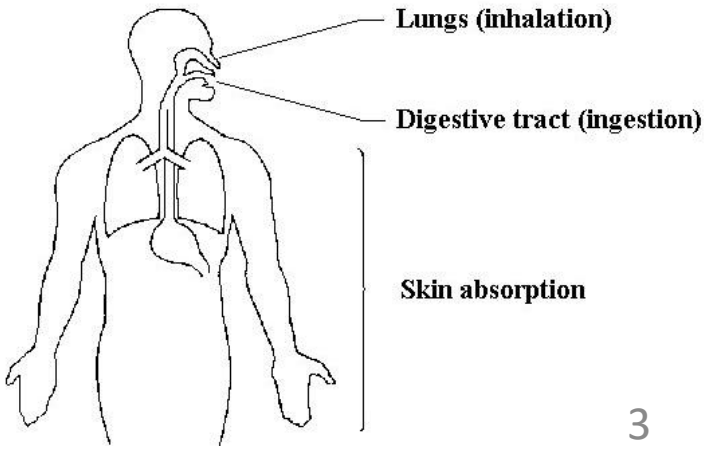
MC09 Respiratory Protection

Introduction

- Respiratory Protection Policy (refer to HSE safety manual Chapter 13)
- Program Logistics
  - Make a request by submitting the application form Request for Occupational Exposure Assessment to HSE
  - HSE staff will conduct a risk assessment to evaluate the working environment and the operation which potentially generates respiratory hazards
  - Successfully complete safety course on respiratory protection (live or online)
  - Undergo a lung function examination by HKUST(GZ) occupational physician (appointment is arranged by HSE once the application is approved)
  - Arrange a fit-testing with HSE to determine the most suitable type and size of respirator
  - Obtain respirator from CLS-Store (Center of Laboratory Supply) by presenting the HSE endorsement slip (a charge-back system)

Respiratory Hazards

- What are respiratory hazards?
  - Substances such as dusts, fumes, vapor, gases and even micro-organisms encountered at work can cause significant damage to health or, in extreme cases, death
- How these substances get into our body?
  - Inhalation
    (Most important industrially, Limited metabolism/ Direct access to blood stream / Can cause significant damage to health or, in extreme cases, death)
  - Skin contact (Most common)
  - Ingestion (Mainly Associated with poor personal hygiene or housekeeping)



Respiratory Hazards

- Gaseous contaminants:
  - Inert gas (helium, argon, nitrogen, etc.) displace air to produce an oxygen deficiency
  - Acid gases (SO_2, H_2S, HCl, etc.)
  - Alkaline gases (NH3, amine, etc.)
  - Organic vapors/gases (butane, acetone, benzene, chloroform, etc.)
  - Organometallic gases (tetraethyl lead, organo-phosphates, etc.)

Respiratory Hazards

- Airborne particulate materials:
  - Bio-aerosols
  - Dusts: Mechanically generated solid particulate (0.5 to 10 µm)
  - Fumes: Solid condensation particles of small diameter (0.1 to 1.0 µm)
  - Mists: Are liquid particulate matter (5 to 100 µm)
  - Smoke: Chemically generated particulate (solid and liquid) of organic origins (0.01 to 0.3 µm)

Respiratory Hazards

- Hazardous operations that generate airborne substances:
  - Bio-aerosols operation: centrifuging
  - Solid operations: pouring and mixing
  - Pressurized spraying: cleaning parts and applying pesticides
  - Shaping operations: cutting and grinding
  - Hot operations: welding, chemical reactions, soldering, melting, burning
  - Liquid operations: painting, degreasing, spraying, coating, etching, cleaning, plating, mixing, chemical reactions especially with epoxy or organic solvent coatings

Respiratory Protection Equipment

- How can we prevent ourselves from breathing in hazardous substances ?
  - Engineering Control (most reliable control measure)
  1. Use of a chemical fume hood to handle hazardous chemicals
  2. Use of biological safety cabinet for bioaerosol generating processes

Respiratory Protection Equipment

- How can we prevent ourselves from breathing in hazardous substances ?
  - Use of Respiratory Protective Equipment (Respirator)
  1. Recommended ONLY when engineering control is not possible or used as extra protection in additional to the existing engineering control
  2. Many limitations !! (will be discussed later on)

What is a Respirator?

- A device that filters the air in the work area or supplies clean air from connecting to a breathable air source:
  - To be worn in a contaminated atmosphere and to protects your lung from airborne hazards in forms of particulates, gases and vapours
  - Includes a very wide range of devices/types, NO one type of respirator can protect wearer from all types of hazard

What is a Respirator?

- Respiratory Inlet Covering:
  - Tight-fitting coverings (usually called facepiece)
  - Facepieces are made of flexible molded rubber, silicone, neoprene, or other materials.
  - There are three basic configurations:
    1. quarter-mask
    2. half-mask (most common type used in our campus)
    3. full-face
- Loose-fitting Covering:
  - Hoods, are light flexible device covering only the head and neck, or head, neck and shoulders
  - Helmets are rigid protective headgear
  - Suits and blouses are covering extend down to the waist and some have wrist-length sleeves

What is a Respirator?

- Air purifying respirator
  - Removes contaminants from the ambient air before it is inhaled
  - Particulate respirators are type of respirators that removing particulate with a filter media
  - Vapour and gas respirators are type of respirators that remove vapours and gas with a chemical cartridges or canisters
- Atmosphere-supplying respirator
  - Provides air from a source other than the surrounding atmosphere
  - Self-contained breathing apparatus (SCBA)
  - Air-lined breathing apparatus

Filter Media

- Function: to remove targeted air contaminant
- Filtration mechanism Interception, sedimentation, inertial impaction, diffusion and electrostatic
- Efficiency: depends on particle size, velocity, shape and electrical charge

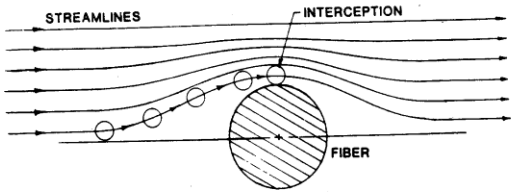


FIGURE 2-13. **Interception capture mechanism[1]**

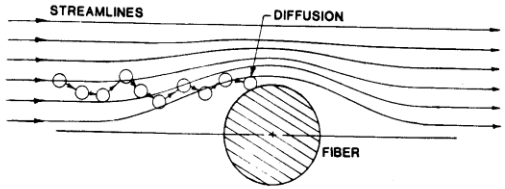


FIGURE 2-16. **Diffusion capture mechanism[1]**

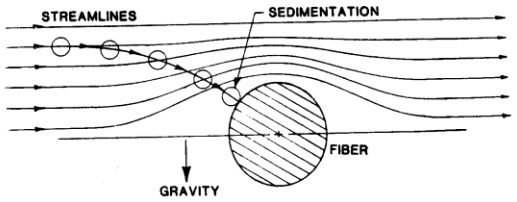


FIGURE 2-14. **Sedimentation capture mechanism[1]**

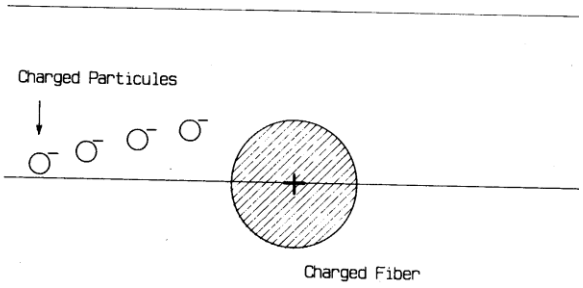


FIGURE 2-17. **Electrostatic capture**

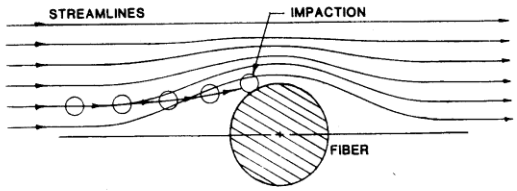


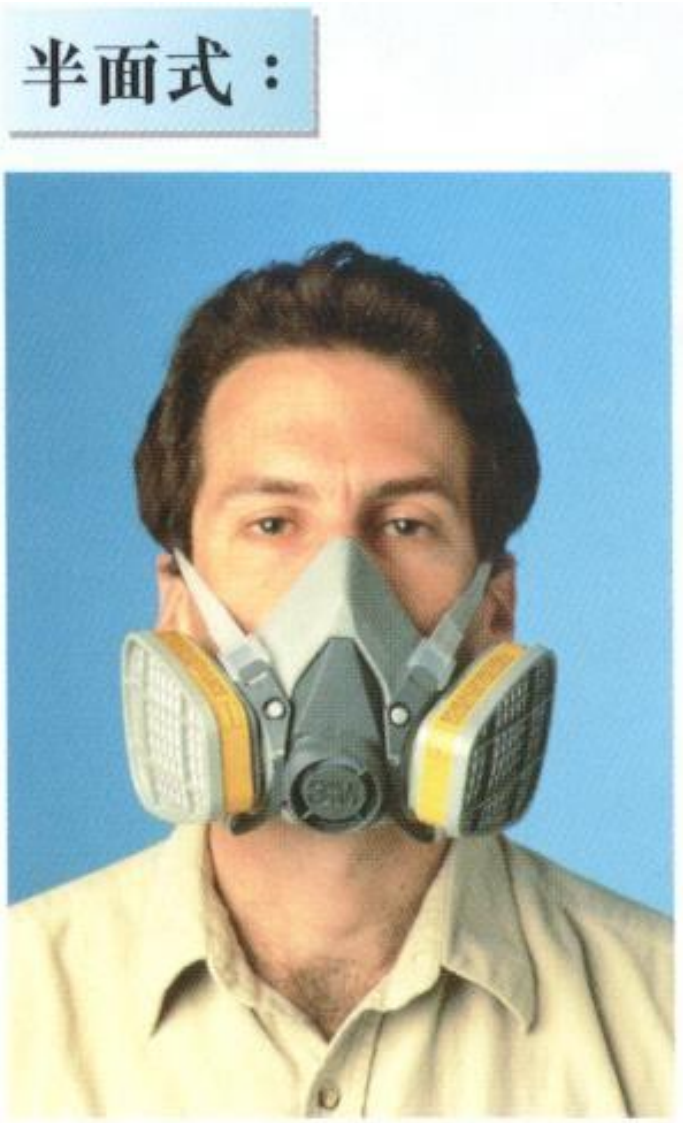
FIGURE 2-15. **Impaction capture mechanism[1]**

Chemical Cartridges and Canisters

- Removal mechanisms:
  - Adsorption - retains the contaminant molecule on the surface of the sorbent granule by physical attraction, e.g. activated charcoal
  - Absorption - retains the contaminant molecule chemically, e.g. mixture of sodium or potassium hydroxide with lime and/or caustic silicates
  - Catalysis - uses catalyst to react with the contaminant to produce a less toxic gas or vapor, e.g. Hopcalite, a mixture of porous granules of manganese and copper oxides which speeds the reaction between toxic carbon monoxide and oxygen to form carbon dioxide

Half Face Air Purifying Respirator

- Works by negative-pressure
- The wearer draws air through the filters
- or cartridges during inhalation
- Tight-fitting: has to fit perfectly on
- your face to form an airtight seal



Full Face Air Purifying Respirator

- It fits the same way as a half-mask: negative pressure respirator and has to fit perfectly
- Filters or cartridges
- Provides additional protection to your face and eyes.
- Has problem with corrective glasses

Powered air-purifying respirator(PAPR)

- It looks like a negative-pressure respirator with an air blower
- Tight-fitting face piece or a loose-fitting helmet, hood or suit
- The pump pulls / blower pushes the air through the filters / cartridges and then supplies purified air through a hose into a mask or hood

Particulate Respirator

- Standard - NIOSH (National Institute for Occupational Safety and Health of USA) adopted a new standard, on July 10, 1995, called 42 CFR 84.
- This standard establishes new performance criteria for all negative pressure particulate air-purifying respirator and prefilters. PAPR are not affected by the new standard.
- Under the standard, there are nine classifications of respirators based on filter efficiency and use limitations.

Particulate Respirator Classifications

Filter Series	Filter Efficiency		
	95%	99%	99.97%
N for Not resistant to oil	N-95	N-99	N-100
R for Resistant to oil	R-95	R-99	R-100
P for oil Proof	P-95	P-99	P-100

- Likely Non-Oil Compounds
  - Water-based pesticides
  - Cadium
  - Cotton dust
  - Wood dust
  - Metal Fumes
  - Asbestos
  - Paint stray

- Likely Oil Compounds
  - Mineral Oil
  - Vegetable Oil
  - Glycerin
  - Phthalates
  - PCBs
  - Triphenyl Phosphate
  - Coke Oven Emmisions
  - Asphalt Fumes
  - Coal Tar Pitch Volatiles
  - Oil/Solvent-Based Pesticides

Air-Line Respirator

- Respirable air from a hose from a compressor or compressed air cylinder
- Exhaled air passes to the ambient atmosphere through a valve in face piece, helmet, suit, or hood

Air-Line Respirator

- Breathing Air Requirement for ASR
  - Carbon monoxide < 5 ppm
  - Carbon dioxide < 500 ppm
  - No odor of oil
  - Temperature 15 to 22 ^{o}C
  - RH < 85% with no condensed water
  - Airflow capacity: minimum of 120 litres per minute for each person
  - Impurities: kept to a minimum and not exceed the PEL

How to select an appropriate respirator?

- Step 1: Assess the hazardous operation and the working environment
  - Nature of the individuals task/ procedures including frequency, duration and physical demands
  - Identification of released airborne contaminant(s)
  - General working environment:
    1. open shop or confined spaces
    2. potential for oxygen-deficient atmosphere
    3. temperature of a job area

How to select an appropriate respirator?

- Step 2: Gather information for the contaminant
  - Physical (gas, vapour, aerosol, or combination), chemical, and toxicologic properties of the contaminant (MSDS is a good reference source)
  - Odor threshold data
  - Eye irritation and skin absorption pot
  - Estimated exposure concentration
  - Applicable occupational exposure limit (PEL, OEL)
  - IDLH concentration

$$\text{Hazard ratio (HR)} = \frac{\text{Airborne contaminant concentration}}{\text{Exposure rate}}$$

How to select an appropriate respirator?

- Step 3: Characteristics of respirator
  - The APF listed for the respirator type
  - Information on service life of cartridges or canisters
  - Comfort and acceptance of the respirator

Respirator Type	APF (NIOSH)
AP (half face)	10
AP (full face)	50
PAPR (loose-fitting hood or helmet)	25
PAPR (half face)	50
PAPR (full face)	100
SAR (full face, positive pressure)	1000
SCBA	10000

How to select an appropriate respirator?

- Protection factor = the concentration of contaminant outside / the concentration of contaminant inside the mask
  - Example:
    dust conc. outside = 300 mg/m^3
    dust conc. Inside = 0.3 mg/m^3
    protection factor = 300 / 0.3 = 1000
  - Protection Factor x PEL = Maximum Exposure Concentration Allowable

Even a most appropriate respirator has limitations

- Limitations of Air-Purifying Respirators
  - Must not used in environments of IDLH or oxygen deficiency
  - Knowing the limitations of the sorbent packings (e.g. breakthrough time, chemical cartridge service life)
  - When working in environments where concentrations are irritating to the eyes (e.g SO_2), full face units must be used
  - Appropriate protective clothing must be worn to prevent absorption of chemicals through skin
  - Physiological burden upon wearer
  - Other factors, facial hair, corrective lens, voice communications, fogging

Limitations of ChemicalCartridges

- Limitations of Air-Purifying Respirators
  - Chemical cartridges are designed to remove very specific chemicals and may not be effective for other chemicals, selecting the correct type of cartridge or canister is important
  - Must not be used if the chemical is extremely toxic at very low concentrations (e.g HCN)
  - Must not be used for exposures to air contaminants with poor warning properties(e.g bromomethane), or the chemical is detectable by odor at harmful concentrations

Limitations of ChemicalCartridges

- Factors affecting the service life of a chemical Cartridges
  - Sorbent type, mesh size and quantity
  - Concentration of the contaminant in air
  - Wearers breathing rate
  - Temperature and humidity
  - Mixture of chemicals can shorten the service life for each individual chemical

Change of Cartridges / Filters

- Warning signs of cartridge or filters failure:
  - Particulate Air-purifying
    1. experience of filter resistance
    2. encounter breathing difficulty
  - Gas / Vapour Air-purifying
    1. chemical sorbent is expended
    2.warning properties occur (odor, taste, eye irritation, respiratory irritation)
  - Atmosphere-supplied respirator / SCBA
    1. compressor or air pressure alarm went off

Respirator Fit testing

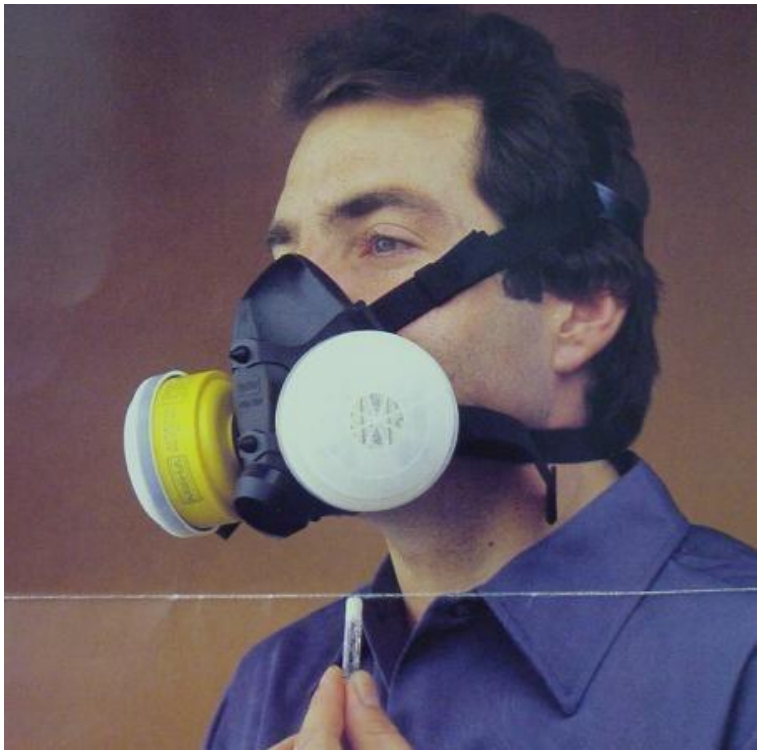
- To determine the ability of each individual respirator wearer
- To obtain a satisfactory fit with any air-purifying respirator
- Quantitative (QNFT) and qualitative (QLFT) fit testing
- Personnel must successfully pass the fit test before being issued an air-purifying respirator

Particle Counting Instrument

- Accurately measure respirator fit by comparing the dust concentration in the surrounding air with the dust concentration inside the respirator.
- The ratio of these concentrations is called the fit factor.
- A modified filter cartridge (or a modified respirator facepiece) equipped with a sampling port is used to collect air from inside the respirator.
- With the sampler attached, the wearer is asked to: breath deeply, move head side to side, move head up and down, and talk. During these movements, any leakage is measured by the particle counting device.
- The fit test data is stored by a computer and a final fit test report is generated.
- An acceptable fit test is a measured fit factor at least 10 times greater than the assigned protection factors (APF). APF's are respirator design characteristics. A fit factor of at least 10 times the APF is used as acceptance criteria because APF's are not considered reliable predictors of performance levels that will be achieved during actual use.

Qualitative Fit Testing

- Perform the test in test environment, i.e. an atmosphere containing an odorant, e.g. Isoamyl acetate
- Breath deeply
- Move head side to side and up and down
- Talk or read the "Rainbow Passage“ showed in next page
- The wearer reports any noticeable odor, taste or nasal irritation that is leaking into the mask.



Qualitative Fit Testing

- "Rainbow Passage”
  When the sunlight strikes raindrops in the air. They act like a prism and form a rainbow. The rainbow is a division of white light into many beautiful colors. These take the shape of a long round arc, with its path high above, and its tow ends apparently beyond the horizon. There is, according to legend, a boiling pot of gold at one end. People look, but no one ever finds it. When a man looks for something beyond his reach, his friend say he is looking for a pot of gold at the end of the rainbow

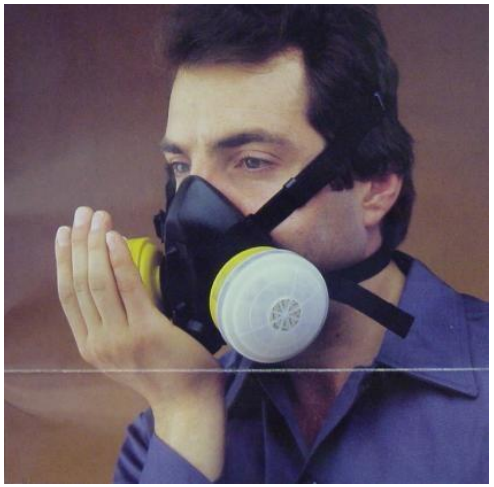
Odorant for QLFT

- Isoamyl acetate (Banana Oil)
  - Has a pleasant, easily detectable odor
  - Respirator equipped with an organic cartridge
  - If the user detects any odor, it is an indication that the fit is faulty, and that adjustment to the respirator seal is required
  - Two limitations; the odor threshold varies widely among individuals and odor fatigue can occur
- Irritant Smoke
  - Exposing the wearer to an irritating aerosol produced by a smoke tube
  - If the user detects any irritant smoke, it is an indication that the fit is faulty, and adjustment to the respirator seal is required
  - Has an advantage in that the wearer usually reacts involuntarily to any leakage by coughing or sneezing
  - Only properly trained personnel should conduct the irritant smoke fit test.

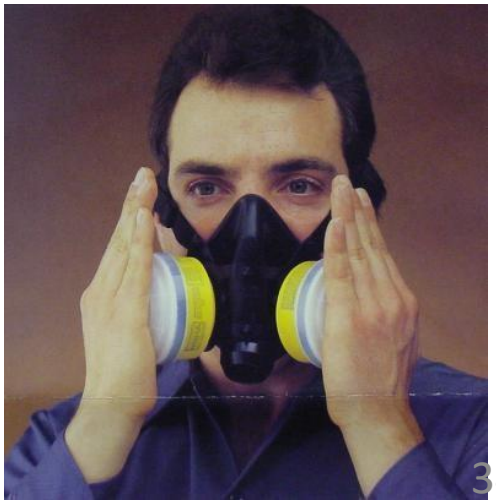
User Seal Check

- Perform the seal check immediately before and periodically during respirator use in the field.

Positive Pressure Check
Cover the exhalation valve with your hand and exhale gently into the facepiece.
If a slight positive pressure is built up inside the facepiece without any evidence of leakage, the fit is satisfactory.



Negative Pressure Check
Cover the cartridges with your hands, inhale gently to collapse the facepiece slightly, and hold your breath for 10 seconds.
If the facepiece remains slightly collapsed and no leakage is
detected, the respirator fits properly.



Considerations For Proper Fit

- Facial Hair
  - A person who has hair (stubble, moustache, sideburns, beard, low hairline or bangs) which passes between the face and the sealing surface of a tight-fitting facepiece shall not be permitted to wear a respirator.
  - A person who has hair (moustache, beard) which interferes with the functions of the respirator valve(s) shall not be permitted to wear a respirator.

- Glasses and Eye/Face Protective Devices
  - If a spectacle, goggle, face shield or welding helmet must be worn with a respirator, it shall be worn so as not to adversely affect the respirator seal.
  - A spectacle which has temple bars or straps which pass between the sealing surface of a respirator facepiece and the wearers face shall not be used.
  - If a full-facepiece respirator is used, special prescription glasses are available if needed.

Repeat of Fit Test

- When there is condition that may interfere with face piece sealing:
- Significant change in weight (10%)
- Significant scarring in the area of face seal, dental changes, cosmetic surgery
- Job duties change and necessitate a change in respirator equipment
- Full face respirator and regular users (over 20 hours a month): fit tested annually is recommended

Maintenance and Care

- Cleaning and Disinfecting
  - respirators or emergency use respirators: cleaned and disinfected after each use
  - personal respirator: weekly or monthly cleaning is usually adequate
  - shared respirators or emergency use respirators: cleaned and disinfected after each use
  - remove any filters or cartridges
  - wash the face piece and associated parts with a mild detergent and warm water
  - rinse in clean warm water
  - disinfect in disinfectants or by disinfectant wipes (70% isopropyl alcohol) and rinse
  - air dry, reassemble and re-inspect

Maintenance and Care

- Storage
  - Kept in cleaned sealed plastic bag
  - Stored in a clean, dry, non contaminated environment
  - Positioned respirator in its natural configuration preventing deformation
  - Kept emergency-use respirator in accessible work area

Maintenance and Care

- Check
  - Report any defects such as holes, cracks, missing valves, etc
  - Disposable respirator:
    1. Holes in filter
    2. Elasticity of straps
    3. Deterioration of straps and metal nose clip
  - AP respirators:

    1.Face piece dirt, cracks, tears, holes, distortion, cracked, loose fitting lenses
    2. Head bands breaks, loss of elasticity, broken buckles or attachment
    3. Valves dust, dirt, cracks, distortion, loss
    4. Filter elements, proper filter / cartridges; worn threads cracks in filter housing
    5. Deterioration, expired (service life indicator)
    6. Prefilter excessive breathing resistance

Maintenance and Care

- Repair
  - Replace damage or missing parts and filters/ cartridges
  - Repair or adjustments to respirators must be done only by appropriately trained personnel
  - Report any problems or malfunction to HSE
- Exclusive Repair Usage
  - To prevent cross contamination, all individuals who wear respirator is to be supplied for their exclusive use
  - An exception to this practice, SCBA for emergency or rescue purposes and PAPR

Case Study – Animal Care Facility

- Job nature: Custodial staff who are responsible for changing of animal bedding
- Potential airborne contaminant: bedding dusts, excreta and waste.
- Working environment: animal house, sometime in hot sterilization room with long working hours
- Other factors: requires eye protection
- Solution: loose fitting PAPR

Case Study – FMO Workshops

- Job nature: repair of laboratory furniture, and operation involves using of glue, welding and spray paint
- Potential airborne contaminant: organic vapor and welding fume
- Control measures: local exhaust ventilation

Important Recap

- Respirators are not perfect
  - Choice depends on contaminant type and concentration
  - Different protection factor (PF)
  - Half face respirator do not offer eye protection
  - Filtration cartridges are chemical specific
  - Respirators are sometimes uncomfortable, hot, and heavy

Important Recap

- Limitations
  - The possibility for human error - less reliable
  - Filter cartridge may be saturated
  - Problem with corrective glasses with full face respirators
  - Cannot grow beard
  - Users must be physically fit, fit tested, and trained.
  - Some users may be claustrophobic

Important Recap

- Dos and Don’ts around Respirators
  - Engineering and administrative controls are always preferable to the use of a respirator.
  - Do make sure you have a good fit.
  - Do get to fresh air immediately if you begin to smell or taste the chemical - your respirator is not working properly
  - Don't just buy a respirator and wear it yourself
  - Don't leave your respirator upside down or uncovered in your workplace. Keep it clean.
  - Don't use the wrong filter/cartridge
  - Never borrow or lend a respirator

Last but not the least reminder

- **"Using the wrong cartridge and filter may be like using no respirator at all“**
- **"Improper use of air-purifying respirators could result in injury and/or fatality"**

Reference

- 《呼吸防护 自吸过滤式防颗粒物呼吸器》(GB 2626-2019)
- 《个体防护装备配备规范 第1部分：总则》（GB 39800.1-2020）
- 《用人单位劳动防护用品管理规范》(2018年修订版)