TRAINING PROGRAMME

Respiration & Respiratory Protection
Contents

• Respiration
  – Why we breathe
  – How we breathe
  – What we breathe

• Respiratory Protection
  – Why protect
  – Who/where to protect
  – How to protect

\[ \text{O}_2 = \text{Oxygen} \]
\[ \text{CO}_2 = \text{Carbon Dioxide} \]
Why we breathe

• We need energy to live

• $O_2$ from air + sugars from diet
  = energy + water + $CO_2$

• We breathe out $CO_2$

• We absorb the water
  – Excreted in urine, faeces, sweat and exhaled breath
Respiratory System
Upper Respiratory System

- Nose
- Mouth
- Pharynx
- Larynx
Lower Respiratory System: Lungs

- Apex
- Pulmonary arteries
- Horizontal fissure
- Primary bronchus
- Hilus
- Pulmonary veins
- Oblique fissure

MEDIAL SURFACE

RIGHT LUNG

MEDIAL SURFACE

LEFT LUNG
Lower Respiratory System: Airways

- Trachea
- Bronchi
- Bronchioles
- Pulmonary Lobules
- Alveoli
Lower Lung Airways

- Bronchioles
- Pulmonary Lobules
- Alveoli
Alveoli

- $O_2$ diffuses from air to blood
- $CO_2$ diffuses from blood to air
- Humans have ~300 million alveoli
- Area ~70 sq m
How We Breathe

**Breathing In**
- Air flows in
- Diaphragm contracts and flattens
- External intercostal muscles contract; ribs move up and out

**Breathing Out**
- Air flows out
- Internal intercostal muscles contract; ribs move down and in
- Diaphragm relaxes into domed shape
How We Control Breathing

• Inspiratory/Expiratory Centre
  - Groups of nerves in brain stem automatically fire 12-15 times per minute
  - Can voluntarily over-ride

• O₂ and CO₂ sensors
  - In brain stem and on carotid and aortic arteries
  - Detect changes in blood O₂ and CO₂ and tell brain to change rate and depth of breathing, eg with exercise
Other Factors Affecting Breathing

• Higher brain centres
  – You can voluntarily alter rate and depth of breathing
  – Response to stress: hold breath or hyperventilate

• Movements of joints
  – Stimulate breathing: helps during exercise

• Reflexes
  – Increasing airflow: coughing; sneezing; hiccup; yawning; sighing
  – Inhibiting breathing: swallowing; vomiting
Lung Volumes and Capacities

Maximum possible inspiration

- Inspiratory reserve volume
- Vital capacity
- Inspiratory capacity
- Tidal volume
- Total lung capacity

Lung volume (mL)

- Maximum voluntary expiration
- Residual volume
- Functional residual capacity

Lung volume (mL)
Lung Function Tests

• Most lung volumes can be measured using spirometers

• Rate of air movement is also important
  – Volumes may be normal, but airways may be restricted by lung disease

• Main measurements
  – Maximum Voluntary Ventilation, usually over 1 min (MVV)
  – Forced Expiratory Volume, usually over 1 s (FEV₁)
  – Peak Flow
How does $O_2$ get from air to blood, and $CO_2$ from blood to air?

- **By Diffusion**
  - Gases move from high pressures to lower pressures
  - Rate depends on difference between pressures

- **The air we breathe in does not reach the alveoli**
  - Residual volume

- $O_2$ diffuses from inspired air to alveolar air, and from alveolar air into blood

- $CO_2$ diffuses the other way
Partial Pressure

• The partial pressure of a gas ($P_{gas}$) is the pressure of that gas in a mixture of gases

\[ = \text{total pressure of all gases} \times \text{fraction of the gas} \]

  - Total pressure of atmospheric air at sea level is 760 mm Hg
  - $P_{O_2}$ is $760 \times 0.21 = 160$ mm Hg
  - $P_{CO_2}$ is $760 \times 0.0004 = 0.3$ mm Hg

• Partial pressure governs diffusion

  - If $P_{O_2}$ in air falls below $P_{O_2}$ in blood, $O_2$ cannot diffuse into blood; this happens at high altitudes
  - If $P_{CO_2}$ in atmospheric air rises above that in alveolar air, then $CO_2$ cannot diffuse out
Partial Pressures of O$_2$ and CO$_2$ in air and body
O₂ Transport in Blood

• 1.5% dissolved in blood plasma

• 98.5% in haemoglobin
  – Protein in red cells; contains iron; specialised to carry O₂

• At rest, body tissues take ~250 ml of O₂ per minute
  – Tissues remove ~4.6 ml of O₂ from each 100 ml of blood passing through

Haemoglobin
CO₂ Transport in Blood

• 88% as carbonate, mostly in blood plasma
  - CO₂ is 20 x more soluble than O₂ in blood plasma

• 6% dissolved
  - Some in plasma; some in red cells

• 6% combined with proteins
  - Mostly haemoglobin in red cells
Features of respiration important for filter respirator design: Moisture and Airflow

• Exhaled air is warm and 100% Relative Humidity
  - Water comes from moist airway lining
  - Can affect filters

• Airflow
  - 6-8 l/min at rest
  - 80-170 l/min with very heavy work (for short time)
  - Increased inspiratory airflow increases leakage
Features of respiration important for filter respirator design: Respiratory Dead Space

• Space between nose/mouth and alveoli, not involved in gas exchange

• About 150ml in 75kg man

• With tidal volume of 500 ml, only $500 - 150 = 350$ ml of inspired air is available to mix with alveolar air

• The internal volume of a respirator increases respiratory dead space

• Decreases $O_2$ and $CO_2$ diffusion: decreases respiratory efficiency
Effects of filter respirator internal volume on respiratory dead space

Normal dead space = 150 ml and tidal volume = 500 ml

<table>
<thead>
<tr>
<th>Internal volume of respirator (ml)</th>
<th>Total dead space (ml)</th>
<th>Amount of inspired air mixing with alveolar air (ml)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 (no respirator)</td>
<td>150</td>
<td>350</td>
</tr>
<tr>
<td>100</td>
<td>250</td>
<td>250</td>
</tr>
<tr>
<td>200</td>
<td>350</td>
<td>150</td>
</tr>
<tr>
<td>300</td>
<td>450</td>
<td>50</td>
</tr>
<tr>
<td>400</td>
<td>550</td>
<td>-50</td>
</tr>
</tbody>
</table>
What do we breathe? Normal air

<table>
<thead>
<tr>
<th>Gases (%)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>78.084</td>
</tr>
<tr>
<td>Oxygen</td>
<td>20.9476</td>
</tr>
<tr>
<td>Argon</td>
<td>0.934</td>
</tr>
<tr>
<td>Carbon dioxide</td>
<td>0.0314</td>
</tr>
<tr>
<td>Neon</td>
<td>0.001818</td>
</tr>
<tr>
<td>Helium</td>
<td>0.000524</td>
</tr>
<tr>
<td>Krypton</td>
<td>0.000114</td>
</tr>
<tr>
<td>Hydrogen</td>
<td>0.00005</td>
</tr>
<tr>
<td>Xenon</td>
<td>0.0000087</td>
</tr>
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</table>

<table>
<thead>
<tr>
<th>Aerosols</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Small particles suspended in air: thousands per cc</td>
<td></td>
</tr>
<tr>
<td>• Dusts</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Solid particles</td>
</tr>
<tr>
<td>• Mists</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Liquid particles</td>
</tr>
<tr>
<td>• Smokes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>From burning</td>
</tr>
<tr>
<td>• Micro-organisms</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Bacteria; viruses; moulds</td>
</tr>
</tbody>
</table>
Why do we need respiratory protection?

• We have lived with normal air for thousands of years without much problem
• But we now manufacture and process more
• New hazards: workers need protection

• Lack of O₂
• Toxic gases
• Toxic aerosols
  – Particles
Lack of $O_2$

- Consumed by fire
- Displaced by other gases
  - eg combustion products; usually in confined spaces

<table>
<thead>
<tr>
<th>$O_2$ Level</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>21%</td>
<td>Normal air</td>
</tr>
<tr>
<td>19%</td>
<td>Minimum safe entry</td>
</tr>
<tr>
<td>15-19%</td>
<td>Reduced work ability</td>
</tr>
<tr>
<td>12-14%</td>
<td>Impaired coordination</td>
</tr>
<tr>
<td>8-12%</td>
<td>Loss of consciousness</td>
</tr>
<tr>
<td>6-8%</td>
<td>Fatal if &gt; 5 min</td>
</tr>
<tr>
<td>4-6%</td>
<td>Fatal in 60 s</td>
</tr>
</tbody>
</table>
Major Toxic Industrial Gases

- Ammonia
- Chlorine
- Cyclohexane
- Dichloromethane
- Ethylene Oxide
- Hydrogen Chloride
- Hydrogen Sulphide
- Nitrogen Oxides
- Sulphur Dioxide

Most gases are colourless; chlorine is yellow-green
Major toxic industrial liquids that can be inhaled as aerosols

- Acetone
- Acetonitrile
- Carbon Disulphide
- Dichloromethane
- Diethylamine
- Dimethylformamide
- Ethyl Acetate
- n-Hexane
- Methanol
- Nitrobenzene
- Sodium Hydroxide
- Sulphuric Acid
- Tetrachloroethylene
- Tetrahydrofuran
- Toluene
Major toxic agricultural/horticultural liquids that can be inhaled as aerosols

- Very wide range of herbicides; insecticides; fungicides, etc
- Permethrin
- Paraquat
- Diquat
- Linuron
- Chlorodyneform
- DDT (Dicophane; chlorophenothane)
- DEET (diethyltoluamide)
- DNOC (dinitro o–cresol)
- Lindane (γ-hexachlorocyclohexane)
- Metaldehyde (metacetaldehyde)
Particles

• Most lung diseases are caused by particles
• Size is important
  – Measured in μm (microns); 1 μm = 0.001 mm
  – Smaller particles are more dangerous because they stay in the air longer and penetrate further into the lungs

Human hair ~50 μm

PM$_{2.5}$ particles < 2.5 μm each

PM$_{10}$ particles < 10 μm each

Finest Beach Sand 90 μm

Yeast Cell 3 μm

0.3 x 0.8 μm – Bacterium
### Particle penetration into the respiratory system

<table>
<thead>
<tr>
<th>Particles</th>
<th>Reach</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;10 μm</td>
<td>Trachea</td>
</tr>
<tr>
<td>5-10 μm</td>
<td>Bronchi</td>
</tr>
<tr>
<td>1-5 μm</td>
<td>Bronchioles</td>
</tr>
<tr>
<td>&lt;1 μm</td>
<td>Alveoli</td>
</tr>
<tr>
<td>&lt;0.1 μm</td>
<td>Bloodstream</td>
</tr>
</tbody>
</table>

Particles reaching bloodstream are carried to other organs and can cause disease there:
- Heart, liver, kidneys, brain
Particle Sizes

Particle size $\mu$m

- Aerosols
- Fumes
- Pigments
- Limestone dust
- Sulphuric dust
- Cement dust
- Foundry dust
- Metallurgical dusts
- Steel furnace dust
- Tobacco smoke
- Mists
- Gas molecules
- Virus
- Bacteria
- Pollen
- Fog
- Rain
How Particles Deposit in Lungs

• Sedimentation
  - Particles fall on to airway walls as a result of gravity
  - Important in lower parts of respiratory system

• Impaction
  - Particles hit sides when airflow changes direction, eg where airway divides
  - Important in upper parts of respiratory system

• Diffusion
  - Particles hit airway walls as result of Brownian Motion
  - Important in alveoli

• Interception
  - Long fibres cannot get round bends and become stuck
  - Important with fibrous materials eg asbestos; mineral wool; fibreglass
Natural Body Defences Against Particles 1

• **Filtering**
  - Hairs in nose filter particles >10 μm

• **Coughing/sneezing**
  - Caused by irritation of trachea and bronchi by particles 2-10 μm

• **Ciliary action**
  - Small hairs (cilia) lining respiratory airways move rhythmically to propel particles (2-10 μm) upwards away from lungs
  - Can move particles ~16 mm/min
Natural Body Defences Against Particles 2

• Macrophage capture
  - Particles <2 μm that reach alveoli are captured by macrophages and carried to lymph nodes

• Immune response
  - Complex system that recognises certain proteins, eg on bacteria and viruses
  - Immunoglobulins; T and B lymphocytes capture particles
  - Can cause allergic reaction
Particle Types

• Bits of you
  – Hair; skin; mucus; micro-organisms

• Particles in your home or office
  – Clothing; carpets; furniture; paper; bits of pets, creepy-crawlies and other people

• Particles in the factory
  – From whatever you are making/processing
  – With respirators: bits of respirators; polymers; metals; filters; paints; adhesives; packaging

• Particles from outside air
  – Dusts, smokes, micro-organisms
Dusts

- Particles picked up and carried about by air movement

- Natural
  - Soil/mineral erosion; biological decay; volcanic ash; sea spay; pollens

- Man-made
  - Mineral/metal dusts from industrial processes, eg construction; demolition; manufacture; mining
Dust/Fibre Particles

- Salt particles
- Asbestos fibres
- Aluminium oxide particles
- Soot particle
Smokes

• Particles produced by combustion

• Natural
  – Spontaneous bush/forest fires; volcanic eruption

• Man-made
  – Deliberate burning of natural or man-made materials
    – Industry
    – Power stations
    – Vehicle exhausts
Smoke Particles

- Diesel exhaust particle
- Coal smoke particle
- Wood smoke particle
- Volcanic smoke particle
Pollen

• Most pollens are harmless, but some can cause allergies in some people
  – Most 50 – 100 µm in size

• In wet weather can absorb water and break up into smaller particles
  – Penetrate further into lungs
Micro-Organisms: Bacteria and Viruses

**Bacteria**
- Free-living single-cell organisms
- Some form spores
- 0.2 - 0.5 by 1 - 8 µm

**Viruses**
- Made of protein, RNA & DNA; require living cells to multiply
- 0.08 - 0.1 µm

Anthrax spores; can live for years

Ebola virus; short lived but deadly
Micro-Organisms: Rickettsiae and Fungi

• **Rickettsiae**
  - Like bacteria have cells; like viruses require living cells to grow
  - 0.2 - 0.5 by 1 - 1.5 µm

• **Fungi**
  - Primitive plants which do not photosynthesise. Live free or on decaying vegetable matter
  - Various sizes
<table>
<thead>
<tr>
<th>Common Respiratory Diseases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acute respiratory distress syndrome (ARDS)</td>
</tr>
<tr>
<td>Alpha-1 antitrypsin deficiency (A1AD)</td>
</tr>
<tr>
<td>Asbestosis / dust diseases</td>
</tr>
<tr>
<td>Asthma</td>
</tr>
<tr>
<td>Beryllium disease; berylliosis</td>
</tr>
<tr>
<td>Black lung disease; coal workers’ pneumoconiosis</td>
</tr>
<tr>
<td>Bronchiectasis</td>
</tr>
<tr>
<td>Bronchitis (chronic)</td>
</tr>
<tr>
<td>Bronchopulmonary dysplasia (BPD)</td>
</tr>
<tr>
<td>Byssinosis; brown lung disease</td>
</tr>
<tr>
<td>Chronic obstructive pulmonary disease (COPD)</td>
</tr>
<tr>
<td>Croup / acute laryngotracheobronchitis</td>
</tr>
<tr>
<td>Cystic fibrosis (CF)</td>
</tr>
<tr>
<td>Empyema thoracis</td>
</tr>
<tr>
<td>Emphysema</td>
</tr>
<tr>
<td>Farmers’ lung / mould diseases</td>
</tr>
<tr>
<td>Flock workers’ lung</td>
</tr>
<tr>
<td>Flu / influenza</td>
</tr>
<tr>
<td>Hantavirus respiratory syndrome</td>
</tr>
<tr>
<td>Hay fever</td>
</tr>
<tr>
<td>Histoplasmosis</td>
</tr>
<tr>
<td>Lymphangioleiomyomatosis</td>
</tr>
<tr>
<td>Legionnaires’ disease / Legionellosis</td>
</tr>
<tr>
<td>Lung cancer</td>
</tr>
<tr>
<td>Meconium aspiration syndrome</td>
</tr>
<tr>
<td>Mesothelioma / dust diseases</td>
</tr>
<tr>
<td>Pertussis / whooping cough</td>
</tr>
<tr>
<td>Pleurisy</td>
</tr>
<tr>
<td>Pneumonia</td>
</tr>
<tr>
<td>Pneumothorax (tension/spontaneous)</td>
</tr>
<tr>
<td>Primary alveolar hypoventilation syndrome</td>
</tr>
<tr>
<td>Pulmonary alveolar proteinosis</td>
</tr>
<tr>
<td>Pulmonary embolus</td>
</tr>
<tr>
<td>Pulmonary fibrosis</td>
</tr>
<tr>
<td>Pulmonary hypertension</td>
</tr>
<tr>
<td>Reactive airways dysfunction syndrome (RADS)</td>
</tr>
<tr>
<td>Respiratory syncytial virus (RSV)</td>
</tr>
<tr>
<td>Sarcoidosis</td>
</tr>
<tr>
<td>Severe acute respiratory syndrome (SARS)</td>
</tr>
<tr>
<td>Sick building syndrome</td>
</tr>
<tr>
<td>Sudden infant death syndrome (SIDS)</td>
</tr>
<tr>
<td>Tuberculosis</td>
</tr>
</tbody>
</table>
Who Needs Respiratory Protection?

• Anybody exposed to harmful gases and/or aerosols
  – Usually air-filtering respirators

• Anybody in atmospheres with lack of oxygen (+ harmful pollutants)
  – Usually airline or SCBA
Military/Police

- Agents used in warfare or by terrorists
  - Chemical; toxins; biological; radiological; nuclear

- Toxic gases/aerosols encountered in peacekeeping

M95

GSR

SCOTT HEALTH & SAFETY
Firefighters

• Usually need SCBA
  - Lack of oxygen; high concentration of smoke; gases that could penetrate filters; inhalation of flame
Agriculture: Pesticides

• Pesticides for plants and animals
  - Many pesticides are organophosphates: same chemical family as nerve gas

Sheep dip

Pesticides with respirator

Pesticides without respirator
Agriculture: Other Particles

• Dusts
  - Soil; crops

• Animal dander
  - Particles of hair, skin, excreta, body fluids

• Farmers’ Lung (extrinsic allergic alveolitis; hyper-sensitivity alveolitis)
  - From working with mouldy crops, eg hay, straw, corn, grain

X-ray of Farmers’ Lung
Asbestos Workers

• **Asbestosis (Diffuse Pulmonary Fibrosis)**
  - Caused by inhaling asbestos fibres; can lead to mesothelioma (cancer)

[Images of asbestos fibres]
Textile Workers

• Wool-Sorters’ Disease
  - Anthrax

• Flock Workers’ Lung
  - From inhalation of certain synthetic fibers, especially nylon

• Byssinosis (Brown Lung Disease)
  - Narrowing of airways due to inhalation of cotton, hemp, flax and jute fibres/dusts
Coal Miners

• Black Lung Disease (Silicosis; Coal workers’ pneumoconiosis)

  - From prolonged inhalation of coal dust, which collects in small airways and causes scarring and destruction of lung tissue and blood vessels
Metal Workers

- Refining; foundries, welding, etc

- Aluminium
- Beryllium
- Cadmium
- Chromium
- Iron
- Lead
- Manganese
- Mercury
- Nickel
- Zinc

Iron particles in lungs

Various metal particles

Iron-chromium-nickel particle
Paint Sprayers

- Paint pigments
- Solvents and thinners
- Lead and cadmium
Wood Workers

- Sawmills; timber processing
- Dust from drilling, planing sanding, etc
- Adhesives: solvents; epoxy resins; cyanoacrylates
- Processed wood

Wood particles
Pharmaceutical Manufacture: Drugs

• Drugs are designed to affect you

• Inhalation is the 2nd fastest way of administering drugs
  – Nicotine from smoking takes 1-2 s to reach brain
  – Many drugs administered by inhalation

• Prolonged exposure to low doses
  – Effects can build up
  – Tolerance: you need higher doses to give the same effect; dangerous if you need to take that drug medicinally
Pharmaceuticals: Other Ingredients

- Filling/binding agents
- Sweeteners
- Preservatives
- Colours
- Anti-caking agents
- Adjuvants
  - Help drug effect, absorption; reduce side effects
Pharmaceutical Manufacture Methods

- Some drug manufacturing plants are modern and well-run; some are not
- Masks are worn not to protect workers, but to protect the drug
Other Occupations 1

• Chemical industry
  - Very wide range of chemicals: acids, alkalis, solvents

• Food processing
  - Mites and fungi carried on food particles cause allergies and asthma

• Construction/demolition
  - Variety of dusts; cement; mineral wool; glass fibre; polyurethane provokes asthma

• Waste processing
  - Wide range of particles
Other Occupations 2

• Medical
  - Protect patients from staff and staff from patients
  - Chemicals used to sterilise instruments
  - Latex particles cause asthma

• Plastics processing
  - Wide range of polymers

• Average man/woman
  - Can be exposed to almost everything listed
  - Exposure duration may be less, but variety is great
  - Especially DIY
RPE Design Principles

• **Protection**
  – Leak paths; fitting/sizing

• **Integration**
  – With other equipment necessary for job

• **Human Factors**
  – Physiology; psychology; ergonomics

Respirators must work and be usable
Leak Paths: Face Seal

• Worst leak path
  – Difficult shape, especially over nose
  – Unusual face size and/or shape
  – Facial features: beards; scars; lesions; soiling;

• Skin adapts slowly to seal
  – Can take 10 minutes or so

• Headstrap/harness
  – Incorrect placement on head
  – Too loose / too tight

Respirator face seal indentation in skin with time after donning
Other Leak Paths

• Filters
  – Leakage related to pressure drop on inhalation
  – Wrong filters, eg particle filters to protect against gases

• Filter Attachments
  – Screw and bayonet fittings; especially if filter not properly attached

• Valves
  – All valves leak, especially if not kept clean; valve deadspaces help

• Material
  – Not usually a problem as most materials impermeable, but can make wearer hot and sweaty, which could breach face seal
Fitting/Sizing

• Bad sizing/fitting will be uncomfortable and will cause faceseal leaks

• Wide range of face sizes

• Material must conform to fit different face shapes

• Straps/harness must hold respirator in correct place
Integration

• The user must be able to use the tools and equipment to do his/her job

• Main problems are with equipment used on or near the head or shoulders
  – Hats; helmets
  – Vision aids; communications systems; head protection; weapons; hoses
  – RPE affects equipment use and/or equipment affects RPE

• Access to confined spaces
  – Bulk of RPE plus associated equipment
Human Factors

• Physiology
  - Breathing resistance; Respiratory dead space
  - Heat / Sweat / Water Balance

• Vision
  - Visual field restriction; distortion; misting

• Speech
  - Muffling; distortion

• Psychology
  - Situational awareness; motivation; expectation; “claustrophobia”

• Ergonomics
  - Pressure; comfort; weight; ease of use and maintenance; consumables
Breathing Resistance

• Resistance imposed by filters; valves; airflow
  – Harder to breathe: tiring; decreases work effort and endurance
  – Expiratory resistance probably more important than inspiratory

• Some expiratory resistance is necessary
  – Need enough pressure build-up to make valves function properly
  – Increased pressure helps reduce faceseal leakage

• If you could reduce breathing resistance to zero, should you?
  – Users expect some resistance – re-assures them that respirator is working
Respiratory Dead Space

• The internal volume of a respirator increases respiratory dead space

• Impairs \( O_2 \) and \( CO_2 \) diffusion

• Causes \( CO_2 \) build-up
  – Affects breathing rate and depth; reduces work effort and endurance

• Reduce internal volume
  – But may cause “claustrophobia” and reduce work endurance
Effects of reducing breathing resistance and dead space on work endurance

- Treadmill with increasing gradient and speed

- Subjects worked until they were exhausted and had to stop

<table>
<thead>
<tr>
<th></th>
<th>Endurance (min)</th>
</tr>
</thead>
<tbody>
<tr>
<td>No resp</td>
<td>18</td>
</tr>
<tr>
<td>Standard</td>
<td>14</td>
</tr>
<tr>
<td>50%</td>
<td>12</td>
</tr>
<tr>
<td>Both</td>
<td>10</td>
</tr>
<tr>
<td>50% dead space</td>
<td>8</td>
</tr>
</tbody>
</table>
Heat/Sweat

• RPE feels hot
  - Effect depends on workload and ambient temperature and humidity
  - Reduces work efficiency

• RPE makes your face sweat
  - Irritates skin and impairs user performance
  - Can affect face seal
  - Sweat must evaporate to provide cooling – removing sweat may reduce irritation but will not have cooling effect
Drinking

• Need to replace fluid/salts lost through sweating
  – Dehydration; sodium loss
    □ Will impair work; can lead to shock

• Have to stop work and doff RPE to drink
  – Can take a long time
    □ Important in emergencies, eg fire; rescue
  – Re-donning can affect PF
  – Build in drinking facility
Visual Field (Peripheral Vision)

- **Visors/eyepieces**
  - Restrict visual field all round
  - Make bigger, but space limited
  - Bring closer to face, but airflow may irritate eyes and impair vision

- **Snout/filters**
  - Restrict downward vision and maybe some sideways, depending on where filter(s) placed
  - Make smaller; also reduces dead space, but may cause claustrophobia
Other Vision Effects

• Visors/eyepieces can mist
  – Sweat; exhaled breath

• Difficult to wear spectacles
  – Can affect mask seal, or mask can affect spectacles

• Recognition; seeing facial expression
  – Important when working in teams

Who are you?
Speech

• Understanding speech is very important
  – People working in teams, eg military; firefighters; rescue
  – Errors can be fatal

• RPE muffles and distorts speech
  – Muffling from facemasks
  – Distortion from valve operation and restriction of lower jaw
  – Radios and telephones can exacerbate effect
  – Speech modules and microphones may help
## Effects of Air Filtering Respirator on Speech Comprehension

<table>
<thead>
<tr>
<th>Speaker</th>
<th>Transmission</th>
<th>Listener</th>
<th>% Errors</th>
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<tr>
<td>Resp</td>
<td>Radio</td>
<td>Hood</td>
<td>7.2</td>
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</table>
Psychological Effects 1

- **Decreased interaction**
  - You feel isolated and you don’t want to communicate with others

- **Decreased intrinsic motivation**
  - You don’t want to work

- **Negative self-image**
  - You feel inadequate and frustrated

- **Psychosomatic illness**
  - Typically headache, stomach/gut upset, “claustrophobia”
Psychological Effects 2

• Increased negative affect (mood)
  – You feel unhappy, anxious, impatient, irritable, uncomfortable, depressed

• Increased subjective workload
  – If you think you have to work harder, you will actually tire quicker

• Cognitive function?
  – Thinking; remembering
  – Some reports of cognitive effects, but actually due to impaired perception, mainly vision
  – But if you think it does, then it probably will
Ergonomics 1: Pressure & Comfort

• Face piece pressure too high/uneven
  – Small areas of high pressure can be a major source of discomfort

• Rubbing/chafing/itching
  – Distract from work; can be maddening

• There must be some pressure to ensure a good seal

Users will not wear an uncomfortable respirator, or they will keep fiddling with it and breach the seal
Ergonomics 2: Weight & Bulk

• Weight
  – Reduces work effort and endurance

• Bulk
  – Hinders use of equipment and access to confined spaces

• Filtering respirators can cause problems;
  SCBAs can cause serious problems

The heavier/bigger it is, the greater the problem
Ergonomics 3: Usage

• Ease of donning/doffing
• Care/Maintenance
• Training
• Consumables
  – Some must be replaced, eg batteries; gas cylinders
  – Some should be replaced, but often are not, eg filters

If it is complicated and/or takes a long time, users will get it wrong or will not do it at all
Ergonomics 4: Looks

• When you have got the protection, integration and human factors right, you can make it look good
  – Shape; colour; cute; mean

If users like it, they will wear it
Top Ten World Pollution Sites

1. **Dzerzhinsk, Russia**
   - Toxic by-products and lead from chemical weapons and industrial manufacturing
   - Number of people potentially affected: 134,000

2. **Norilsk, Russia**
   - Heavy metals and particulates from mining and smelting
   - Number of people potentially affected: 300,000

3. **Linfen, China**
   - Particulates and gases from industry and traffic
   - Number of people potentially affected: 140,000

4. **Chernobyl, Ukraine**
   - Radioactive materials from nuclear reactor explosion
   - Number of people potentially affected: 5.5 million

5. **Sumgayit, Azerbaijan**
   - Organic chemicals and mercury from petrochemical and industrial complexes
   - Number of people potentially affected: 275,000

6. **Sukinda, India**
   - Hexavalent chromium from chromite mines
   - Number of people potentially affected: 2.6 million

7. **Tianying, China**
   - Heavy metals and particulates from industry
   - Number of people potentially affected: 140,000

8. **Lina, India**
   - Wide variety of industry effluents
   - Number of people potentially affected: 71,000

9. **La Oroya, Peru**
   - Lead and other heavy metals from mining and metal processing
   - Number of people potentially affected: 35,000

10. **Kabwe, Zambia**
    - Lead from mining and smelting
    - Number of people potentially affected: 255,000