性，这是由于它们光谱线都在远紫外线串。氢化物产生法解决了这个问题。砷和硒被转化成其氢化物 AsH3 和 H2Se。当这些氢化物穿过火焰或加热石英电池被扫描时，很大部分的元素到达光路，导致敏感性提高。

b） 无焰原子吸收光谱

AAS 的敏感度不足以分析血液等生物样本中的低浓度金属。在 AAS 期间高流速样本会穿过火焰。如果使用的材料较少，应采用敏感度更高的方法。

• 石墨炉

利用电流就能在不使用火焰的情况下将元素雾化（电热雾化）。将样本放在一个中空石墨管中，用高电流迅速加热会导致样本雾化。

(Source: University of Wollongong)
（来源：伍伦贡大学）

Figure 7.3 – Graphite Furnace AAS
图 7.3– 石墨炉 AAS

• *Cold vapour generation*

This technique is used for the analysis of mercury because of the volatility of mercury at room temperature. Mercury compounds are reduced to metallic mercury and the mercury vapour is transported to the absorption cell by a stream of gas for determination.

• 冷蒸汽产生

该技术用于分析汞，这是由于汞在室温下有挥发性。汞化合物被还原为金属汞，而蒸汽形态的汞被气流转移到吸收池，用于测定。

c) **Atomic Emission Spectrometry**

This technique is also based on the flame excitation of an element, but is looking at the emission of energy when the excited element is returned to its ground state.

c） 原子发射光谱法

该技术还以元素的火焰激发为基础，但着眼于当被激励元素返回地面状态时能量的散发。

• *Flame Emission*

Atomic absorption spectrometers can be

• 火焰发射

原子吸收光谱仪可以用发射模型操

operated in the emission mode or a separate instrument, a flame photometer can be used. Typically the elements where this technique is used are the alkali and some alkaline earth metals eg Sodium and Potassium.

作，或者单独使用火焰光度计这种仪器。如果采用这种技术，那么元素通常是碱和一些碱土金属，例如钠和钾。

• *Inductively Coupled Plasma Spectrometry*

An extension of atomic emission spectrometry is inductively coupled plasma spectrometry (ICP). By using gas plasma temperatures up to 10,000°C can be obtained resulting in a large increase in excited atoms and hence sensitivity. Plasma is a cloud of highly ionised gas comprising ions, electrons and neutral particles. In ICP the gas used is usually argon because it is easily ionised with radio frequency electromagnetic fields.

• 电感耦合等离子体光谱测定法

电感耦合等离子体（ICP）是原子辐射光谱测定法的一个延伸使用。通过使用气体等离子体，可获得高达 10，000°C 的温度，从而导致受激原子数量和敏感性大大提高。等离子体是一种高度雾化的气体云，由离子、电子和中性粒子组成。通常使用的 ICP 气体是氩，这是因为它比较容易被雷达频率电磁场雾化。

Since all elements in a sample emit their characteristic wavelengths simultaneously it is possible to measure a large number of elements, up to 60, simultaneously or sequentially.

由于样本中所有元素同时都在散发其典型波长，因此可能会同时或先后测定高达 60 种元素。

The scanning ICP has a distinct advantage over AAS in that a separate lamp for each specific element is used in AAS but up to 60 elements can be analysed by ICP on the same sample.

扫描 ICP 与 AAS 相比有独特优势，在 AAS 中，每个元素都使用一个单独的灯进行分析，但是 ICP 最多可用来分析同一样本中 60 种元素。

d) **Molecular Spectrophotometry**

• *UV-Visible Spectrophotometry*

This technique is used for metals or

organic compounds. Samples are collected by conventional sampling methods onto filters or by impingement into solutions.

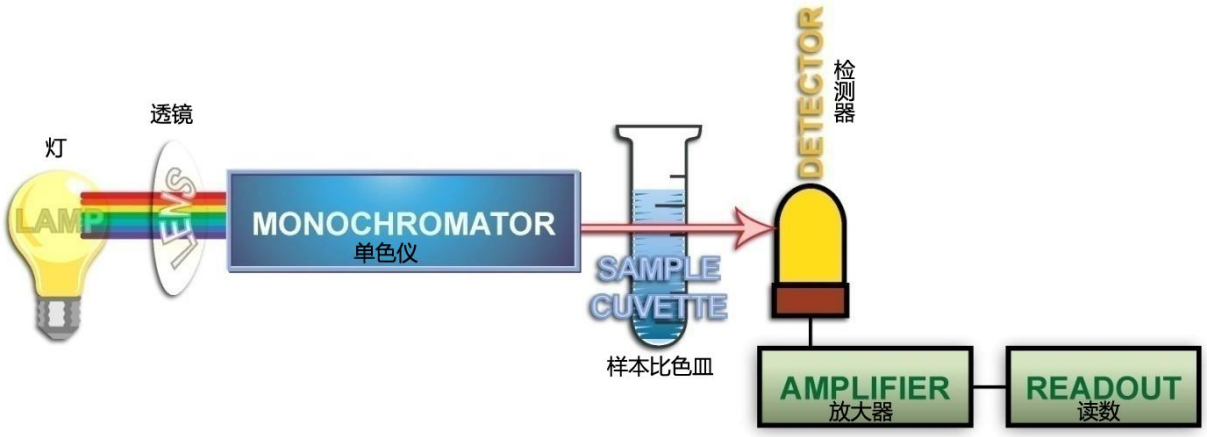
The principle of the method is based on the absorption of ultraviolet and visible radiation by the excitation of bonding electrons in molecules.

d） 分子分光光度仪

- 紫外可见光分光光度仪

本技术用于金属或有机化合物。样品通过传统采样方法采集到过滤器上或撞击成溶剂。

这个方法的原理是基于通过激励分子中的成键电子吸收紫外线和可见辐射。



(Source: BP International)
（来源：英国石油国际有限公司）

Figure 7.4 - Schematic of a Single Beam UV-Vis Spectrophotometer
图 7.4 -单光束紫外可见分光光度仪示意图

Most chemicals species absorb UV or Visible radiation and thus can be quantified, eg oil. For non absorbing compounds a reaction with a colour producing reagent (a chromophore) may allow its quantification.

大多数化学物吸收紫外线或可见辐射，因此可以被量化，例如石油。对于非吸收性化合物，可用与生成颜色的试剂（发色团）的反应进行量化。

Eg the reaction of hexavalent chromium with s-diphenyl carbazide to produce a red complex with an absorption peak at 540 nm.

如六价铬与二苯卡巴肼反应生成吸收峰为 540nm 的红色化合物。

• *IR Spectrophotometry*

Infra-red spectrometry provides a way of identifying pure species as each molecular species has its own unique absorption spectrum, ie fingerprint.

Absorption or emission of infra-red radiation results in the change in vibration or rotation of a molecule. The number of ways a molecule can absorb energy is related to the number of atoms and the number of bonds it contains. IR is particularly applicable to organics and covalently bonded metal complexes.

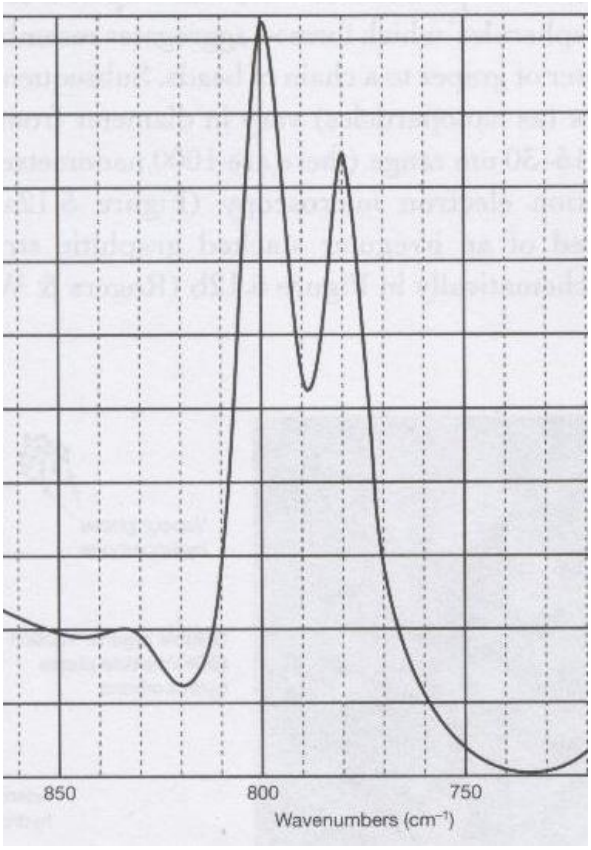
The IR spectrum for quartz is provided in Figure 7.5. Note the distinctive quartz "doublet" at 798 and 779 cm^{-1} wavenumbers.

• 红外分光光度仪

由于每种分子都拥有自己独一无二的吸收光谱，正如"指纹"，因此红外光谱可用来对纯粹的物种进行鉴别。

红外线辐射的吸收或发射都会导致分子振动或转动方式的改变。一个分子吸收能量的途径原子的数目和所包含的键的数目有关。红外线尤其适用于有机物和共价键金属化合物。

石英红外光谱见图 7.5。请注意在波数 798 和 779 cm-1 石英的特殊双重线。



187.
(Source: University of Wollongong)
（来源：伍伦贡大学）

Figure 7.5 – IR Spectrum for Quartz
图 7.5– 石英红外光谱

The main application of infra-red spectrophotometry is identification of compounds and in occupational hygiene is also used for direct gas and vapour monitoring using portable instruments and for the measurement of quartz in dust.

红外分光光度仪的主要用于识别化合物，在职业卫生领域，人们用便携式光度仪来直接监测气体和蒸汽。而且还用于测量粉尘中的石英。

• *Molecular Fluorescence*

• 分子荧光

Fluorescence is one of the ways a molecule returns to its ground state after excitation. It involves the emission of radiation at characteristic wavelengths of the molecule and different from the exciting wavelengths. Fluorescence can be used to measure compound which fluoresce such as aromatic hydrocarbons.

荧光是分子在被激发后恢复基本状态的一种方式。它涉及典型分子波长，不同于与被激发的分子波长的辐射。荧光可以用来衡量发出等荧光的复合物。例如碳氢化合物。

7.2.2 Chromatography

7.2.2 色谱分析法

Chromatography is a separating method that relies on differences in partitioning behaviour between a flowing mobile phase and a stationary phase to separate the components in a mixture.

色谱分析法是一种分离方法，为了分离混合物中的化合物，依赖于流动相和固定相的分区行为。

A column or other support holds the stationary phase and the mobile phase carries the sample through it. Sample components that partition strongly into the stationary phase spend a greater amount of time in the column and are separated from components that stay predominantly in the mobile phase and pass through the column faster.

固定相由一根柱体或其它支架支撑，而流动相将通过它的样品截留。主要分为固定相的化合物会在柱体上停留很长时间，与通过柱体，主要以流动相停留的化合物分离开来。

There are a number of different chromatography techniques and include:

当前有许多种色谱分析技术，具体包括：

• Gas chromatography (GC)

Applied to volatile organic compounds. The mobile phase is a gas and the stationary phase is usually a liquid on a solid support or sometimes a solid adsorbent.

• 气相色谱法（GC）

用于挥发性有机化合物，流动相是一种气体，固定相通常是固定支架（有时是固定吸附剂）上的液体。

• High-performance liquid chromatography (HPLC)

A variation of liquid chromatography that utilizes high-pressure pumps to increase the efficiency of the separation.

• 高效液相色谱法（HPLC）

用于高压泵来增加分离效率的各种液相色谱法。

As the components elute from the column they can be quantified by a detector and or collected for further analysis. An analytical instrument can be coupled with a separation method for on line analysis and includes gas and liquid chromatography with mass spectrometry.

从色谱柱上洗脱的成份可用探测器量化或收集，然后进行进一步分析。可采用分离法来操作分析工具，进行在线分析。具体分析方法包括气相和液相色谱与质谱法。

(Source: University of Wollongong)

（来源：伍伦贡大学）

Figure 7.6 – Gas Chromatograph

图 7.6–气相色谱仪

(Source: University of Wollongong)

（来源：伍伦贡大学）

Figure 7.7 – Gas Chromatograph Mass Spectrometer

图 7.7–气相色谱质谱联用仪

7.2.3 Other Analytical Techniques

• ***X-Ray Diffraction***

X-Ray diffraction (XRD) can help identify and quantify crystalline substances. However it cannot give information on the elements present in the sample. An example where XRD is used is in the analysis of materials containing silicon and oxygen:

- Quartz (SiO_2) has a TLV of 0.1 mg/m^3 (respirable)

- Kaolin is a hydrated aluminium silicate $Al_2Si_2O_5(OH_4)$ has a TLV of 10 mg/m^3 (inhalable)

- Amorphous Silica has a TLV of 10 mg/m^3

Conventional analysis only showing the amounts of silica and oxygen is not helpful in this situation; we need to know the form that the silica and oxygen is in. XRD is

7.2.3 其它分析技术

• X射线衍射

X射线衍射（XRD）可用来确定并良好结晶物质，但是它不能给出样本中元素的信息。使用XRD的例子是分析包含硅和氧的材料：

- 石英（SiO_2）的TLV是0.1mg/m^3（可吸入）

- 高岭土是水和硅酸铝$Al_2Si_2O_5$（OH_4），TLV为10mg/m^3（可吸入性）

- 无定型二氧化硅的TLV为10 mg/m^3

传统的分析只显示硅和氧的含量，适用这一情形；我们需要知道硅和氧的形式。XRD能够识别和量化不同晶相，这

able to both identify and quantify the different crystalline phases that have quite different potential health effects.

• **X-ray Fluorescence**

X-ray fluorescence (XRF) is widely used for the identification of elements. The absorption of x-rays produces an excited atom that returns to its ground state via a series of electronic transitions. These transitions are accompanied by an emission (fluorescence) of X radiation which is characteristic of the element.

Multi channel instruments permit up to 24 elements to be analysed simultaneously for samples such as ashes, ores, minerals, ceramics, alloys and metals.

• **Mass Spectroscopy**

This technique is based on the conversion of a sample into gaseous ions and their separation on the basis of charge to mass ratios. This provides both qualitative and quantitative information.

The spectra obtained are relatively easy to interpret since they provide information based on the mass of structural components and the total molecular weight of the compound.

Its critical that BEFORE sampling is carried the occupational hygienist talks to the laboratory who will undertake the analysis.

7.2.4 Detection Limits, Sensitivity, Chemical Interferences Detection

些晶相对健康具有不同的潜在影响。

• X射线荧光

广泛用于识别元素。吸收X射线会产生受激原子，通过一系列的电子跃迁返回基态。这些转变都伴随着X射线的发出（荧光）进行，这是X射线的特征。

多通道仪器允许同时为样本分析多达24种元素，如灰烬、矿石、矿物、陶瓷、金属和合金。

• 质谱分析

该技术根据荷质比将样本转化成气态离子，提供定性和定量的信息。

得到的光谱相对容易解读，因为它们根据结构部件的质量和化合物的总分子量提供了信息。

必须在采样前与进行分析的实验室进行职业卫生方面的沟通。

7.2.4 检测限、灵敏度和化学干扰

Limits

• Detection Limits

The occupational hygienist should talk to the laboratory BEFORE undertaking sampling. One of the most important things is to know what the limit of detection (LOD) of the method is as this dictates the minimum sampling volume and therefore the length of sampling time required. It may be impossible to collect enough of the material in a 15 minute period for subsequent analysis. Ideally the limit of detection
should be lower than 1/10th of the exposure standard.

Example

Sampling rate 2 L/min Limit of Detection 10 µg

If the TLV is 0.1 mg/m^3

Minimum sampling time = $\frac{\text{10 x analytical limit of detection}}{\text{Exp standard x flow rate}}$

= $\frac{\text{10 x 10 µg}}{}$

= 100 µg/m^3 x 2 x 10^{-3} m^3/min

= 500 mins ie full shift sample required

In a similar fashion each laboratory analytical method also has its own limit of detection that must be considered before sampling.

• Method Sensitivity

Does the analytical method cover the concentration range of interest? Some analytical methods may not have

• **检测限**

职业保健专家在进行采样之前需告知实验室。其中一个最重要的事情是知道方法的检测限（LOD），因为这会表明最小采样量和采样所需的时间。不可能在15分钟内采集足够的材料用于随后分析。理想的检测限应低于解除标准的十分之一。

例子

采样率2L/min

检测限10µg

如果TLV为0.1mg/m^3

最少采样时间= $\frac{\text{10x检测分析限}}{\text{标准 x流率}}$

= $\frac{\text{10x10µg}}{}$

=100 µg/m^{3}x2x10^{-3}m^3/min

=500mins

即要求全采样

同样地，各实验室分析方法也有自己的检测限，在采样之前必须考虑。

• **方法敏感性**

分析方法覆盖相关的浓度范围吗？一些分析方法可能没有检测低限检查短期暴

sufficiently low limits of detection to measure short term exposures. Is there another method that could be used to get better sensitivity eg the use of ICP rather than AAS for the analysis of metals.

露。有其它的方法可以用来获得更好的灵敏度，如使用ICP而不是AAS进行金属分析。

• Chemical Interferences

What other substances are likely to be present in the sample and are they likely to interfere with the proposed analytical method?

For example if a welder is being sampled for “welding fumes” the gravimetric determination, ie the filter weighing, will be adversely affected if “grinding dusts” have also been sampled during the fume collection period. This is especially a problem if chemical speciation of individual contaminants is required.

• 化学干扰

样本中还有可能存在其它物质可能干扰分析方法吗？

例如，如果一个焊工由于“焊烟”重量法测定而被采样，即过滤器称重将受到不利影响，如果烟雾采集过程中对“粉尘”也进行采样的话。如果需要对个别污染物进行化学形态分析的话，这种干扰问题尤其严重。

7.2.5 Sources of Analytical Methods

There are a number of recognised sources of standard and recognised methods that are used for occupational hygiene analysis. These include:

• NIOSH Manual of Analytical Methods (NMAM) – a collection of over 1,700 methods for sampling and analysis of contaminants in workplace air, and in the blood. Available on line at: www.cdc.gov/niosh.nmam (accessed December 2006)

• UK HSE Methods for the determination of hazardous

7.2.5 分析方法来源

职业健康分析有许多公认的标准来源和公认的方法，包括:

• 《NIOSH分析方法手册（NMAM）》- 收集了超过工作环境空气和血液污染物采样和分析的方法。网址：www.cdc.gov/niosh.nmam（2006年12月访问）

• 《英国HSE 危险物质测定方法》（MDHS系列），超过100种方法，网址 www.hse.gov/uk/pubns/mdhsindex.htm

substances (MDHS Series) more than 100 methods available on line at: www.hse.gov/uk/pubns/mdhsindex.htm (accessed December 2006)

（2006年12月访问）

• OSHA – Standard methods for sampling
www.osha.gov/dts/osta/otm/otm_toc.html (accessed December 2006)

• OSHA－采样的标准方法
www.osha.gov/dts/osta/otm/otm_toc.html（2006年12月访问）

• ISO – Standard methods for sampling and analysis
www.iso.org/iso/en/ISOOnline.frontpage (accessed December 2006)

• ISO－采样和分析的方法
www.iso.org/iso/en/ISOOnline.frontpage（2006年12月访问）

• National Standard – A number of standards including the sampling for respirable and inspirable dust, welding fumes and organic vapours are available through the National Standards organisations of a number of countries.

• 国家标准——许多标准，包括呼吸的和吸入的灰尘、焊接烟尘和有机蒸气的采样可通过多个国家的国家标准机构获得。

• SKC Inc Comprehensive Catalog and Sampling Guide – annual publication and also on their website www.skcinc.com(accessed December 2006) provides references to the method, sampling parameter, analysis and equipment for over 2,500 specific compounds.

• 《SKC公司综合目录和采样指南》——年度出版物，并在他们的网站上www.skcinc.com（2006年12月）提供了超过2500特殊化合物的参考资料、采样参数、分析和设备。

7.3 FILTERS

Many analytical methods used in workplace monitoring require the use of some form of filtration, usually to extract the contaminant of interest from the air being sampled.

The choice of collection media will

7.3 过滤器

现场分析所使用的许多分析方法通常需要使用许多过滤方式，从被采样空气中提取相关污染物。

normally be dictated by the choice of sampling instrument and by analytical considerations. In general there are three types of mechanisms which capture particles during filtration. These are:

采集媒介的选择通常取决于采样仪器的选择和分析方面的考虑。过滤过程中通常有三种类型的机制来采集颗粒，包括：

• Interception (impingement) – This occurs when the particle is smaller than the pore of the filter.

• 拦截（撞击）–在颗粒小于过滤孔时发生。

• Inertial Impaction – This occurs with a change in direction of airflow and requires high velocities and dense fibre packing of filters.

• 惯性碰撞–在气流方向出现变化时发生，需要过滤器速度较高，纤维填料比较致密。

• Diffusion – This occurs with very fine particles and occurs at low flow rates and is assisted by electrostatic forces.

• 扩散–在颗粒较细时且流率较低且有静电力辅助时出现。

There are a number of properties that are desirable (but not always present) in filter media. These include:

过滤器媒介中有一些属性是可取的（但不总是），包括

• High collection efficiency that is known

• 已知的较高采集效率

• Manageable resistance (particularly as the load on the filter increases)

• 可控的阻力（尤其是当过滤器上荷载增加时）

• Low moisture pick up or loss

• 吸湿性或水分损失较低

• Low electrostatic properties

• 静电属性低

• Compatibility with the selected analytical technique

• 与所选的分析技术兼容

• Low cost

• 成本低

Not all these properties are achievable in one filter so the selection of a particular filter media for a particular measurement becomes one of compromise.

不是一个过滤器拥有所有这些属性，因此特殊测量的特殊过滤器介质的选择可以商议。

The filter selection guide below provides assistance on which filters can be used for particular contaminants but local or statutory requirements may necessitate using an alternative.

下面的滤波器选择指南有助于选择特殊污染物所使用的过滤器，但当地或法定要求，可能需要使用一个替代品。

Table 7.1 – Filter Selection Guide
表 7.1–过滤器选择指南

Material	Main Properties	Air Sampling Applications
材料	主要属性	气体采样应用
Mixed Cellulose Ester	Hydrophilic Readily soluble for atomic absorption analysis Readily rendered transparent for transmitted light microscopy Dissolve and clear easily	Metal dust analysis Asbestos and man-made fibres
混合性纤维素酯	亲水性 易溶解，进行原子吸收分析 透明，进行透射光显微镜法 容易溶解，清洗	金属粉尘分析 石棉和人造纤维
Polyvinyl Chloride (Pure Homopolymer)	Hydrophobic Non-oxidising surface Silica-free Low ash Low tare weight for gravimetric analysis	Gravimetric analysis of dusts Hexavalent chromium Quartz analysis by IR spectrophotometry
聚氯乙烯（纯粹均聚物）	疏水性 非氧化表面 无硅 低灰分 重量分析，低皮重	粉尘重量分析 六价铬 红外分光光度法分析石英
Polytetrafluoroethylene (Teflon)	Hydrophobic Inert to solvents, acids and bases Autoclavable	Alkaline dusts Polynuclear aromatics Pesticides Isocyanates
聚四氟乙烯（特氟纶）	疏水性 惰性溶剂、酸和碱 耐高压	碱性粉尘 多环芳香烃 杀虫剂 异氰酸酯

Material	Main Properties	Air Sampling Applications
材料	主要属性	气体采样应用
Polycarbonate	Hydrophobic Microscopically smooth surface Straight-through pores Extremely thin (10 – 20 µm) and transparent Autoclavable	Scanning electron microscopy Asbestos fibres
聚碳酸酯	疏水性 微观表面光滑 直通孔 非常薄（10-20µm） 透明 耐高压	扫描电子显微镜 石棉纤维
Silver	Wide solvent compatibility Higher temperature tolerance Autoclavable Uniform porosity and thickness	Bromine Asbestos by TEM Silica by x-ray diffraction
银	溶剂相容性较广 耐高温 耐高压 空隙和厚度均匀	溴 X射线衍射TEM硅的 石棉
Glass Fibre (MMMF)	Partially hydrophobic Higher temperature tolerance Autoclavable High particulate retention	Pesticides Coarse gravimetric analysis Isocyanates Ethylene glycol
玻璃纤维（MMMF）	部分疏水 耐高温 耐高压 颗粒保留	农药 粗重量分析 异氰酸酯 乙二醇
Quartz	Low level metals content High temperature 300°C Autoclavable	PM10 Diesel particulates
石英	金属含量较低 温度高 300° C 耐高压	PM10 柴油微粒
Cellulose	Autoclavable Uniform strength Ashless (Type 40)	AA HPCL

纤维素	耐高压 强度均匀 无灰（类型40）	AA HPCL

(Source: SKC Inc – *Reproduced with permission*)
（来源：SKCInc－许可转载）

Notwithstanding the information provided above, many Occupational Hygienists choose not to use mixed cellulose ester filters for metal fume – metal dust analysis due to the poor electrostatic properties which make them difficult to weigh. Alternatives commonly used include glass fibre or polyvinyl chloride.

尽管有以上所提供的信息，许多职业保健专家选择不使用混合纤维素酯过滤器进行金属烟－金属粉尘分析，因为静电属性较差，难以称重。其它通常使用的方法包括玻璃纤维或聚氯乙烯。

One aspect of filter selection that is sometimes confusing concerns pore size. When sampling for respirable dust (50% cut at 4 µm), it is not uncommon to use a filter (PVC) of nominal pore size 5 µm. This seems illogical but it is possible due to the fact that the construction of most membrane filters is such that the airways follow a torturous path and thus collection of aerosols well below 1 µm is common. The only exception to this is polycarbonate filters, which has drilled holes straight through the filter rather than a torturous pathway.

选择过滤器的一个方面是有时会混淆孔径。对呼吸性粉尘（4µm时为50%）采样时，使用公称孔径5µm的过滤器（PVC）也不少见。这似乎不合逻辑，但是也是可能的，因为大多数膜滤器的构造使得通风孔为曲折的路径，从而容易采集到1µm以下的气溶胶。聚碳酸酯过滤器是唯一的例外，其钻孔直接穿过过滤器而不是曲折的通道。

For some contaminants it may be necessary to use a filter impregnated with a stabilising agent or a backing pad treated with a collection media where the contaminant may be present in the gaseous form or in both the particulate and gaseous form.

对一些污染物来讲，如果污染物以气体形式存在或以微粒和气体两种形式存在，需要使用浸渍了稳定剂的过滤器，或用采集介质处理过的支撑垫。

Examples of this are:

Glutaraldehyde - Glass fibre (MMMF) filter impregnated with
2,4 – dinitrophenylhydrazine

Fluoride-PTFE (Teflon) membrane filter with sodium carbonate treated cellulose backing pad

These examples demonstrate the need for close communication with the laboratory conducting any analysis before sampling.

Two other features of filters are critical and can cause significant errors in gravimetric analysis if not considered. These are moisture and electrostatic charge. In the case of some filters (especially membrane filters), moisture pick-up or loss can be significant. This can be corrected for by the process of “equilibration”. This process requires that sample filters and a suitable number of blanks be placed in clean containers with the lids slightly ajar, in the balance room where they are to be weighed. They are then left for a suitable time to come to equilibrium with the balance room atmosphere (overnight, but this may depend on the filter type) before weighing.

At the end of the sampling exercise the process is repeated and a correction made for any gain or loss of mass in the blank filters (this should be minimal if the

例子包括：

戊二醛 - 玻璃纤维（MMMF）过滤器，浸渍2，4-二硝基苯肼

氟化物 - PTFE（聚四氟乙烯）膜滤器，带碳酸钠处理过的纤维素支撑垫

这些例子表明，在采样之前需要和进行任何分析的实验室进行密切交流。

过滤器的另外两个特征非常重要，如未考虑到话可能会造成重量分析的严重错误，即水分和静电电荷。在某些情况下（特别是膜滤器），吸湿或水分损失可能非常明显。这可在“平衡”的过程中纠正。该过程要求将样本过滤器和合适数量的空白试剂放在干净的容器内，容器盖子半开，放在配平的房间内。称重前在室温下放置一段合适的时间（过夜，但这可能取决于过滤其类型）。

在采样行为结束时重复该流程，并纠正空白过滤器中质量的增加或减少正

balance room atmosphere is well controlled).

空白（如果配平房间气温控制良好的话，应为最小的）。

The other critical issue is electrostatic charge. This can be overcome by the use of a static eliminator (usually an Americium 241 or Polonium 210 source). A high voltage static eliminator may be used but it should be checked to ensure that it does not punch holes through the filter.

另一个重要的问题是静电电荷。这可通过使用静电消除器克服（通常是一个镅241或钋210源）。可使用高压静电消除器，但应检查以确保它不会在过滤器上穿孔。

One final aspect needs to be considered and that is the transportation of dust-laden filters after collection. Experience has shown that the layer of dust on the filter is fragile and any shocks or vibration may cause loss of material unless precautions are taken.

最后一个方面需要考虑的是运输采集后带灰尘的过滤器。经验表明，过滤器上的灰尘过滤层很脆弱，任何冲击或振动可能造成损失的材料，除非采取预防措施。

The best method is delivery by hand, but if this is not possible the filters should be packed in such a way that normal transportation shocks do not cause loss of material.

最好的方法是用手传递，但如不可能的话对过滤器进行堆放时应时正常交通的冲击不会造成材料损失。

7.4 LABORATORY BALANCES

7.4 实验室天平

While weighing is often considered the simplest of the analytical tools, there are a number of sources of error that must be considered.

称重时通常考虑最简单的分析工具，必须考虑许多错误来源。

The analyst is often weighing sub milligram quantities of material and greater care has to be taken during both filter/sample head preparation and filter reweighing after sampling.

分析师通常衡量材料的毫克量，过滤器/样本采样后头的制备过程中以及采样后对过滤器重新称重时必须非常小心。

Insufficient sampling time may mean not enough material is collected and cannot be detected unless an appropriate laboratory balance is used.

采样时间不足可能意味着没有采集到足够的材料，不能进行检测，除非使用适当的实验室平衡方法。

Calibration of the microbalance is a key aspect and the following extract from AS3640 can be used as a guide to what is required.

微量天平的校准是一个重要的方面，从AS3640中摘选的以下内容可用作指导。

“The accuracy of the microbalance used in the gravimetric measurements shall be checked in the following manner:

应使用以下方式检查“重力测量中使用的微量天平的准确度”：

a) *Repeatability*
Every 6 monthly, an appropriate repeatability test shall be conducted on the microbalance.

a） 可重复性

每6个月对微量天平进行合适的重复性测试。

b) *Before every weighing session*
Before weighing the filters –
i) check the balance with a reference weight at or near to full electrical capacity; and
ii) check the linearity of the balance inside or near to the working range.

b） 每个称重阶段之前

对过滤器称重之前 –

i） 在全电容量或接近全电容量时用参考重量检查天平；以及

ii）检查工作范围内或附近的天平直线性

c) *During every weighing session*
When weighing filters –
i) conduct a zero check after each sample/blank filter weight determination; and
ii) verify that electrostatic effects are insignificant by repeat sample weighing.

c） 每次称重过程中

对过滤器称重时——

i） 每次样本/空白滤波器重量测定之后，进行零位检查；以及

ii） 重复样本称重，确认静电影响是

d) *After every weighing session*

Check the calibration of the balance with a reference weight at or near to full electrical capacity.

e) *Long weighing sessions*

If a series of filters is being weighed the microbalance accuracy shall be checked at appropriate intervals during the procedure."

可忽略的。

d）每次称重之后

用参考重量在全电容量或接近全电容量检查天平的校准。

e）较长的称重期间

如对一系列过滤器进行称重，程序过程中应以合适的间隔检查微量天平的准确度。

7.5 MICROSCOPY

Microscopy or to be more correct polarised light microscopy together with dispersion staining is the technique is used for the identification and phase contrast microscopy for counting of fibres.

Fibres are particles that have a needle-like or thread-like appearance with a specific length to width ratio. Some examples of fibres include asbestos, fibreglass, rockwool and ceramic fibres.

Monitoring for asbestos fibres is carried out following the appropriate Standards methods such as:

- Determination of Airborne Fibre Number Concentrations: A recommended method by phase contrast optical microscopy (membrane filter method) published by the WHO (1997)

- NIOSH Method 7400 Asbestos and other fibres by PCM

7.5 显微镜

显微镜，或更准确来说，带分散染色的极化光显微镜可用来区分，相差显微镜用来计数纤维。

纤维有针状或线状的外观，特定的长宽比。纤维的一些例子包括石棉纤维、玻璃纤维、石棉和陶瓷纤维。

按照以下适当的标准方法对石棉纤维进行监测，包括：

- 空气中纤维数量浓度的测定：WHO公布的相差光学显微镜（膜滤法）的建议方法（1997）

- PCM的NIOSH法7400石棉和其它纤维

- HSG 248 – Appendix 1: Fibres in air: Sampling and evaluation by Phase Contrast Microscopy (UK)

- HSG248 －附件1：空气中的纤维：相差显微镜的采样和使用（英国）

- NOHSC Code Asbestos: Code of Practice and Guidance Note or the Membrane Filter Method for Estimating Airborne Asbestos Dust (Australia)

- NOHSC石棉法规：实践和指导说明法规或估算空气中石棉粉尘的膜过滤法（澳大利亚）

Microscopy should only be performed by a trained and certified person. Typically such persons routinely participate in an inter laboratory system to maintain their skills and validate their consistency with international standards.

显微镜只能由受过培训和认证的人操作。通常来说，这些人会经常加入实验室内部系统来维持他们的技能，并用国际标准验证它们的一致性。

The principle of the method is air samples are collected on a grided mixed cellulose ester or cellulose nitrate filter mounted in a cowled asbestos sampling head.

该方法的原理是，将空气样本收集在一个预混合纤维素酯或硝酸纤维素过滤器上，该过滤器安装在一个带帽的石棉采样头上。

After sampling the filters are mounted on a microscope slide by collapsing the membrane using acetone vapour making it transparent. Glyceryl triacetate is added to the slide to provide a suitable medium for seeing the fibres.

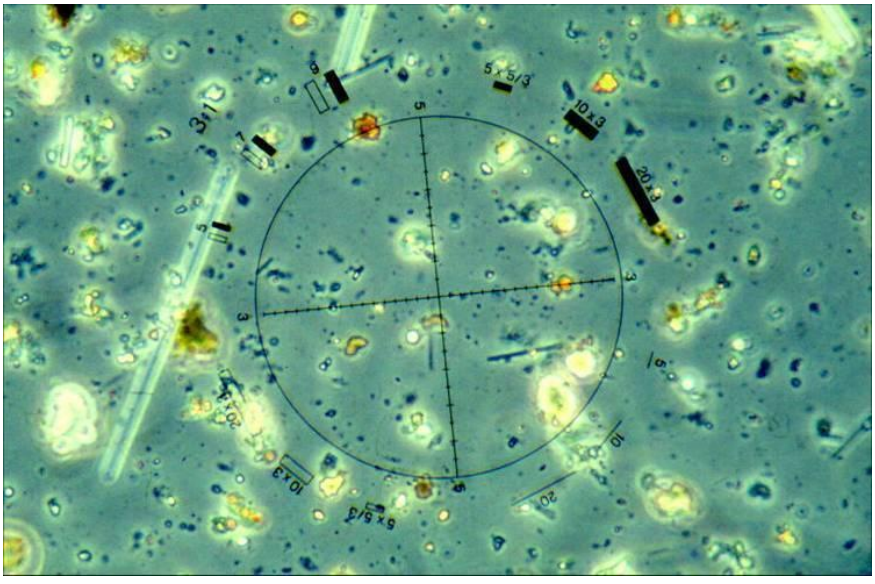
采样后，使用丙酮蒸汽使过滤器安装在显微镜载玻片上，使其透明。将三醋酸甘油酯添加到载玻上，为观察纤维提供合适的介质。

(Source: University of Wollongong)

（来源：伍伦贡大学）

Figure 7.8 – Sampling Head for Asbestos Fibres

图 7.8–石棉纤维的采样头



(Source: A Rogers – *Reproduced with permission*)

（来源：ARogers－许可转载）

Figure 7.9 – Phase Contrast Microscopy – Amosite Fibres & Synthetic Mineral Fibres

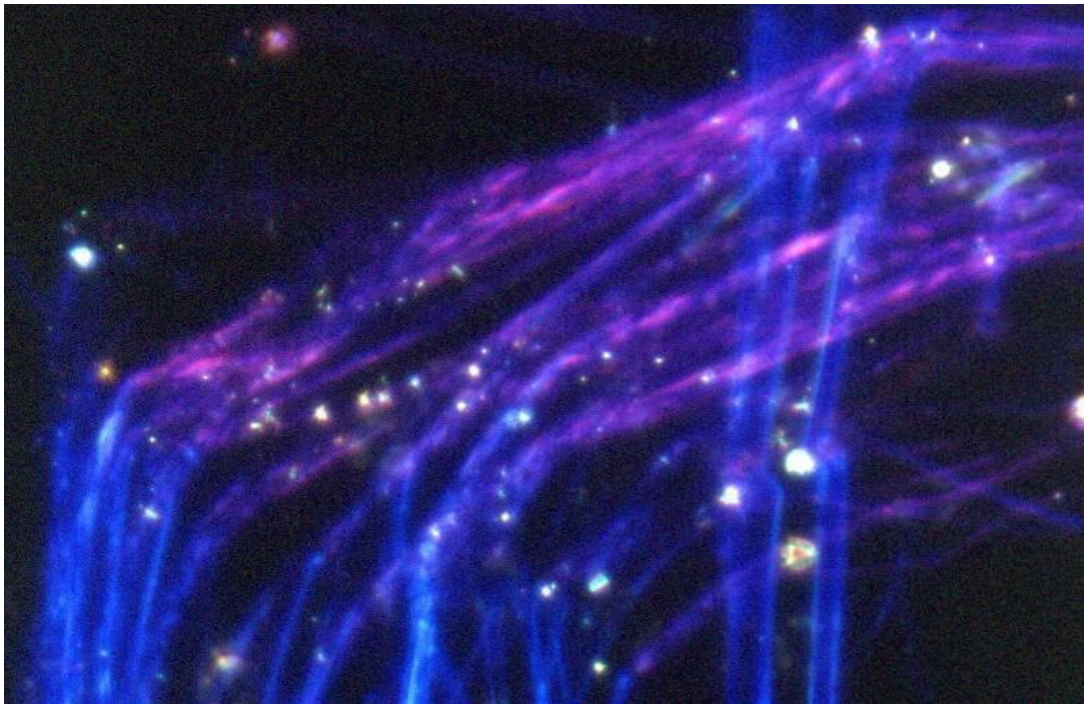
图 7.9–相差显微镜–铁石棉纤维和合成矿物纤维

The fibres are then counted using phase contrast microscopy following standards fibre counting rules. Results are expressed as numbers of fibres/ml of air.

然后用相差显微镜按照标准纤维计数规则对纤维进行计数。结果表示为纤维数量/空气毫升。

The other area of analysis in regard to asbestos fibres is that of identification in bulk materials. This involves the suspension of fibres in liquids of known refractive indices and observation of the colours displayed under polarised light at different orientations of the fibres. A variety of microscope configurations can be used, including dispersion staining and crossed polars with first order red compensator plate. This technique is both rapid and sensitive in the hands of a trained operator. Figure 7.10 shows chrysotile using dispersion staining, while Figure 7.11 shows amosite but with 1st order red retardation.

石棉纤维的其它分析领域在于散装材料的鉴定。这涉及到在折射率已知的液体中悬浮的纤维，和极化光在纤维不同方向下液体的颜色显示。各种显微镜配置都可使用，包括用补色器进行分散染色和正交偏光。在经过培训的操作人员手中，该技术既快速又灵敏。图7.10显示了分散染色的温石棉，而图7.11显示了用补色器的铁石棉。

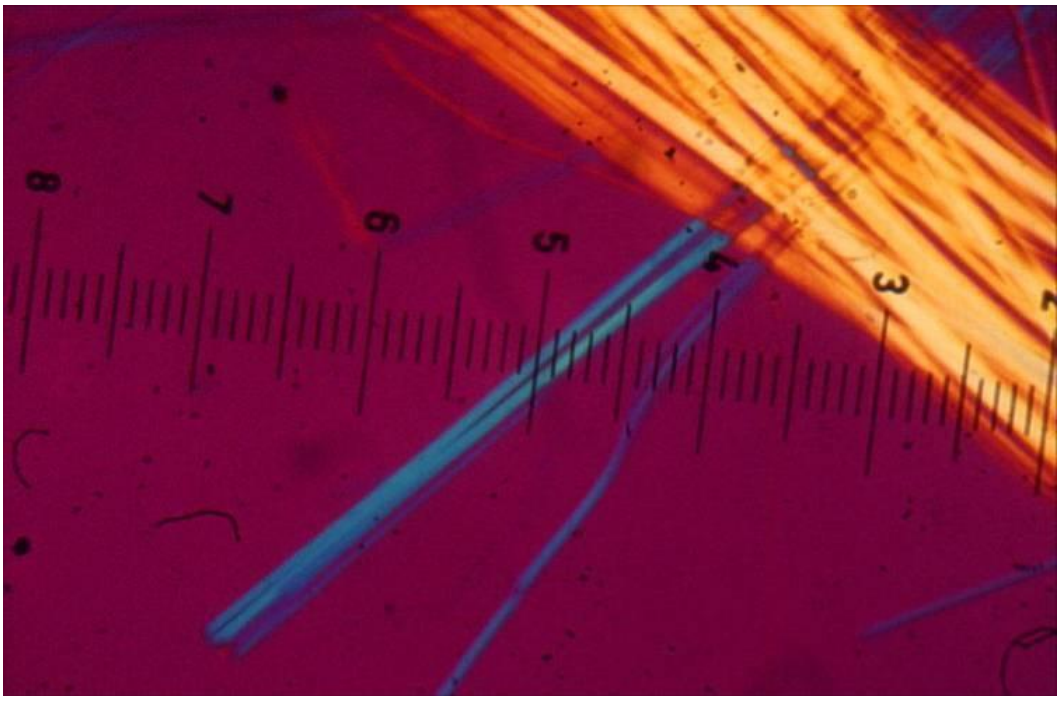


(Source: A Rogers – *Reproduced with permission*)

（来源：ARogers－许可转载）

Figure 7.10 – Chrysotile

图 7.10–温石棉



(Source: A Rogers – *Reproduced with permission*)
（来源：ARogers－许可转载）

Figure 7.11 – Amosite (1st Order Red Retardation)
图 7.11－铁石棉（补色器）

7.6 QUALITY ASSURANCE OF ANALYSIS

7.6.1 Internal Quality Control

The internal quality control process is the set of procedures adopted by a laboratory to assess whether the results from each set of tests are consistent. Occupational hygiene samples can often pose quality control concerns including the very low levels being measured, matrix effects from the sampling medium, interfering substances, incomplete recoveries, degradation in storage or transport etc. The procedures typically used include method validation, the use of standards, blanks and controls, recoveries and quality control charts.

7.6 分析质量保证

7.6.1 内部质量控制

内部质量控制过程是实验室采用的整套程序，用来访问各个组的测试结果是否一致。职业健康样本通常注重质量控制方面，包括非常低的水平测量、采样介质的矩阵影响、干扰物质、不完全回收率、储存或运输损耗等。使用的程序通常包括方法验证、标准的使用、控制实际和控制样本、回收率和质量控制图。

• **Method validation**

Before use an analytical method must be validated to ensure it is sufficiently accurate and precise.

Its accuracy may be tested by analysing known concentrations of the analyte. For example, by adding known amounts of solvent to charcoal tubes, desorbing it and analysing it by gas chromatography; or by spiking blood or urine samples with lead for example and analysing by atomic absorption. The recovery of the analyte is the percentage of added analyte recovered, ie measured in the analysis.

Precision is determined by analysing enough replicate samples to enable the calculation of the standard deviation or coefficient of variation. Several different concentrations over the range should be selected.

The measurement range is a guide as to the usual operating range of the method. At the lower end this involves an estimate of the limit of detection (LOD) and the limit of quantitation (LOQ).

Other factors to be evaluated include:

- Interfering substances
- Capacity of the collection media (eg breakthrough volume for sorbent tubes)
- Stability of samples
- Critical steps in the analysis where special care must be taken

• **方法验证**

使用前必须对分析方法进行验证，确保足够准确和精确的。

其精度可通过对已知浓度的被分析物的检测。例如，通过对炭管添加已知量的溶剂，然后释放并用气相色谱法进行分析；或用带铅的飙升血液或尿液样本为例，通过原子吸收分析。分析物的回收是添加的分析物的回收百分比，即在分析中测定。

通过分析足够量的复制样本确定精度，以便计算标准偏差和变异系数。应选择不同的浓度范围。

测量范围可用作该方法通常的操作范围。在较低一段涉及到检测限（LOD）和定量限（LOQ）。

其它访问因素包括：

- 干扰物质
- 采集介质的能力（如采样管的突破体积）
- 样本的稳定性
- 必须特别注意分析的关键步骤

There are well established and validated methods for many common chemicals.

许多常见化学品有许多完善的经验证的方法。

• **Standards**

• **标准**

Standard reagents: are chemicals of known purity and composition. These materials are often available from external agencies eg Standard Reference Materials from the US National Bureau of Standards.

标准试剂：纯度和成分已知的化学物。这些材料可以从外部机构获得，如美国国家标准局的标准参考材料。

Calibration standards: these are reference standards against which all test and control samples are compared.

校准标准：这些参考标准用来比较所有测试和控制样本。

Where standard calibration curves are prepared at least 5 points should be used and appropriate regression analysis should be undertaken to ensure the viability of the calibration curve.

如制备标准校准曲线，应使用至少5个点，并进行适当的回归分析确保校准曲线的可行性。

• **Blanks**

• **空白试剂**

Field sampling blanks should be submitted with field samples to determine if there has been contamination during sample handling and storage. The blank is treated in the same manner as the field sample but with no air being drawn through it.

现场采样空白试剂应和现场样本一起提交，以确定样本处理和储存过程中有没有污染。空白试剂应和现场样本采用相同的方式处理，但是没有空气通过。

Reagent blanks are used in the laboratory to correct for any contribution made by the laboratory reagents used in the analysis.

空白试剂在实验室中可用来纠正分析中所使用的实验室试剂的任何结果。

• **Control Materials**

• **控制材料**

These have been previously analysed and are analysed with the test samples

这些之前已经分析过并和测试样本一

so that a comparison between actual and expected result can be made.

起分析的，从而在实际结果和预期结果之间进行比较。

• **Recoveries**

Recoveries should be assessed both as part of the method validation process, but also on an ongoing basis as part of the quality control process.

• **回收率**

回收率应当作为方法验证过程的一部分进行访问，也可在持续的基础上作为质量控制过程的一部分进行访问。

• **Duplicates**

Duplicate samples, ie from the field are more useful in assessing the reproducibility of the sampling or analysis than are duplicate analysis, ie two chromatograph injection from the one air sample.

• **复样**

现场重复采样在访问采样或分析的重现性方面比重复分析更有效，即同个空气样本中进行两次色谱仪进样。

• **Quality Control Charts**

These can provide a means of showing the reliability of each method and to identify trends or cyclical changes in laboratory performance.

• **质量控制图**

这些可以提供显示每个方法可靠性的一种手段，能够识别实验室性能的趋势或周期性变化。

7.6.2 External Quality Assurance

• **Proficiency Testing Schemes**

Many countries run inter-laboratory testing schemes and some of these are International:

- NIOSH - Proficiency Analytical Testing (PAT) – solvents on charcoal, asbestos, silica and metals on filters

- UK HSE – Workplace Analysis Scheme for Proficiency (WASP) – solvents on charcoal, metals on filters

7.6.2 外部质量保证

• **水平测试计划**

许多国家实行实验室内部测试计划，有些计划是国际性的：

- NIOSH - 能力分析测试（PAT）- 过滤器上木炭、石棉、硅和金属上的溶剂

- UKHSE - 工作场所能力分析计划（WASP）- 过滤器上木炭、金属上的溶剂

They involve the distribution of control samples to laboratories by an outside agency. The material is analysed and the results returned to the coordinating body for statistical analysis.

由外部机构向实验室分发控制样本。对材料进行分析，将结果返回到协调机构进行统计分析。

• Laboratory Accreditation

•实验室认证

The purpose of accreditation is to ensure a laboratory"s results are reliable. A laboratory applying for accreditation is visited by assessors, who examine all aspects of the laboratory"s operations including the qualifications and experience of staff, quality, calibration and maintenance of instruments, accommodation, laboratory practice including sample handling, quality control, recording and reporting, and the test methods used. If satisfied, the appropriate approval to undertake the type of analysis being sought is granted.

认证的目的是确保实验室的结果可靠。访问人可参观申请认可的实验室，审查实验室业务的所有方面，包括人员的资格和经验、仪器的质量、校准和维护，住宿、实验室运行包括样本处理、质量控制、记录和报告，以及使用测试方法。如果满意的话，会批准试实验室承担相关类型的分析。

Similar schemes, eg UKAS in the UK, AIHA programme in the USA, NATA in Australia, all follow the principles outlined above.

类似的认证，如英国的UKAS，美国的AIHA方案、澳大利亚的NATA，都遵守上述原则。

8. AIR SAMPLING EQUIPMENT - DUSTS, FUMES & FIBRES

8.1 INTRODUCTION

Dust, including fumes and fibres, in the occupational environment can be described as airborne particles that can be hazardous to health and is one of the common issues found in workplaces. Dust usually comprises solid particles generally greater than 0.5 µm in size, formed by crushing or other forces on a parent material (which may be natural or synthetic). Fume is produced from the condensation of vapourised materials (usually metals) and consists of particles typically less than 0.05 µm in size that have a tendency to agglomerate. Fibres are either natural (eg asbestos) or synthetic materials (eg glass wool) of thread-like characteristics which is three or more times longer than its width.

Particulates is a generic term used to refer to particulate aerosols such as dust, fumes, mists and smoke.

From a health perspective the two key factors which are important when assessing exposure from dusts, fumes or fibres are the chemical composition of the material (toxic effect) and particle size (where it deposits in the body).

When assessing worker exposure to dusts, fumes or fibres two different

8. 气体采样设备-灰尘、烟尘和纤维

8.1 介绍

职业环境中的粉尘，包括烟雾和纤维等，可以描述为空气中对健康有害的颗粒，是工作场所常见的问题。粉尘通常包括尺寸超过0.5µ的固体颗粒，对母体材料施加破碎或其它力（可以是自然的或人为的）而形成的。烟雾是由蒸发材料（通常是金属）的冷凝形成的，由小于0.05µ有结块倾向的颗粒组成。纤维是天然的（如石棉）或合成的有线形特征的材料（如玻璃棉），比宽度长三倍或更多。

颗粒物是一个通用的术语，指气溶胶如灰尘、烟尘、雾和烟雾。

从健康的角度来看，访问对灰尘、烟尘或纤维的暴露情况时有两个关键因素非常重要，即材料的化学组成（毒性）和粒径（沉积在体内时）。

访问工人对粉尘、烟尘或纤维的暴露情况时，大多数情况下采用两种不同

approaches can be adopted in the majority of cases. These are filtration samplers and direct reading instruments; both of which have advantages and disadvantages. However the most common approach in workplace exposure assessment is the use of filtration samplers.

的方法，即过滤采样器、直读仪器；两者都有优点和缺点。然而工作场所暴露访问最常用的方法是使用过滤采样器。

8.2 SAMPLING PUMPS

8.2 采样泵

There are many sampling pumps commercially available that are designed for use with appropriate capture devices to collect dust, fumes and fibres in the workplace environment. Some operate from mains power but most are small battery-powered pumps which can be worn by the person being sampled.

市售采样泵有许多配有适当的采集装置，能够采集工作环境中的粉尘、烟雾和纤维。有些是电源驱动，但大多数泵由小型电池供电，可由被采样人员佩戴。

These pumps can operate at flowrates between 0.5 to 5 litres/minute (L/min), however most particulate sampling is carried out at flowrates between 1.0 to 2.5 L/min.

这些泵可以在流率为0.5至5升/分钟（L/min）范围内运行，但是大多数颗粒采样是在1.0至2.5L/min的流率下进行的。

While there is no defined list of requirements for a sampling pump, the following list gives a number of features which have been found to be very useful when sampling particulates.

虽然没有针对采样泵的规定，以下列出的是对颗粒物采样时非常有用的一些功能。

• *Automatic flow control:* A stable airflow is important as this value in the calculation of exposure. Automatic flow control ensures that the flow rate remains constant as the sample builds up on the filter thus creating backpressure on the pump.

• 自动流量控制：稳定的气流在计算曝光度中非常重要。自动流量控制能够确保在样本在过滤器上堆积时流量能够保持稳定，从而在泵上产生背压。

• *Pulsation dampening:* This is critical when sampling using a size selection device (eg miniature cyclone) as variations in the flow alter the cut off point of the sampling device. Pulsation dampening is needed on reciprocating pumps but is not necessary on rotary vane pumps (Table 8.1).

• 脉动衰减：如采样时适用尺寸选择装置（如小型旋风式）时非常重要，因为流量的变化会改变采样装置的切割点。往复泵需要脉动衰减器，但是旋转叶片泵不一定需要（表8.1）。

• *Capacity to operate at a reasonable backpressure:* As material builds up on the capture filter the backpressure on the sampling pump will also increase.

• 在合适的背压下运行的能力：材料在捕获滤波器上增加时，采样泵上的背压也会增加。

• *Ability to set flowrates over a reasonable flow range:* Necessary as not all capture devices operate at the same flowrate.

• 将流率设定在超出合理流量范围的能力：必要，因为不是所有的捕获装置都以同样的流率运行。

• *Good battery capacity:* This allows continuous operation for the full duration of a work shift.

• 良好的电池容量：能够一次轮班的全部时间内连续运行。

• *Intrinsically safe:* This is a mandatory requirement for those pumps that are used in workplaces where the risk of an explosion may be high (eg coal mines, oil refineries).

• 安全：对于爆炸危险较高的工作场所（如煤矿，炼油厂）使用的泵，这是强制性的要求。

Historically three different types of operating systems have been used in sampling pumps (diaphragm, piston and rotary vane), all of which have advantages and disadvantages (Table 8.1).

过去共有三个不同类型的操作系统用于采样泵（膜片、活塞和旋转叶片），所有这些操作系统都有优点和缺点（见表8.1）。

Table 8.1 – Advantages & Disadvantages of Various Pump Operating Systems
表 8.1 – 各种泵吸系统的优劣势

	Diaphragm	**Piston**	**Rotary Vane**
	振动膜	活塞	旋叶
Power Consumptio	Low	Medium	High
耗电量	低	中	高
Battery Size	Small	Medium	Large
电池尺寸	小	一般	大
Weight	Low	Medium	High
重量	低		高
Repair	Simple	Difficult	Moderate
修理	简单	难	一般
Cost	Cheap	High	Medium
成本	便宜	高	一般
Flow Smoothnes	Strongly pulsating	Mildly pulsating	Smooth
电流顺畅性	强烈跳动	温和跳动	顺畅
Pressure Drop Limits	About 5 kPa	None	None
压降限值	约 5 kPa	无	无
Valve Problems	Can leak	Can leak	None (no valves)
阀的问题	会泄露	会泄露	无

Over the past 10 years, diaphragm operated sampling pumps have become the most common and they operate as indicated in Figure 8.1.

在过去 10 年，采样泵振动膜已得到广泛应用，运行原理详见图 8.1。

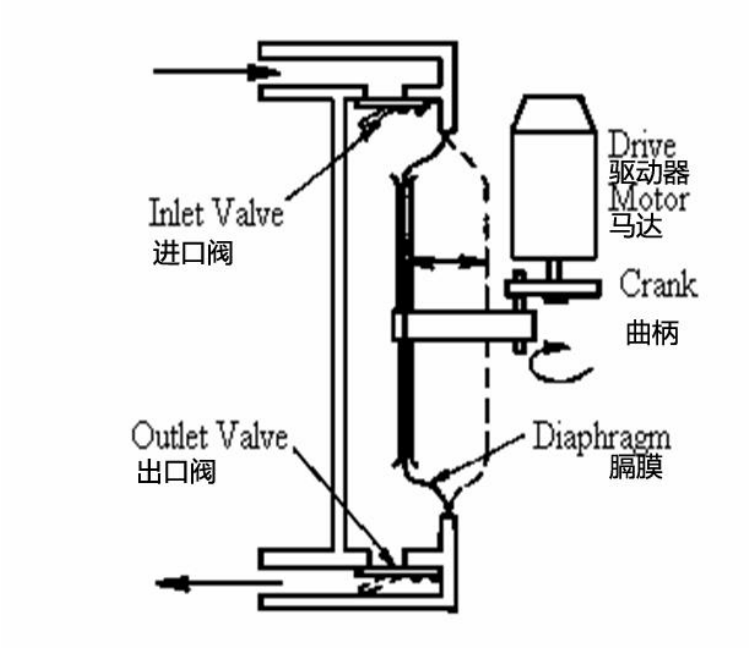


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Figure 8.1 – Schematic of a Diaphragm Sampling Pump

图 8.1– 隔膜采样泵示意图

No matter which sampling pump is used, there are several factors that need to be considered and appropriately managed if accurate results are to be obtained. These are:

无论使用哪种采样泵，如果要得到准确结果，必须考虑和管辖处理几个因素，具体包括：

• *Maintenance:* All sampling pumps need to be kept in good operating order. This includes ensuring that the automatic flow compensation system is operating correctly and that the internal inline filters (to protect the diaphragm) are not placing an excessive backpressure on the system. The manufacturer"s instructions should have

维护：所有采样泵都需要保持良好运行状态，包括确保自动流补偿系统正常运行，内部内联过滤器（保护膜片）不对系统施加过度反压力。制造商指导应包括维护方法和维护频率。

guidance on the appropriate maintenance to be carried out and at what frequency.

• *Battery charge:* Some battery types (eg Nickel-Cadmium) have an unusual characteristic in that if they are operated for short periods and recharged, they will develop a “memory effect” and thus only operate for a short period. This can be overcome by “cycling” the battery by operating it until it is nearly exhausted and then recharging. This should be repeated several times. If after this process the battery still has a “memory effect” a new battery should be installed. This effect is less common with Nickel Metal Hydride batteries.

充电：有些电池（例如镍镉电池）有一个显著特点：如果在短期运行和充电，他们就会产生“记忆效应”，因此只能短期运行。只要一直运行，直到电量几乎耗尽，然后再充电，就会解决这个问题。这个过程应重复若干次。如果完成这个过程后电池仍维持“记忆效应”，那么应安装一个新电池。镍金属氢化物电池很少出现这种情形。

Modern chargers are designed to adjust the flow of current to the battery so that they are not overcharged but maintained on “trickle” charge so that they are ready for instant use. Some also have a discharge/recharge facility which makes cycling of batteries very simple.

现代充电器的设计可调整进入电池的电流，使电池不会过度充电，而是保持“细流”充电，以便随时准备使用。一些也有放电/再冲电设施，使电池的循环变得非常简单。

• *Internal flowmeters:* Most sampling pumps which have built-in flowmeters suffer a serious design flaw and should not be considered as an accurate measure of flow. Calibration with an appropriate flowmeter is necessary at all times.

• 内部流量计：有内置流量计的大部分采样泵有严重设计缺陷，不应被视为流量的准备测量。用合适的流量计进行校正是任何时候都是必要的。

8.3 CAPTURE DEVICES

8.3.1 Deposition Curves

The fraction of airborne particles which can be inhaled by the human body is dependent upon the properties of the particles, the speed and direction of air movement near the body, the rate of breathing and whether breathing is through the nose or mouth. Inhaled particles can subsequently then deposit somewhere in the respiratory tract (depending on size) or can be exhaled.

The International Standards Organisation (ISO 1995) has defined sampling conventions for use in assessing the possible health effects of airborne particles in the workplace. Conventions are defined for the inhalable, thoracic and respirable fractions. These are:

• *Inhalable fraction:* The mass fraction of total airborne particles which is inhaled through the nose and mouth.

In general terms the inhalable fraction includes all particles <100 µm, however it may include some larger particles but experimental data does not exist to confirm this statement.

• *Thoracic fraction:* The mass fraction of inhaled particles which penetrate beyond the larynx.

In general terms the thoracic fraction includes all particles <50 µm and having

8.3 捕捉装备

8.3.1 沉积曲线

空气中可吸入人体的颗粒微粒取决于颗粒的特性、空气运行到人体附近的速度和方向、呼吸速度以及是否通过鼻子或口进行呼吸。吸入的颗粒物随后沉积在呼吸道的某处（取决于大小）或被呼出。

国际标准化组织（ISO 1995）定义了采样标准，用于访问工作场所空气中颗粒对健康可能产生的影响。这些标准为可吸入性、胸吸入性和呼吸性微粒，即：

• 可吸入性微粒：通过鼻子和嘴吸入的气载颗粒总质量微粒。

一般来说，可吸入微粒包括<100 µm的所有微粒，但它可能会包括一些较大微粒，但实验数据不存在证实该论述。

• 胸吸入性微粒：穿过喉部吸入的颗粒的质量微粒。

一般来说，胸吸入性微粒包括包＜50µm和拥有50%（总悬浮粒子）约10µm的所有

a 50% cut (of total airborne particles) of about 10 µm.

颗粒。

• *Respirable fraction:* The mass fraction of inhaled particles which penetrate to the unciliated airways (alveoli).

•呼吸性微粒：穿过呼吸道（肺泡）的吸入粒子的质量微粒。

In general terms the respirable fraction includes all particles <16 µm (majority <10 µm) and having a 50% cut at about 4 µm.

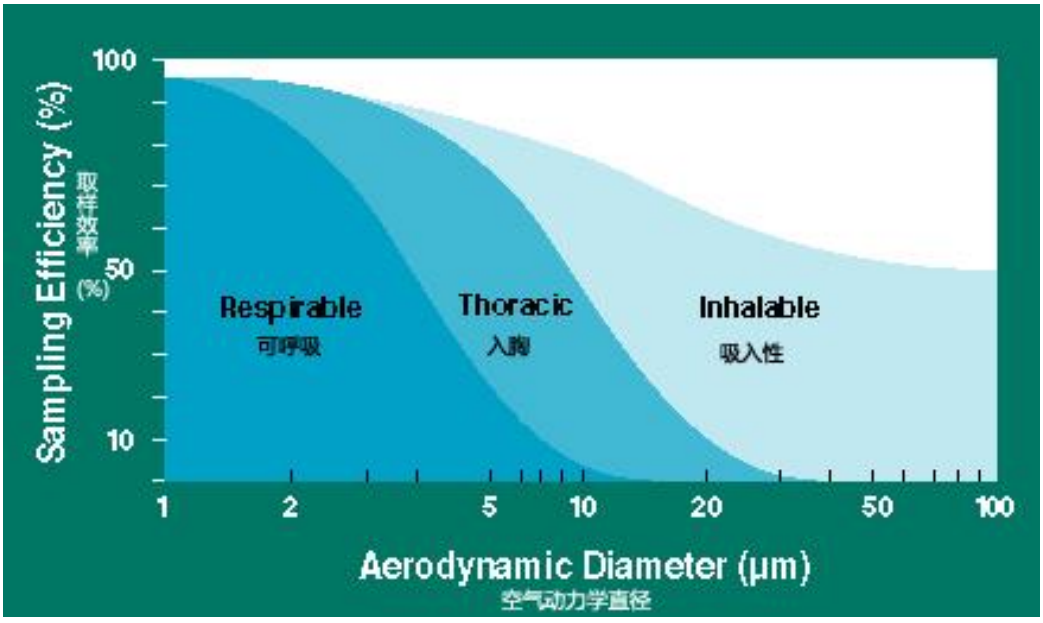
一般来说，呼吸性微粒包括＜16µm（多数＜10µm），4µm处有50%削减。

Over the years, various terminology has crept into the literature (eg inspirable, total inhalable, total) and while this may still persist in some countries, there is general consensus that the ISO nomenclature (ISO 1995) is the most appropriate.

多年来，各种术语已悄悄进入文献（如可吸入性、总的可吸入，总数），但许多国家仍然坚持该分类，人们普遍的共识是，ISO术语（ISO 1995）是最合适的。

The interactions of the various size fractions are best described graphically, as can be observed in Figure 8.2.

图8.2以图示方式显示了各种尺寸的微粒之间的相互作用。



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（来源：TSIInc–许可转载）

Figure 8.2 – ISO Size Fractions for Particles

图 8.2–ISO 颗粒粒径微粒

The importance of the above definitions of the deposition curves cannot be overstated as this links the potential health effect with the sampling device necessary to assess the potential health risk.

对沉积曲线的上述定义的重要性不能被夸大，因为这将潜在的健康风险与访问潜在健康风险所需的采样装置联系起来。

For example, let"s consider two dusts common in the international mining environment, coal and lead dust. If we first consider the health effect of each:

例如，考虑下国际采矿环境中常见的两种粉尘，煤尘和铅尘。如果我们首先考虑其分别对健康的影响：

• *Coal dust:* Gives rise to the respiratory disease “pneumoconiosis” whereby normal lung tissue is replaced by fibrous scar issue due to the long term inhalation of coal dust.

• 煤尘：引起呼吸道疾病“尘肺”，正常肺组织由于长期吸入煤尘被纤维疤痕所取代。

• *Lead dust:* Lead is a systemic poison which has been associated with kidney dysfunction, increased blood pressure and sperm abnormalities. Historically the major toxic effect of lead has been on the blood system, resulting in anaemia.

• 铅尘：铅是全身性毒物，可导致肾功能不全、血压升高、精子畸形。历史上的铅中毒主要影响血液系统，导致贫血。

Clearly these two dusts are operating on two separate target organs (lungs and blood), hence it is appropriate to sample each accordingly.

显然这两种粉尘在两个不同的靶器官上运行（肺部和血液），因此应分别进行相应采样。

For coal dust, collection of the respirable fraction is important and for lead dust collection of the inhalable fraction is important.

对于煤尘，采集呼吸性微粒非常重要，对于铅灰，采集可吸入微粒非常重要。

8.3.2 Sampling Heads

As a result of the various size fractions definitions, a number of sampling devices (heads) have been developed and are commercially available. These, when operated at a particular flowrate, collect one or more of the size fractions indicated in section 8.3.1.

Typical sampling heads are:

• Inhalable Dust

- *IOM Sampling Head:* This device (Figure 8.3) was developed by the UK Institute of Occupational Medicine (IOM) and consists of a single orifice entry and a filter contained within a cassette. The sampler requires a sampling pump operating at 2 L/min and an appropriate filter.

- *United Kingdom Atomic Energy Authority* (*UKAEA) 7 hole Sampling Head:* This device (Figure 8.4) comprises a filter holder with a multi-orifice entry (7 holes) and requires a sampling pump operating at 2 L/min.

- *Conical Inhalable Sampler (CIS):* This device (Figure 8.5) was developed in Germany and is known as either the CIS or GSP sampler. It requires a sampling pump operating at 3.5 L/min. This device can also be used with porous foam plugs and specific cassettes so as to sample the respirable or thoracic fractions.

8.3.2 采样头

由于各粒级的定义，许多采样装置（头）已开发出来并销售。以特定流率运行时，这些装置会采集第8.3.1节中规定的粒径微粒。

典型的采样头为：

• 可吸入性粉尘

-IOM采样头：这种装置（图8.3）由英国职业医学研究所（IOM）开发，包括一个单孔入口和一个位于盒子内的过滤器。采样器需要采样泵在2L/min的流率运行，需要合适的过滤器。

-英国原子能管理局（UKAEA）7孔采样头头：该装置（图8.4）包括一个过滤器支架，支架上一个多孔入口（7孔），要求采样泵以L/min的流率运行。

-锥形可吸入采样器（CIS）：该装置（图8.5）是在德国开发的，被称为GIS或GSP采样器。它要求采样泵以3.5L/min的流率运行。该装置还可以和多孔泡沫插头和特殊的盒子一同使用，以便对呼吸性或胸吸入性颗粒进行采样。

- *SKC Button Aerosol Sampler:* This device (Figure 8.6) was originally developed for the collection of inhalable bioaerosols but has been found to closely follow the ISO sampling criteria for inhalable dust when operated at a flowrate of 4 L/min.

-SKC纽扣式气溶胶采样器：该装置（图8.6）最初是为了采集吸入性生物气胶而开发的，但是被发现以4L/min的流率运行时更符合ISO对吸入性粉尘的采样标准。

- *Pre-Loaded Cassettes:* The approach common in the USA is to use 37 mm membrane filter loaded into a plastic cassette (Figure 8.7) to measure “total inhalable dust”. It should be understood that this does not equate to the ISO definition and thus this device should not be used to sample in accordance with the ISO criteria.

-预加载盒：在美国常见的方法是使用37mm的膜滤器载入到塑料盒（图8.7）内来测量“总的可吸入性粉尘”。应该认识到，这并不等同于ISO定义，因此按照ISO标准这种装置不应该用于样品。

Over the years a number of comparative studies have been undertaken involving all or some of the instruments listed above. In general, the IOM sampler has been shown to give the best agreement to the ISO criteria for inhalable dust under the widest range of workplace conditions and is therefore the preferred method of sampling inhalable dust in many (but not all) countries.

多年来人们用上述所有或部分仪器进行了许多比较研究。一般来说，IOM采样器已被证明能最好地满足工作场所条件最大范围内吸入性粉尘的ISO标准，因此是许多国家（但不是全部）可吸入性粉尘采样的首选方法。

(Source: University of Wollongong)
（来源：伍伦贡大学）

Figure 8.3 – IOM Sampler
图 8.3–IOM 采样器

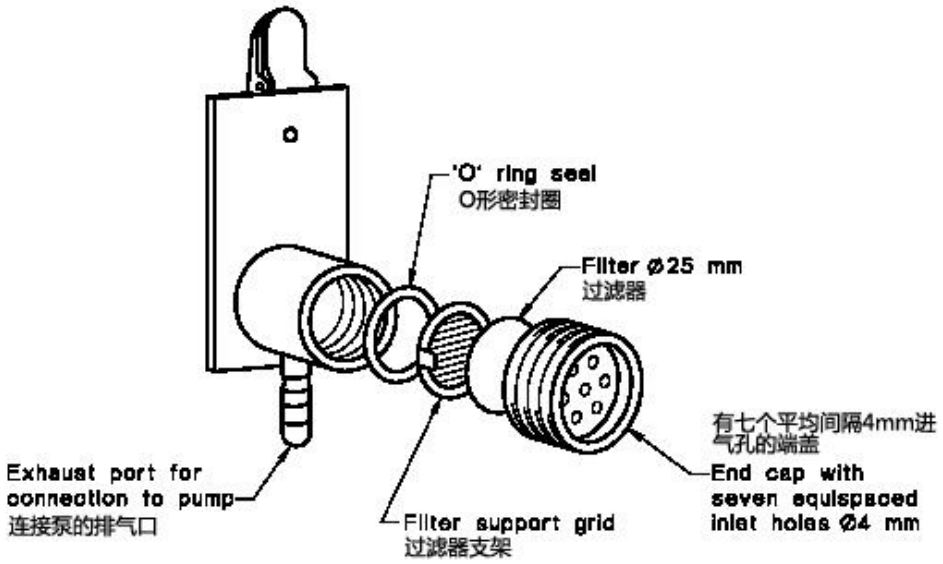

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Figure 8.4 – UKAEA 7-Hole Sampler
图 8.4–UKAEA 7-孔采样器

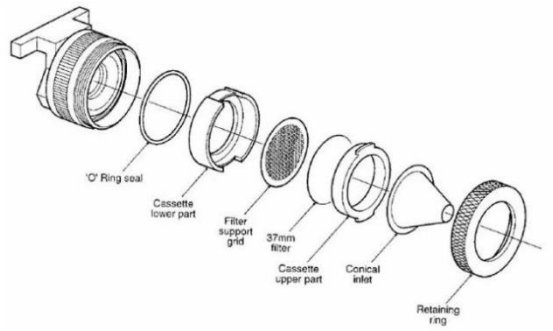

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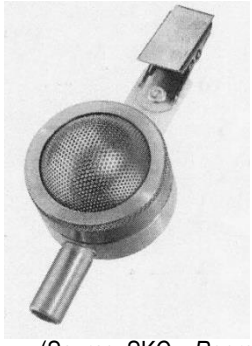
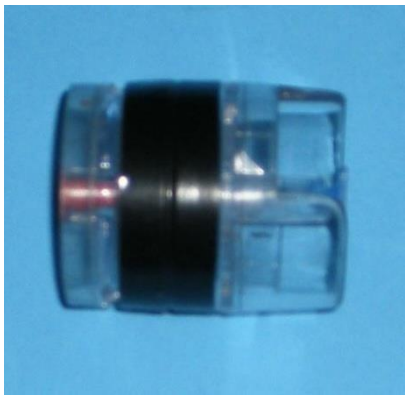
Figure 8.5 – CIS Sampler
图 8.5–CIS 采样器



(Source: SKC – *Reproduced with permission*)
（来源：SKC–许可转载）
Figure 8.6– SKC Button Sampler
图 8.6–SKC 纽扣式采样器



(Source: University of Wollongong)
（来源：伍伦贡大学）
Figure 8.7 – Pre-Loaded Plastic Cassettes
图 8.7– 预载塑料盒

• ***Respirable Dust***

- *Miniature Cyclone:* A number of miniature cyclones have been developed over the past 30+ years (BCIRA, SIMPEDS, Dorr-Oliver, Aluminium), all of which operate under the same principle (Figure 8.8), albeit at different flowrates. In all cases (no matter what the flowrate) a steady flowrate is required if the cyclone is to selectively size the sampled aerosol into the correct fraction (ie 50% cut at 4 µm). The flowrates of the commonly used cyclones are listed in Table 8.2.

• **可吸入粉尘**

- 微型旋流器：30年来已开发了许多小型的旋流器（BCIRA，SIMPEDS，Dorr-Oliver和Aluminium），所有这些都以相同的原则运行（图8.8），尽管流率不同。所有的情况下（无论流率是多少），如果旋流器选择性地将采样的气溶胶变成尺寸正确的微粒（即4µm时为 50%）。常用的旋流器流量见表8.2中所列。

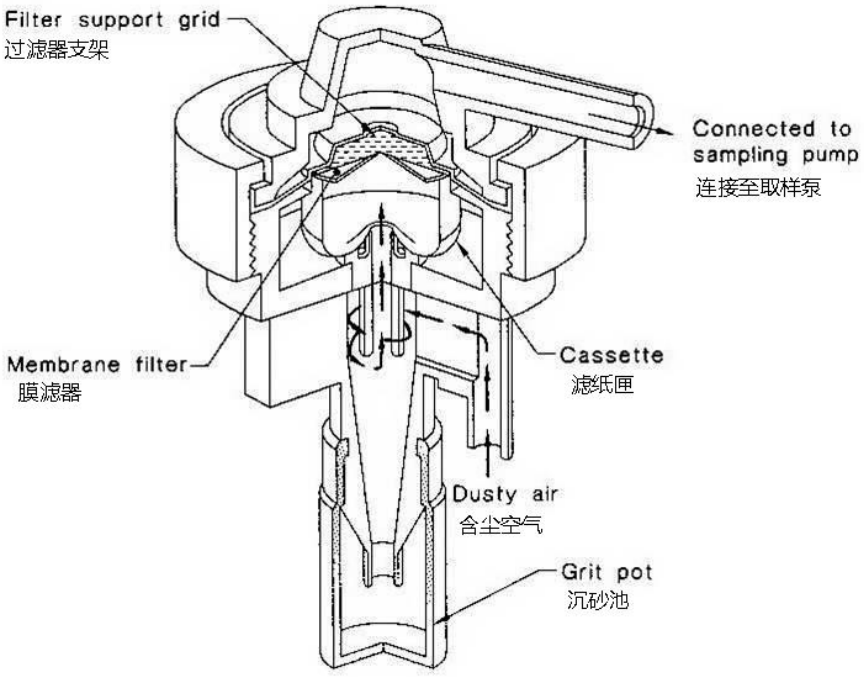


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Figure 8.8 – Operation of a Miniature Cyclone

图 8.8–微型旋流器的运行

Table 8.2 – Designated Flowrates for Size Selective Samplers

表 8.2–各尺寸采样器的规定流率

Size-Selective Sampler **各尺寸采样器**	**Designated Flowrate (L/min)** **规定流率（L/min）**
BCIRA Cyclone BCIRA 旋流器	2.2
SIMPEDS Cyclone SIMPEDS 旋流器	2.2
Aluminium Cyclone Aluminium旋流器	2.5
10 mm Nylon Cyclone (Dorr-Oliver) 10mm 尼龙旋流器（Dorr-Oliver）	1.7

• ***Thoracic Dust:*** Several different approaches have been taken in an attempt to measure the thoracic fraction of a dust cloud. One device, the "Respicon" (Figure 8.9) is a multistage virtual impactor that traps the various size

• **胸吸入性颗粒粉尘**：为了测量胸吸入性尘埃云，已经采取多种不同的方法。一种装置叫"Respicon"（图8.9）是一个多阶段虚拟撞击器，能将各种尺寸的微粒圈在直径37毫米的单个采

fractions onto individual collection filters of 37 mm diameter (Figure 8.10). A sampling pump operating at 3.1 L/min is required as is a 4 µm stage 1 cut module.

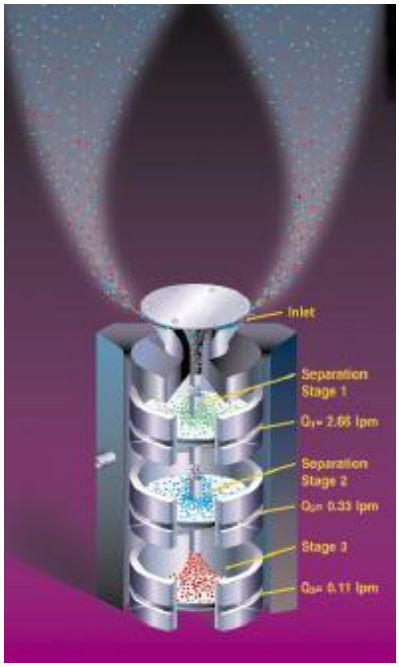
集过滤器中（图8.10）。在3.1L/min下运行的采样泵要求4µm 1期切割模块。

(Source: TSI Inc – *Reproduced with permission*)

（来源：TSIInc–许可转载）

Figure 8.9 – Respicon Sampler

图8.9–Respicon采样器



(Source: TSI Inc – *Reproduced with permission*)

（来源：TSIInc –许可转载）

Figure 8.10 – Schematic of Respicon Stage Impaction

图 8.10–of Respicon 阶段撞击图示

The other approach to measuring the thoracic fraction is the use of polyurethane foam filters which are specifically designed to separate the individual fractions. These foam filters can be inserted into either the CIS or IOM sampling head to act as size selection devices, with the individual dust fractions being collected on membrane filters.

测量胸吸入性颗粒的另一个方法是使用专为个体部分设计的聚氨酯泡沫体过滤器。这些泡沫过滤器可以作为尺寸选择装置插入CIS或IOM采样头，膜滤器上采集个体灰尘微粒。

A third device called the CIP 10 has been developed in France by the French National Institute for Research and Safety. The apparatus is based on the novel method of separation using annular impaction within a rotating housing containing a miniature filter made of polyurethane foam. The device comes in three versions depending on the inter-connectable selector that is installed. Both the respirable and inhalable versions operate at a flowrate of 10 L/min but the thoracic version operates at 7 L/min.

第三台装置叫CIP 10，是法国国家研究和安全研究所在法国开发的。该装置使用环形撞击法的新分离发发为基础，旋转的外壳内包含一个由聚氨酯泡沫体组成的迷你过滤器。根据安装的跨连接选择器，该装置有三个版本。可吸入的版本以10L/min的流率运行，但是胸吸入性版本以7L/min的流率运行。

8.3.3 Special Sampling Heads

For some particular aerosols, specific sampling heads have either evolved or have been specially developed. These include:

8.3.3 特殊采样头

对于一些特殊的气溶胶，已专门开发出特殊的采样头，包括：

• Asbestos and Synthetic Fibres

Sampling for asbestos or synthetic mineral fibres is usually performed using an open faced cassette with an electrically conductive cowl.

• 石棉和合称纤维

通常使用带电导通风盖敞开的盒子对石棉或合成矿物纤维进行采样。

The original design was made of metal (Figure 8.11) but in recent years the three-piece graphite impregnated plastic cassette (Figure 8.12) has become common. A 0.8 µm (1.2 µm used in some countries) mixed cellulose ester membrane filter is used to collect the fibres as this has the advantage of being able to be destroyed with acetone vapour at a later stage during the analysis process.

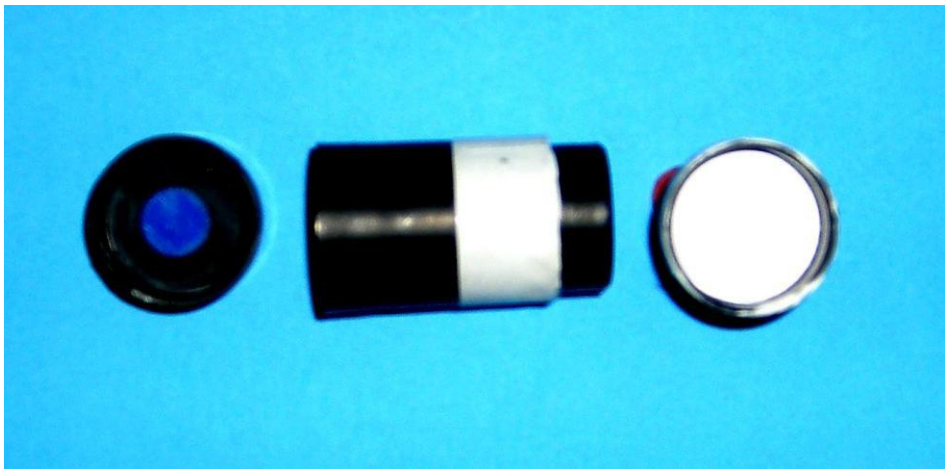
原来的设计是由金属制成（图8.11），但近年来三件式石墨浸渍塑料盒（图8.12）变得更常见。0.8µm（一些国家使用1.2µm）的混合纤维素酯膜过滤器用来收集纤维，优点是在分析过程中后期能够用丙酮蒸气破坏。

Sampling rates of between 1 to 4 L/min are commonly used (in some countries rates of 8 or 15 L/min are used), depending on the type of sampling being undertaken (workplace exposure assessment or control monitoring after removal).

经常使用的采用率介于1至4L/min之间（一些国家使用8或15L/min的流率），这取决于采样的类型（工作场所暴露访问或去除后的控制monitoring after removal).监测）。

(Source: Gully Howard Technical – *Reproduced with permission*)
（来源：GullyHowardTechnical–许可转载）

Figure 8.11 – Metal Cowl and Sampling Head for Fibre Sampling
图8.11–纤维采样的金属盖和采样头



(Source: University of Wollongong)

（来源：伍伦贡大学）

Figure 8.12 – Three-Piece Conductive Plastic Cassette for Fibre Sampling
图8.12–纤维采样的三段式传导塑料盒

• ***Diesel Particulate***

The development of a commercial specialised sampling head for diesel particulate has only occurred within the past 10 years. Prior to this, all sampling for this contaminant was via the use of research samplers which were expensive and complex.

• **柴油微粒**

商业化的柴油颗粒采样头只在过去10年才获得。在此之前，该污染物的所有采样都是通过使用研究采样器进行的，这种采样器非常昂贵且复杂。

The current commercial device (Figure 8.13) uses a cassette containing an integral precision-jewelled impactor which screens out particles >1 µm. In situations where diesel particulate is the only contaminant present such separation is not important, however in many workplaces other contaminant dusts may be present. This is especially the case in coal mines where the coal dust in the sample needs to be separated from the diesel particulate before analysis. The cassettes also contain a heat treated quartz filter which

目前的商用装置（图8.13）使用一个盒子，内装镶精密珠宝的撞击器，能够筛选出> 1µm的颗粒。如柴油颗粒是唯一的污染物，则隔离不重要，但是在许多工作场所还存在其它污染物灰尘。分析之前样本中的煤炭灰尘需要和柴油颗粒分离开来时更是如此。盒子中还含有一个热处理的石英功率器，有助于分析。盒子使用时可带旋流器或不带，在灰尘负荷较高并可能对撞击器造成过载时旋流器是必要的。

assists in the analysis process. The cassette can either be used with or without a cyclone, the cyclone being necessary when high dust loads are present which could overload the impactor.

(Source: SKC Inc – *Reproduced with permission*)
（来源：SKCInc –许可转载）

Figure 8.13– Diesel Particulate Cassette
图8.13–柴油微粒盒

• ***Rosin-based Solder Flux Fume***

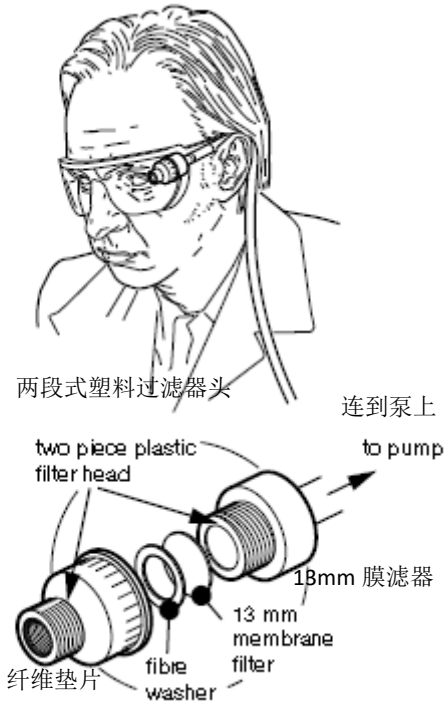
One unique approach is prescribed by the UK Health & Safety Executive for the sampling of rosin acids in rosin (colophony) solder flux fume (MDHS 83/2).

Sampling in this case is performed by using a 13 mm Millipore Swinnex type sampling head containing a 5 µm pore size mixed cellulose ester filter. Sample rates of between 1 and 2 L/min are recommended, depending on the fume load in the atmosphere. The sampling head is attached to the worker"s safety glasses as indicated in Figure 8.14.

• **松香类助焊剂烟雾**

英国健康与安全执行委员会为松香酸（松香）助焊剂烟雾规定了一种独特的方法（MDHS 83 / 2）。

这种情况下，使用带一个5µm孔径的13mm的Millipore Swinnex型采样头进行采样。根据大气中的烟雾符合，建议采样率在1和2L/min之间。采样头连接到工人的安全眼镜，见图8.14所示。



(Source: HSE – *Reproduced with permission)*
（来源：HSE–许可转载）

Figure 8.14 – Sampling for Rosin-based Solder Flux Fume
图 8.14–松香类助焊剂烟雾的采样

There are no doubt many more specific sampling heads in use throughout the world, however their use is likely to be localised due to historic or statutory requirements. Consequently, there is a need for practising occupational hygienists to familiarise themselves with any such local requirements.

毫无疑问，全世界使用许多更具体的采样头，但是它们的使用是由于历史或法定的要求而变得当地化。因此，执业的专业保健专家需要熟悉这些当地化要求。

8.4 SAMPLING TRAINS

After the selection of the most appropriate sampling head, sample pump and filter (section 7.3.1), the time has come to link all these components together into what has become known as a “sampling train”.

8.4 采样器

选择最合适的采样头、采样泵和过滤器之后（图7.3.1），将所有组件连接起来构成一个“采样器”。

The individual components of a sampling train for respirable dust using a miniature cyclone are shown in Figure 8.15.

图8.15显示的是使用微型旋流器的可吸入粉尘采样器的单独组件。

(Source: University of Wollongong)

（来源：伍伦贡大学）

Figure 8.15 – Respirable Dust Sampling Train

图 8.15–可吸入性粉尘采样器

Similar sampling trains can be constructed for inhalable dust, diesel particulate and organic vapours using the appropriate components for each. Connection of the sampling train to a worker usually involves placing the pump on the worker"s belt (or in a pocket if it is a miniature pump) and then connecting the sampling head in the breathing zone of the worker (Figure 8.16). If a belt is not available, a suitable harness can be worn by the worker to support the equipment.

类似的采样器可适合可吸入粉尘、柴油微粒和有机蒸汽，每个采样器使用适当的组件。采样器连接到工人身上通常将泵放在工人的腰带上（或装在口袋中，如果是微型泵的话），然后将采样头连接到工人的呼吸区域（图8.16）。如果没有腰带，工人可穿戴合适的皮带以支持起设备。

(Source: University of Wollongong)

（来源：伍伦贡大学）

Figure 8.16 – Sampling Train Connected to a Worker

图 8.16–采样器连接到工人身体

In some cases special care needs to be exercised when attaching the sampling head. One such case is when sampling for welding fume where the sampling head must be placed under the welder"s protective face shield. This is because the level of contaminant exposure outside the shield is significantly higher than inside.

某些情况下，安装采样头时需要特别小心。其中一种情况是为焊接烟尘进行采样时，样本头必须放在焊工的防护面罩下面，这是因为面罩外的污染物暴露水平比里面高得多。

Once the sample train is attached to the worker, note the time and any other relevant data (see section 8.5 with regard to calibrating pumps before use). Check the sampling head and pump periodically during sampling to ensure that the equipment is still operating, and if necessary re-measure and adjust the flowrate (this should not be necessary with good quality well-maintained sampling pumps). At the end of the sampling period, carefully remove the sampling equipment (recording the time) and in a dust-free area re-calibrate the sampling pump. The sample should be considered invalid if the pre and post sampling rates vary by more than ±5%. Some international standards suggest pre and post sampling rates may vary by ±10%, however this is considered too high by most hygienists. The collection filter (or filter cassette) should then be removed from the sampling head and either re-weighed on site or transported to a laboratory for re-weighing (see Sections 7.3 and 7.4).

采样器连接到工人身上后，注意时间和其它相关的数据（见8.5节关于使用前校准泵）。采用过程中定期检查采样头和泵，确保设备仍在运行，如需要的话重新测量并调整流率（质量良好维护良好的采样泵不需要）。采样结束时，小心地拆下采样设备（记录时间）并在无灰尘的区域重新校准采样泵。如果采样之前和之后的采样率变动±10%，样本应被视为无效。一些国际标准建议，前后采样率可变动±10%，但是大多数保健专家认为该数字过高。采集过滤器（或过滤器盒）应从采样头上拆除，或现场重新称重或运到实验室进行重量分析（见第7.3和7.4节）。

Once all the information is available (eg mass of dust on filter, flowrate of pump and sample duration) the actual concentration in the workplace can be calculated (section 8.6).

如果所有的信息都可用（如过滤器上的灰尘量、泵的流率和采样时间），可计算工作场所中的实际浓度（第8.6节）。

8.5 CALIBRATION OF SAMPLING EQUIPMENT FOR DUSTS, FUMES & FIBRES

8.5 灰尘、烟雾和纤维采样设备校准

The accurate analysis of atmospheric dust concentrations is dependent on the determination of the mass of dust, fume or fibre on the collection media (either gravimetrically, chemical analysis or microscopy) and the total volume of air sampled (ie total number of m^3 of air sampled).

大气灰尘浓度的准确分析取决于采集介质上灰尘、烟雾或纤维质量的测定（无论是重量分析、化学分析或显微镜）以及采样空气的总体积（即采样空气的立方米总数）。

When calibrating sampling pumps (and other sampling equipment), it is important that a path of traceability is established and maintained.

校准采样泵（和其它采样设备）时，重要的是建立并维护追踪路径。

This is usually performed via the use of a primary and secondary standard. A primary standard is one which is directly traceable to a national standard and a secondary standard is one which has to be calibrated at regular intervals against a primary standard. Examples of such standards commonly used in occupational hygiene monitoring are:

通常通过使用初级和二级标准而达到该目的。主要标准之一是直接溯源到国家标准，二级标准必须定期对照主要标准而校准的标准。职业健康监测常用的此类标准包括：

• ***Primary Standards***

Soap film meters

Wet-test gas meter

• **主要标准**

皂膜计

Bell spirometer

测湿气表

贝尔肺活量计

• ***Secondary Standard***

Electronic meters*

Rotameters

Magnehelic gauges

* In some countries some particular types of electronic meters are considered primary standards (eg BIOS frictionless piston), however third party accreditation bodies in other countries do not agree.

• **次要标准**

电子计*

转子流量计

差压计

* 在有些国家，一些特殊类型的电子计被视为主要的标准（如BIOS无摩擦活塞），但是其它国家第三方认证实体不同意。

Primary standards are usually not suitable for field measurements and thus it is common practice to use a calibrated secondary standard.

主要标准通常不适合现场测量，一些使用校准过的次要标准是常见做法。

Examples of primary and secondary standards for airflow measurement are shown in Figures 8.17 – 8.19.

图8.17–8.19显示了气流测量的主要标准和次要标准的例子。

(Source: SKC – *Reproduced with permission*)

（来源：SKC–许可转载）

Figure 8.17 – Soap Film Meter

图8.17–皂膜计

(Source: University of Wollongong)
（来源：伍伦贡大学）

Figure 8.18 – Electronic Meter
图8.18–电子表

(Source: SKC – *Reproduced with permission*)
（来源：SKC–许可转载）

Figure 8.19 – Rotameter
图8.19–转子测速仪

When measuring airflow, the following points should be considered.

1. Always calibrate a sampling pump using a sample head identical to that used in the field.

2. Allow the sample pump to stabilise for at least 5 minutes after it has been switched on and adjust the flow to the required flowrate.

3. Measure the flowrate of the pump until three consecutive results are within ±1% of the mean (this may not be possible if using rotameters but easily achievable with electronic or soap film meters). Calculate the mean value of the three consecutive results and use this in the total airflow calculation (section 8.6).

4. It is also important to appreciate changes in environmental conditions which can adversely affect the accuracy of a calibration device. Such factors can be:

• Flowrate determinations are made at altitudes differing by more than 500 m from the previous calibration.

• Temperature differing by more than 15°C from that at the previous calibration.

Examples of a sampling train being calibrated with a soap film meter and an electronic meter are provided in Figures 8.20 and 8.21.

测量气流时，应考虑以下几点。

1. 使用和现场一样的采样头对采样泵进行校正。

2. 开机后，让采样泵稳定至少5分钟，调整的要求的流率。

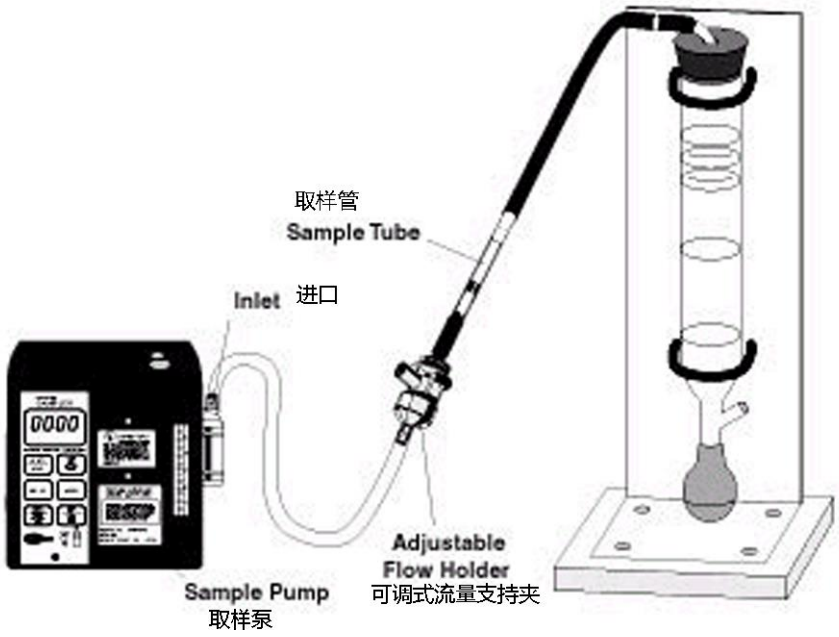
3. 测量泵的流率，直到三次连续测量结果平均数在±1%内（如果使用转子流量计的话不可能，但是用电子计或皂膜计的话很容易达到）。计算连续三次结果的平均数，并将该数值用于总气流计算（第8.6节）。

4. 重要的是注意到可能对校准装置的准确性产生不利影响的环境条件下的变化，这些因素包括：

• 在与之前的校准海波超过500米落差的海拔测量流率。

• 温度与之前的校准相差超过15°C。

图8.20和8.21给出了用皂膜计和电子计对采样器进行校准的例子。



(Source: SKC – *Reproduced with permission*)

（来源：SKC–许可转载）

Figure 8.20 – Calibration Using a Soap Film Meter

图8.20–使用皂膜计进行校准

(Source: University of Wollongong)

（来源：伍伦贡大学）

Figure 8.21 – Calibration Using an Electronic Meter

图8.21–使用电子计进行校准

The following suggested calibration schedule for sampling equipment is provided as guidance only and reference should be made to national standards or local statutory authorities.

以下建议校准表仅用于指导，应参考国家标准或地方法规。

Item	**Maximum Period Between Successive Calibrations**	**Comments**
项目	**连续校准的最大期间**	**评论**
Pumps	On use	Before and after measurement
泵	使用中	测量之前和之后
Pumps -Direct Automatic Flow Control -Indirect Automatic Flow Control	Initially 12 months but after three consecutive tests (ie two years) showing results within ±5% of the expected result, the interval can be lengthened to three years Initially six months, but after three consecutive tests (ie 12 months) showing results within ±5% of the expected result, the interval can be extended to 12 months	Constant flow compensation Constant flow compensation
泵 -直接自动流量控制 -间接自动流量控制	最初12个月，但是连续3次测试（即2年）之后，显示结果为预计结果的±5%，间隔可延长到3年 最初6个月，但是连续3次测试（即12个月）之后，显示结果为预计结果的±5%，间隔可延长到12个月	连续流量补偿 连续流量补偿
Rotameters	Monthly for three months then if measurements are within ±3% of expected result, the interval can be extended (one year small bore and two years large bore)	Calibrated against a primary flowmeter over range of use
转子流量计	每月进行，连续 3 个月，如果测量结果为	在使用范围内按照最初流量计进行校准

	预计结果的±3%，间隔可以延长（小孔 1 年，大孔两年）	
Soap Film Meter	On commissioning	Check volume marks
皂膜计	调试中	检查体积标记
Electronic Meters	Monthly for three months then if measurements are within ±3% of expected results, the interval can be extended to six months	Calibrated against a primary flowmeter over range of use
电子计	每月进行，连续 3 个月，如果测量结果为预计结果的±3%，间隔可以延长到 6 个月	在使用范围内按照最初流量计进行校准
Stop Watch	Six monthly	Against a national time system (speaking clock) over at least one hour
停止观察	6 个月	至少一个小时按照当地时间系统（时钟）
Balances (Electronic)	One month Six months 12 months 36 months	One point check Repeatability check Service Full range calibration by external accredited calibration authority
平衡（电子）	1 个月 6 个月 12 个月 36 个月	一点检查 重复性检查 维修 由外部认证校准机构进行全程校准

While the above recommendations may appear overly conservative they represent best practice as detailed by a group of experienced occupational hygienists. Observance of the indicated calibration schedule should meet the majority of statutory requirements.

虽然上述建议可能显得过于保守，它们代表了一批经验丰富的职业保健专家的最佳行业实践。应遵守校准计划，这符合大多数法定要求。

8.6 CALCULATION OF RESULTS

8.6 结果的计算

As indicated in section 8.5, two components are necessary to establish the atmospheric concentration of dust, fume or fibre in the atmosphere of a workplace. These are the quantity of contaminant on the collection media (filter) and the total volume of air sampled.

如第8.5节所示，确定工作场所大气中的灰尘、烟雾或纤维浓度需要两个数据，即采集媒介（过滤器）上的污染物数量和采样空气的总体积。

The calculation of fibre results is complex and beyond the scope of this course, but the calculation of dust and fume concentrations are provided below.

对纤维的计算很复杂，超出了本文的范畴，但是下文给出了灰尘和烟雾浓度的计算方法。

• Calculation of Total Volume of Air Sampled

• 对采样空气总体积的计算

If we know the flowrate of a sampling pump (as detailed in section 8.5) and the time that sampling was undertaken, we can calculate the total volume of air sampled. For example, if the flowrate was 2.2 L/min and sampling was performed for 7 hours 42 minutes, we can make the following calculation.

如果我们知道采样泵的流率（如第8.5节所述）以及进行采样的时间，我们可以计算出采样空气的总体积。例如，如果流率是2.2L/min，采样进行了7小时42分钟，我们可以进行如下计算。

Volume (Litres) = 2.2 x 462

= 1,016.4

体积（升）

$$\text{Volume } (m^3) = \frac{1{,}016.4}{1{,}000}$$

体积（m^3）

= 1.0164

(Note: 1 m^3 = 1000 L)

（注：1m^3=1000L）

• Calculation of Mass on Filter

If, for example, we are sampling for respirable or inhalable dust and analysing by gravimetric means, we need to establish the total amount of dust on the filter (usually in mg). This is done by subtracting the pre weight of the filter from the post weight of the filter and correcting for moisture pick-up or loss via a blank correction. Thus the weight of the dust on the filter is:

• 对过滤器上质量的计算

例如，如果我们用重量分析法对呼吸性或可吸入粉尘进行采样，我们需要确定过滤器上灰尘的总量（通常为mg），然后将过滤器之后的重量中减去之前的重量，通过空白矫正剂纠正吸湿或水分损失。因此过滤器上的灰尘重量为：

Mass (mg) = post – pre weight of filter (mg) – blank correction (mg)

质量（mg）= 过滤器之后的重量–之前的重量（mg）–空白校正剂（mg）

Thus, if the pre weight of the filter was 5.76 mg and the post weight of the filter was 7.84 mg and the blank was -0.01 mg, then:

因此，因过滤器之前的重量为5.76mg，之后的重量为7.84mg，空白剂为0.01mg，那么：

Corrected Mass on Filter (mg) = 7.84 – 5.76 – (-0.01)

过滤器上的校正质量（mg）

= 2.08 – (-0.01)

= 2.08 + 0.01

= 2.09

and the concentration of dust in the atmosphere would therefore be:
大气中灰尘的浓度为：

$$\text{Concentration (mg/m}^3\text{) 浓度（mg/m}^3\text{）} = \frac{2.09}{1.0164}$$

$$= 2.056$$

$$= 2.1^*$$

* (Rounded depending on the uncertainty of the balance used as per AS 3640 - which was a 5 place microbalance in this case)
*（依照 AS 3640 使用的天平的不确定性进行四舍五入——本例中使用 5 位微量天平）

If subsequent analysis for some specific contaminant was undertaken, then the calculation is dependent on the concentration of that contaminant on the filter.
如果对特定污染物进行后续分析，计算结果取决于过滤器上该污染物的浓度

For example if an inhalable dust sample was analysed for zinc (Zn) and the amount on the filter was found to be 256 µg (ie 0.256 mg), then the concentration of Zn in the sample would be:
例如，如果分析可吸入性粉尘样本中的锌（Zn），发现过滤器上锌的含量为 256µg（即 0.256mg），则样本中的锌浓度为：

$$\text{Zn (mg/m}^3\text{)} = \frac{0.256}{1.0164}$$

$$= 0.252$$

$$= 0.25^{*}$$

* (Rounded based on the accuracy of the analytical method)
*（根据分析方法的准确性进行四舍五入）

8.7 DIRECT READING INSTRUMENTS

While the use of direct reading instrumentation for measuring gases and vapours is common, the case is not the same in respect to dust monitoring. Over the past 40 years numerous devices have been released onto the market, however they have only attracted limited use, usually in very specific situations.

One type of direct reading device which has some success is based on the principle of a laser photometer which detects light scattered by the presence of dust particles. One such device is shown in Figure 8.22 and this particular instrument can be very useful in evaluating control procedures within a workplace and for pinpointing sources of emissions. Unfortunately, most optical-based instruments over-respond in locations where high moisture is present (eg sprays, water mist), making their application very limited in many situations.

8.7 直读仪器

使用直读仪器测量气体和蒸汽很常见，但是灰尘监测情况不同。过去40年里，许多设备已投放到市场上，但是它们的使用很有限，通常是在非常特殊的情况下。

一种直读仪器具有一定的成功是基于激光光度计检测存在的尘埃粒子光散射原理。图8.22显示了一台这样的仪器，这种特殊的仪器在工作场所内访问控制程序以及准确查找光源非常有用。不幸的是，大多数基于光学的仪器在湿度较大的地方反应过度（如喷雾剂，水雾），使其应用在许多情况下非常有用。

(Source: TSI Inc – *Reproduced with permission*)
（来源：TSIInc–许可转载）

Figure 8.22 – Dust Trak
图8.22–Dust Trak

The response of a laser scattering instrument depends on the size, shape and reflectivity of the airborne particles rather than on their mass. Some instruments can give a mass readout, but this is only accurate if calibrated for the specific dust in question.

一种激光散射仪的响应取决于空气中微粒的大小、形状和反射率而不是它们的质量。有些仪器可产生质量读数，但是只有为特定灰尘进行过校准之后该读数才可能准确。

In recent years one development has the potential to alter this situation. This is the Personal Dust Monitor (PDM) currently being developed for the US coal mining industry. This device (Figure 8.23) is based on the principle of the tapered element oscillating microbalance (TEOM) and has an internal heater to overcome moisture issues. Testing to date has demonstrated comparable results to current sampling practices and appears to

近年来个人粉尘监测器（PDM）的发展可能改变这种情况，该装置目前开发用于美国的美国煤炭开采业。该装置（图8.23）以锥形元件振荡天平（TEOM）的原则为基础，有个内部加热器克服水汽问题。最新的测试显示了当前采样行为的对比结果，似乎是一个重大突破。

be a significant breakthrough.

(Source: Thermo Fisher Scientific – *Reproduced with permission*)

（来源：赛默飞世尔科技–许可转载）

Figure 8.23 – Personal Dust Monitor

图 8.23–人员灰尘检测器

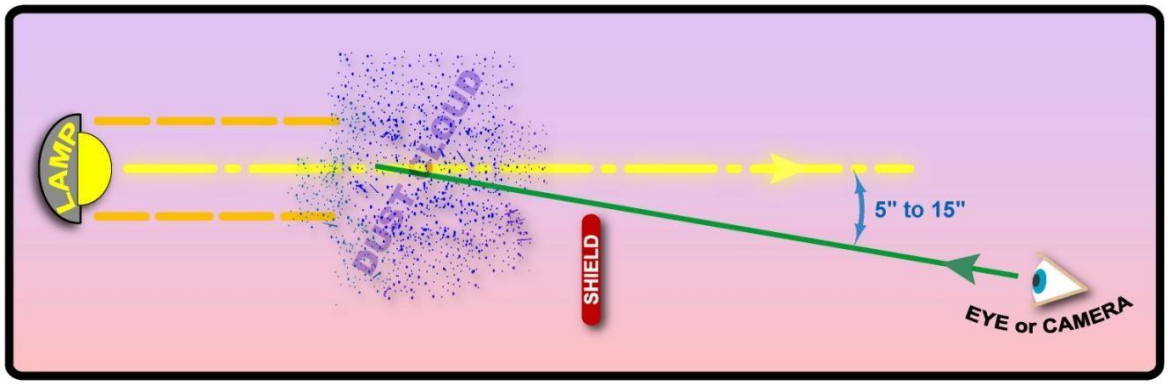
One device that is not a direct reading instrument but has value in highlighting the presence of dust particles is the “Dust Lamp”. The application of this device is adequately explained in MDHS 82 and is based on the “Tyndall effect” discovered by John Tyndall in the mid 1800"s.

“防尘灯”不是直读仪器，但是能够照亮灰尘粒子。MDHS 82详细解释了该装置的应用，以约翰廷德尔19世纪80年代中期发现的“廷德尔效应”为基础。

Essentially, a bright beam of light is shone through the area where it is thought a particle cloud may be present. The particles present diffract the incident light and an observer looking up the beam to the source of the illumination (at an angle of about 5 – 15°) can see the dust particles. The process is described schematically in Figure 8.24 and can be a powerful tool if linked to

基本上，明亮的光束可射穿认为存在粒子云的地方。存在的微粒将入射光衍射，观察员将光束抬高到光源（约5–15°角）可以看到的灰尘颗粒。图8.24以图示描述了该过程，如果连接到摄影或数字视频设备的话是一个强大的工具。

photography or digital video equipment.



(Source: HSE – *Reproduced with permission*)

（来源：HSE–许可转载）

Figure 8.24 – Principle of the Dust Lamp

图 8.24– 粉尘灯原理

This device has been included to demonstrate how a simple beam of light can be used to investigate possible sources of dust exposure but as with most things some level of knowledge and skill is required to achieve good results (see MDHS 82).

该设备的原理是一个简单的光束可用于调查可能的粉尘来源，但是为了取得有效结果，仍要了解许多知识和技术（参看 MDHS 82）。

8.8 SELECTION GUIDE

The following information has been included to provide basic guidance on the selection of the appropriate sampling head, capture mechanism and flowrate for a range of contaminants. It is based on the experience of the authors and may not reflect local statutory requirements.

8.8 选择指南

以下信息的目的是为了提供适当的污染物采样头、捕获设备和流率一个基本选择指导方针。作者基于过去的经验提供这些信息，不一定符合当地法律要求。

Contaminant	**Sampling Head**	**Collection Medium**	**Typical Flowrate (L/min)**
污染物	**采样头**	**采样媒介**	**标准流量（L/min）**
Asbestos and synthetic mineral fibres	Open faced filter with conductive cowl (3-piece cassette)	Mixed cellulose ester membrane filter (0.8 µm pore size)	1 – 4 (8 – 16 used in UK)
石棉和合成矿物纤维	带有传导性通风罩的开面过滤器（每盒三件）	混合纤维素脂薄膜滤器（孔径 0.8 µm ）	1– 4 （英国采用 8– 16）
Respirable dust (including respirable silica)	Miniature cyclone	PVC (5.0 µm pore size)	1.7 – 2.5 depending on type of cyclone
呼吸性粉尘（包括可吸入二氧化	小气旋式	PVC（孔径 5.0 µm ）	1.7– 2.5 取决于气旋类型
Inhalable dust	IOM (or equivalent)	PVC (5.0 µm pore size) or glass fibre	2 (can be subsequently analysed for metals, etc)
可吸入粉尘	IOM（或等价物）	PVC（孔径 5.0 ）或玻璃纤维	2（可随后对金属等进行分析）
Welding and other metal fumes	IOM (or equivalent)	PVC (0.8 µm pore size)	2
焊烟和其它金属烟雾	IOM（或等价物）	PVC 孔径 5.0 µm）	2
Rosin solder flux fume	Millipore, Swinnex	Mixed cellulose ester membrane filter (5.0 µm pore size)	1 - 2 depending on fume load in atmosphere
松香焊烟	微孔，Swinnex	混合纤维素脂薄膜滤器（孔径 0.5 µm ）	1 - 2 取决于大气中烟雾的量

9 AIR SAMPLING EQUIPMENT – VAPOURS & GASES

9 空气采样设备-蒸汽和气体

9.1 INTRODUCTION

9.1 简介

A simple definition of gases and vapours is:

气体和蒸汽可简要定义为：

Gas – a substance which is airlike. It is neither solid nor liquid at room temperature.

气体是与空气相似的一种物质，在室温下呈固态或液态。

Vapour – the gaseous form of a substance which is a solid or liquid at room temperature.

蒸汽-是物质的一种气态形式，在室温下呈固态或液态。

Gases are formless fluids that expand to occupy the space or enclosure in which they are confined. Examples are nitrogen, oxygen, chlorine and ammonia. Vapours are the gaseous form of a substance that is normally a solid or liquid at room temperature and pressure. Example: organic solvents give rise to vapours in the air by their evaporation, heating or spraying.

气体是无形的液体，扩散占领所在空间或场地，例如氮、氧、氯和氨。蒸汽是物质的一种气态形式，通常在室温下呈固态或液态。例如：有机溶剂产生的蒸汽通过加热或喷洒在空气中蒸发。

Sampling or monitoring can be undertaken by two main approaches:

主要有两种采样或监控方法：

- sample collection with subsequent laboratory analysis
- direct reading instruments for use in the workplace

- 样本收集然后进行实验室分析。
- 工作场所使用直读仪器进行样本采集。

9.2 WHOLE OF AIR SAMPLING OR "GRAB SAMPLING"

9.2 整体空气采样或瞬时采样

The air can be collected in a container passively (ie by evacuating the container prior to sampling) or actively (ie by using

空气可以用被动方式（即在采样前将容器排空）或主动方式（即使用泵抽

a pump). The container is subsequently sealed and transported to the laboratory for analysis. The sample is referred to as a “whole air sample” or “grab sampling” and the compounds remain in the ambient air inside the container. The method is often used when the concentration of the contaminant is constant or where peak concentrations need to be measured. The method can also be used for the identification of unknowns and to evaluate contaminant sources. The samples are typically collected over a short period of time from a few seconds to several minutes.

取）被收集到容器，随后将容器密封并送往实验室进行分析。样品被称作“整体空气样本”或“简单采样”，化合物仍留在容器内的周围空气中。这种方法通常用于当污染物的浓度是常数或需要测定峰值浓度时。该方法还可用于识别和评估未知污染物来源。收集样本时间通常很短，从几秒到几分钟。

As a general rule whole air sampling is best done when the target compounds are chemically stable and have vapour pressures greater than 0.1 torr at 25 degrees C and 760 mmHg. Recoveries are very much dependent on the humidity of the sample, the chemical activity of the sample matrix and the inertness of the container.

一般来说，当完成目标化合物在 25 摄氏度和 760 毫米汞柱时具有化学稳定性，蒸汽压力大于 0.1 托时，最好采用整体空气采样法。复原情况很大程度上取决于样品湿度、样品基质化学活性和容器惰性。

The common types of containers used for whole air sampling are stainless steel canisters, air sample bags, gas bottles or even gas syringes.

整体空气采样的常见容器类型包括不锈钢罐、空气样品袋、燃气瓶，甚至气体注射器。

- **Canisters**

- 过滤罐

Canisters can be spherical or cylindrical and are typically made from stainless steel, have superior inertness, hold time to analysis and ruggedness for field use and do not require the use of a

过滤罐可以是球形或圆柱形，通常为结实的不锈钢材质，具有卓越的惰性，在现场使用时能将样本保存很长

sampling pump. A Summa canister is a stainless steel container that has the internal surfaces specially treated using a “summa” process. This process combines an electro polishing step with a chemical deactivation step to produce a surface that is nearly chemically inert. The degree of chemical inertness of a whole of air container is critical to minimising reactions with the sample and maximizing recoveries of the collected material.

时间，以进行分析。苏马过滤罐是一种不锈钢容器，其内表面经 苏马这一工艺进行特殊处理。工艺结合电镀抛光，然后进行化学失活，产生的表面在化学上几乎是完全惰性的。整体空气采样容器的化学惰性程度对于使样本与容器之间的化学反应最小化和使收集到的材料复原的最大化来说是至关重要的。

The canister is evacuated by vacuum prior to use. Opening of the valve allows the air to enter and fill the container, the valve is then closed and canister returned to the laboratory for analysis. Canisters range in volume from less than 1 litre to about 10 litres. Canisters need to be cleaned prior to use and the degree of cleaning (10% or 100%) required is dependent on the analytical requirements for the sampling and as a rule of thumb can be used down to the ppb range.

真空过滤罐在使用之前必须排空。打开阀门允许空气进入和填充容器，然后关闭阀门，将过滤罐带回实验室进行分析。罐的容量范围不等，有的不到 1 升，有的约 10 升。罐在使用前需要清洗，清洁度（10%或 100%）取决于采样和分析要求，根据经验法，清洁度可达到“10 亿分之…”的范围。

- **Gas Sampling Bags**

- 气体采样袋

Gas bags are relatively inexpensive, can be carried to site in a brief case, filled in seconds and shipped easily to the laboratory for analysis.

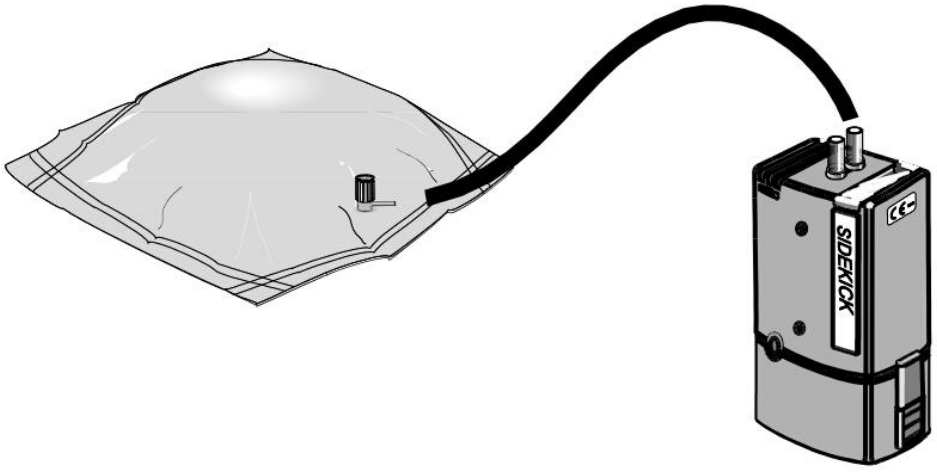
气体袋成本相对低廉，可装在公文包中带到现场，用几秒钟就填充完毕，然后很轻松地带到实验室进行分析。

Gas bags come in different sizes up to 250 litres but typically for occupational hygiene sampling purposes bags are typically between 5-15 litres. The bags are constructed from a number of materials including polyester,

气体袋大小不一样，有的容量达到 250 升，但职业卫生采用的普通采样袋容量通常介于 5 - 15 升。气体袋制作材

polyvinylene chloride, Teflon (polytetrafluoroethylene), and tedlar (polyvinyl fluoride). They often comprise of two films or are laminated with aluminium to reduce permeation through the walls. Sample loss and adsorption on to the bag material are concerns and samples should be analysed as soon as possible after collection. Levels down to the ppm range can be measured using gas sampling bags.

料各种各样，包括聚酯、聚次亚乙烯氯化物、特仑氟（聚四氟乙烯），和泰德拉（聚氟乙烯）。每个袋子一般包含两层薄膜或压有一层铝膜，尽量减少袋子渗透。样品损失与袋子的吸附能力有密切关系，因此收集样本后应尽快进行分析。如测定范围达到“10 亿分之…”，采用气体采样袋。



(Source: SKC Inc – *Reproduced with permission*)

（来源：SKC Inc–许可转载）

Figure 9.1 – Air Sampling Bag Being Filled by Pump

图 9.1 –泵吸式空气采样袋

Gas bottles or gas syringes have also been used in the past, but their use has generally been replaced by other sampling methods.

过去人们还使用气瓶或气体注射器采样，但现在人们一般不使用这些容器采样，而且是采用其它方法了。

9.3 ACTIVE SAMPLING

Active sampling occurs when air is drawn through an absorbing medium and the contaminants are collected / “scrubbed out”. Active sampling usually employs a calibrated, battery powered sampling pump that is connected by flexible tubing to a solid sorbent tube or to a reagent-

9.3 主动采样

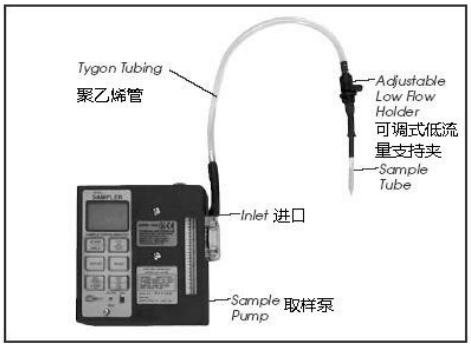
当空气通过介质吸收时采用主动采样法，就是将污染物进行收集/“擦掉”。主动采样通常采用经过校准的电池供电的采样泵，泵由一条柔软的油管连接到固体吸附剂管或试剂溶液中，用撞击器或其它类似设备进行采样。如

solution in an impinger or other similar collection device. A known volume of air is then drawn through the tube or collection device and contaminants collected or removed by the sampling medium.

果空气体积已知，那么通过管或收集装置抽取收集到的或采样介质转移过来的污染物。

If the final flowrate differs from the initial flowrate by greater than ±10% (Australia), ±5% (UK) the sample should be discarded and sampling repeated. The flowrate variation used in Australian Standards (10%) is considered too high by many occupational hygienists and a value of 5% would represent best practice.

如果最终流量与初始流量的差别大于±10%（澳大利亚）、±5%（英国），那么应丢弃样本，重新采样。许多职业卫生专家认为澳大利亚标准中的流量变化值（10%）太高了，5%最合适。



(Source: SKC Inc – *Reproduced with permission)*

Figure 9.2 – Sampling Train Using Adjustable Low Flow Holder
图 9.2 – 采用可调节低流量固定器的采样器

(Source: 3M Australia – *Reproduced with permission*)

Figure 9.3 – Personal Sampling With Sorbent Tube Collection
图 9.3 – 用吸附剂管进行人体采样

This removal process can be achieved by both absorption/derivatisation and adsorption techniques as described below:

通过以下吸附/衍生和吸收技术可完成这个移除过程：

- **Absorption/Derivatisation**

- 吸收/衍生

Absorption (or solvation) is the technique whereby the gas or vapour is collected by passing it through a liquid where it is collected by dissolution in the liquid. There

吸收（或溶解）是一种通过使气体或蒸汽经过溶液，然后在溶液中溶解而实现的采样技术。有许多机制能使收

are a number of mechanisms whereby the gas or vapour is collected by a reaction with the liquid and can include derivatisation, oxidation, neutralisation and several others.

集到的气体或蒸汽与液体发生化学反应，包括衍生、氧化 中和等。

Typically the gas is drawn through the collection device(s), Figure 9.4, by use of a sampling pump connected to:

- a midget impinge
- gas wash bottle or
- fritted glass bubbler

通常是使用图 9.4 中的采样装置通过一个采样泵来收集气体。采样泵应与以下装置连接：

- 一个小型除尘器
- 气洗瓶；或
- 一个多孔玻璃喷嘴。

The collection efficiencies of the three different devices rely on the size and number of bubbles ie the surface area produced in the liquid, the volume of liquid, the sampling flow rate and the reaction rate. Sometimes bubblers are connected in series to increase efficiencies and to collect any liquid carryover.

三种不同设备的采样效率取决于喷口的大小和数目，即在液体中产生的表面积、液体体积、采样流率和反应速率。有时喷口串联，以提高效率和采集任何穿过的液体。

(Source: University of Wollongong)

（来源：伍伦贡大学）

Figure 9.4 – Midget Impingers

图 9.4– 小型撞击器

The devices suffer from a number of disadvantages including the need to keep the device upright to prevent loss of the liquid into both the atmosphere and also loss into the pump. This can make personal sampling quite difficult, but the technique can be used for a number of contaminants including:

这种设备有许多劣势，包括需要保持直立以防止液体进入大气和采样泵。这样导致很难进行人体采样，但这项技术可用于许多污染物，包括：

- Formaldehyde collected in water or bisulphate solution
- Oxides of nitrogen collected in sulphanilic acid
- Ozone collected in potassium iodine solution
- Toluene diisocyanate collected in 1-(2-methoxyphenyl) - piperazine in toluene

- 在水或硫酸氢盐溶剂中收集到的甲醛；
- 磺胺酸中收集的氮氧化物
- 钾碘溶液中收集的臭氧
- 1 -（2-甲氧基苯基）中收集的甲苯二异氰酸酯-甲苯中收集的哌嗪

NB: The use of liquid collection methods have largely been superseded by the use of treated or impregnated filters, eg for isocyanates.

注：液体收集方法基本已被经处理或浸渍的过滤器所取代，例如异氰酸酯。

- **Adsorption**

吸附

Adsorption is the technique whereby the gas or vapour is collected by passing it over and retained on the surface of the solid sorbent media such as activated charcoal, silica gel, porous polymers and molecular sieves.

吸附是通过使气体或蒸汽停留在活性炭、硅胶、多孔聚合物和分子筛等固体吸附剂介质表面的一种收集方法。

The adsorbent material is usually packed in a glass tube as shown in Figure 9.5. Immediately prior to use both ends of the glass tube are carefully broken off and the tube connected into the sampling train. The printed arrow on the sampling tube shows the direction of the airflow and

吸附剂材料通常装在一个玻璃管中，如图 9.5 所示。使用前才能将玻璃管两端小心拧开，然后把玻璃管与采样器连在一起。采样管上印制的箭头指示气流方向，应指向泵的方向。如果管上没有箭头，将吸着剂最小部分（即

should point towards the pump. If there is no arrow on the tube, insert the tube with the smallest sorbent section (ie the back up section) into the tube holder thus allowing the air flow to be through the main bed first.

备份部分）插入管中，然后放在管架，使气流首先通过主 bed。

After sampling the tubes are capped and sent to the laboratory for analysis. Migration of the contaminant from the main sorbent bed section to the back up section can occur at room temperature. Field samples should also be kept under cold conditions eg use of dry ice in an insulated container and then stored under refrigeration in the laboratory. The collected material is desorbed in the laboratory using solvents such as carbon disulphide, or by vacuum or by thermal desorption prior to analysis

在采样后立即将管口盖上，送交实验室进行分析。在室温下，污染物会从主吸附剂床部分移到备份部分。而且野外采集的样本应存放在低温条件下，例如使用隔热容器中的干冰，然后在实验室中冷藏存储。收集到的材料在实验室中使用二硫化碳等吸附剂，利用真空或热解吸附工艺进行解吸附，然后进行分析。

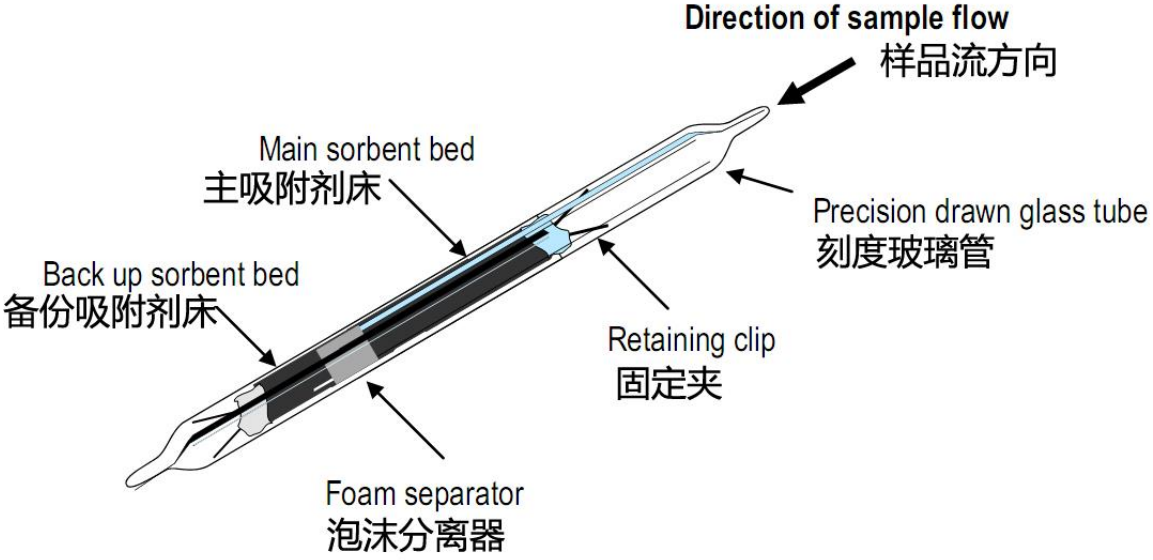


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Figure 9.5 – Sorbent Tube

图 9.5– 吸附剂管

Collection efficiencies are affected by temperature, humidity, sampling rate, the

收集有效性会受到温度、湿度、采样

presence of other contaminants and breakthrough.

- **Breakthrough**

When a sorbent is full to capacity, breakthrough occurs. Breakthrough is when the tube becomes full and releases the collected material and is lost in the air leaving the tube. Breakthrough of contaminants through the sorbent bed can occur if the sample flow rates are too high, if the concentrations are such that the sample volume collected is too high or if the contaminant is not retained effectively on the collection media. Breakthrough can be checked for by using a glass tube with two sorbent beds, the main sorbent trapping bed and a back up bed. Breakthrough of a substance through a sorbent is said to occur in the NIOSH air sampling methods when the concentration in the back up section exceeds 20 % of the concentration in the front section.

率和其它污染物及泄露的影响。

- 渗漏

如果吸附剂达到满负荷时，就会出现渗漏。当玻璃管达到满负荷程度，收集到的材料就会从管中释放到空气中。如果样本流率太高，如果密度太高导致收集的样本量太大或如果污染物不能有效停留在收集媒介上时，污染物就会通过吸附床渗漏出去。可通过一个有两个吸附床-一个主吸附床和一个备用吸附床-的玻璃管检查渗漏。当后部浓度超过前部 20%时，如果用 NIOSH 空气采样法就会发生通过吸附剂的物质渗漏。

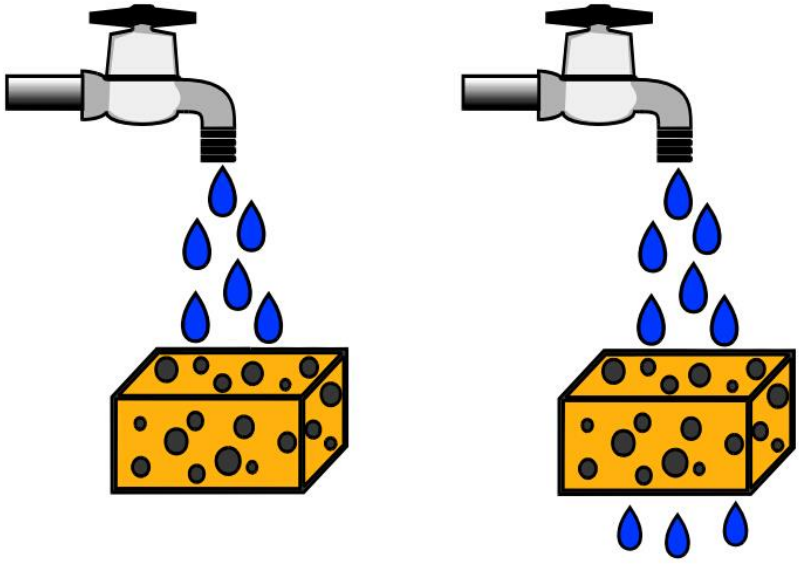

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Figure 9.6 – Breakthrough

图 9.6– 渗漏

9.3.1 Types of Adsorbent Tubes

- **Activated Charcoal**

Activated charcoal (carbon) is usually derived from coconut shells or coal. It is crushed and conditioned at high temperatures and low oxygen levels creating an extensive network of internal pores with a very large surface area. It is non polar and preferentially adsorbs organic vapours rather than polar molecules. It is therefore an excellent sorbent for a wide range of common industrial organic compounds such as hydrocarbons, chlorinated hydrocarbons, ketones, esters and ethers.

However activated carbon has poor recovery capabilities for reactive compounds, some polar compounds such as amines, phenols, aldehydes, low molecular weight alcohols, low boiling point compounds such as ammonia, ethylene and methylene chloride and other sorbents must therefore be used.

- **Silica Gel**

Silica gel is typically used for polar substances such as glutaraldehyde, amines and some inorganic substances which are difficult to desorb from charcoal. A disadvantage of silica gel is its affinity for water vapour which can displace other polar substances from its surface.

Sample volumes may therefore have to be

9.3.1 吸附管类型

- 活性碳

活性碳（碳）通常来源于椰壳或煤。它在高温和低氧水下下被碾碎和处理，从而出现一个内部包含无数小孔的网络，这样就产生一个面积非常大的表面。

它是非极性的，优先吸收有机蒸汽，而不是极性分子。因此，对于各种一般工业有机化合物，例如碳氢化合物、氯化烃、酮、酯和醚来说，它是一种极其出色的吸附剂。

- 硅胶

硅胶一般用于极性物质，例如戊二醛、胺和一些很难用碳吸附的无机物。硅胶的优势是它能对于水蒸汽的亲合力，置换表面的其它极性物质。

reduced when sampling in high humidity environments. When using silica gel polar solvents such as water and methanol are used for desorption of the collected material.

因此在高湿度环境下采样时，样本体积必须减小。当使用硅胶时，使用水和甲醇等极性吸附剂来吸收收集到的材料。

- **Porous Polymers**

There are a number of commercial porous polymers that are used for where the gas and vapour are either not collected effectively from activated charcoal or where there are poor recoveries. Examples include:

- 多孔渗水聚合体

如果无法从活性碳中有效收集气体或蒸汽，或收集率很低，那么可使用各种商用多孔渗水聚合体来进行收集，例如：

Tenax – for low level contaminants

XAD 2 – for pesticides

Chromosorb - pesticides
Porapaks – has polar characteristics

苯基对苯醚 –低水平污染物

XAD 2– 杀虫剂

红硅藻土– 杀虫剂

帕拉派克– 具有极性

Other solid sampling media for gases and vapours also include: Molecular sieves Florisil for PCBs

其它用于气体和蒸汽的固体采样介质还包括：

用于 PCB 的硅酸镁载体

Polyurethane foam (PUF) for pesticides, PNAs

用于杀虫剂的聚亚安酯（PUF），PNA

Specific advice should be sought from the Standard Air Sampling Methods from the Internationally recognised testing authorities such as NIOSH, OSHA, HSE or the local standards organisation and industry guides (SKC 2006) for the contaminant of interest.

至于使用的具体设备，请参考国际公认的测试机构，例如 NIOSH、OSHA、HSE 或当地标准组织和行业指南（SKC2006）指定的有关污染物标准空气采样法的规定。

- **Thermal Desorption**

Use of pumped sampling onto glass tubes packed with charcoal, followed by carbon disulphide (CS_2) extraction and gas chromatography (GC) analysis was developed for volatile organic compounds in the 1970"s.

It is still used for personal exposure assessment ie occupational hygiene and stack emission testing, but is fundamentally limited with respect to sensitivity and has been superseded to a degree, especially in Europe, by thermal desorption for the following reasons:

- **Sensitivity**

Solvent extraction requires dilution with at least 1 to 2 ml of CS_2 followed by injection of only 1µl of extract into the GC, thus giving a 10^3 dilution of the sample right at the start of the process. Other factors limiting sensitivity include: solvent artifacts, interferences from the solvent itself (masking volatile target analytes) and low desorption efficiencies. Conversely TD allows complete transfer of all target analytes to the analytical system with no dilution or solvent interference. Detection limits offered by TD are typically10^3 to 10^4 higher than equivalent solvent extraction methods facilitating ambient monitoring at ppt/ppb levels as well as higher ppm (and % level) concentrations.

By comparison, charcoal / CS_2 methods are invariably limited to concentrations >0.1ppm.

- 热解吸附

二十世纪七十年代，人们开发出一种用于挥发性有机化合物采样法：先在填充木炭的玻璃管上进行泵吸法采样，然后进行二硫化碳提取和气相色谱分析法（GC）分析。

这种方法今天仍用于人身暴露风险评估，也就是职业卫生和烟囱排放测试，但是在敏感性方面受到重大限制，由于以下一些原因，目前在一定范围内已经被热解吸附取代，尤其在欧洲：

- 敏感性

吸附剂吸收要求用至少 1-2 毫升的 CS2 进行稀释，然后将仅 1 微升的抽取物注入 GC，因此假定在流程开始时进行 10^3 稀释。其它限制敏感性的因素包括：吸附剂、溶剂制品、吸附剂本身的干预作用（干扰对挥发性目标分析物的识别）和较低解吸附管效率。相反，TD 使所有目标分析的完整转移到分析系统，不会产生稀释或溶剂干预。TD 的探测限值一般比同等的溶剂提取法高 10^3-10^4，有利于进行 ppt/ppb 级别和较高百万分率（和% 级）浓度的环境监测。

- **Desorption Efficiency**

Thermal desorption efficiency is readily validated and is always above 95%, independent of ambient conditions and the nature of the target analytes – polar/apolar, volatile/semi-volatile etc. The desorption efficiency of charcoal/CS_2 extraction methods is typically in the order of 80% under best conditions. Additionally charcoal is hydrophilic and adsorbs water from humid air. The presence of water can reduce desorption efficiencies (eg 20-30%), especially in the case of polar compounds.

-Reproducibility

As described above, the desorption efficiency of solvent extraction is usually lower than that of TD and can vary from 20 to 80% depending on target analyte and atmospheric humidity. This significantly comprises reproducibility. Other issues include the evaporation of CS_2 during sample preparation and its absorption into the rubber septa of autosampler vial caps.

- **Analytical Performance**

Originally, charcoal/CS_2 methods were intended for used with packed column GC technology and FID detection. In this case, the limitations of CS_2 are minimised by its very low response on FID. However even under these conditions, impurities in the solvent, solvent related baseline disturbances and the large dilution factor

通过比较，炭/ CS2 法得出的浓度总是大于 0.1 百万分率。

- 解吸附效率

热解吸附效率很高，总是高于 95%，不受环境条件和目标分析物的性质-极性/非极性，挥发/半发挥性等因素的影响。炭/CS2 提取解吸附法效率在最佳条件下为 80%。水压能降低解吸附管效率（例如 20-30%），尤其对于极性化合物。

- 再现性

如上所述，溶剂提取解吸附效率一般低于TD法效率20%-80%，取决于目标分析物和大气湿度。这主要取决于可再现性。其它问题包括 CS2 在样本准备过程中的蒸发和其在自动采样瓶盖的橡胶隔片上的吸附性。

- 分析性能

all contributed to limit method sensitivity to ppm level atmospheric concentrations. With the modern preference for GC"s configured with mass spectrometer (MS) detectors, CS_2 brings additional limitations. It generates a large response on the MS, often requiring deactivation of the detector ionisers until after the solvent has completely passed through the system. This means that target compounds co-eluting with the solvent will not be measured at all.

炭/CS2 法本来用于包括柱状 GC 技术和 FID 探测。在这方面，CS2 的限制由于其对 FID 的低响应性而减到最少。但是即使在这些条件下，溶剂的杂质、与溶剂有关的基线干扰及其它主要稀释因素都会限制百万分率级大气浓度的方法敏感性。随着现化人与配置质谱仪（MS）探测器的 GC 的偏爱，CS2 带来更多限制是。它产生了对 MS 的巨大响应，通常要求探测器离子发生器的钝化，轩到溶剂已经完全穿过系统、这意味着用溶剂洗脱的目标化合物完全无法测定。

- **Thermal Desorption Tubes**

The “industry standard” for TD tubes is ¼ inch (6.4 mm) OD x 3½ inch (88.9 mm) long stainless steel sorbent tube pre-packed with the sorbent of choice. In addition, a ¼ inch brass SwageLok type storage cap (fitted with a PTFE ferrule) for the non sampling end of the tube, and a diffusion cap at the end of the tube is normal practice.

- 热解吸附管

TD 管的工业标准是预先用吸附剂填充的¼英寸（6.4 毫米）直径 x3½ 英寸（88.9 毫米）长不锈钢吸附剂管。另外通常情况下管的非采样商还配有一个¼英寸铜接头套管型储帽（用 PTEE 金属环安装）和一个散射帽。

A suitable sorbent must be selected for the compound or mixture to be sampled. If more than one sorbent is required (due to the different volatilities of the compounds in question), two or more samplers packed with different sorbents should be exposed simultaneously.

对于采集到的化合物或混合物样本，必须选择适当的吸附剂、如果要求使用多种吸附剂（由于有关化合物的挥

It is essential that tubes are conditioned before they are used for sample collection. Once sampling or analysis is completed, tubes should be recapped with the brass storage caps as soon as possible and returned to a clean environment for storage.

发性不同），用不同吸附剂填充的多个样本应同时暴露。

Specific details including the general handling of TD tubes, selection of the sorbent, conditioning of tubes, short and long term storage of tubes after sampling should be obtained from the manufacturer prior to use.

有一个重要问题：在采样前必须使吸附剂管达到预定条件。一旦采样或分析完成，就要尽快重新用黄铜储帽装管口盖上，放回一个清洁的环境储存。

包括 TD 管的一般处理、吸附剂的选择、吸附剂管的条件准备和吸附剂管的长短期储存的具体细节请在使用前咨询制造商。

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Figure 9.7 – General Thermal Desorption Tubes

图 9.7–普通热解附管

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Figure 9.8– Thermal Desorption Unit with GC/MS

图 9.8– 采用 GC/MS 的热解附设备

9.3.2 Collection Efficiency of Adsorption Tubes

Factors that can affect the collection efficiency of adsorption tubes include:

Temperature – adsorption is an exothermic process and is reduced at higher temperatures. Some compounds can migrate through the sorbent bed and should be stored after sampling by keeping them cool/cold in a coolbox, fridge or freezer.

Humidity – charcoal has a great affinity for water vapour and hence reduces its collection of other contaminants

Sampling flow rate - if sampling pump flow rates are too high contaminants do not have sufficient residence time to be removed by the sorbent resulting in collection losses.

9.3.2 吸附管采样效率

影响吸附管采样效率的因素包括：

温度– 吸附是一个放热过程，在高温情况下会减缓。一些化合物能通过吸附床转移，因此应在采样后放在冷却/低温容器、冰箱或冷藏机中保存。

湿度–炭与水蒸汽有很大的亲合力，因此能减少对其它污染物的收集。

采样流率-如果采样泵流率太高，吸附剂就没有充足时间移走污染物，就会导致采样损失。

Channeling – if the sorbent tube is incorrectly packed, channels or gaps in the bed can be formed through which the gases flow and hence are not in contact and not adsorbed on to the surface of the sorbent.

裂隙–如果吸附剂管包装错误，基部就会出现裂隙，使气流通过，因此无法接触或被吸附在吸附剂表面。

Overloading of sorbent tubes can occur if concentrations/sampling times are too long or by the presence of other contaminants including water vapour that preferentially occupy the adsorption sites.

如果浓度/采样时间过长，或吸附所在地方事先存在其它污染物，包括水蒸汽，就会出现吸附剂管装载过量现象。

The manufacturers‟ information and standard sampling methods eg NIOSH, OSHA, HSE, ISO Standards Australia etc should be referred to for specific details pertaining to the sampling for the particular contaminant.

关于具体污染物采样的具体细节，参见制造商信息和标准采样方法，例如 NIOSH、OSHA、HSE、ISO 澳大利亚标准。

9.3.3 Desorption Efficiencies

9.3.3 解吸附管效率

While adsorption of a contaminant from the atmosphere onto a tube of some specific type is a very effective way of collecting the contaminant, difficulties arise during the laboratory analysis in the recovery of that analyte from the tube.

而从大气中将污染物吸附到某些类型的管是收集污染物一个有效方法，在实验室分析过程中遇到的困难是如何从管中取出污染物。

In essence, some of the material that has been collected from the atmosphere cannot be recovered from the tube and thus, if this is not accounted for in the calculation of an exposure, will lead to errors. To overcome this, a “desorption efficiency” for each batch of tubes must be established. There are varying

从本质上说，一些从大气中收集到的材料无法从管中收集，因此如果这无法解决暴露计算问题，就会导致错误。为了克服这一点，每一批吸附剂管的解吸附效率必须事先确定。在这方面有许多方法，加仑量 是一般是将该批管中一些管中装上不同数量的污染物，然后正常处理吸附剂管，这样

methods for doing this but the general approach is to load a number of tubes from a batch with varying amounts of the contaminant of interest and then process the tubes as normal. The percentage recovered (eg 80% or 0.8) is deemed the desorption efficiency for that particular batch of tubes and for that particular contaminant.

获得的百分比（例如 80%或 0.8）就视为该批吸附剂管具体污染物的解吸附效率。

It is important that the laboratory understand the reasons for this process and be familiar with the appropriate methods to establish such values. In some circumstances manufacturers publish a list of typical desorption efficiencies for common contaminants which can be a useful guide to the laboratory.

实验室必须理解这个流程的原因，熟悉建立这些值的适当方法。有些制造商发布典型的普通污染物解吸附管效率表，用于指导有关实验室工作。

9.4 SAMPLING PUMPS

9.4 采样泵

The operation of the various types of sampling pumps is discussed in section 8.2. The major difference between sampling pumps used for dust and vapour sampling is the operating flowrate. For most organic vapour sampling the required flowrate is typically 20-200 mL/minute, thus giving rise to the generally used terminology “low flow” pumps.

各种采样的泵的操作方法详见 8.2 部分。用于粉尘和蒸汽采样的采样泵的主要差别就是工作流率、对于大多数有机蒸汽采样来说，流率一般为每分钟 20-200 毫升，这就是我们通常所说的“低流率”泵。

The other main difference is in respect to flow pulsation. In organic vapour sampling it is the total volume of air collected which is important not the need to maintain a low pulsation flow; hence some low flow pumps do not have as sophisticated flow control systems as dust sampling pumps. Pre and

其它主要差别就是关于流量脉动在有机蒸汽采样过程中，收集到的空气总量很重要，而不是需要维持一个很低的脉动流量；因些一些低流量泵没有像粉尘采样泵那样复杂的流量控制系

post sampling rates should not vary by more than ±5%. If outside this recommended range the sample should be considered invalid.

统。采样前后流率应是不同的，约在5%左右。如果这个超过这个范围，样本应视为无效的。

For the collection of gases, flowrates of about one litre/minute are usually required and this can be achieved by “throttling down” a dust sampling pump, provided it has an exhaust port for the collection of the gas into a Tedlar bag, etc.

对于采集气体来说，一般要求流率达到每分钟 1 升左右，这可以通过减低粉尘采样泵的速度来完成，但是必须有一个抽风口能将气体抽入一个泰德拉袋或类似装置。

9.5 MIXED EXPOSURE TO SOLID/LIQUID/AEROSOL/GASES/VAPOURS

9.5 固体/液体/浮质/气体/蒸汽混合暴露

Where contaminates are present in a mix of solid, liquid, aerosol and gas or vapour phases particular care must be taken to ensure that levels are not underestimated. Three examples highlight issues for mixed phase sampling:

当污染物以固体、液体、浮质和气体或蒸汽阶段的混合存在时，必须特别小心来确保不会低估污染程度。三种样本突出了混合阶段采样存在的问题：

Example 1

例 1

The “traditional method” for sampling and measurement of coke oven emissions was to collect and analyse the “Benzene Soluble Fraction of the Total Particulate Matter” collected on a membrane filter. However it has been shown that the polyaromatic hydrocarbons emitted from coke ovens are present in a mix of a particulate phase and a vapour phase and hence sampling for just the particulate phase was an underestimation of the concentration of coke oven emissions.

传统焦炭炉排出物采样和测量方法是用一个过滤膜收集和分析全部颗粒物质苯可溶部分。但是，它显示了焦炭炉排出物多环芳香族碳氢化合物是多种颗粒的混合体，因此如果只是对特定阶段进行采样的话，就会低估焦炭炉排出物的浓度。

Samplers have now been developed which include a sorbent layer behind the particulate membrane filter to collect the vapour phase which passes through the membrane filter.

当前已研制的采样器包括薄膜过滤器后一层吸附剂来收集穿过薄膜过滤器的蒸汽。

Example 2

例 2

Practical difficulties associated with the use of impingers (eg liquid loss due volatilisation of solvents, sample carry over and liquid spillage, the need to keep sampler upright and breakage of the glass components) led to the development of impregnated filters to assist in overcoming these issues for contaminants such as isocyanates, formaldehyde and glutaraldehyde.

由于使用撞击器有一些实际困难（例如由于溶剂挥发而导致的液体损失，样本携带和液体溢出，采样器需要保持直立和玻璃组件破损），因此对于人们对异氰酸酯、甲醛和戊二醛等污染物开发出一些能注入的过滤器来协助解决这些问题。

However, during the spraying of “two pack” isocyanate containing paints, the isocyanates may be present in both the particulate and vapour phase. Particles may not react completely with the impregnated filter. Similarly, if just using an impinger small particles may not be collected efficiently. To overcome these potential under sampling issues a sampling train comprising of an impinger followed by an impregnated filter can be used

但是，在包含涂料的“两包”异氰酸酯的喷洒过程中，异氰酸酯能以颗粒和蒸汽状态同时存在。颗粒可能无法与被浸渍的过滤器的发生完全反应。同样，如果只使用一个撞击器，可能无法有效收集很小的颗粒。为了克服这些潜在的采样问题，可使用由撞击器组成的采样器，然后再使用一个浸渍过滤器。

Example 3

例 3

In the smelting of aluminium for example, fluorides can exist as a particulate, as a hydrofluoric acid mist or as gaseous hydrofluoric acid and need to be sampled separately when determining hydrogen fluoride and fluorides in air, HSE MDHS

例如，在铝冶炼过程中氟化物可以以颗粒状态存在，作为氢氟酸雾或气态氢氟酸，这样的话在确定空气中氟化氢和氟

35/2.

化物（HSE MDHS 35/2）时就需要分别采样。

Samples are taken by drawing a measured volume of air through a PTFE (Teflon) membrane filter and a sodium carbonate impregnated paper pad mounted in an inhalable sampler. The PTFE filter removes the particulate fluorides, whilst the sodium carbonate impregnated pad collects the hydrogen fluoride. Hydrofluoric acid mist is not retained on the filter so it is also collected on the sodium carbonated impregnated paper pad.

通过绘制穿过一个安装在可吸入性采样器上的聚四氟乙烯（特仑氟）薄膜过滤器和碳酸钠浸渍纸垫的空气的体积测量值进行采样。聚四氟乙烯过滤器能去除微粒氟化物，而碳酸钠浸渍垫能收集氟化氢。氢氟酸雾不会停留在过滤器上，因此可用碳酸钠浸渍纸垫收集。

9.6 DIFFUSION OR PASSIVE SAMPLERS

9.6 扩散或被动采样器

Passive sampling is the collection of airborne gases and vapours at a rate controlled by a physical process such as diffusion through a static layer or permeation through a membrane without the active movement of air through an air sampling pump.

被动采样即以物理流程控制的速度来收集空气中的气体和蒸汽，例如静态层扩散或薄膜渗入，不涉及使用气体采样泵实现主动空气运动。

Diffusion is the natural process by which gases and vapours flow from a higher concentration to a lower concentration in the absence of bulk flow. Most diffusion or passive samplers operate on the principle of gaseous diffusion across a permeable membrane (AS 2986). Fick"s first law of diffusion can be applied to the mass uptake rate:

扩散是一个自然的过程，气体和蒸汽从一个高浓度地方流向一个低浓度地方，不存在批量流动。大多数扩散或被动采样的原则就是气体穿过一个渗透膜（AS 2986）扩散、Fick 的扩散第一法则可用于解决质量替换率：

$$\frac{m}{t} = \frac{AD}{L}(c - c_0)$$

$$\frac{m}{t} = \frac{AD}{L}(c - c_0)$$

where m = mass of adsorbate collected in grams

t = sampling time in seconds

A = cross sectional area of the diffusion path in square cm

D = diffusion coefficient for the adsorbate in air in square cm per second – available from manufacturer of the sampler for a given chemical

L = length of the diffusion path in cm (from porous membrane to sampler)

c = concentration of contaminant in ambient air in gram per cubic cm

c_0 = concentration of contaminant just above the adsorbent surface in gram per cubic cm

From the above equation, if c_0 is zero (ie the collection medium is effective) the mass transfer or collection rate is proportional to the ambient concentration c.

The sampling rate of a diffusion monitor is dependent on the diffusion coefficient of the contaminant and the geometry of the monitor. The 3M and SKC badge monitors and Dräger ORSA monitors have the diffusion path axial to the sorbent while the diffusion path to the Radiello is radial to the sorbent surface. Therefore, every contaminant on every brand of monitor has its own unique, fixed sampling rate.

在这里，

m =收集到的被吸附物的质量，以克为单位

t =采样时间，以秒为单位

A =扩散路径横截面面积，以平方厘米为单位

D =空间中被吸附物扩散系数，以平方厘米/秒为单位-特定化学品系数可从样本制造商处索取

L =扩散路径长度（从多孔渗水薄膜到样本），以厘米为单位

c =环境空气污染物浓度，以立方厘米为单位

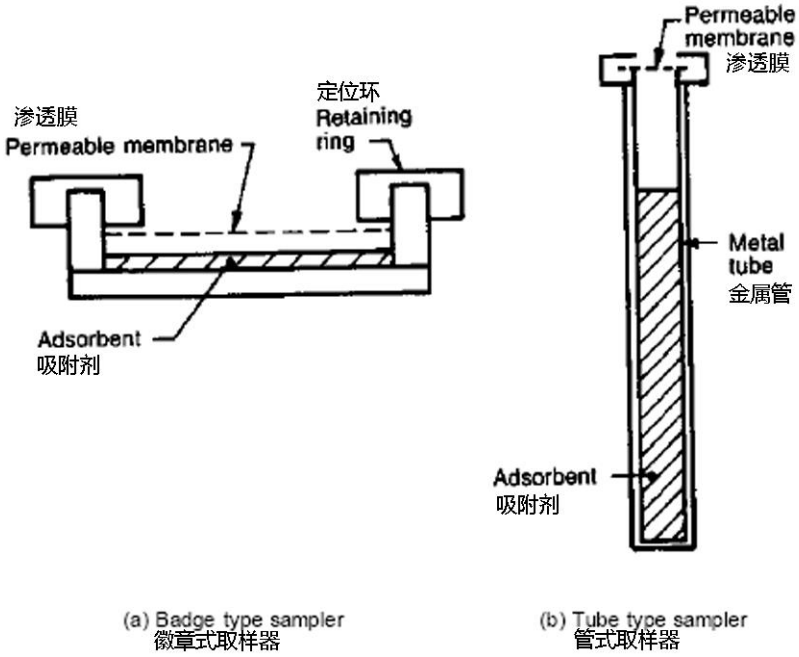
c0 =吸附剂表面上污染物的浓度，以克/立方厘米为单位

在以上等式中，如果 c0 为零（即收集媒介有效），那么转移质量转移和采样率与空气浓度 c 成比例。

扩散监控仪的采样率取决于污染物扩散系数和监控仪的几何学特征。当对 Radiello 的扩散路径向吸附剂表面放射，3M 和 SKC 监测器和 Dräger ORSA 监控仪的扩散路径与吸附剂成轴向。因此对于每个品牌的监控仪，每种污染物都有独一无二的固定采样率。

The sampling rate remains constant as long as the sorbent media does not reach its capacity and as long as adequate airflow is maintained across the face of the monitor. The manufacturers of the monitors supply the sampling rate and capacity information.

只要吸附剂介质没有达到设计容量，只要监控仪表面有充足气流，那么采样率就会保持稳定。采样率和容量信息由监控仪制造商提供。



(Source: HSE – *Reproduced with permission*)
（来源：HSE–许可转载）

Figure 9.9 – Typical Passive Samplers
图 9.9– 典型被动采样器

(Source: 3M Australia – *Reproduced with permission*)
（来源：3M 澳大利亚–许可转载）

Figure 9.10 – 3M Diffusion Monitor
图 9.10– 3M 扩散监控仪

Organic vapour diffusion monitors are typically loaded with activated charcoal and contaminants that can be actively sampled with a charcoal tube can generally be sampled with a diffusion monitor as well.

有机蒸汽扩散监控仪一般装有活性碳，能用炭管主动采样的污染物一般也用扩散监控仪采用。

Similarly charcoal and other sorbents can be treated with chemical impregnants that rely on chemisorption to collect materials that have poor capture, retention and recovery with activated charcoal. For example, a solid sorbent can be treated with 2-(hyroxymethyl) piperidine and used to collect formaldehyde, or activated charcoal can be treated with a bromine compound and used to collect ethylene oxide. Other diffusion monitors have been developed for inorganic mercury and more recently for amines.

同样，木炭和其他吸附剂也可用化学浸渍剂处理，原理是依靠化学吸收作用来收集很难捕获的材料，用活性炭进行保留和恢复。例如，固体吸附剂可以用 2 -二羟甲基哌啶处理，用于收集甲醛，有时用溴化合物处理活性炭来收集环氧乙烷。关于无机汞的其他扩散监测仪已经开发出来，而且最近胺扩散监测仪也已面世。

Diffusion monitors meet or exceed an accuracy of ± 25% at 95% confidence for many workplace contaminants. They are simple and easy to use and do not require the use of sampling pumps, tubing, and batteries or air flow calibration. They are light weight and can be simply clipped on to the collar of the worker for personal sampling (TWA or STEL) or can be used for area monitoring as long as there is sufficient airflow.

如果扩散监测达到或超过±25%的精度要求，在许多工作场所的污染物采样效率就能达到 95%。这些监控仪简单易用，不需要使用采样泵、油管、电池或空气流校准。其特点是重量轻，可以简单地夹在工人衣领进行人体采样（TWA 或 STEL）或用于区域监控，只要有足够的气流。

If used for area monitoring or static sampling they should be placed in the open away from corners and where the

如果用于监测或静态采样，应放置在远离角落的开放场所，任何方向的空

air movement is at least 25 ft/min or 0.13 m/sec in any orientation.

气流动速度至少达到 25 英尺/分钟或 0.13 米/秒。

Some of the disadvantages of diffusion monitors are that they cannot be used to sample everything, eg they cannot sample low vapour pressure organics such as glutaraldehyde, reactive compounds such as phenols and aldehydes. Diffusion badges using charcoal suffer from the same moisture and recovery issues associated with the use of active sampling tubes. Additionally, with some diffusive samplers (depending on design) inaccuracies can occur at wind speeds >2.5 m/s. The “sampling rate” is supplied by the manufacturer and is different for each compound. While some diffusion monitors have a back up section most do not making it difficult to know if breakthrough has occurred especially for the more volatile compounds such as methylene chloride.

扩散监视仪也有缺点：不适用于所有样品。例如它们不用能进行低蒸气压有机物采样，例如戊二醛、活性化合物酚类和醛类等。由于使用活性采用管，使用炭的扩散标志也有同样的湿度和恢复问题、而且，使用一些扩散采样器（取决于设计），风速误差可达到> 2.5 米/秒。“采样率”是由制造商提供，每个化合物的采用率不同。虽然一些扩散监测仪有一个备份截面，但多数情况下，对于二氯甲烷等更多挥发性化合物来说，很容易发现是否发生渗透。

The manufacturers" information and standard sampling methods eg NIOSH, OSHA, HSE, ISO Standards Australia etc should be referred to for specific details pertaining to the sampling for the particular contaminant.

关于具体污染物采样具体信息，参见制造商信息和标准采样方法例如 NIOSH、OSHA、HSE、澳大利亚 ISO 标准等。

9.7 CALCULATION OF RESULTS

9.7 结果计算

9.7.1 Active Sampling

9.7.1 主动采样

Two components are necessary to establish the atmospheric concentration of gas and vapour in the atmosphere of a

两个因素对于计算工作场所气体和蒸汽的大气浓度来说是必要的。就是采样介质上的污染物浓度和采集的空气

workplace. These are the concentration of contaminant on the collection media and the total volume of air sampled.

- **Calculation of Total Volume of Air Sampled**

If we know the flowrate of a sampling pump (as detailed in section 8.5) and the time that sampling was undertaken, we can calculate the total volume of air sampled. For example, if the flowrate was 100 mL/min and sampling was performed for 5 hours, we can make the following calculation.

Volume (Litres) = 5 x 60 x 100 / 1,000
= 30

Volume (m^3) = 0.030 ($1m^3$ = 1,000 L)

- **Calculation of Mass on Sample Media**

If the laboratory analysis resulted in 6.3 µg of toluene being measured on the charcoal tube with an assumed desorption efficiency of 100% and zero breakthrough and zero blank, then

$$\text{Mass} = \frac{6.3}{1000} = 0.0063$$

- **Calculation of Concentration**

Using the formula

$$\text{Conc (mg/m}^3\text{)} = \frac{M_F + M_R - M_B}{D \times V}$$

Where M_F = mass of analyte in front

总量。

- 采样气体总量计算

一旦知道采样泵的流量（详见 8.5 部分）和采样时间，就能计算采样空气总量。例如，如果流率为 100 毫升/分钟，采样进行 5 小时，计算公式如下。

体积（升） = 5 x 60 x 100 / 1，000

= 30

体积（立方米）= 0.030（1m3 = 1，000 L）

• 样本介质质量计算

如果实验室分析结果是炭管中甲苯测定值为 6.3 µg，假定解吸附效率为 100%，零渗透，零空隙，那么：

甲苯质量（毫克）= $\frac{6.3}{1000}$ = 0.0063

- 浓度计算使用公式

浓度（毫克/立方米） = $\frac{M_F + M_R - M_B}{D \times V}$

section (mg)

M_R = mass of analyte in backup section (mg)

M_B = mass of blank

D = desorption efficiency (as a fraction)

V = volume in m^3

Concentration of toluene mg/m^3 = $\frac{0.0063}{1 \times 0.03}$

= 0.21

这里 M_F = 截面前被分析物质量（毫克）

M_R = 备份截面被分析物质量（毫克）

M_B = 空隙质量

D = 解吸附系数（分数）

V = 体积（立方米）

甲苯浓度（毫克/立方米）= $\frac{0.0063}{1 \times 0.03}$

= 0.21

9.7.2 Diffusion/Passive Sampling

The time weighted average concentration of the environment sampled can be calculated by knowing the length of the sampling period, the contaminant weight determined by the laboratory, the recovery coefficient and the calculation constant either A or B. The calculation constant "A" is used to calculate the concentration when expressed in units of milligram per cubic metre (mg/m^3) and the constant "B" when expressed in units of parts per million (ppm).

NB These calculation constants are determined and supplied by the particular manufacturer for use with certain contaminants sampled using their particular monitor.

$$A = \frac{1000}{\text{Sampling Rate}}$$

$$B = \frac{1000 \times 24.45}{\text{Sampling Rate} \times \text{Molecular Weight}}$$

Air temperature will slightly influence the sampling rate of the diffusion monitor. The expressions can be multiplied by a

9.7.2 扩散/被动采样

采样环境时间加权平均数浓度可通过知道采样时间长度计、实验室测定的污染物重量、收集系数和计算常数 A 或 B 得出。计算常数 A 用于计算单位为毫克/立方米的浓度，常数 B 用于计算单位为百万分率时的浓度。

注：特定污染物计算常数由监测仪制造商测定和提供。

$$A = \frac{1000}{\text{采样率}}$$

$$B = \frac{1000 \times 24.45}{\text{采样率} \times \text{分子重量}}$$

空气温度会略微影响扩散监控仪的采样率。公式可乘以采集到的样本在超过 25°C 时的温度修正系数。压力差不

temperature correction factor for samples collected at other than 25°C. No correction is needed for differences in pressure

需要修正。

Table 9.1 – Sampling Temperature Correction Factors
表 9.1– 采样温度修正系数

(C)	(F)	**Correction factor** 修正系数
44	111	0.97
37	99	0.98
31	88	0.99
25	77	1.00
19	66	1.01
13	55	1.02
7	45	1.03
2	36	1.04
-3	27	1.05
-8	18	1.06

(Source: 3M – *Reproduced with permission*)
（来源：3M–许可转载）

Example - Procedure for the 3M Organic Vapour Monitor

案例 - 3M 有机蒸汽监测仪程序

The time weighted average concentration of contaminant in mg/m^3 can be calculated from the following expression:

污染物时间加权平均数浓度（毫克/立方米）可用以下公式计算：

$$C\ (mg/m^3) = \frac{W\ (micrograms) \times A}{r \times t\ (minutes)}$$

$$C（毫克/立方米）= \frac{W（微克）\times A}{r \times t（分钟）}$$

The time weighted average concentration of contaminant in ppm can be calculated from the following expression:

污染物时间加权平均数浓度（百万分率）可用以下公式计算：

$$C\ (ppm) = \frac{W\ (micrograms) \times B}{r \times t\ (minutes)}$$

$$C（百万分率）= \frac{W（微克）\times B}{r \times t（分钟）}$$

Example Calculations

Contaminant: Benzene

Length of sampling time (t) 420 minute

Temperature (T) 75 °F

Calculation Constant A 28.2

B 8.82

Contaminant weight (W) 27.2µg Recovery coefficient (r) 0.97

$$C\ (mg/m^3) = \frac{27.2 \times 28.2}{0.97 \times 420}$$

$$= 1.88\ mg/m^3$$

$$C\ (ppm) = \frac{27.2 \times}{0.97 \times 420}$$

$$= 0.59\ ppm$$

案例计算

污染物： 二甲苯

苯采样时长（t）420 分钟

温度（T）75 °F

计算常数 A 28.2

B 8.82

污染物重量（W） 27.2µg

采样系数（r） 0.97

$$C（毫克/立方米）= \frac{27.2 \times 28.2}{0.97 \times 420}$$

=1.88 毫克/立方米

$$C（百万分率）= \frac{27.2 \times 8.82}{0.97 \times 420}$$

=0.59 百万分率

9.8 DIRECT READING INSTRUMENTS

9.8.1 Introduction

Significant advances in this area of occupational hygiene monitoring over the last 10 to 20 years. Often in the past they were large bulky instruments unsuitable for personal monitoring, but with advances in the technology they can now be worn as personal sampling devices for an ever increasing number of gases and vapours.

Direct reading instruments allow real time measurements of gases and vapours and aerosols. Many are available with data logging capability that allows analysis of

9.8 直读仪器

9.8.1 简介

在过去 10-20 的中职业卫生监测领域取得重大进步。过去的仪器体形庞大，不适合人体监测，但是随着技术的进步，这些人体采样设备可直接穿戴在身上，用来采集不断增加的气体和蒸汽。

直读仪器能实时测定气体和蒸汽和浮

instantaneous (seconds), short term 15 minute STEL concentrations and 8 hour TWA concentrations of the particular contaminant.

Gas or vapour monitors can measure:

- Single gas or vapour
- Specific multiple gases and vapours
- Multiple gases and vapours without differentiating between them

The uses of these direct reading instruments include:

- Where immediate data is needed
- Personal exposure monitoring
- Help develop comprehensive evaluation programmes
- Evaluate effectiveness of controls
- Emergency response
- Confined spaces
- For difficult to sample chemicals
- Multi sensors/multi alarms
- Stationary installations for both a record of exposure levels and when connected to an alarm to indicate hazardous levels
- Fit testing
- Video monitoring etc

Some of the types of commonly used direct reading instruments are listed in Table 9.2. A discussion of some of the instruments will be made during the practical session.

质。许多都有数据记录功能，能分析颗粒污染物的瞬时（数秒）、短期 15 分钟 STEL 浓度和 8 小时 TWA 浓度

气体和蒸汽监控仪可测量

- 单一气体或蒸汽
- 多种具体气体和蒸汽
- 多种混合在一起的气体和蒸汽

这些直读仪器的用途包括：

- 如需要直接数据
- 个人暴露监测
- 帮助开发综合评估方案
- 评估控制有效性
- 紧急响应
- 密闭空间
- 在很难对化学品采样的情况下
- 多传感器/多报警器
- 记录暴露水平和连接指示危险程度的警报器的静态安装
- 适合性测试
- 视频监控器等

表 9.2 列举了一些常用的直读仪器。在实践课上我们要对一些仪器进行具体讨论。

Table 9.2 – Commonly Used Direct Reading Instruments for Gases and Vapours
表 9.2– 气体和蒸汽通常使用的直读仪器

Instrument	Uses	Principle of Operation	Range
仪器	使用	操作原理	范围
Combustible gas detectors	Combustible gases and vapours – non specific.	Hot wire – test gas is passed over a heated wire (sometimes in the presence of a catalyst). The test gas burns changing the temperature of the filament and the electrical resistance is measured.	Usually measured in percentage of lower explosive limit. Some models measure down to ppm.
可燃气体探测器	可燃气体和蒸汽-未指定	热丝– 测试气体经过加热电线（有时使用催化剂）。试验气体燃烧使灯丝变化，测量电阻。	通常以爆炸下限百分率测量。一些模型的测量范围达到百万分率。
Colorimetric detectors	Various gases and vapours including formaldehyde, hydrogen sulphide, sulphur dioxide, toluene diisocyanate	Reaction of the test gas with a chemical reagent (either as a liquid or in some cases an impregnated paper or tape) and measurement of the colour produced.	Variable
比色探测器	各种气体和蒸汽，包括甲醛、硫化氢和氧化硫、甲苯二异氰酸盐-指定	实验气体与反应试剂（有时是气体，有时是浸渍纸片或纸带）发生反应，对产生的颜色进行测定。	可用。
Electrochemical sensors	Carbon monoxide, nitric oxide, nitrogen dioxide, hydrogen sulphide, sulphur dioxide, - specific.	Chemical oxidation of test gas	1 to 3,000 ppm
电气化学传感器	一氧化碳、氧化一氮、一氧化氮、硫化氢、二氧化硫 - 指定	实验气体化学氧化性	1 -3，000 百万分率

Infrared gas analysers	Organic and inorganic gases and vapours – specific.	Measures infrared absorbance of test gas.	Sub ppm to low percentage levels.
红外气体分析仪	有机和无机气体和蒸汽– 指定	测量实验气体红外吸光率	百万分率以下至较低百分率
Metal oxide sensors	Hydrogen sulphide; nitro, amino, alcohol and halogenated	Metal oxide sensor is chemically reduced by the test gas increasing its electrical resistance.	1 to 50 ppm
金属氧化物传感器	硫化氢、硝基、氨基、酒精和卤代烃	随着实验气体增加其电阻，金属氧化物传感器的化学读值减小。	1 - 50 百万分率
Thermal conductivity sensors	Carbon monoxide, carbon dioxide, nitrogen, oxygen, methane, ethane, propane and butane.	Uses specific heat of combustion of a gas or vapour	Percentage
热传导传感器	一氧化碳、二氧化碳、氮气、氧气、甲烷、乙烷、丙烷和丁烷。	使用气体或蒸汽燃烧产生的热量	百分率
Portable gas chromatographs	Organic and inorganic gases and vapours – specific.	Uses a packed column to separate complex mixture of gases. Detectors available include flame ionization, electron capture, thermal conductivity, flame photometric and photoionisation.	0.1 to 10,000 ppm
便携式气相色谱仪	有机和无机气体和蒸汽– 指定	使用填充柱来分离复杂的分体混合物。可用探测器包括火焰电离、电子捕获、热导率、火焰光度和光离子探测器	0.1 -10，000 百万分率

9.8.2 Limitations

The disadvantages and/or limitations of direct reading instruments include:

- Often costly to purchase
- Need for frequent and regular calibration
- Lack of specificity
- Effect of interferences
- Cross sensitivity
- Need for intrinsically safe instruments in many situations
- Battery life
- Sensors (finite life, poisoning, lack of range)

The advantages and disadvantages for each type of instrument must be assessed for the particular needs in relation to the measurement of particular gases and vapours in the workplace.

An appreciation of the issues that arise from the cross sensitivity of sensors can be gained from the following example.

If, for example, we have an electrochemical cell designed to measure carbon monoxide and apply 100 ppm of the following gases across the cell we will typically obtain the following carbon monoxide readings on the instrument:

Hydrogen Sulphide ≈315 ppm
Sulphur Dioxide ≈50 ppm
Nitric Oxide≈30 ppm
Nitrogen Dioxide≈-55 ppm
Chlorine≈-30 ppm

9.8.2 局限性

直读仪器的劣势和/或局限性包括：

- 一般来说价格很高
- 需要频繁和定期校准
- 缺少针对性
- 有干预性
- 交叉敏感性
- 在许多情况下需要本身具有安全性的仪器
- 电池寿命
- 传感器（寿命有限、有毒性、测量范围不明）

为了测量工作场所具体气体和蒸汽，根据不同用途分析每种仪器的优势和劣势。

传感器交叉敏感性评价可通过以下案例获得。

例如，如果我们有一个用来测量一氧化碳的电化电池，而且我们使用以下电池对应的亿分率气体，我们通常就能在仪器上得到以下一氧化碳读值：

硫化氢 ≈315 ppm
二氧化硫 ≈ 50 ppm
氧化一氮 ≈ 30 ppm
二氧化氮 ≈-55 ppm
氯 ≈-30 ppm
氢 <40 ppm

Hydrogen<40 ppm
Hydrogen Cyanide≈40 ppm
Ethane≈90 ppm

氰化氢 ≈ 40 ppm
乙烷 ≈90 ppm

Such false positive or false negative readings can give rise to a lack of confidence in the instrument to the point that alarms are ignored when they should not be.

假阳性或假阴性等读值能减少仪器的可靠性，会使人忽略本不应忽略的警报。

To overcome this problem, manufacturers fit a filter to the sensor which typically results in the following changes:

为了解决这个问题，制造商在传感器上安装了一个过滤器，这一般会导致以下变化：

		Unfiltered 未过滤	**Filtered** 过滤
Hydrogen Sulphide	硫化氢	315 ppm	<10 ppm
Sulphur Dioxide	二氧化硫	≈ 50 ppm	<5 ppm
Nitric Oxide	氧化一氮	≈ 30 ppm	<10 ppm
Nitrogen Dioxide	二氧化氮	-55 ppm	-15 ppm
Chlorine	氯	-30 ppm	≈ <-5 ppm
Hydrogen	氢	<40 ppm	<40 ppm
Hydrogen Cyanide	氰化氢	≈ 40 ppm	<15 ppm
Ethane	乙烷	≈ 90 ppm	<50 ppm

Obviously, it is important that these filters are maintained and that the limitations of the device are well understood by those using it in the workplace.

显然工作场所操作人员进行维护这些过滤器，并深刻理解这些设备的局限性。

9.8.3 Maintenance and Calibration

Readings obtained from direct reading instruments are only as good and are a reflection of both the maintenance and calibration of the equipment. One approach used in the mining industry and has also found use in general

9.8.3 维护和校准

直读仪器上获得的读值只适用于设备的维持和校准，并反映有关情况。采矿业和其它一般行业使用的一个方法是基于用途设定不同类别设备检查和校准要求和责任。

industry is to set out the requirements and responsibilities for the examination and calibration of different classes of equipment based on their use.

Group I All equipment which is hand held or portable

第一组：所有设备都是手持的或便携式的

Ia – provides a scaled output indication of actual gas concentration

Ia–提供了一个按比例缩小的实际气体浓度读值

Ib – provides an alarm output indication of actual gas concentration

Ib–提供了一个实际气体浓度警报读值

Group II Severe use conditions of equipment eg mounted on operating equipment and can include vibration and high levels of dust and water vibration.

第二组：设备严格使用条件，例如需要安装的操作设备，能包括震动和高度粉尘和水振动

Group III Equipment installed at a fixed location for appreciable periods of time with a local read out of concentration

第三组：适当时期安装在固定位置的设备，显示本地浓度读值

Group IV Equipment permanently installed with remote readout of concentration

第四组：永久安装设备，显示远程浓度读值

Table 9.3 – Suggested Examination Schedules

表 9.3– 建议的检查方案

Group	**Group Type**	**Suggested Examination & Maintenance Schedule***
组别	类型	建议的检查和维护时间表*
Ia	Handheld/portable	Shift / or before use Weekly Calibration 6 Monthly Service
Ib	Handheld/ portable with alarms	Shift / or before use Weekly Calibration 6 Monthly Service
II	Machine mounted	Shift / or before use Zero – Weekly Calibration – Weekly Alarm - Weekly Switching – Weekly 6 Monthly Service Overhaul - 4 Yearly
III	Underground fixed	Status – Daily System – Daily After relocation Switching – Monthly Yearly Service
IVa	Surface fixed	

Ia	手持/便携	每班次/或使用前 每周校准一次 每半年维护一次
Ib	手持/便携，带有警报	每班次/或使用前 每周校准一次 每半年维护一次
II	安装在机器上	每班次/或使用前 每周校准一次 每周检查警报一次 每周开关一次 每半年维护一次 每四年大修一次
III	固定在地面上	状态– 每日 系统– 移位后每日 开关-每月 每年维护一次
IVa	固定在表面上	状态– 每日 系统-每月 每年维护一次

Group	Group Type	Suggested Examination & Maintenance Schedule*
组别	类型	建议的检查和维护时间表*
IVb, IVc	Surface fixed	Status – Daily System – Monthly Line Integrity – Monthly Yearly
IVb，IVc	固定在表面上	状态– 每日 系统– 每月 生产线完好性-每月

* Daily – typically by user
Weekly – typically by maintenance person / department
Monthly – typically by maintenance person / department
Yearly – typically by external authority
* 每日检查维护– 通常由用户进行
每周检查维护– 通常由维护人员/部门进行
每月检查维护-通常由维护人员/部门进行
每年检查维护-通常由外部人员进行

The standard also sets out the requirements for a Certificate of Compliance, recordkeeping, accuracy requirements and the minimum competencies for persons and accredited authorities engaged in the examination, maintenance and testing of equipment covered by the standard.

标准同时提出合规性证书、记录、精度要求和标准涉及的设备的检查、维护和测试人员和部门的基本能力要求。

Advice is also provided for the technique and equipment guidelines for carrying out span and zero tests on gas detecting equipment. Span test is the test of response to certified test gas(es). Zero test is test of response to zero gas conditions.

同时标准还提出关于气体检测设备寿命和零测试的技术和设备指南的建议。寿命测试指测试认证测试气体的

响应情况。零测试指测试零气体条件的响应情况。

The test equipment and techniques described below are considered suitable for carrying out span and zero checks on gas detecting equipment.

人们认为以下测试设备和技术适合开展气体检测设备的寿命和零测试。

Suitable test equipment for carrying out single point span checks consists of a cylinder containing the certified test gas fitted with either a calibrated flow meter with a precision regulator or a flow restrictor and pressure gauge.

用于单点寿命检查的测试设备应包括一个气缸和一个压力计，其中气缸里装有经认证的气体，配有带有精密调节器的校准流量计或流量限制器。

For equipment in which the external atmosphere reaches the sensor or detector by diffusion, the test procedure usually involves dispensing the certified test gas to the sensor or detector of the equipment via a gas line and suitable calibration cup. Calibration cups conforming to the design of the manufacturer of the equipment under test, or supplied by that manufacturer should be used at all times.

对于外部大气扩散到达传感器或探测器的设备来说，测试程序通常涉及通过输气管道和合适的设备校准仪将认证测试气体传输到设备传感器或检测器。请使用符合设计测试设备制造商设计标准的或由制造商提供的校准仪。

For sample-draw equipment containing an integral pump or hand held aspirator, the sample inlet is connected to a gas line containing a plastic bag reservoir pre-flushed and filled with the certified test gas.

对于包括一个完整的泵或手持呼吸器的采样设备来说，样品进口与一个燃气管相连，后者包括一个塑料袋，里面预先充满了认证试验气体。

9.8.4 Intrinsic Safety of Instruments

The International Electrotechnical Commission Scheme for standards relating equipment for use in explosive atmospheres is known as IECEx.

Across the world there has been a general move towards the adoption of IECEx Standards and in particular the 60079 Series for Gases and Vapours and the 61241 Series for dusts by the different Standard setting organisations including those from Europe, United Kingdom, South Africa, USA, Canada, Asia and Australia and New Zealand.

The modern day automation of industry has meant an increased need to use equipment in Explosive or Ex areas. Such equipment is termed “Ex equipment” and is found in areas such as:

- Automotive refueling stations or petrol stations
- Oil refineries, rigs and processing plants
- Chemical processing plants
- Printing industries, paper and textiles
- Hospital operating theatres
- Aircraft refueling and hangars
- Surface coating industries
- Underground coalmines
- Sewerage treatment plants
- Gas pipelines and distribution centres
- Grain handling and storage
- Woodworking areas
- Sugar refineries

9.8.4 内在安全的工具

国际电工委员会制定的关于爆炸性气体中使用的设备的标准方案即 IECEx。

全球各地正在逐渐采用 IECEx 标准，特别是针对气体和蒸汽的 60079 系列和针对粉尘的 61241 系列，它们由来自欧洲、英国、南非、美国、加拿大、亚洲及澳大利亚和新西兰的不同的标准化机构制定。

现代工业自动化意味着需要在爆炸性或防爆地区使用更多设备，这样的设备称为“防爆设备”，一般出现在以下地方：

- 汽车加气站和加油站
- 炼油厂、钻井平台和加工厂
- 化学加工厂
- 印刷、造纸和纺织品行业
- 医院手术室
- 飞机加油和机库
- 表面涂料行业
- 地下煤矿
- 污水处理厂
- 燃气管道和传输中心
- 粮食处理和存储

- Metal surfaoe grinding, especially aluminium dusts and particles

An explosion can only take place if the following three factors are present:

- A flammable substance
- Oxygen
- An ignition source

An explosion only occurs if the substance-air mixture lies within a certain concentration range – the explosive limits.

- 木工区
- 炼糖厂
- 金属表面研磨，尤其是铝粉和颗粒

如果以下三个因素同时出现，就会发生爆炸：

- 易燃物质
- 氧气
- 火源

如果物质和空气混合达到一定浓度范围-爆炸限值，就会产生爆炸。

Explosion Protection

The hierarchy for explosion protection are:

- Reduce or avoid the use of flammable substances
- Do not allow any releases of flammable substances to form potentially explosive atmospheres
- Remove sources of ignition from the potentially explosive atmosphere
- Use adequately designed equipment that reduces the probability ofcausing an explosion
- Provide measure to reduce the effects of explosions

Guidance is provided in the IECEx Standards to enable the choice of suitable equipment based on the following processes.

爆炸保护

爆炸保护级别包括：

- 减少或避免使用易燃物质
- 避免释放的任何易燃物质形成潜在爆炸性空气
- 将火源远离潜在爆炸性空气
- 使用经过合理设计的设备来减少爆炸的可能性
- 采取减少爆炸影响的措施

IECEx 标准包含一个基于以下流程选择适当设备的指南。

Classifications of Zones

It is necessary to firstly identify the

分区

likelihood of an explosive atmosphere being present. The explosive atmosphere may be caused by the presence of a flammable liquid, gas or vapour or by the presence of combustible dust in suspension or layers or a combination of dust and gas explosive atmospheres.

首先必须识别是否可能有爆炸性空气。爆炸性空气会以可燃性液体、气体或蒸汽，或可燃粉尘悬浮层，或尘埃和爆炸气体的混合层或混合体形式存在。

Gases, Vapours, Mists	**Dusts**	**Explosive Atmosphere is Present**
气体、蒸汽、烟雾	粉尘	爆炸性空气存在
Zone 0	Zone 20	Most of the time
区域 0	区域 20	大多数时间
Zone 1	Zone 21	Some time
区域 1	区域 21	有时
Zone 2	Zone 22	Seldom or short term
区域 2	区域 22	很少或短期

(Source: TestSafe – *Reproduced with permission*)

（来源：TestSafe–许可转载）

The area may also be classified as “Safe Area” if the explosive material or air is not expected to be available in quantities that would allow it to be explosive.

如果预计不存在可能导致爆炸的大量爆炸性材料或空气，那么就属于安全区域。

Explosion Groups

爆炸组

When the zone classification takes place, the explosive materials are examined and the explosion protected electrical equipment is divided into two groups depending on where it is used:

当分区时，检查爆炸性材料，将防爆电气设备根据用途分为两组：

I equipment used in underground mining – explosive materials being mainly methane and coal dust

I 组 用于地下采矿的设备-爆炸性材料主要是甲烷和煤尘。

IIequipment used in other hazardous areas ie other industries with additional subgroups for Group II according to the

II 组 用于危险地区，即根据爆炸性气体性质使用其它 II 组设备的其它行业：

nature of the explosive gas atmosphere for which is intended:

IIA – least readily ignited gases such as propane and benzene

IIB – more readily ignited gases such as ethylene and diethyl ether

IIC – most readily ignited gases such as hydrogen and acetylene

IIA 组-不太容易点燃的气体，例如丙烷和苯

IIB 组-容易点燃的气体，例如乙烯和二乙醚

IIC 组-更容易点燃的气体，例如氢和乙炔

Temperature Classes

To prevent the hot surfaces of electrical equipment from creating ignition the maximum surface temperature of electrical equipment exposed to gas must not exceed the ignition temperature of gases that may be in the area.

温度等级

为了防止电气设备炙热表面温度达到燃点，暴露在气体中的电气设备的温度不得高于该区域或能存在的气体的燃点。

Group I electrical equipment requires the temperature of the components and surfaces exposed to dust and methane to be limited to less than 150°C.

I 组设备要求暴露在粉尘和甲烷中的部件和表面温度低于 150°C。

In case the components and surfaces are protected from the ingress of dust, the maximum temperature of such components may be higher, but must be less than 450°C.

如部件和表面受到粉尘燃烧保护，此类部件的最高温度可以更高一些，但必须低于 450°C。

For Group II electrical apparatus the maximum surface temperature must not exceed the values in the Table 9.4 which corresponds to the temperature class of the equipment. For convenience, a temperature class may be assigned to a gas or vapour based on its ignition temperature.

对于组 II 来说，电气仪表最大表面温度不得高于表 9.4 中与设备温度等级对应的值、为了方便起见，必须基于燃点确定每种气体或蒸汽的温度等级。

Table 9.4 – Maximum Surface Temperature / Ignition Temperature

表 9.4–最高表面温度/燃点

Temp Class 温度等级	**Maximum Permissible Surface Temp of the** 设备最高允许表面温度（°C）
T1	450
T2	300
T3	200
T4	135
T5	100
T6	85

(Source: TestSafe – *Reproduced with permission*)

（来源：TestSafe–许可转载）

Levels of Protection and Zones of Application

Intrinsic Safety has 3 levels of protection:

“ia” – means that the type of protection „intrinsic safety” (no release of spark energy or thermal energy that can cause ignition) is maintained with up to two faults.

“ib” – means intrinsic safety is maintained with up to one fault

“ic” – means intrinsic safety is maintained, but no requirement to apply faults. Safety factors are applied and the equipment evaluated for spark andthermal ignition energy after the application of faults

保护级别和适用区域

固有安全性保护分三级：

“ia”–指保护类型，具有固有安全性（不会释放会引燃性火花或热能），但有两项问题。

“ib”– 指具有固有安全性，但有一项问题。

“ic”– 指具有固有安全性，但是不存在问题。安全因素适用，设备在出现问题后经过引燃性火花或热能评估。

Level of Protection	保护级别	**Suitable for**	不同使用区域
“ia”	Ia	Zones 0, 20	区域 0，20
“ib”	Ib	Zones 1, 21	区域 1，21
“ic”	Ic	Zones 2, 22	区域 2，22

(Source: TestSafe – *Reproduced with permission*)

（来源：TestSafe–许可转载）

In areas where explosive atmospheres can occur despite the explosive protective measures employed, only explosive protected equipment can be used.

在可能发生爆炸的地区，尽管已经采取爆炸防护措施，但是只能使用爆炸保护设备。

Explosive protective equipment can be manufactured to IEC protection type levels which are subject to the requirements of their own specific standards. Intrinsic safety, Flameproof, Increased Safety, Encapsulation etc are some of the common types of protection used for explosion protected electrical equipment.

爆炸保护设备可按 IEC 保护标准生产，同时符合各自标准要求。固有安全性、防爆性、安全强化、封装等是常见的一些防爆电气设备保护措施。

The Ex marking label

爆炸性标志标签

Only appropriate certified and marked electrical equipment may be used in hazardous areas. Users of electrical equipment must ensure that the equipment complies with the relevant regulations and local standards.

只有经适当认证和标记的电气设备才能用于危险地区。电气设备用户必须确保设备符合有关规定和当地标准。

The information of the name of the manufacturer, model number, Ex code and certificate number are attached to the equipment.

设备所附制造商名称、型号、代码和交货证书。

An example is: Smith Electronics
Model TRE Ex ia IIC T4 Cert 098X
Serial No 8765

例如：史密斯电器

模型 TRE Ex ia IIC T4

Cert 098X 序列号 8765

“ia” equipment is suitable for zone 0 application

“ia”设备适用于区域 0。

IIC the equipment is suitable for Groups IIA, IIB, IIC

IIC 设备适用于 IIA、IIB、IIC 组。

T4 the equipment is suitable for gases with auto ignition temperature greater

T4 设备适用于自动点火温度高于 135°C 的气体。

than 135°C.

Further and much more detailed information for the use of gas detection equipment in potentially explosive atmospheres including the Classification of Zones, Explosion Groups, Temperature Classes, the Types of Protection provided by equipment, the requirements for Certification and Marking is available from the different National Standards and Certification bodies.

关于潜在爆炸性大气中气体探测设备使用的更多信息，包括分区、爆炸组、温度等级、设备保护类型、证书要求和标志可从各个国家标准和认证机构获得。

9.8.5 Detector Tubes (Colorimetric Tubes)

Colorimetric tubes are often widely used to provide an initial and convenient gas and vapour assessment in a workplace.

The use of colorimetric tubes is based on the change in colour of a specific reactant when it comes in contact with a particular gas. The most commonly used are tubes that contain a solid reactant and a known volume of air is drawn through the tube using a manual pump and the concentration of the particular contaminant, if present, is able to be determined

9.8.5 检测管（比色管）

比色管通常广泛用于在工作场所提供初步的和简易的气体和蒸汽评估。

比色管的使用原理是当特定反应物接触特定气体时颜色会产生变化。人们最常使用的是包含固定反应物的玻璃管，利用一个手工泵将已知体积的空气抽取出来，这样任何存在的具体污染物的浓度能够测定。

(Source: Dräger Safety – *Reproduced with permission*)
（来源：Dräger Safety–许可转载）

Figure 9.11 – Gas Detector Pump
图 9.11– 气体探测泵

The substance conversion in the tube is proportional to the mass of reacting gas. Generally it is possible to indicate the substance as a length of stain indication. When a length of stain indication is not practical the indication is based on the interpretation of colour intensity according to a given reference standard or set of standards.

比色管的物质转换与反应气体的体积成正比。一般来说，可以用染色指示剂长度来指示物质。当染色指示剂长度无法使用，根据给定的一个或一组参考标准，基于颜色强度进行解释。

The accuracy of colorimetric tubes is dependent on a number of factors including sample pump volume, efficiency of the chemical reaction, humidity, temperature, manufacturer"s calibration of the graduations and interpretation of the length or colour of the stain and is typically quoted as being 10 – 30%.

比色管的准确性受多种因素影响，包括样本泵容量、化学反应效率、湿度、温度、制造商对刻度的校准和染色指示剂长度或颜色的解释，一般为10– 30%。

(Source: Dräger Safety – *Reproduced with permission*)

（来源：Dräger Safety–许可转载）

Figure 9.12 – New and Used Colorimetric Detector Tube

图 9.12–未使用和使用过的比色检测管

Direct reading colorimetric tubes are available from a number of different manufacturers including Dräger, Kitagawa, Gastech and MSA for grab or short term (seconds to minutes) measurement of approximately 300 gases. It must be noted that tubes from one manufacturer CANNOT be used with the pump from another manufacturer.

用于近 300 种气体的瞬间和短期（秒-分钟）测定的直接读值比色管可从制造商处处获得，例如 Dräger、Kitagawa、Gastech 和 MSA。必须注意到一个制造商提供的管不得与另一个制造商提供的泵一起使用。

Also available are direct reading long term colorimetric tubes utilizing low flow battery operated pumps or diffusion type badges for long term measurements of 1 to 4 hours.

对于 1-4 小时长期测量，也可使用与低流蓄电池驱动泵或配套的扩散证章式直读长期比色管。

Some of the advantages of direct reading colorimetric tubes include:

直读比色管的优势包括：

- Relatively inexpensive and cheap to use
- Wide range of gases and vapours
- Immediate results
- No expensive laboratory costs
- Can be used for spot checks
- No need for calibration (tubes are pre-

- 相对便宜，使用成本低廉
- 适用于各种气体和蒸汽
- 即时获取结果
- 无昂贵的实验室成本
- 可用于现场检验

calibrated)

- No need for charging or electric power during operation

The limitation of such devices must also be noted and include:

- Interferences from other contaminants (cross sensitivities)
- Need to select correct tube and correct range of tube
- Results should not be compared to TWA
- Correct storage requirements
- Limited shelf life of tubes

Before selecting and or using any colorimetric tube the particular manufactures" instructions for that tube must be read to ensure the correct tube is both chosen and used correctly and the effect of any interference are known and understood before any measurement is carried out.

- 无需校准（管经过提前校准）
- 操作期间无需充电或耗电

此类设备的局限性也很重要，具体包括：

- 与其它污染物冲突（交叉敏感性）
- 需要选择合适的管和合适的范围
- 结果不能与 TWA 比较
- 要求适当存储
- 管的有效期有限

在选择和使用任何比色管前，必须阅读有关说明书，尤其是制造商指导，以确保正确选择和使用，在测定前必须了解和理解任何干预的影响。

10. PRESENTATION OF RESULTS

Reporting of data in an appropriate format is of equal importance to collecting the actual results. As part of the reporting process it is important to identify at an early stage the stakeholders who require a report. In general, stakeholders would include:

a) The individual who was sampled (if this was the case) – If any person is required to wear a sample collection device then they are entitled to be told the results of that sampling. How this process is accomplished can take several forms but experience has shown that just sending an individual a document with results without any explanation can result in misinterpretation and unnecessary anxiety. If it is possible the results should be presented in person by someone familiar with their interpretation so that any questions can be addressed.

b) Management or person/group requesting the survey.

c) Statutory authorities – if involved in the exercise.

d) Workforce representatives (unions) – if involved in the process.

A review of some national standards (eg BSEN689, AS2985) presents slightly different approaches to the information required in a report.

10. 结果报告

以适当格式报告数据对于收集实际结果来说非常重要、作为报告流程的一部分，必须在早期识别应收到报告的利益相关者。一般来说，利益相关者应包括：

a）被采样的个人（如情况是这样）-如果某个人需要穿戴采样设备，那么他有权知道采样结果、这个过程可采用不同过程完成，但是经验告诉我们，只向被采样人员送一份包括采样结果，但没有解释的报告只会引起误解和不必要的焦虑。尽可能由能解释结果的人亲自把报告送给此人，以解答任何问题。

b）要求进行调查的管理人员/组织。

c）法定机构-如实际涉及的话。

d）工人代表（工会）–如过程涉及。

一些国家标准（例如 BSEN689，AS2985）对于报告所需信息提出的要

BSEN689 requires the following:

“Reports shall be written of the occupational exposure assessment and of any periodic measurement. Each report should give reasons for the procedures adopted in the particular workplace.

The report has to contain

- the name of the person(s) or institutions undertaking the assessment and the measurements;
- the name of the substances considered;
- name and address of company;
- the description of the workplace factors including the working conditions during the measurements;
- the purpose of the measurement procedure;
- the measuring procedure;
- the time schedule (date, beginning and end of sampling);
- the occupational exposure concentrations;
- all events or factors liable to influence appreciably the results;
- details of quality assurance if any;
- results of the comparison with the limit value.”

AS2985 requires the following:

The test report shall include:

a) Identification of sample either as name of person wearing sample or sampler

求略有不同：

BSEN689 要求：

“报告应采取书面形式，包括职业暴露评估和任何定期测定。每份报告都应提供为什么在某个工作场所要采用某个程序的理由。

报告必须包括：

- 评估和测定人员的姓名或评估和测定机构的名称；
- 考虑的物质的名称；
- 公司地址和名称；
- 在测定过程中工作条件等工作场所因素的描述；
- 测定程序的目的；
- 测定程序；
- 时间表（采样日期、开始和结束日期）；
- 职业暴露浓度；
- 对结果有不明显影响的所有事件或因素；
- 质保细节，如有；
- 结果与限值之间的比较。

AS2985 提出以下要求：

试验报告包括：

a)样本标记穿戴样本的人员的姓名或采样地点名称。

location.

b) Activities being conducted during sampling.

c) Any personal protective equipment worn.

d) Name of laboratory or authority which performed the test.

e) Date on which the test was carried out and sampling duration.

f) If uncertainties are not formally derived, for sampling periods greater than 60 minutes the concentration should be reported to two decimal places and three significant figures for six place microbalances, and to one decimal place and two significant figures for five-place microbalances.

g) Net weight of dust on filter.

h) The identity of any reference material used to assist in the validation of the test results.

i)Any observation, in relation to either the test sample or the performance of the test, which may assist in the correct interpretation of the test results.

j)References to the test method used."

While each of these provides a "laboratory style" report on the samples collected, they do not provide sufficient information to be considered appropriate occupational hygiene reports.

A well-based occupational hygiene report should be written in easy-to-read language, address all questions raised in the original scope of work and be able to

b）采样过程中正在进行的活动。

c）穿戴的任何个人防护设备。

d）开展实验的实验室或机构的名称。

e）实验日期和实验持续时间。

f）如果没有正式得出不确定性，如采样时间超过 60 分钟，对于六位微量天平浓度，浓度结果包括小数点后两位和三位有效数字，对于五位微量天平，包括小数后一位和两位有效数据。

g）过滤器上粉尘净重。

h）在验证实验结果中使用的任何辅助参考资料的特殊信息。

i）可能有助于修正实验结果解释的关于实验样本或实验性能的任何观察报告。

j）采用的实验方法。

当基于收集的样本，根据当以上任何内容制定一份实验室风格报告时，它们并无法提供职业卫生报告所需的充分信息。

一份有理有据的职业卫生报告应以书面形式，采用通俗易懂的语言解决原始工作范围涉及的所有问题，而且能

satisfy an experienced occupational hygienist that the work was properly conducted and appropriate conclusions drawn.

以适当的工作方式和合理的结论来满足经验丰富的职业卫生专家的要求。

One national professional occupational hygiene association has produced a guideline (AIOH 2006) for its members and suggests that a typical report should have the following contents:

一个国家职业卫生协会曾为其成员制定了一份指南（AIOH 2006），并建议一份典型的报告应包括以下内容：

- Executive summary
- Title
- Introduction
- Process description
- Methods and measurements
- Results and discussion
- Conclusions and recommendations

- 执行摘要
- 名称
- 简介
- 流程描述
- 方法和测定
- 结果和讨论
- 总结和建议

The difference between this approach and that of the two standards associations is the added focus on:

本方法和两个标准制定协会采用的方法的差别还表现在：

a) Process description
b) Results and discussion
c) Conclusions and recommendations

a） 流程描述

b） 结果和讨论

c） 总结和建议

The AIOH (2006) describes the requirements for each of these sections, which have been produced with permission, below:

AIOH（2006）描述了每个章节的要求，这些要求都已经过授权制定，具体如下：

Process Description

流程描述

Where a survey of an area, plant or process is conducted, the following should be described:

在对一个区域、厂房或流程进行调查时，应描述以下信息：

- Area/plant/process surveyed, eg*"a*

survey of the area known as cold press or CP was conducted".

- Conditions at the time (ie personnel, process conditions, risk controls in place) eg *"usual operator unavailable", "shutdown", "worst case situation, with no controls", "as normal, believed to be a representative working day", "only Blender No.2 was operating", "protective equipment worn other than overalls".*

- Identify any items examined, eg *"Toolmaster serial number 123", "machine called the hot block curer".*

- Number of employees, duration of workshift(s) and task frequency and duration, eg *"9 employees work an 8 hour day, 5 day week with 2 hours overtime worked infrequently", "it takes about 30 minutes for 5 bags to be opened and poured daily".*

Diagrams and photographs are useful for clarifying sampling locations and conditions

Results and Discussion

- Results may be presented in the body of the report or as appendices.

The level of information, considering the complexity of the processes, tasks and risks, should satisfy the technical reader but not unnecessarily complicate the report. Results should be traceable to the original field notes to enable verification of supporting data (eg identity of equipment

- 所调查的区域/厂房/流程，例如"'冷压'或 CP 区域调查"。

- 当时条件（例如个人、流程条件和落实的风险控制），例如"一般配备操作人员"，"停工"，"最坏情形，失控"，"和往常一样，是一个典型的工作日"，"只有 2 号搅拌机在运行"或"保护性设备磨损，并非全部磨损"。

- 对任何检查的设备做出标识，例如"高精度工具 123"或"热块矫正仪"

- 员工数量，班次持续时间，以及任务频率和持续时间，例如"9 名员工，每天 8 小时，每周工作 5 天，很小加班 2 小时"，或"每天用约半小时时间打包和倾倒"。

图表和照片用于澄清采样点和条件

结果和讨论

- 结果可包含在报告内容或附件中。信息水平，考虑到流程、任务和风险的复杂性，应满足技术人员的要求，但没必要使报告变得复杂。在必要时应从结果追溯到原始现场笔记，对辅助数据进行验证（例如识别使用的设备、校准等）。

used, calibration, etc) should this be needed.

- Results of personal sampling should be compared with the relevant exposure standard. If there is no relevant exposure standard, it will be necessary to either modify or adapt an existing guideline or develop a guideline. The rationale justifying the guideline used should be provided.

eg for airborne contaminants

a) time weighted average (TWA) and short term excursions limits (STEL), or

b) TWA and general excursions limits (if no STEL is set), or

c) peak/ceiling limits.

- Results should be compared with any previous surveys at the premises and data from similar premises if available, eg *"…. The process produced results that are similar to other coating operations.* An explanation of general trends and unusual high or low trends should be included.

- The level of risk should be determined (preferably quantitatively) to allow for the adequacy of controls to be assessed and the prioritisation of control options.

Conclusions and Recommendations

Conclusions should be drawn about whether or not the relevant exposure standard(s) have been exceeded and if the

- 个人采样结果应与有关暴露标准进行比较。如果没有相关暴露标准，必须对现有指南进行修订或修改或制定新指南。而且还要提供检验指南正确性的基本原理。

例如　　对于机载污染物

a）时间加权平均数（TWA）和短期偏移限值（STEL），或

b）TWA 和一般偏移限值（如未设定 STEL），或

c）峰值/上限。

- 将结果与生产场地此前调查结果和相似生产场地数据（如可用）进行比较，例如"流程导致的与其它涂层操作类似的结果"。而且还应对一般趋势进行解释，并考虑到不寻常的过高或过低趋势。

- 确定风险水平（最好量化），以评估控制的充分性和控制方案的优先级。

结论和建议

无论是否已经超过有关暴露标准，如果工作可能对员工健康造成伤害，就应做出结论，例如"暴露可能接近，甚

work could harm employee health, eg *"Exposure is likely to approach and may exceed the exposure standard and there is a significant risk", "It is believed that exposures are unlikely to approach the exposure standard and the risk is not significant", "The risk is uncertain due to the state of knowledge (or level of exposure)".*

至超过暴露标准，存在重大风险"，"相信暴露不会导致超过暴露限制，而且风险不大"和"由于认知（或暴露水平）有限，风险不确定"。

Conclusions should also be drawn about adequacy of control and any further practical actions to eliminate or reduce the assessed risk so far as is practicable, eg *"existing controls adequate if maintained"…"existing controls not adequate and need to be upgraded".*

另外还应总结控制措施的充分性进和为了消除或减少评估到的风险应采取的当前可行的进一步实际行动，例如"最好继续执行原有控制措施"或"原有控制措施已不合适，应进行升级"。

Recommendations should be selected using the hierarchy of control approach (personal protective equipment being the last resort) and guidance on an appropriate implementation time frame (eg urgent, short, medium or long term) should be provided. eg *"Temporarily cease work on No.123 process until corrective actions (see below) have been implemented", "Personal protection is a short term interim control. In the longer term engineering controls…", "A preventive maintenance programme should be implemented as soon as practicable", "Periodic reviews to determine if control measures need to be modified should occur at least once a year".*

利用控制方法层次性（个人防护是最后一道防线）来选用所推荐的标准，应提供一个关于适当的执行时间框架的指南（例如紧急、短期、中期或长期）。例如"123 号流程暂时中止，直到执行正确行动（见下文）"，"个人防护是短期性暂时控制措施，从长期来说要进行工程控制…"，"应尽快执行预防性维护计划"和"至少每年进行一次定期审核，确定控制措施是否需要修改"。

Recommendations arising from regulatory requirements or similar guidelines should reference the relevant source document(s),

eg *"The xxx Occupational Health and Safety (Noise) Regulations 1992 require that…", "xxx Standard 4114 Spray Painting Booths states that a minimum velocity of …".* "

对于监管要求或类似指南提出的推荐标准，需援引有关源文件，例如"《1992 年 xxx 职业健康和安全（噪声）条例》要求…"，"《xxx 标准 4114：喷漆棚》规定最低速度为…"。

Clearly the AIOH approach provides the reader with more information and options if control measures may be necessary. This approach is only one suggested example of report preparation and individual organizations will most probably have their own approach. What is fundamental in all cases is that the information collected and evaluated is communicated to all the stakeholders involved in the exercise in a manner and format that meets their needs or expectations. In almost all cases this will be different for each of the stakeholders.

显然，如必须采取控制措施，AIOH 方法会向读者提供更多这方面的信息和方案。本法仅作为报告编制法一个例子，每个组织都有自己的习惯做法。但任何情况下都要坚持一个原则：根据所有利益相关方的需求和期望向其提供所收集的信息和评估结果。一般来说，每个利益相关方的需求和期望都是不同的。

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