



Occupational Health and Welfare in Tunnelling

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Occupational Health and Welfare in Tunnelling

- ◆ Summary of presentation
 - Introduction
 - Fitness for work
 - Ill health due to work
 - ◆ Sources of guidance
 - ◆ Health hazards
 - ◆ Legislation
 - ◆ Mitigation
 - Welfare

Occupational Health in Tunnelling

- ◆ Why there is a problem
 - General low level of concern over occupational health in construction
 - Previous lack of “safety culture” in industry and macho image
 - Lack of ownership of problem by some clients, designers and contractors
 - Transient workforce
 - Nature of the work and working environment

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PLANT NEWS

Viewpoint

Kevin Minton



Safe, but also healthy

Health considerations should not be a poor relation to worker safety on site.

NCE Viewpoint - Kevin Minton

Construction Plant Hire Association

"A construction worker is 100 times more likely to die of work related ill-health than from an accident"

"The aim is to work towards a position where health risks are managed at least as well as the safety risks"

Occupational health

- ◆ There are two aspects to occupational health
 - To ensure fitness for work
 - To address ill health due to work

Occupational Health Team

- ◆ Occupational Physician
- ◆ Occupational Health Nurse
- ◆ Occupational Hygienist
- ◆ H & S Specialist
- ◆ Ergonomist
- ◆ Occupational Physiotherapist
- ◆ E.M.A.S.

Occupational health

Fitness for work



Fitness for work in tunnelling

- ◆ Tunnelling is a physically demanding activity undertaken in an often hot and humid confined space remote from the surface
 - Good practice suggests that all working underground should undergo basic occupational health surveillance
 - Higher level of fitness required for safety critical occupations

Basic occupational health surveillance

◆ Pre-employment screening

- To assess basic medical fitness for work
 - ◆ Height, weight, blood pressure, heart/lungs, sight, hearing, diabetes, smoking, alcohol consumption
- To identify pre-existing occupational ill-health conditions
 - ◆ Noise induced hearing loss, HAVS

◆ Periodic reassessment

Working patterns

- ◆ Long shifts
 - Physically tiring
- ◆ Shift work
 - Affects body clock
- ◆ Both covered by Working Time Regulations
- ◆ Both require a level of fitness for work

Drug and alcohol screening

- ◆ Health related or socio-politically motivated?
 - Substance abuse can result in unfitness to work
 - ◆ Physical and mental fitness
 - Choice of recreational drugs can be influenced by retention period in body

Safety critical occupations

- ◆ Plant operators

- ◆ Crane operators, loco drivers, other plant operators
 - Not obviously unwell e.g. heart disease
 - Eyesight,
 - Colour blindness
 - Hearing

- ◆ Site rescue team

- Higher level of fitness required
- Physically demanding work
- Heat strain

Statutory fitness for work

- ◆ Work in compressed air
 - Only those medically fit can enter compressed air
 - Medical fitness for work in compressed air assessed by “Appointed Doctor”
 - ◆ Comprehensive annual medical
 - ◆ Periodic long bone MRI/X-ray
 - ◆ Periodic checks depending on pressure
 - 28 days for exposures >1 bar
 - 3 months for exposures <1 bar

Statutory fitness for work

- ◆ Asbestos

- Control of Asbestos Regulations

- ◆ Medical examination required in the 2 years prior to employment

Contaminated ground

- ◆ Work in contaminated ground
 - Use of respiratory protective equipment
 - Protective clothing
 - ◆ Both can lead to heat strain
- ◆ Higher standard of fitness required



Occupational health

Ill health due to work

Ill health due to work

- ◆ The Physical Hazards of tunnelling
 - Noise
 - Vibration
 - Manual handling
 - Heat/cold
 - Pressure

Ill health due to work

- ◆ The Chemical Hazards of tunnelling
 - Asbestos
 - Lead
 - Dust
 - Silica
 - Cement
 - Epoxy resins, additives, solvents etc.
 - Ground contaminants
 - Atmospheric contaminants

Ill health due to work

- ◆ The Biological Hazards of tunnelling
 - Ground contaminants
 - Contaminated water

Ill health due to work

- ◆ The Radiological Hazards of tunnelling
 - Radon

Occupational Health in Tunnelling

- ◆ Sources of guidance
 - HSE publications
 - HSE website
 - BS 6164 – Safety in Tunnelling
 - BTS publications
 - ◆ HAVS
 - ◆ NO guidance

Occupational Health in Tunnelling

◆ HSE research

- Heat strain in compressed air tunnelling
- Behaviour of nitrogen monoxide in tunnel atmospheres
- Behaviour of RPE under pressure
- Behaviour of atmospheric monitoring equipment under pressure
- Monitoring of effectiveness of decompression regimes in real time

Ill-health in tunnelling

- ◆ General occupational ill health in construction
 - Very little published data in UK
 - Not much published data worldwide
- ◆ Decompression illness
 - UK data published
 - Some data published for other countries also

Occupational Health

- ◆ Scale of the health problem in UK industry
 - Under-reporting
 - Symptoms vs disability
 - “Healthy worker” effect
 - ◆ The working population is healthier than the whole population –
 - ◆ Illness = inability to work
- ◆ How much ill-health in construction?
 - What proportion in tunnelling?

Relevant general legislation

Management of H&S at Work Regulations

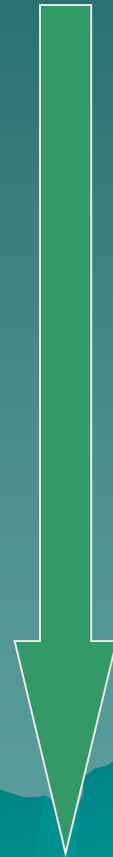
- ◆ Extension of HSW Act requirements
- ◆ Reg 3 – Risk assessment
 - Employer (and self employed) to undertake a suitable and sufficient assessment of risk to employees whilst at work and non-employees affected by his undertaking for the purposes of identifying measures needed to comply with Relevant Statutory Provisions

Management of H&S at Work Regulations

- ◆ Reg 4 – Employer shall implement preventative and protective measures in accordance with the Principles of Prevention

Principles of prevention

- ◆ Avoid hazard
- ◆ Combat risk at source
- ◆ Adapt work to individual
- ◆ Adapt to technical progress
- ◆ Substitute by less/non dangerous means
- ◆ Collective protection over individual protection
 - **PPE** is individual protection (**P**ersonal **P**rotective **E**quipment)!
- ◆ Instruction, training and supervision



Management of H&S at Work Regulations

- ◆ Reg 5 – Employer shall put into effect preventative and protective measures as appropriate to his undertaking
- ◆ **Reg 6 – Employer shall undertake health surveillance as appropriate for the risks**
- ◆ Reg 7 – H&S assistance for employer
- ◆ Reg 10 – Provide information on risks to employees as relevant

PPE at Work Regs 1992

- ◆ Reg 4 - Provision of PPE
 - Every employer shall provide PPE unless the risk has been adequately controlled by other means which are equally or more effective.
 - i.e. PPE is not first choice

PPE at Work Regs

- ◆ Reg 4 - PPE shall be fit for purpose
- ◆ Reg 5 - Multiple items of PPE shall be compatible
- ◆ Reg 6 - PPE provided will be suitable
- ◆ Reg 7 - Employer's responsibility to maintain/replace
- ◆ Reg 8 - Appropriate accommodation shall be provided for the PPE when not in use

PPE at Work Regs

- ◆ Reg 9 - Information, instruction and training
 - The employer shall provide sufficient information, instruction and training to enable the employee to know —
 - ◆ the risks which the PPE will avoid or limit
 - ◆ how the PPE is to be used
 - ◆ action to be taken by the employee to ensure the PPE remains in good working order

PPE at Work Regs

- ◆ Reg 10 - Use of personal protective equipment
 - Supervise use of PPE by employees.
 - Employees shall use and look after PPE
- ◆ Reg 11 - Reporting loss or defect

COSHH

- ◆ Control of Substances Hazardous to Health Regulations 2002 (as amended) (COSHH)
- ◆ General requirements covering mitigation of risk from exposure to hazardous materials
 - COSHH principles – similar to the principles of protection and prevention
- ◆ Exposure limits for a wide range of hazardous materials are listed in EH40

Physical hazards

Noise

- ◆ Occurrence
 - Drilling
 - Pneumatic tools
 - Machinery
- ◆ Regulations
 - Control of Noise at Work Regulations 2005



Noise

- ◆ Consequences of excessive exposure
 - Hearing impairment
 - Diminished quality of life
 - Incapacity for work
 - No obvious physical disability
 - ◆ Extent of problem not recognised by society
- ◆ 50% of miners have significant hearing impairment

Noise

- ◆ Control of Noise at Work Regulations 2005
 - Set out exposure action and limit values for noise exposure and for peak sound pressure
 - Require
 - ◆ risk assessment
 - ◆ elimination or reduction of exposure to noise (sfairp)
 - ◆ measures, **excluding the provision of PPE** to be taken at the upper exposure action values
 - ◆ provision of personal hearing protectors
 - ◆ designation Hearing Protection Zones
 - ◆ health surveillance
 - ◆ information, instruction and training

Noise

- ◆ Mitigation
 - Noise enclosures
 - Good maintenance
- ◆ Health surveillance
 - Audiometry
- ◆ PPE
 - Hearing protection



Vibration

- ◆ Occurrence
- ◆ Hand arm and whole body vibration
 - HAVS - use of hand held vibrating pneumatic tools
 - WBV – ride-on operation of vibrating machinery e.g. locomotives, hard rock TBM,
- ◆ Regulations
 - Control of Vibration at Work Regulations 2005



Vibration

- ◆ Consequences of excessive exposure
 - Hand Arm Vibration Syndrome (HAVS)
 - ◆ Loss of sensation in hands
 - ◆ Incapacity for work
 - Whole body vibration (WBV)
 - ◆ Back pain
 - ◆ Internal organ damage
 - ◆ Incapacity for work

Vibration

◆ HAVS - Signs and symptoms

- Tingling, numbness and loss of feeling in the fingers
- Loss of strength in your hands (inability to pick up or hold heavy objects).
- In the cold and wet, the tips of fingers going white then red and being painful on recovery (vibration white finger).



Control of Vibration at Work Regulations 2005

- ◆ Exposure limit values and exposure action values (8 – hour average)
- ◆ Risk assessment
 - Employer shall ensure risk from exposure to vibration is eliminated at source (sfairp)
- ◆ Employer shall ensure employees not exposed above ELV
 - Measures, **excluding the provision of PPE** to be taken at the upper exposure action values
 - Health surveillance
 - Information, instruction and training

HAVS Exposure calculation aids

There are various exposure calculation aids

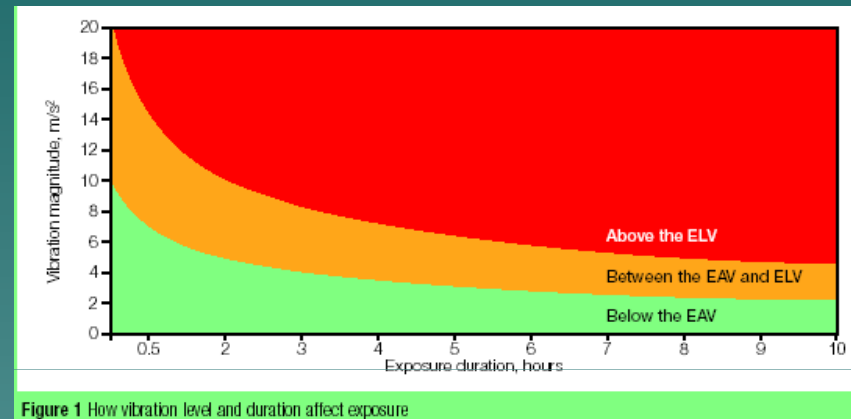


Figure 1 How vibration level and duration affect exposure

Tool vibration (m/s ²)	3	4	5	6	7	10	12	15
Points per hour (approximate)	20	30	50	70	100	200	300	450

Multiply the points assigned to the tool vibration by the number of hours of daily 'trigger time' for the tool(s) and then compare the total with the exposure action value (EAV) and exposure limit value (ELV) points.

100 points per day = exposure action value (EAV)
400 points per day = exposure limit value (ELV)

Table 2 Simple 'exposure points' system

Tool type	Lowest	Typical	Highest
Road breakers	5 m/s ²	12 m/s ²	20 m/s ²
Demolition hammers	8 m/s ²	15 m/s ²	25 m/s ²
Hammer drills/combi hammers	6 m/s ²	9 m/s ²	25 m/s ²
Needle scalars	5 m/s ²	-	18 m/s ²
Scabblers (hammer type)	-	-	40 m/s ²
Angle grinders	4 m/s ²	-	8 m/s ²
Clay spades/jigger picks	-	16 m/s ²	-
Chipping hammers (metal)	-	18 m/s ²	-
Stone-working hammers	10 m/s ²	-	30 m/s ²
Chainsaws	-	6 m/s ²	-
Brushcutters	2 m/s ²	4 m/s ²	-
Sanders (random orbital)	-	7-10 m/s ²	-

Table 1 Some typical vibration levels for common tools

Vibration

- ◆ Mitigation
 - Elimination of vibration at source
 - Good tool maintenance
 - Job rotation
 - Keep hands warm
- ◆ Health surveillance
 - Physical examination
- ◆ PPE
 - Anti-vibration gloves
 - ◆ Of doubtful value

Manual handling

- ◆ Occurrence
 - Hand excavation, erection of segments, general tunnelling activity
 - Handling TBM cutters and tools
- ◆ Regulations
 - Manual Handling Operations Regulations 1992



Manual handling

- ◆ Consequences of excessive exposure
 - Musculo-skeletal disorders
 - ◆ Work related upper limb disorder
 - Incapacity for work
 - Obvious physical disability

Manual Handling

- ◆ Manual Handling Operations Regulations 1992
 - Require elimination of manual handling (sfaip)
 - Assessment of manual handling operations
 - Mitigation of risk from manual handling
 - Provision of information to those undertaking manual handling (lifting, pulling, pushing)
 - Reassessment as necessary

Manual Handling

◆ Mitigation measures

- Make things too heavy to lift manually
- Mechanical excavation
- Use of segment erectors
- Lifting points in cutter head
- Handling aids for cutters



Manual Handling

- ◆ HSE guidance on manual handling
 - Avoid heavy lifting
 - Avoid repetitive work
 - Avoid manual handling in confined spaces
 - Avoid manual handling in hot/humid conditions
 - Avoid twisting and turning when manual handling
 - Avoid manual handling when pregnant

Heat/cold

◆ Occurrence

– Heat

- ◆ In most TBM tunnels
- ◆ Deep rock tunnels
- ◆ Hand excavation
- ◆ Use of face masks/BA
- ◆ Chemical suits
- ◆ Manual work in compressed air

– Cold

- ◆ Ground freezing
- ◆ Altitude



Heat/cold

- ◆ Consequences of excessive exposure
 - Heat
 - ◆ Sweating
 - ◆ Dehydration
 - ◆ Unconsciousness/death
 - Cold
 - ◆ Hypothermia
 - ◆ Poor circulation in extremities

Heat/cold

◆ Mitigation

– Heat

- ◆ Ventilation
- ◆ Job rotation
- ◆ Cool rest areas
- ◆ Fluids

– Cold

- ◆ Warm clothing
- ◆ Heated welfare areas

Heat/cold

- ◆ Health surveillance
 - Heat
 - ◆ Body core temperature
- ◆ Regulations – no specific regulations
- ◆ HSE research into heat stress in compressed air

Pressure - Work in compressed air

- ◆ Consequences of exposure
 - Acute decompression illnesses
 - ◆ Decompression sickness Types 1 and 2
 - ◆ Barotrauma
 - ◆ Gas embolism
 - ◆ Pneumothorax
 - Chronic decompression illness
 - ◆ Dysbaric osteonecrosis

Mitigation

- ◆ Follow HSE guidance L96 “Work in Compressed Air Regulations 1996 – guidance on regulations”



Asbestos

- ◆ Occurrence – in older tunnels as PC4 or similar caulking material
- ◆ Legislation
 - Control of Asbestos Regulations 2006

Asbestos

- ◆ Consequences of excessive exposure
 - Asbestosis
 - ◆ Lung damage
 - ◆ Incapacity for work
 - ◆ Severe loss of quality of life
 - Mesothelioma
 - ◆ Malignant lung disease
 - ◆ Death

Asbestos

- ◆ Mitigation
 - Asbestos surveys in old tunnels
 - Use of licensed contractors for removal
- ◆ Health surveillance
 - Medical examinations at intervals of 2 years and health record to be maintained
- ◆ Statutory medical examination
- ◆ PPE
 - High efficiency masks

Lead

- ◆ Occurrence – as lead caulking or red lead paint in older tunnels
- ◆ Regulations - Control of Lead at Work Regulations 2002
 - Require an assessment of the risk from exposure to lead
 - Require employer to
 - ◆ prevent or adequately control exposure to lead
 - ◆ care for and decontaminate PPE
 - ◆ keep individual records of air monitoring
 - ◆ carry out medical surveillance

Lead

- ◆ Consequences of excessive exposure
 - General ill health - range of symptoms
 - Kidney damage
 - Neurological damage
- ◆ Contact pathways
 - Inhalation of lead dust or fume
 - Ingestion

Lead

- ◆ Mitigation
 - Avoid disturbing existing caulking
 - Good personal hygiene
- ◆ Health surveillance
 - Blood or urine testing

Dust

- ◆ Occurrence -
 - Drilling rock
 - Cutting rock e.g. roadheader, hard rock TBMs
 - Lifted from invert by ventilation or movement
 - Shotcrete
- ◆ Silica
 - Particularly hazardous



Dust

- ◆ Inhalable dust
 - Enters nose, mouth and respiratory tract
 - 10 mg/m³ exposure 8-hour TWA limit
- ◆ Respirable dust
 - Enters gas exchange region of lungs
 - 4 mg/m³ TWA
- ◆ Respirable crystalline silica
 - 0.1 mg/m³ limit

Dust

- ◆ Regulations
 - COSHH
 - Application of COSHH principles
- ◆ WELs – workplace exposure limits
 - Replace OELs, MELs
 - 15-minute or 8-hour time weighted averages
 - See EH 40

Dust/silica

- ◆ Consequences of excessive exposure
 - Lung damage
 - Loss of quality of life
 - Incapacity for work
 - Silicosis
 - Death

Dust

- ◆ Monitoring
 - Air sampling
 - Personal samplers
 - Dust lamp



Dust

- ◆ Mitigation
 - Ventilation
 - ◆ Forced and extraction
 - Dust suppression and capture
 - ◆ EN 12111 - Roadheaders



Dust

- ◆ Mitigation
 - Wet shotcrete



Dust

- ◆ Health surveillance
 - Lung function/spirometry
 - X-ray/MRI scanning
- ◆ PPE
 - Dust masks

Cement/resins/chemicals etc

- ◆ Manifestation
 - Dermatitis/skin damage
 - ◆ Can be very incapacitating
 - ◆ Not always obvious to society



Cement/resins/chemicals etc

- ◆ Cementitious materials – dermatitis
- ◆ Epoxy materials – dermatitis and respiratory problems
- ◆ Soil conditioners



Cement/resins/chemicals etc

◆ Mitigation

- Choice of materials
- Avoid contact
 - ◆ Gloves/boots etc
- Barrier creams
- Good personal hygiene/welfare

◆ Health surveillance

- Physical examination

Atmospheric contaminants

- ◆ Nitrogen monoxide
 - Long term exposure leads to chronic loss of lung function
 - Exposure limits reduced from 25ppm to 1ppm
 - ◆ Now increased to 5ppm in tunnelling
- ◆ Has impacted on construction methods
 - Electrical plant to reduce emissions at source
 - Additional ventilation
 - ◆ “Fresh” air may already be contaminated
- ◆ BTS guidance

Atmospheric contaminants

◆ Radon

- Occurs in “hot spots” around the UK
- Ionising Radiations Regulations may apply if dose high enough
 - ◆ Particular restrictions on exposure of young persons and women of reproductive capacity

Contaminated land

- ◆ Benzene, toluene, xylene
 - Carcinogens
- ◆ Need for full protective suits and RPE
 - Heat strain problem
 - Cool breaks
 - Shift length limits



Stress

- ◆ Effects of pressure to complete challenging project to budget and on schedule
 - Some stress can improve performance
 - Too much can damage mental health
- ◆ An increasingly common occupational health issue

Combination of hazards

- ◆ Hand tunnelling
 - Manual handling + noise + vibration + heat
- ◆ Guidance for Designers
 - based on excavation technique
- ◆ Endorsed by BTS/PJA/HSE

Guidance for Designers
Internal dimensions for pipejacks and tunnels below 3.0m diameter and indicative drive lengths

Table 1 - Nominal internal diameter of pipejacks or tunnel bores

Excavation technique	<0.9m	0.9m	1.0m	1.2m	1.35m	1.5m	1.8m	>1.8m
Pipejack - machine; remote operation surface	Acceptable (BS 7445:2)							
Pipejack - machine; operator controlled below ground	Not acceptable		Acceptable					
Pipejack - hand dig	Not acceptable		Avoid					
Tunnel - machine; operator controlled mechanical erector	Not acceptable					Avoid		Acceptable
Tunnel - hand dig + mechanical erector	Not acceptable					Avoid		
Timber heading - hand dig	Not acceptable		Avoid					

Table 2 - Indicative drive lengths (e.g. between shafts) and maximum number of drives

Excavation technique	<0.9m	0.9m	1.0m	1.2m	1.35m	1.5m	1.8m	>1.8m
Pipejack - machine; remote operation surface	Drive length limited only by capacity of jacking system							
	Max entry not acceptable		Avoid (max 140m)		250m	400m	>500m See note 7	>500m See note 7
Pipejack - machine; operator controlled below ground	Not acceptable			125m	200m	300m	500m	>500m See note 7
Pipejack - hand dig See Note 6	Not acceptable			*25m - 1 drive length	*50m - 2 drive lengths	*75m - 2 drive lengths	*100m - 1 drive length Plan to use riser/digger if over 2.1m dia	>500m See note 7
Tunnel - machine; operator controlled mechanical erector	Not acceptable					*250m	*500m	>500m See note 7
Tunnel - hand dig + mechanical erector See Note 6	Not acceptable					*50m - 1 drive length	*100m - 1 drive length Plan to use riser/digger if over 2.1m dia	>500m See note 7
Timber heading - hand dig See Note 6	Not acceptable			*75m - 2 drive lengths Minimum cross section inside frames 1.2m high x 1.0m wide				

Combination of hazards

- ◆ Swansea – hand tunnelling in compressed air in contaminated ground
- ◆ West Ham - hand tunnelling in contaminated ground
- ◆ Ilford - hand tunnelling with asbestos contamination in compressed air

Welfare in tunnels

Welfare

- ◆ Basic toilet facilities
- ◆ Washing facilities
- ◆ Drinking water
- ◆ Messing facilities
- ◆ First aid



Welfare

- ◆ Benefits
 - Respect for people
 - Reduction in low level ill health
 - ◆ Improves performance of workforce



Welfare

- ◆ Tunnellers are often a peripatetic workforce
 - They often lack access to basic NHS services
- ◆ Consider provision of GP services for tunnel sites in remote locations
 - Also dentistry and chiropody

Conclusions

- ◆ A wide range of physical and chemical hazards arise in tunnelling
- ◆ The risks arising from them can be mitigated during both the design and construction stages of tunnel projects.
- ◆ Apart from compressed air, none of the hazards discussed in this presentation is unique to tunnelling
 - What is unique is the complexity of the combinations in which they are found

Thank you for your attention.